# SOBA 4.2: AQUACULTURE IN THE AYEYARWADY BASIN

*AYEYARWADY STATE OF THE BASIN ASSESSMENT (SOBA)*

*Status:* FINAL
*Last Updated:* 09/01/2018
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**Disclaimer**
*"The Ayeyarwady State of the Basin Assessment (SOBA) study is conducted within the political boundary of Myanmar, where more than 93% of the Basin is situated."*

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# ACKNOWLEDGEMENTS

We would like to thank Michael Akester, WorldFish country director, and his predecessor Gareth Johnstone for their strong support to the project. Warm thanks to the WorldFish team in Yangon too, for its assistance throughout project implementation. We are also grateful to Visidh Koum, Yumiko Kura and the WorldFish teams in Cambodia and Malaysia for their dedicated and patient institutional and administrative support.

This project was made possible thanks to the proposal design contribution by Frank Momberg, Gurveena Ghataure and Tony Whitten of Fauna and Flora International (FFI). The early support by the Department of Fisheries (DoF) and of Dagon, Maubin and Yangon Universities is truly appreciated. Sincere thanks to Xavier Tezzo (WorldFish) as well for his assistance, in particular during the preparation phase.

Pelle Gätke (consultant), Ouch Kithya (WorldFish), Gurveena Ghataure (FFI) and Frank Momberg (FFI) supported overall project implementation and coordination. The Myanmar Information Management Unit (MIMU) helped with mapping.

Last but not least, special thanks to Tarek Ketelsen (SOBA-C1) whose role in coordinating all components and harmonizing the requirements and constraints of all parties was essential.

The present document was written by Olivier Joffre (WorldFish) with contributions from Htin Aung Kyaw (consultant). The authors would like to thanks Dr. Khin Maung Soe (consultant), Rick Gregory (consultant), Ben Belton (Michigan State University) and Karim Mandjurul (WorldFish) for providing detailed and updated insights on the Myanmar aquaculture sector.

**Report citation:**

Joffre, O., Htin Aung Kyaw. 2017. *Aquaculture in the Ayeyarwady Basin*. Ayeyarwady State of the Basin Assessment (SOBA) Report 4.2. National Water Resources Committee (NWRC), Myanmar.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ARDC | Agriculture and Rural Development Corporation |
| DoF | Department of Fisheries |
| FAO | Food and Agriculture Organization of the United Nations |
| FAO FIGIS | Food and Agriculture Organization of the United Nations – Fisheries Global Information System (http://www.fao.org/fishery/statistics/global-production/query/en) |
| FAO-NACA | Food and Agriculture Organization and Network of Aquaculture Centres in Asia-Pacific |
| ha | hectare |
| kg | kilogram |
| LEI | Landbouw-Economisch Institut |
| m | metres |
| $m^2$ | square metres |
| m.d. | missing data |
| MFP | Myanmar Fisheries Partnership |
| MMK | Myanmar Kyat |
| MYFish | Project ‘Improving Research and Development of Myanmar’s Inland and Coastal Fisheries’, |
| MYSAP | Project ‘Improving the production, nutrition and market values of small-scale aquaculture in Myanmar’s Shan State and Sagaing Region’ |
| NGO | non-government organisation |
| SME | small and medium enterprise |
| SOBA | State of the Basin Assessment |
| t/day | tonnes per day |
| t/ha | tonnes per hectare |
| UNDP | United Nations Development Programme |
| UR | Universiteit en Researchcentrum |
| USD | United States dollar |

# EXECUTIVE SUMMARY

### PRODUCTION AND SPATIAL DISTRIBUTION OF AQUACULTURE

In 2017, aquaculture production is estimated to reach approximately 958,000 tons for the Ayeyarwady Basin, accounting for 91% of the total aquaculture production of the country. This production makes Myanmar the third-largest freshwater fish aquaculture sector in Southeast Asia. Based on Department of Fisheries (DoF) data, the sector's average fitted growth was estimated to be approximately 8.7% between 2004 and 2014 (Belton et al., 2015). However, aquaculture statistics in Myanmar need to be considered with caution. Researchers estimate that over-reporting of aquaculture production amounts to 164% of the actual figure, based on national consumption figures and trade of fish (Belton et al., 2015). In addition, the pond area for aquaculture did not increase as fast as production in recent decades. Moreover, calculating average productivity per hectare (ha), based on township data, results in unrealistically high productivity figures. Thus, in a context where aquaculture intensification did not happen yet, over-reporting of the aquaculture production is expected.

Within the Ayeyarwady Basin, the total area dedicated to aquaculture is about 278,841 acres in 2017, accounting for an estimated 57% of total aquaculture area in Myanmar. Recent studies, however, show a more complex picture of the aquaculture sector, made of not only large farms, but also numerous small and medium size farms that contribute significantly to the sector and that are not usually acknowledged.

The production and pond areas within the Ayeyarwady and Yangon Regions provide 90% of Myanmar farmed fish production, and production has rocketed 250% over the past decade. The three largest aquaculture area townships reach a production level of more than 100,000 tonnes of fish per year.

The Twantay Township in the Yangon Division and Maubin, Pantanaw, and Nyaungdon Townships in the Ayeyarwady Division account for nearly 52% of the basin's estimated pond area (143,710 acres in 2017). These townships are characterized by medium- and large-scale farms compared to other regions of the basin.

### SPECIES AND PRODUCTION SYSTEMS

Rohu is still the dominant production species, representing 70% of Myanmar aquaculture production. Aquaculture experts perceived this singularity as an overdependence on a single species and a constraint to further growth in the sector. Production targets the domestic market, with limited market export potential for rohu (Bangladesh and the Middle East). Other main species are mrigal and catla, as well as pangasius, tilapia, silver barb, puntius, and other types of carp (common carp or grass carp). Major aquaculture species in Asia are absent, such as walking catfish (*Clarias batrachus*), sea bass (*Lates calcarifer*), climbing perch (*Anabas testudineus*), stinging catfish (*Heteropneustes fossilis*), and striped snakehead (*Channa striata*), although they feature a high price on local markets. Producing these species will require access to cheaper inputs, higher quality feeds, equipment (paddle wheels), fingerlings, and upgraded infrastructure (e.g., regular electricity supply).

According to DoF officers interviewed within the basin, the species raised and their importance has not significantly changed in the last 10 years.

Carp polyculture in a semi-intensive system dominates the sector with external homemade and manufactured pelleted feed. Productivity is limited and ranges from as little as one tonne per hectare (t/ha) to a maximum of 10 t/ha, with a mean of 3.7 t/ha. Feed represents 70% of the operational cost, followed by fingerlings (9%) and non-feed inputs (fuel and fertilizer [7%] and labor [4%]).

Sub-optimal pond management practices are common (e.g., limited use of fertilizer that could enhance the natural productivity of the pond).

Fingerling production is underdeveloped in Myanmar with a small number of hatcheries operating at a limited technological level. There were 26 active government hatcheries in 2016, producing about 644 million fish fingerlings (DoF, 2017), of which 68% were rohu. In addition to government hatcheries, an increasing number of private hatcheries (approximately 100 units) support the sector. In 2016, they produced 1,875 million fry and fingerlings.

A recent increase in productivity is mostly due to improved management practices with stocking larger fingerlings to reduce the culture period from 12 to 9 months and increasing feed. Productivity increases may be responsible for at least a third of the output growth that occurred over the past 10 years. However, intensive systems in Myanmar are limited to a small number of specialized farms producing marine fin fish or white shrimp (*Litopenaeus vannamei*), and a few farms producing pangasius and pacu.

Smaller-scale farmers depend on private hatcheries and the dense network of nurseries that have boomed with the increasing demand for large-scale fingerlings.

An aquaculture feed sector is emerging in Myanmar. Until recently, feed was mainly homemade feed, composed of locally available agricultural by-products, particularly rice bran and peanut oil cake. The total production capacity in Myanmar is increasing sharply, from 200 tonnes per day (t/day) in 2000 to 1,000 t/day in 2010. Until recently, the sector was dominated by one producing and distributing company (Htoo Thit). Other companies existed, but their share was limited. The cost of manufactured pellet is 10% to 30% higher than in other countries in the region due to a lack of competition in the sector.

Commercial feed pellets are not commonly used due to their high price. Only 15% of surveyed farms in the Ayeyarwady Delta and Yangon Regions (where the most intensive aquaculture is found) currently use manufactured pellets. Small-scale aquaculture farms base their feeding system on rice bran, peanut oil cake, and occasionally trash fish.

### VALUE CHAIN

There is rapid proliferation and development of small and medium enterprises (SMEs) in off-farm segments of the supply chain (ice manufacture and rural transport) linked to the intensification of fish farming (e.g., pond digging services, hatcheries and nurseries, and feed traders).

The feed market is highly concentrated and fish marketing channels are short, with the majority of farms selling to a single fish trader in the San Pya Market in Yangon. Access to credit is limited for small- and medium-scale fish farmers who borrow from informal lenders.

### ECONOMIC VALUE

The economic value of Myanmar's freshwater aquaculture production was estimated at 1.6 billion United States dollars (USD) in 2014, but recently dropped to USD 1.3 billion in 2015. The value of aquaculture depends marginally on its exports, with a maximum 14% of the total production exported. The sector is over-dependent on a single species, and other major internationally traded fish (i.e., tilapia and pangasius) do not represent a major share of the sector's production.

At the household level and in terms of job creation, aquaculture holds significance with important spillover effects along the value chain:

- In the Yangon and Ayeyarwady Regions, aquaculture generates a higher return per hectare than crops, with an average gross margin of USD 1,600/ha.
- Aquaculture's impact on the local economy is significant, creating four times more labor demand per acre than crop farms, especially in small fish farms. Fish farm wages are higher than crop farm wages and more beneficial to women when compared to wages in the crop sector.
- In small-scale aquaculture systems in the delta region, aquaculture makes a significant contribution to household incomes.
- Aquaculture fish have a higher price on the market than other sources and, therefore, may be less accessible to the poorest consumers compared to fish from other sources.

### INSTITUTIONAL AND LEGAL FRAMEWORK

Aquaculture is considered a nonagricultural land use. Thus, the conversion of any paddy land or other agriculture land into aquaculture is forbidden, and failure to cultivate agricultural land can result in confiscation.

Enforcement of the regulatory framework is context-dependent and varies from place-to-place. For example, some townships tolerate aquaculture development in rice fields or irrigation reservoirs while in other townships the law is strictly enforced.

### BARRIERS TO AQUACULTURE DEVELOPMENT

Institutional barriers to convert agricultural land to aquaculture are key constraints to aquaculture development within the basin. Legal barriers to fish trade between states are, to some extent, additional barriers to aquaculture development.

The aquaculture support system, including private and public extension service, remains weak, with a limited capacity and coordination with the development aid sector.

The overall value chain is functioning at a sub-optimal level, with limited access to input and inputs of low quality.

The sector lacks diversification and has an over-reliance on a single species (rohu), thus making the entire sector vulnerable and less resilient to shock (i.e., market fluctuations and diseases) and limiting exportation prospects.

Access to water is a constraint in certain parts of the basin, such as the Central Dry Zone.

### OPPORTUNITIES AND POTENTIAL INTERVENTION

As highlighted by the Myanmar Fisheries Partnership in 2016, the aquaculture sector in Myanmar has unique and competitive characteristics:

- Aquaculture is a high return activity with much higher earnings per hectare than crop farming in the delta region.
- Aquaculture creates more on-farm employment opportunities than agriculture.
- Small fish farms create more employment than large ones.
- Wages are higher on a fish farm than a crop farm, a finding that applies particularly to women.

The following drivers of change and interventions were identified for the development of a more competitive, spatially diversified, and small-holder inclusive sector:

- Enact the regulatory reform, creating a less restrictive legal framework for land and reservoir use for aquaculture and interstate trade.
- Support feed and input sector development to facilitate access by small scale farmers.
- Improve hard (i.e., road and electricity) and soft (i.e., extension services) infrastructure.
- Invest in fingerling production, hatchery infrastructure, and the capacity to diversify the production.
- Increase access to formal sources of credit for fish farmers and SMEs in the aquaculture supply chain. This can be achieved through the development of tailored lending instruments. Increasing credit to the sector would result in a less risky investment climate, increases in farm productivity, and greater volumes of investment along the supply chain.
- Train the workforce to meet the industry’s future needs. This requires a structured approach to educational curriculum development and capacity building, with coordination between universities, the private sector, DoF, and the civil society.
- Support small-scale aquaculture development to generate employment, to address food-security concerns, and to contribute to income generation.

# 1. INTRODUCTION

With a large network of natural waterways and a diverse aquatic environment, the Ayeyarwady Basin is characterized by a growing aquaculture sector. In this document, we present a review of the sector. Commonly available figures describe the national level, but where available, we present data specific to the Ayeyarwady Basin. Based on township mapping provided by the State of the Basin Assessment (SOBA) project, we counted 208 townships within the Ayeyarwady Basin, spread across the Sagaing, Magway, Bago, Ayeyarwady, Yangon, Nay Pyi Taw, Mandalay Divisions, and Chin, Kachin, and Shan States. Within these 208 townships, we obtained aquaculture production data from 174 townships, 23 of which have no record of aquaculture production. In the remaining townships, data were either not available or not collected at the district level.

# 2. AQUACULTURE HISTORY AND TRENDS

## 2.1. A Brief History of Modern Aquaculture in Myanmar

The aquaculture sector was institutionalized in 1954 with the establishment of an Aquaculture Section within the Agriculture and Rural Development Corporation (ARDC; Figure 1). Aquaculture expanded based on the capture and nursing of wild carp species fingerlings (i.e., rohu, catla, and mrigal). Tilapia was introduced from Thailand in the late 1950's followed by common carp from Israel and Indonesia in 1964. From there, the sector rapidly grew. In 1988, the annual growth rate of the sector was estimated to be as high as 40%, and the expansion of the sector continued with the introduction of hybrid clarias (1990) and pangasius culture (1994).

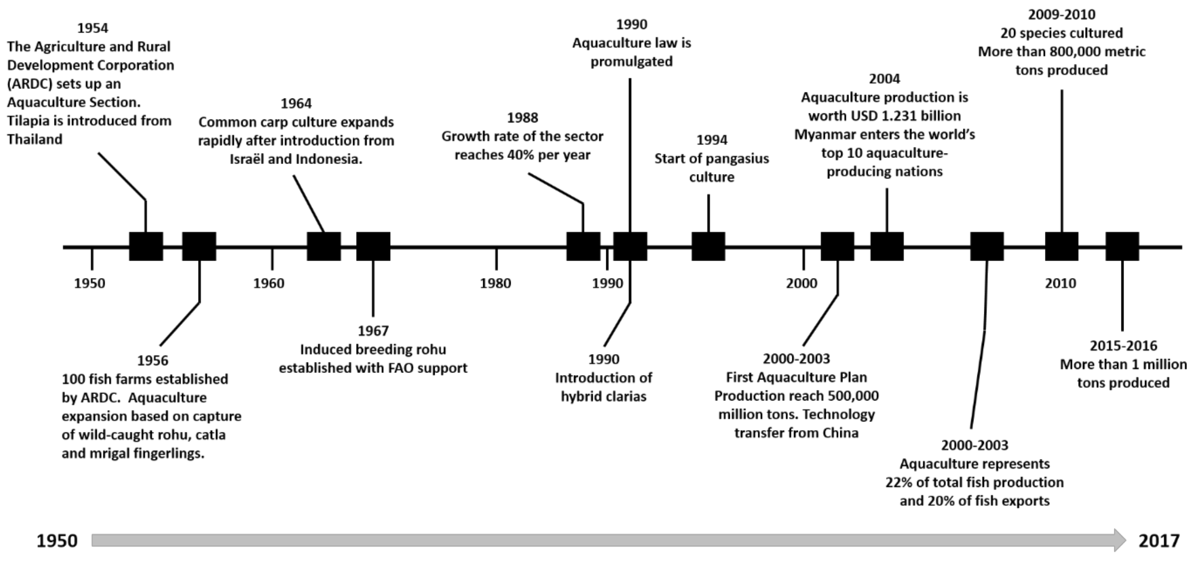


**Figure 1 – Timeline of the aquaculture development in Myanmar, 1950 to 2015 :***(FAO-NACA, 2003; Khin Maung Soe, 2008; DoF, 2011; Kye Baroang, 2013; FAO FIGIS, 2016)*

In 2000, the aquaculture sector continued its expansion, and Myanmar's first aquaculture plan was implemented, with a focus on shrimp and finfish aquaculture development. The sector had a production yield of 0.5 million metric tons. In 2004, Myanmar was listed among the world's top 10 aquaculture-producing nations, with a production value of USD 1.231 billion. By 2010, more than 20 species were cultured and the freshwater pond surface area reached 87, 134 hectares (ha). By 2016, annual freshwater aquaculture production was more than 900,000 metric tons. This rapid growth of aquaculture is illustrated in the production statistics presented in the section below.

### 2.2. Aquaculture Yields and Pond Area

In Table 1, we present two sources regarding aquaculture production: i) Department of Fisheries (DoF) data (2016 and 2017) and ii) Food and Agriculture Organization of the United Nations – Fisheries Global Information System (FAO FIGIS) data (2016). Although some Food and Agriculture Organization of the United Nations (FAO) data were derived from DoF data, discrepancies can be found between the two data sets, even after 2007 when FAO data originated from DoF and not from an available source of information or calculated based on specific assumptions as it had been in years prior. Aquaculture statistics in Myanmar need to be considered with caution. In their recent study, Belton et al., (2015) estimate over-reporting of aquaculture production by as much as 164% after calculating production based on national consumption figures and trade of fish. Comparisons between the two data sets are challenging, since DoF data are presented on a seasonal rather than an annual basis and do not distinguish freshwater from marine fish or finfish from crustaceans. Nevertheless, aquaculture statistics from FAO estimate freshwater aquaculture to account for 90% to 95% of total production. Production more than doubled in a decade (2004 to 2014) with an average fitted annual growth rate of 8.7% based on DoF data (Belton et al., 2015). Most freshwater aquaculture is located within the boundary of the Ayeyarwady Basin.

At the regional level, freshwater aquaculture production reaching more than 900,000 metric tonnes annually makes Myanmar the third largest freshwater fish aquaculture sector in Southeast Asia , and is larger than Thailand since 2007), behind Indonesia and Vietnam (FAO FIGIS, 2016). In 2017, aquaculture production in the Ayeyarwady Basin reached an estimated 958,000 metric tons s, accounting for 91% of the total aquaculture production of the country.

**Table 1 – Comparison of FAO and DoF data on aquaculture production in Myanmar, in metric tons.** *(DoF, 2016; FAO FIGIS, 2016)*

| | FAO FIGIS Data | | | DoF Data Total Aquaculture | |
|---|---|---|---|---|---|
| | Freshwater Aquaculture | Total Aquaculture | | | |
| 2003 | 232,989 | 252,010 | | 2003-04 | 400,360 |
| 2004 | 370,810 | 400,360 | | 2004-05 | 485,220 |
| 2005 | 436,580 | 485,220 | | 2005-06 | 574,990 |
| 2006 | 525,864 | 574,990 | | 2006-07 | 616,350 |
| 2007 | 556,357 | 604,660 | | 2007-08 | 687,670 |
| 2008 | 617,859 | 674,665 | | 2008-09 | 775,250 |
| 2009 | 697,299 | 750,656 | | 2009-10 | 858,760 |
| 2010 | 772,396 | 823,348 | | 2010-11 | 830,480 |
| 2011 | 760,939 | 815,382 | | 2011-12 | 898,960 |
| 2012 | 826,944 | 883,438 | | 2012-13 | 929,380 |
| 2013 | 870,256 | 926,175 | | 2013-14 | 964,120 |
| 2014 | 902,706 | 946,551 | | 2014-15 | 999,630 |
| 2015 | 944,108 | 999,630 | | 2015-16 | 1,014,420 |
| | | | | 2016-17 | 1,048,690 |

With a total pond area of more than 455,000 acres nationwide (Table 2), experts distinguish between approximately 220,000 acres (90,000 ha) of freshwater aquaculture and approximately 220,000 acres of brackish water aquaculture (shrimp farming; Landbouw-Economisch Institut [LEI] Wageningen Universiteit en Researchcentrum [UR], 2012; Improving Research and Development of Myanmar's Inland and Coastal Fisheries [MYFish], 2013a; Gregory, 2013). For the latter category, most of the surface area is located outside the Ayeyarwady Basin in Rakhine State.

Pond surface area for aquaculture did not increase as quickly as production increased (Table 2 and Figure 2). Since 2006, the annual growth rate is limited to 0.5%, after a sharp increase of 10.6% per annum between 2004 and 2007. According to Belton et al. (2015), such an increase in production without significant pond area expansion, in a context where aquaculture intensification did not yet happen, is somewhat implausible and led to assumptions of over-reporting aquaculture production. If we consider only townships within the Ayeyarwady Basin, the total area dedicated to aquaculture is approximately 278,841 acres in 2017, accounting for an estimated 57% of total aquaculture area in the country.

**Table 2 – Area of aquaculture ponds (acres) and fish ponds (acres) between 2003 and 2017 in Myanmar and in selected states and divisions of the Ayeyarwady Basin*** *(DoF, 2017)*

| | Area of Pond in Myanmar (Acres) | Area of Fish Ponds (Acres) | Area of Pond in Ayeyarwady Basin* (Acres) |
|---|---|---|---|
| 2003–2004 | 360,357 | | |
| 2004–2005 | 389,806 | | |
| 2005–2006 | 405,855 | | |
| 2006–2007 | 436,825 | 212,234 | |
| 2007–2008 | 441,098 | 215,373 | |
| 2008–2009 | 440,585 | 215,930 | |
| 2009–2010 | 442,702 | 217,835 | |
| 2010–2011 | 443,695 | 218,746 | |
| 2011–2012 | 448,469 | 220,171 | |
| 2012–2013 | 449,692 | 221,395 | |
| 2013–2014 | 450,324 | 222,028 | |
| 2012–2013 | 469,153 | 232,515 | |
| 2015-2016 | 478,002 | 239,671 | 255,835 |
| 2016-2017 | 487,525 | 245,807 | 278,841 |

*The Ayeyarwady Basin includes: Kachin State; Sagaing, Magway, Bago, Ayeyarwady, Yangon, Nay Pyi Taw, and Mandalay Divisions; Chin State; and part of Shan State for a total of 208 townships.

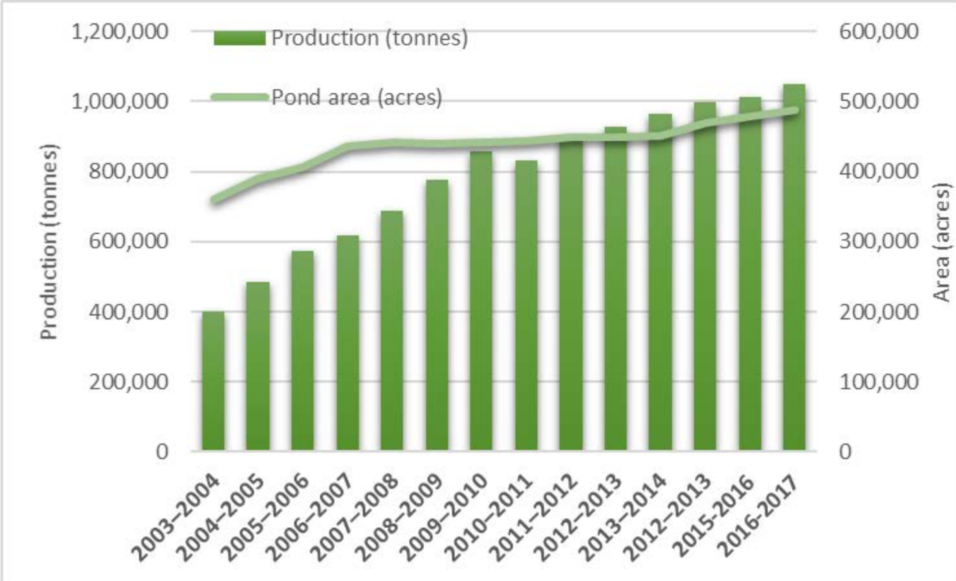


**Figure 2 – Trends in area of aquaculture ponds (acres) and production (metric tons) between 2003 and 2016 in Myanmar.** *(DoF, 2017)*

In addition to over-reporting of aquaculture production, a recent study in the Ayeyarwady and Yangon Regions showed that pond areas are significantly under-reported in both regions (Belton et al., 2017a). Only ponds larger than 64 square metres ($m^2$) are reported, since smaller ponds do not require licencing. Past studies (FAO-NACA, 2003; MYFish, 2014a) report only a limited number of small ponds below 1 acre (0.4 ha), while a recent survey of satellite images identified more than 200,000 small backyard ponds (0.002 ha to 0.2 ha) in the southern Ayeyarwady Delta. These homestead ponds were originally dug for domestic water supply, but field visits confirm that they are increasingly used for growing fish, essentially for family consumption (Belton et al., 2015). Although this increasing small-scale activity is not formally recorded, it likely contributes to an increased total production and depicts a number of households significantly dependent on small-scale aquaculture for their livelihood.

Ayeyarwady and Yangon Regions are the source of 90% of Myanmar's farmed fish production, where the production rocketed 250% over the past decade. In these regions, large farms (more than 100 acres) account for 8% of farms, but 60% of the total pond area (Belton et al., 2017a). Farms in the 10 to 50-acre bracket (4 to 20 ha) account for 32% of the total number of farms and 24% of the total farm area. The majority of farms (49%) are of medium size (10 acres), but these are often absent in literature and national debate (Belton et al., 2017a). This analysis of farm size distribution, together with Belton et al. (2015) and WorldFish's (2014) previous analyses, provides a more complex picture of the aquaculture sector. These numerous small- and medium-scale farms contribute significantly to the sector, yet are not usually acknowledged.

# 1. SPATIAL DISTRIBUTION OF AQUACULTURE

Aquaculture in the Ayeyarwady and Yangon Regions (West of Yangon and near Bago)is highly concentrated in clusters of farms. The latter account for almost 80% of Myanmar's inland fish ponds. The Ayeyarwady and Yangon Regions account for 51% and 31% of the basin's pond area, respectively, while the Bago, Sagaing, and Mandalay Regions account for only 10%, 2%, and 2%, respectively. Other states represent less than 1% of the basin pond area in 2017. Since 2006, the growth rate was limited, with records below 1% in the Ayeyarwady Region, 2.3% in the Yangon Division, and only a 7% annual growth rate recorded in Kachin State. The current spatial distribution of aquaculture originated before 2006, with limited expansion over the last decade.

Four townships[1] account for nearly 52% of the basin's estimated pond area (143,710 acres in 2017). Maps depict these clusters of aquaculture, located in the Ayeyarwady Delta around Yangon, with townships where aquaculture pond area is recorded as being more than 10,000 acres (up to 54,000 acres). In the rest of the basin, townships account for less than 5,000 acres (Figure 3). Only Bago and Mandalay Regions count one township with more than 5,000 acres of aquaculture ponds. Two townships, located in Kachin (1,004 acres) and Sagaing (2,748 acres), report more than 1,000 acres allocated to aquaculture.

As for aquaculture area, the number of aquaculture farmers follows the same spatial distribution, with a concentration of farmers in the Ayeyarwady Delta (Figure 4). Kawa Township in the Bago Region shows the highest number of registered aquaculture farmers (2,126 farmers registered in 2017), with an average farm size of one acre. This may indicate the highest concentration of small-holder aquaculture farmers. Some townships in the higher part of the basin, in Chin and Kachin States and Mandalay and Sagaing Regions, record more than 500 farmers, which is more than most of the other townships. Besides Shewbo Township, the other townships have a limited aquaculture area, indicating that this sector is mostly composed of small-holder aquaculture farmers.

The average farm size per farmer shows wide disparity between townships. The average farm size is more than 50 acres in the main producing townships of Yangon and Ayeyarwady Regions, with a clear accumulation of land in the Kyauktan Township. Here, the average farm size is 156 acres and is characterized by large extensive aquaculture ponds. Using the land size classification according to Belton et al. (2017b), seven townships have an average farm size below 10 acres, 25 between 10 and 40 acres, and 7 above 40 acres.

The three townships with the largest aquaculture area reach production levels above 100,000 metric tons per year (Figure 5). Only 10 other townships had a production record above 10,000 metric tons in 2017, of which only three are located outside Yangon and Ayeyarwady Divisions (in Bago and Mandalay). Outside the Bago Division and the delta area, only Shwebo Township in the Sagaing Division and Madaya Township in the Mandalay Division produced more than 5,000 metric tons of aquaculture product.

Aquaculture production is clearly concentrated in the delta region within several clusters of aquaculture farms (the main producing areas in the country). Spillover effects from other townships exists, with higher production in the Bago Division and neighboring townships in the delta. The Sagaing Region and the region around the city of Mandalay represent the second highest concentrated production area, but of lower production intensity than in the delta.

According to available data, the entire basin (174 townships) includes 70 townships that produce less than 100 metric tons per year of aquaculture products. Computing statistical data to estimate average productivity per hectare results in aberrant data with exceptionally high productivity, thus bringing into question the accuracy of the data recorded at the township level and the real productivity of the farms.

1 Twantay Township in the Yangon Division and Maubin, Pantanaw, and Nyaungdon Townships in the Ayeyarwady Division

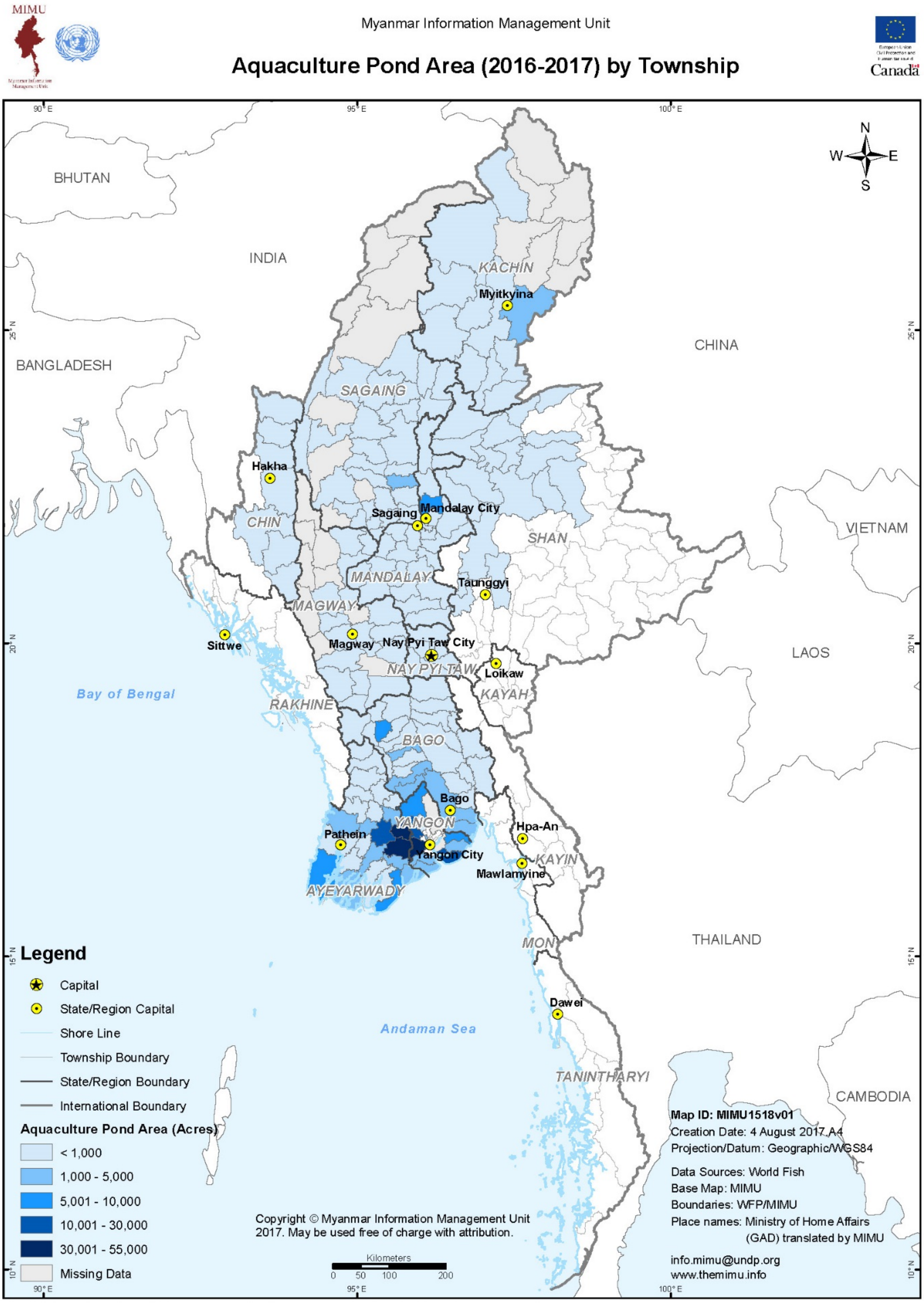


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**Figure 3 – Aquaculture area (acres) in the Ayeyarwady Basin by township (2016 to 2017)**

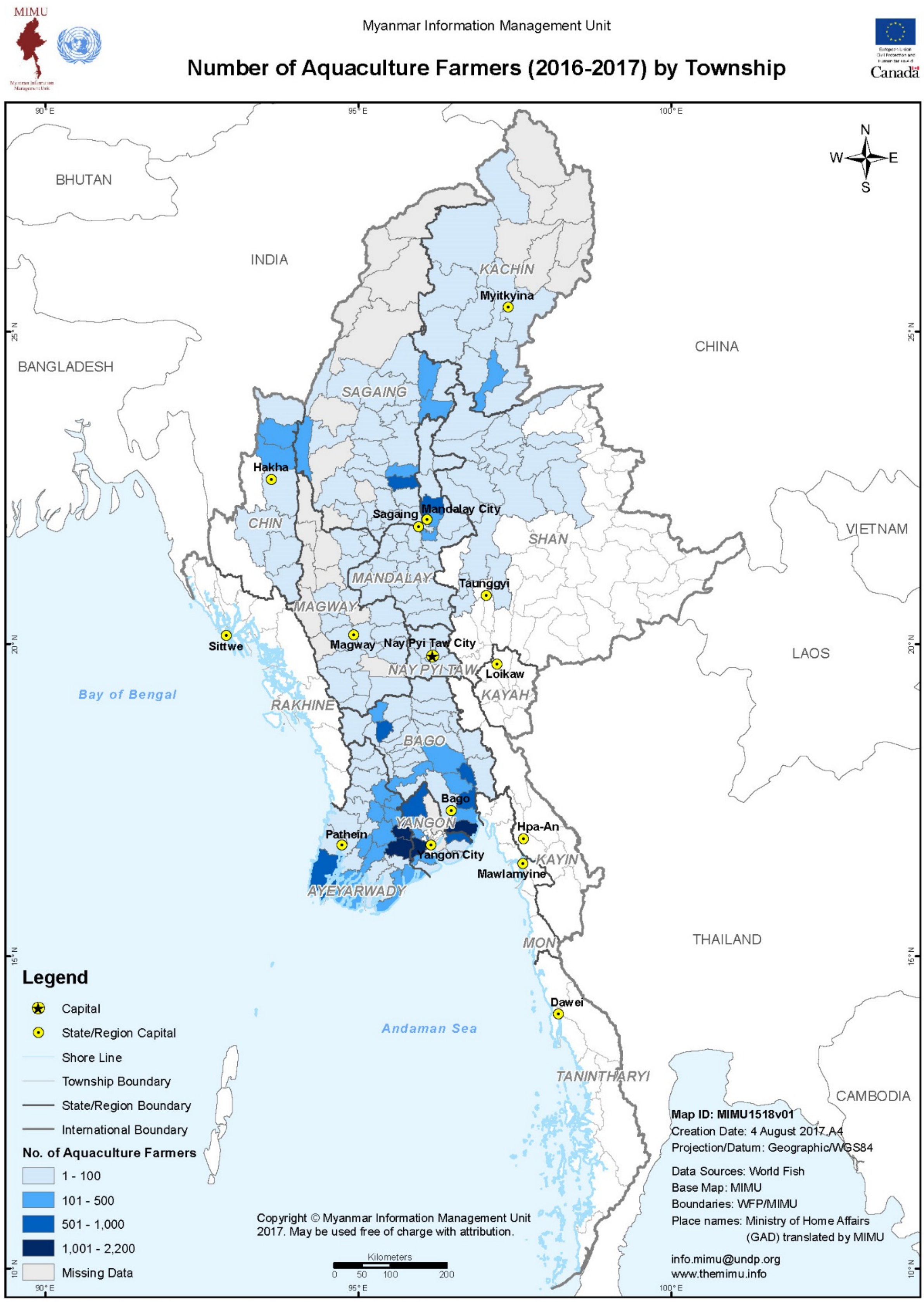


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**Figure 4 – Number of aquaculture farmers in the Ayeyarwady Basin by township (2016 to 2017)**

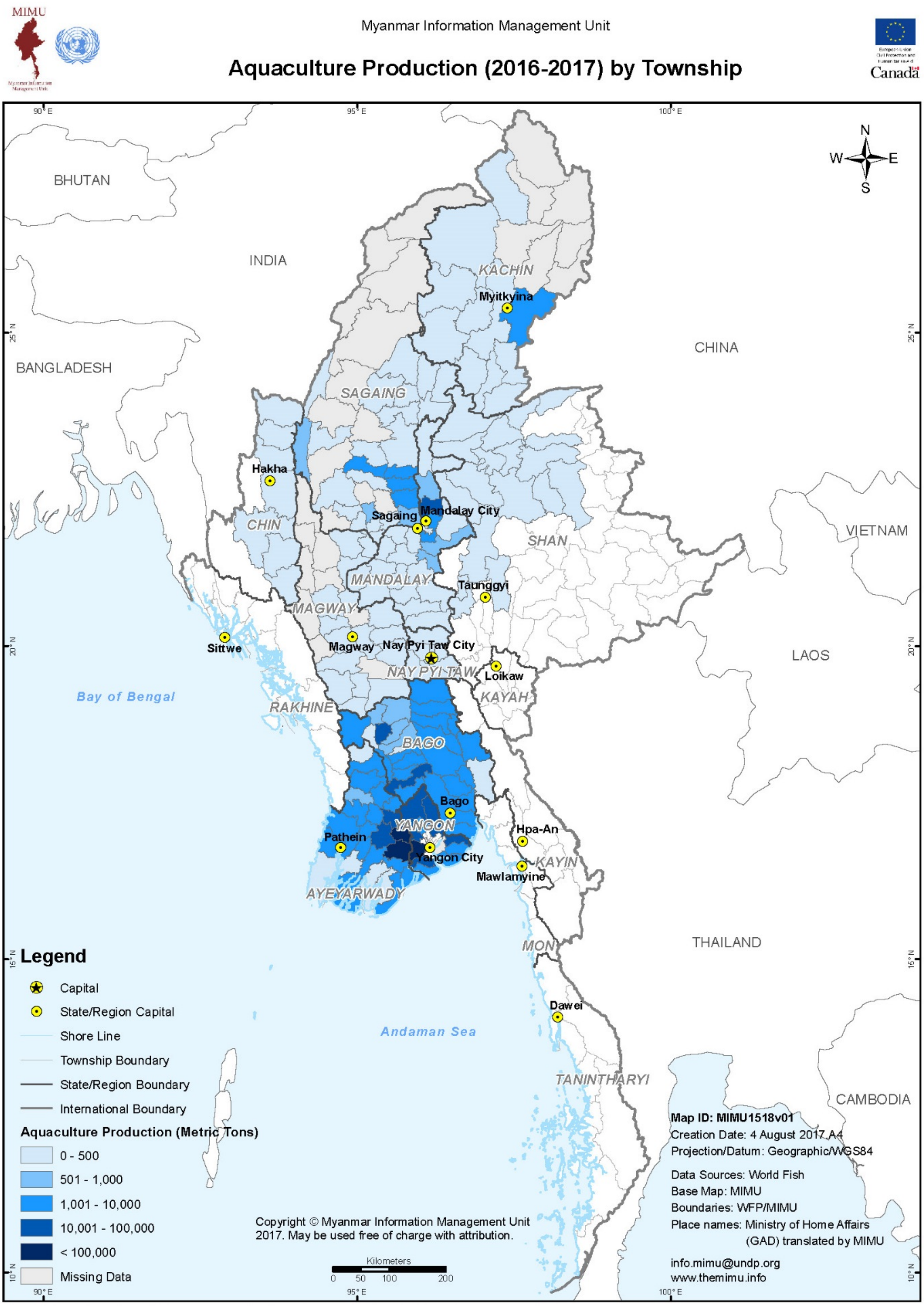


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Figure 5 - Aquaculture production (metric tons) in the Ayeyarwady Basin by township (2016 to 2017)

# 2. AQUACULTURE SPECIES

The selection of aquaculture species is dictated by the availability of fingerlings, ease of culture method, and market access.

Aquaculture clusters in the delta increased at various rates between 2004 and 2017. These clusters are located in an area with facilitated access to transport, water, and urban centre markets. In these clusters, carp polyculture (with rohu as the dominant species) is the main production system. Other commonly stocked species in these polyculture systems are mrigal, catla, pangasius, and pacu. Giant freshwater prawn and tilapia exist, but stocking these species is limited by the absence of proper seed production (Belton et al., 2015). DoF (2017) reports freshwater prawn and fish polyculture farms of approximately 7,500 ha in the country.

In saline water areas of the delta, there are more diverse aquaculture species. These include swamp eel (*Monopterus albus*) culture; high-market value fish, such sea bass (*Lates calcarifer*); featherback (*Notopterus notopterus*, *Chitala spp.)*, swamp eel and/or whisker catfish (*Wallago attu*); mud crab (*Scylla olivacea*); tiger shrimp (*Penaeus monodon*); and tilapia, both *Orechromis niloticus* and *O. Mossambicus* (WorldFish, 2014). These species are cultured in the delta area.

Carp monoculture is the most common system in the Central Dry Zone (i.e., parts of the Middle and Lower Ayeyarwady Basin), but rohu, catla, mrigal, and puntius species are also found there. Carp polyculture with organic fertilization and supplementary feeding is not practiced by small-scale aquaculture farmers as frequently as in other regions of Myanmar. In the middle area of the basin, aquaculture is more dynamic and diversified with pangasius, silver bar (*Barbonymus gonionotus*), and grass carp (*Ctenopharyngodon idella*) in medium-scale farms.

In the western part of the basin, in Chin State, rohu is dominant in small-scale systems. Other primary species are pangasius, pacu, tilapia, puntius, common carp, and mrigal. These are raised at low density with limited productivity. Main aquaculture species in each region and agro-ecological zones are summarized in Table 3.

**Table 3 – Main aquaculture species by region and agro-ecological zone in Myanmar** *(MYFish, 2014a and b; Belton et al., 2017a; Johnstone et al., 2013)*

| Region | Agro-Ecological Zone | Species and Systems |
|---|---|---|
| Ayeyarwady Delta | Freshwater | Carp monoculture and polyculture |
| | Brackish water | Carp monoculture and polyculture<br>Eel culture<br>Wild fish culture<br>Crab fattening<br>Shrimp culture |
| Lower Ayeyarwady<br>Magway, Pyay | Freshwater<br>Lowland – limited water availability | Rohu, mrigal, catla, and big head |
| Middle Ayeyarwady | Lowland and irrigated areas | Rohu – small and medium scale<br>catla, mrigal, grass carp, pangasius, silver barb, tarpian, and spiny turbot |
| Chin State | Freshwater<br>Lowland and irrigated areas | Rohu – small scale<br>pangasius, pacu, tilapia, puntius, common carp, and mrigal |

# 1. PRODUCTION SYSTEMS

## 1.1. Production by Species and End Market

Between 2003 and 2010, the number of species cultivated in ponds increased from approximately four species (rohu and common carp along with some tilapia in larger ponds and grass carps in Shan State) to more than 20 species (DoF, 2011). Rohu made up 80% of the fish harvest from 2006 to 2016 in the primary fish growing regions of Myanmar (Belton et al., 2017a). Currently, rohu remains a dominant species (Figure 6), representing 70% of Myanmar's aquaculture production (Belton et al., 2015).

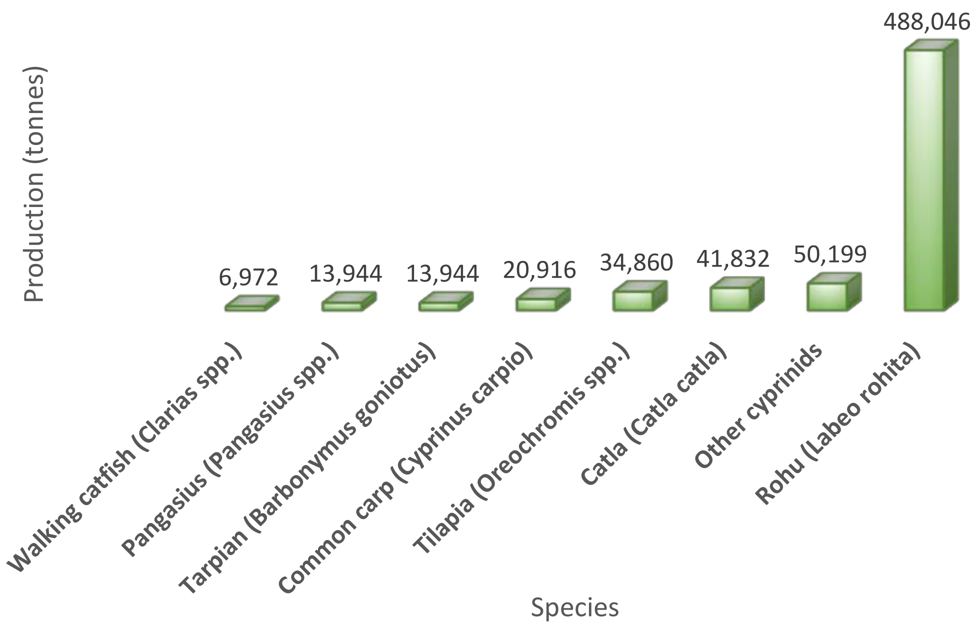


**Figure 6 – Freshwater aquaculture production in Myanmar in 2009 by major species (metric tons)** *(SEAFDEC, 2012)*

Generally, production targets the domestic market (Belton et al., 2015), with an estimate of no more than 14% of farmed fish exported between 2004 and 2014. Rohu, mrigal (*Cirrhinus cirrhosis*), and catla (*Gibelion catla*) are the main exported species. Myanmar is the largest exporter of rohu in the world (Johnstone et al., 2012). The destination market is neighboring countries with a dense South Asian expatriate population. China and Singapore are target markets for the export of mud crab from coastal and delta regions (LEI Wageningen UR, 2012). Tilapia farms are now emerging outside of the Ayeyarwady Basin in the Shan State bordering China, with technology transfer from China and supply to the Chinese market (R. Gregory, pers. com).

Recent interviews with DoF representatives from different townships across the basin depict rohu, mrigal, and catla as the top-three species. Other popular species identified are pangasius, tilapia, silver barb, puntius, and other type of carps (common carp or grass carp) grown in small-scale farms. This production is aimed at the domestic market and usually sold locally. Between 2010 and 2017, the types of species raised and their importance did not significantly change according to the DoF officer interviewed.

Major aquaculture species in Asia, such as walking catfish (*Clarias batrachus*), sea bass (*Lates calcarifer*), climbing perch (*Anabas testudinaeus*), stinging catfish (*Heteropneustes fossilis*), and striped snakehead (*Channa striata*), are absent despite featuring a high price in local markets. Farming these species will require better access to cheaper inputs, higher quality feeds, equipment (paddle wheels), fingerlings, and upgraded infrastructure (stable electricity supply). Introducing this technology from neighboring countries could be a potential area for expansion (and diversification) of aquaculture in Myanmar.

## 1.2. Aquaculture Management Practices

Intensive systems in Myanmar are limited to a small number of specialized marine farms producing fin fish and white shrimp (*Litopenaeus vannamei*) and a few farms producing pangasius and pacu. Polyculture in a semi-intensive system dominates the sector, with rohu accounting for 50 to 80% of the stocked biomass (Belton et al., 2017b). In these systems, where fish derive nutrients from both natural feed produced in the pond (phytoplankton and zooplankton) and from external inputs of supplemental feed, productivity ranged from as little as one tonne per hectare (t/ha) to a maximum of 10 t/ha, with a mean of 3.7 t/ha.

Analysis of the production system shows that technology applied to these fish farms is sub-optimal (Belton et al. 2017b). Van Driel and Nauta (2013) showed that large-scale units in the Ayeyarwady Delta strategized their production on slow growing commercial units, reaching a grow-out period of up to 24 months. More recently, a study in the delta showed that the use of fertilizer and pelleted feed is limited, with only 15% of the farms using manufactured pelleted feed (Belton et al., 2017a). Similar sub-optimal practices are also found in the Central Dry Zone (Seng Lat et al., 2014). Because of these practices, yields are modest, averaging 4.8 t/ha in carp polyculture. Productivity is highly variable due to significant differences in operation investments between farms. Larger farms that record higher yield also record twice as much investment in feed cost than small farms with limited investment capacity (Belton et al., 2017a). In the sub-section below, we review key literature on management practices (stocking density and feed) and the productivity of main production systems.

### *1.2.1. Fingerlings and stocking density*

Fingerlings are either sourced from a hatchery and wild source (carp and tiger shrimp) or, in a few cases, depend entirely on wild stock (swamp eel, mud crab) (MYFish, 2014a). Fingerling production is under-developed in Myanmar, with a small number of hatcheries operating at a limited technological level. There were 26 active government hatcheries as of 2016, producing about 644 million fish fingerlings (DoF, 2017), 68% of which are rohu. Fingerling production is concentrated in the Yangon and Mandalay Regions (DoF, 2016), but most of the production is used to stock natural waterbodies (Belton et al., 2015). The contribution of state hatcheries to national production is limited, especially in the delta where private sector seed production is well-developed. In addition to government hatcheries, an increasing number of private hatcheries and backyard hatcheries (approximately 100 units) support the sector (Belton et al., 2015). Their production reached 1,875 million fry and fingerlings in 2017 (DoF, 2017).

The most common technology used in hatcheries is the ‘hapa-based’ system for spawning carps. More advance systems, such as manually stripping brood fish of eggs and milt following hormone injection or using funnel shaped incubator nets suspended in concrete tanks for hatching, are less common (Belton et al., 2015).

Large, vertically integrated farms usually own their own hatchery and nursery (Belton et al., 2017b). Small-scale farmers depend on private hatcheries and a dense network of nurseries that flourished with increasing demand for large-scale fingerlings. Belton et al. (2017b) estimate that, among the aquaculture clusters surveyed, specialized nurseries growing juvenile fish (“seed”) for sale to grow-out farms account for 41% of all aqua-farms. Overall, 66% of all grow-out farms obtain their fingerlings off-farm.

Stocking size differs according to the region and the strategy deployed by producers:

- In the Yangon and Ayeyarwady Regions, farmers prefer to stock yearlings 12 to 15 centimetres to shorten the culture cycle and reach market size within 9 months, with smaller farms stoking larger fingerlings.
- In the Lower and Middle Ayeyarwady Basin, it is common practice to stock fingerlings of 2 to 5 centimetres and to have a longer grow-out period.

In addition to regional differences, there are also different stocking strategies between large and small farms. Large farms tend to stock at low density (0.11 fish/$m^2$), with a high feeding rate and a longer production cycle to target large-scale fish with high unit value and high total biomass. Small farms have more of a short-term strategy due to constraints in resource availability. They tend to stock large-sized fingerlings at higher density (0.47 fish/$m^2$), with relatively less feed, for a quick harvest (Belton et al., 2017a). Examples of stocking density and productivity of various production systems are given in Table 4.

**Table 4 – Stocking density, production, and gross income for different aquaculture systems in the Ayeyarwady Delta and Central Dry Zone** ***(Belton et al., 2017a; WorldFish, 2014a and b)***

| Aquaculture Systems | Stocking Density (Pieces/$m^2$) | Production (kg/ha/year) | Gross Income (x 1,000 MMK/ha/year) | Source |
|---|---|---|---|---|
| **Ayeyarwady Delta** | | | | |
| Carp monoculture | 0.4 - 0.8 | 378 | 482 | *MYFish, 2014a* |
| Carp polyculture | | 1,507 | 1,912 | *MYFish, 2014a* |
| Carp polyculture | 0.1 - 0.4 | 3,800 - 6,100 | 1,937 | *Belton et al., 2017a* |
| Swamp eel culture | 3.6 | 633 | 3,178 | *MYFish, 2014a* |
| Mud crab fattening | 0.8 | 6,387 | 14,069 | *MYFish, 2014a* |
| Tiger shrimp culture | 2.4 | 254 | 763 | *MYFish, 2014* |
| Wild fish culture | 1.9 | 546 | 601 | *MYFish, 2014a* |
| **Lower and Middle Basin** | | | | |
| Carp monoculture | 0.5 - 1.9<br>0.2 - 0.4 | 1,925 - 2,357<br>800 - 4,800 | 3,530 - 3,981* | *MYFish, 2014b DoF*** |
| Tilapia monoculture | 0.3 | 1,771 - 1,925 | 3,284 - 3,612* | *MYFish, 2014b* |
| Polyculture | 1.0  1.1 | 1,503 - 2,108 | 3,183 - 3,506* | *MYFish, 2014b* |
| Wild fish culture | 0.8 | 1,788 | 4,044* | *MYFish, 2014b* |
| Pangasius | 0.24 | 3,167 | m.d | *DoF*** |
| Silver barb | 0.24 | 2,400 | m.d | *DoF*** |
| **Chin State – Western Basin** | | | | |
| Tilapia | 0.25 | 2,909 | m.d | *DoF*** |
| Rohu | 0.49 | 3,878 | m.d | *DoF*** |
| Pacu | 0.37 | 4,363 | m.d | *DoF*** |
| Common carp | 0.12 | 727 | m.d | *DoF*** |
| Pangasius | 0.49 | 5,817 | m.d | *DoF*** |
| Grass carp | 0.02 | 121 | m.d | *DoF*** |

*Note: Conversion from USD/ha to MMK done by the authors: 1 USD = 1,366 MMK.
Average pond size in Central Dry Zone: 3.3 ha (MYFish, 2014a) and 0.5 ha (*MYFish, 2014b*) in the Ayeyarwady Delta.
m.d. = missing data
**DoF= Interview with DoF at township level

Stocking densities reported by DoF during interviews are similar to what is found in the literature; however, productivity seems to be higher. For example, carp monoculture is said to reach more than 4 tonnes/ha, which may be an over-estimate or represent a limited number of semi-intensive farms.

In the Ayeyarwady Basin, stocking density is variable, but it is generally lower than in Andhra Pradesh in India (Belton et al., 2017b). Yields reported in Table 4 are low for the broader region, where average yields reach nine tonnes/ha (Belton et al., 2017b), and pangasius farming is far from reaching a productivity level comparable to Vietnam (200 to 400 t/ha).

The recent increase in productivity is mostly due to improved management practices, stocking larger fingerlings to reduce the culture period from 12 to 9 months and increase in feed use (Belton et al., 2017b). The latter authors estimate that increases in productivity may be responsible for at least one-third of the output growth that occurred over the past 10 years. Doubled pond area is the other major factor explaining the rapid increase of aquaculture production. However, farm productivity has increased less rapidly than the apparent yields would suggest (calculated from official statistics) (Belton et al., 2015).

### *1.2.1. Feed and pond management*

In extensive and semi-intensive systems, fertilization is a simple technique to enhance the natural productivity of the pond. However, only 25% of farms surveyed used any kind of fertilizer, and in those farms, fertilizers accounted for less than 1% of total operating costs (Belton et al., 2017a). This limited use of fertilizer is identified as an area of improvement for pond management. Currently, fish farmers in Myanmar do not maximize their productivity by enhancing the natural productivity of the pond.

Feed is the main operating cost for aquaculture farmers (Hla Win, 2004; Belton et al., 2015; Belton et al., 2017a). On average, feed represents 70% of the operational cost (average cost of USD 3,300/ha), followed by fingerlings (9%), non-feed inputs (fuel and fertilizer, 7%) and labor (4% of the operating costs) (Belton et al., 2017a).

An aquaculture feed sector is emerging in Myanmar. The total production capacity is sharply increasing, from 200 tonnes/day in 2000 to 1,000 tonnes/day in 2010. Until recently, the sector was dominated by one producing and distributing company - Htoo Thit. Other companies exist, but their share is limited. International companies are now investing in an aquaculture feed mill in Myanmar.

Most feed used by fish producers is homemade feed, made up of locally available agricultural by-products, such as rice bran and peanut oil cake. Other, less frequently used agro-processing by-products include sesame, sunflower, and other oil cakes; wheat bran; broken rice; processing waste from pulses and cassava; and brewery waste (Belton et al., 2015).

Belton et al. (2015) estimate that 80% of aquaculture production in Myanmar is dependent on the use of agricultural by-products and waste as feed, with the remainder using manufactured pellets. Commercial pellets are not commonly used due to their high price. Only 15% of surveyed farms in the Ayeyarwady Delta and Yangon Region, where the most intensive aquaculture is found, currently use manufactured pellets (Belton et al., 2017a). In the delta (Hlegu and Kayan cluster) and Chin State, integrated poultry-aquaculture farms are found, with different operational models. Belton et al. (2017) reports that 75% of the ponds in Hlegu Township are designed with broiler or layer chickens housed over fish ponds.

Of small-scale aquaculture farms surveyed in the delta, none used commercial pellets with a feeding system based on rice bran, peanut oil cake, and, occasionally, on trash fish (MyFish, 2014a). A similar pattern was observed in the Central Dry Zone, with limited use of commercial pellets and peanut oil cake. Seng Lat et al. (2014) observed that more than 80% of small-scale fish farmers and 33% of medium-scale fish farmers in Shwebo usually find it difficult to feed their fish. The cost of manufactured pellet is considered to be 10% to 30% higher than in other countries in the region, due to a lack of competition in the sector. Farmers' practices focus on combining rice bran and peanut oil cake at a lower cost to optimize fish growth. Feed management and overall pond management techniques are sub-optimal, with potential for important margins of progress.

## 1.1. Value Chain Segments

In-depth studies of aquaculture value chain segments are found in Belton et al. (2015 and 2017a) and are limited to the Ayeyarwady Delta and Yangon Regions. Authors found that there is a rapid proliferation and development of small and medium enterprises (SMEs) in off-farm segments of the supply chain (ice manufacture and rural transport), linked to intensification of fish farming (e.g., pond digging services, hatcheries and nurseries, and feed traders). The feed market is highly concentrated, with more than 50% of the farms using commercially manufactured pellets and buying that feed from a single company. Marketing channels are simple, with many farms selling to a single fish trader who then trades in the San Pya Market in Yangon.

The vast majority of investment and operating capital for aquaculture is raised from informal sources of which fish traders appear to be the most important, particularly for larger farms. Access to credit is limited for small- and medium-scale fish farmers who borrow from informal lenders at 4 to 6% per month. Large farms can access credit to buy feed from large fish traders at interest rates of 3% per month, resulting in an increasing debt burden (WorldFish, 2014).

# 1. ECONOMIC VALUATION AND LIVELIHOOD IMPORTANCE

## 1.1. Macro-Economic Role

Only FAO FIGIS produced statistics about the economic value of the aquaculture production. The economic value of Myanmar's freshwater aquaculture production was estimated at USD 1.6 billion in 2014 (FAO FIGIS web database query, July 2017), corresponding to USD 1,645 per metric tonne. This value has increased steadily since 2007, but recently dropped to 1.3 billion in 2015 (Figure 7).

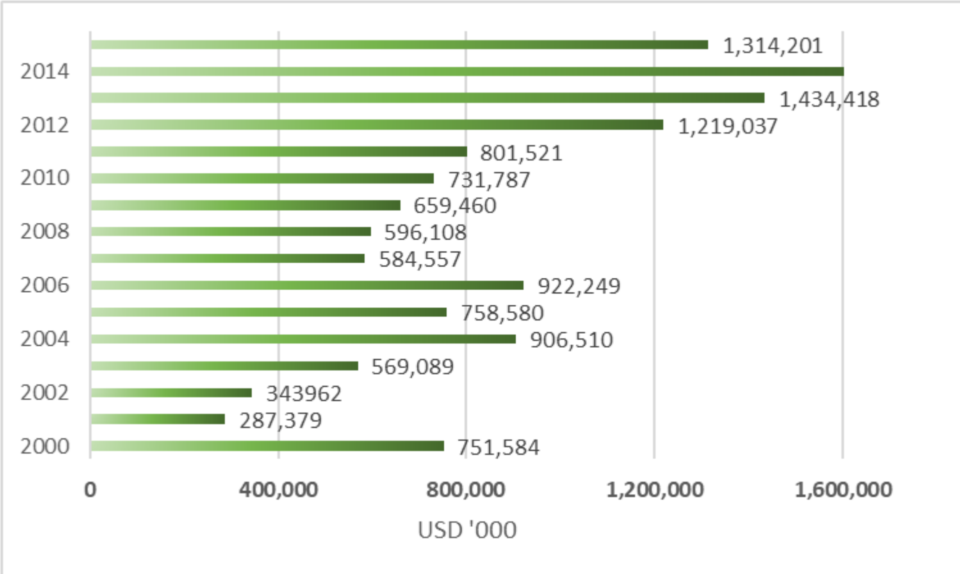


**Figure 7 – Value of freshwater aquaculture in Myanmar (USD x 1,000) between 2000 and 2015** *(FAO FIGIS database query, July 2017)*

The market price and economic value of aquaculture production varies seasonally, with a strong influence from capture fisheries on aquaculture product's market price. Leasable fisheries are closed from May to July. During this time, the price of aquaculture fish rises. Farmers produce less from November to January to avoid competition with the capture sector (Johnstone et al., 2013).

The value of aquaculture depends marginally on its exports, with a maximum of 14% of the total production exported. Export is dominated by rohu, representing 86% of the total export in volume in 2012 (Belton et al., 2015). This export targets a South Asian expatriate population, primarily in Kuwait, Saudi Arabia, and Bangladesh. Belton et al. (2015) define this export strategy as an 'ethnic niche,' suggesting that rohu export for the international market has limited expansion potential. Aquaculture experts perceive this singularity as an over-dependence on a single species and a constraint to further growth of the sector. With recent political tensions with Bangladesh, export to this country is now limited. The same applies to exports to the Gulf countries, this time due to a non-profitable exchange rate.

## 1.2. Importance at the Household Level

In aquaculture clusters located in the Yangon and Ayeyarwady Regions, aquaculture generates higher return per hectare than crops, with an average gross margin of USD 1,600/ha (Belton et al., 2017a). Fish farming households are twice as well-off as the general population. In small-scale aquaculture systems of the delta, aquaculture makes a significant contribution to household income (WorldFish, 2014). The impact of aquaculture on the local economy is significant, as it creates four times more labor demand per acre than crop farms, especially in small-fish farm. Fish farm wages are also higher than crop farms and are more beneficial to women than in the crop sector (Belton et al., 2017a).

There is a debate over the accessibility of aquaculture fish, which requires some nuancing. Some specialists consider that aquaculture fish have a higher market price than wild fish, and therefore, may be less accessible to the poorest consumers (Belton et al., 2015). However, people consulted during the course of the study indicate that wild fish is seen as more tasty and valuable than aquaculture fish, but this actually applies to top-quality capture species, such as large catfishes. In fact, high grade aquaculture fish (e.g., rohu and mrigal) are cheaper than high quality wild fish (e.g., whiskered catfish and hilsa). Trend analysis shows that the price of aquaculture fell by an average of 2% between 2008 and 2014, highlighting the future role of aquaculture in Myanmar's fish supply (Belton et al., 2015).

# 2. INSTITUTIONAL AND LEGAL FRAMEWORK

Duties of the Aquaculture Division within DoF include the following:

- Overseeing the development of the aquaculture industry;
- Providing technical assistance and capacity building to the sector;
- Seeking technologies to improve the sector;
- Adapting aquaculture techniques to local climatic conditions and monitoring the impacts of climate change;
- Collecting revenue in the form of taxes.

The DoF is organized into central, regional, and state levels; district; and township and sub-township offices with an average of five officers per township to support aquaculture development, including farmers and technology transfer personnel. DoF enforces the 1989 "Law relating to aquaculture" (FAO, 2014). The provision of aquaculture leases and licences are under the DoF's authority. The main point of this regulatory framework is summarized as follows (FAO, 2014):

- The exercise of aquaculture is subject to the issuance of a lease grant.
- The sale of fish seeds produced through artificial propagation or breeding of aquarium fish is issued by licence.
- Licence holders shall pay a grant fee or licence fee, according to the procedure set out by DoF.
- The department may designate aquaculture land from agricultural or virgin land for aquaculture development for no more than 10 years.

Land in Myanmar is classified either as 'agricultural' or 'nonagricultural.' Aquaculture is considered as a nonagricultural land use, thus the conversion of any paddy land or other agriculture land into aquaculture is forbidden, and failure to cultivate agricultural land can result in confiscation. Conversion is possible but requires legal procedures to change the legal land title, which is under the control of the Agriculture Department. This procedure is long, complex, and requires additional resources for informal fees, which undermines the capacity of many smaller prospective fish farmers to obtain permission to engage in aquaculture.

Legal restrictions to convert rice land into fish ponds were not always such a constraint to pond construction in the delta, especially for large commercial farms. In recent years, enforcement of this legislation has been less strict (WorldFish 2014) and excavation of ditches around the edges of rice fields is now allowed for rice-fish culture. Overall, enforcement of the regulatory framework is context-dependent and varies from place to place.

# 1. BARRIERS TO AND OPPORTUNITIES FOR AQUACULTURE DEVELOPMENT

## 1.1. Identified Barriers

Below is a summary of several reports (Hla Win, 2004; Khin Maung Soe, 2008; Johnstone et al., 2012; MYFish, 2013 a and b; Gregory, 2013; Belton et al., 2015; Belton et al., 2017a) that identify barriers to aquaculture development in different institutional and legal dimensions. Barriers also include value chain organization and the aquaculture support system that can enable (when present) or constrain (when absent or malfunctioning) aquaculture development.

Institutional and policy barriers to aquaculture development over land title conversion remains long and complex and not accessible to small-scale farmers. Optimization of land use for the integration of aquaculture, such as reservoir cultured-based fisheries, reservoir cage culture irrigation canals, excavation of ponds and ditches in rice fields, or integrated livestock-fish systems, are discouraged by the Administration (Myanmar Fisheries Partnership [MFP], 2016). Interstate transport of harvested fish is legally constrained, and the distribution of fish is limited to a number of licenced traders.

Recently, aquaculture activities also faced security issues, with reports of organized thieveries aimed at raiding the production, which constrains farmers to stop activities in ponds difficult to guard (far from settlements). Security context is a new factor to take into account when planning aquaculture development.

Current extension services to promote aquaculture are inefficient, with unclear and overlapping responsibilities of DoF and of the Myanmar Fisheries Federation. Coordination and the overall relationship between government and non-government organisations (NGOs) is weak and does not contribute to building capacity and learning from previous lessons. Within DoF, the capacity of the Aquaculture Division to support aquaculture development is limited. Current and future programs to develop and support specific curriculum are just being implemented (MYSAP project) and outcomes are not yet realized.

The support system is weak and segments of the value chain are operating at a sub-optimal level. Access to feed and seed is limited and expensive when compared to prices in neighboring countries. The quality of fingerlings is questionable, leading to inbreeding, and the technology deployed by local hatcheries is limited. Sub-optimal homemade feed is the dominant feed, especially in small-scale aquaculture. New technology and high-quality inputs are not available to farmers.

Marketing is an issue for small-scale farmers unable to compete with large-scale farms. Production costs are high due to the cost of feed. Therefore, farmers continue using inefficient homemade feed instead of commercially manufactured pellet. The sector lacks diversification – its over-reliance on a single species (rohu) makes it vulnerable, less resilient to shock (i.e., disease), and limits export prospects.

Biophysical constraints affect aquaculture in the Central Dry Zone, with a low availability of water in the dry season and low temperatures in the winter. WorldFish (2007) explored future constraints related to climate change including the following:

- Higher water temperatures will decrease water quality and dissolved oxygen.
- Changes in rainfall and water availability may lead to higher costs to maintain pond water levels and may also create conflict with other water users.
- Increased frequency and/or intensity of storms may create more shocks.

## 1.1. Opportunities and Potential Interventions for Aquaculture Development

The aquaculture sector features some interesting characteristics from a development perspective (Belton et al., 2017a; MPF 2016). These characteristics should be used to mitigate the constraints listed above to support and enhance the sector's growth and resilience:

- Aquaculture is a high return activity with much higher earnings per hectare than crop farming in the Delta Region.
- Aquaculture creates more on-farm employment opportunities than agriculture.
- Small-fish farms create more employment than large ones
- Wages are higher in fish farming than in crop farming, a finding that applies particularly to women.

In the past decade, even without a strong policy support, small-scale aquaculture has been rapidly developing. In the future, this sector might face limitations if policy amendments, research investment, and infrastructure investments are not decided and supported. According to Belton et al. (2015) and MPF (2016), the sector in Myanmar has significant potential for growth and will develop further by becoming more competitive, spatially diversified, and small-holder inclusive. The authors identified several policy implications including:

- Land use restrictions regarding conversion to aquaculture should be relieved, allowing farmers to opt for the most relevant farm product for a more efficient utilization of the land (MPF, 2016).
- Licensing access to cage culture in reservoir and canals would not only generate additional revenue for the government but would also contribute to sector development by creating incentives for private sector investment and increasing efficiency of water resource utilization.
- Facilitating private investment along the value chain, particularly in the feed sector, would increase competition and reduce feed prices for fish producers.
- Improvement of hard infrastructure (road, electricity access, and water control) and soft infrastructure (extension and veterinary services, private sector services) is required to increase the efficiency at the production level and along the different segments of the value chain.
- Public investment in fingerling production technology for promising species would support diversification within the sector of new fish and prawn species, as small-scale farmers have a competitive advantage to produce non-carp species.
- Deregulation of fish trading between states and regions would facilitate domestic trade and reduce unnecessary transaction costs.

Beyond current reliance on domestic markets, export to major markets such as US or Europe should be included in future strategies for aquaculture development.

Belton et al. (2017b) concluded that small farms and nurseries should be the principal target of policy and interventions. Small-scale aquaculture has a role to play in the development of the sector and can substantially contribute to employment generation, addressing food security concerns and improving income generation among rural households (United Nations Development Programme [UNDP], 2004; MYFish, 2014a and b; MPF, 2016).

The following interventions could unleash the perceived potential of small-scale aquaculture in Myanmar:

- Improve management techniques for better use of inputs by i) increasing stocking density, ii) improving feed quality, iii) better feed management and iv) fertilization to increase the natural productivity of the pond (MPF, 2016).
- Linked to the above point, research in pond management and fertilization is required to optimize production and reduce feed cost.
- Better management techniques can be achieved with the development of an efficient support system, including private-sector and government extension services specifically targeting small-scale producers and providing adapted responses to their needs (MPF, 2016).
- DoF has a central role to play in the modernization and sustainability of the sector by regulating the use of chemicals and drugs, developing safe farm practices in Myanmar, and ensuring their implementation.
- A skilled work force is lacking in the aquaculture sector. Educational curriculum and capacity building is required and necessitates a joint and coordinated effort between DoF and universities, as well as the private sector and civil society (MPF, 2016).
- Research of aquaculture technology is required to help small-scale farmers adapt successful aquaculture systems from neighboring countries. This would diversify the production with monosex tilapia, pacu, and freshwater prawn. It would also diversify the carp-based system with the introduction of small nutrient rich fish for improved human diet and nutritional security (Thilsted, 2012).
- Research is required to assess the profitability and sustainability of the emerging aquaculture system in Myanmar (mud crab, swamp eel) and guide policy and aquaculture planning.
- Specific research is required for innovative technologies that are adoptable by small-scale fish farmers in the Central Dry Zone. Short-cycle fish farming techniques with local species, such as snakehead, walking catfish, and stinging catfish, as well as fish culture methods with water-saving technologies (e.g., using water from bathing in the household) should continue to be explored.
- Access needs to be improved to financial capital to invest in new technologies and intensify small-scale aquaculture systems for resource-poor households. Better access to formal credit would also reduce the costs of informal borrowing (Belton et al., 2015).

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