Feed the Future Innovation Lab for Food Security Policy

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AQUACULTURE IN TRANSITION: VALUE CHAIN TRANSFORMATION, FISH AND FOOD SECURITY IN MYANMAR

By

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EXECUTIVE SUMMARY

Introduction

Fish farming (aquaculture) is important to Myanmar's food security and is developing and transforming quickly. This study presents findings from a new field survey of the farmed fish value chain that is more detailed and broader than any previous study conducted in Myanmar. Many of our findings are at odds with what we perceive as conventional wisdom about fish farming in Myanmar. The findings have important policy implications to unlock the sector's full growth potential and food security contributions.

Our Field Study of 250 Value Chain Actors in the Delta in 2014

The study is based on a field survey, conducted September-December 2014, by six researchers from Myanmar Development Resource Institute-Centre for Economic and Social Development (MDRI-CESD) and Michigan State University. The survey focused only on inland (freshwater) fish farming, which is responsible for 95% of Myanmar's reported aquaculture. We started by identifying, measuring, and cataloguing inland fish ponds in the Delta (where 90% of Myanmar's aquaculture takes place), using satellite images from Google Earth. We then traveled to seven townships accounting for 75% of total fish pond area, and to San Pya market – the main fish wholesale market in Yangon which receives most of the fish produced in the Delta. In each location we did an inventory of all the segments of the value chain, with numbers of fish farms, rural traders, hatcheries and nurseries, feed mills and feed traders, fish wholesalers and linked services like transport and ice suppliers. We asked groups of key informants about the numbers now, five years ago, and 10 years ago to examine growth and structural change. Then we randomly sampled actors from different size strata in each value chain segment. We interviewed 251 persons in detail, using structured interview guides. These included: 23 nurseries, 19 feed traders, 14 hatcheries, 87 fish farms, 35 fish traders, and 19 transporters and ice sellers.

Fish Farming is Important to Myanmar's Food Security

Fish is important for domestic food security – it is the leading purveyor of animal protein and the lead provider of micronutrients, important especially for child development, to Myanmar consumers. Fish is important in the food budget of households: nearly as much is spent on fish (14% of food expenditure) as on rice (19% of food expenditure). Fish farming also generates a lot of employment – about twice as much per acre as paddy farming. Fish- farming accounts for about 20% of domestic fish consumption in Myanmar. This is a long way behind neighboring Thailand and Bangladesh (about 80% and 55%, respectively); farmed fish already accounted for about 20% of the fish consumed in both these countries by the late 1980's.

We also find that, on average, as household expenditure climbs one quintile the amount of fish consumed per capita goes up by 16%, but the amount of farmed-fish goes up 34% and capture-fish by only 10%.[1] This means that as incomes rise in Myanmar, farmed-fish consumption will

[1] Expenditure is used as a proxy for income. Expenditure quintiles are created by ranking all households in the population from highest to lowest expenditure, and dividing them into five equally sized groups, with each group representing 20% of households.

grow fast as a share of fish consumption, and capture-fish from rivers, lakes and the sea will decline in share. This is a common trend all over Asia. Thirty percent of Myanmar's population lives in cities. About 26% of the fish they eat is farmed, compared to 19% of the fish eaten by the 70% of people who live in rural areas. Of the total volume of farmed-fish sold domestically, urban consumers buy 38% and rural consumers buy 62%. As urbanization proceeds and incomes grow, cities will gain an increasing share of the farmed-fish market, perhaps rising to more than half of the farmed-fish consumed in a decade or so.

Even though it is a common perception that aquaculture output is mainly exported, in fact, roughly 20% is exported, and 80% goes to the domestic market. We anticipate that the export share will even decline further in the near to medium term as the Myanmar urban market grows.

Fish Farming is Growing Fast and Restructuring

We found fish-farming output from the Delta, which accounts for 90% of Myanmar's farmed fish, went up about 250% over the past decade. This is due to a combination of growth in pond area and yields. Our pond inventory census using satellite data from the past ten years showed rapid expansion - approximately a doubling of area - in clusters of pond farms all around the Delta. Of course this varies over clusters, newer and older; for example, in the largest cluster, in "Nyaungdon Island", pond area grew from 9,700 acres to 34,000 acres (a 3.5 times increase) in only 10 years. In the oldest cluster, Twantay, there was no change; in Hlegu, there was an increase from 680 to 1720 acres (2.5 times), and in Latkyargi in Maubin, from 2240 to 3110 acres (nearly 1.5 times). But this measured "doubling of area" underestimates the full increase of volume, because yields of fish per acre also increased rapidly: the length of the production cycle (season) reduced from 12 to 9 months (hence a third gain) for many farms, as a result of stocking larger fingerlings, and some increase in feed use.

Despite this rapid growth, there is little diversity in the production technologies used, or in the species produced. A single type of fish - the indigenous carp, rohu - constitutes roughly 70% of all farmed fish. Exotic species such as pangasius catfish and tilapia, which are important for both domestic markets and export elsewhere in Asia, are only produced in small quantities at present. There is even less production of other higher value 'niche' species commonly farmed in the region. One can expect these to become more important commodities for domestic consumption over time. Further product diversification will help meet local demand, especially among poorer consumers, and improve farm income and rural development in the medium term while setting the stage for possible export growth in the long term.

Farm Size and Spatial Distribution

Aquaculture in Myanmar is highly concentrated spatially. The main configuration is within 50km of Yangon, with a big set of clusters to the West of Yangon and then a swath to the North and Northeast, with growth occurring towards Bago and spreading further North and West, with a lot of room for expansion. This pattern occurs because near Yangon transport times are low, boats can use the river system to deliver fish and feed, energy grids exist, and water is neither too abundant nor too scarce.

Contrary to conventional wisdom, which holds that it is impossible to convert paddy land to fish ponds, we find that most ponds are constructed on rice paddy land. Fish farming is highly concentrated, with very large farms (including several vertically integrated companies) accounting

for well over half of total pond area. This farm size distribution is far more concentrated than in Thailand, Bangladesh, or China. The sector in Myanmar is thus "dualistic", with two poles of larger and smaller fish farms. One reason for this pattern of development is the 1989 Aquaculture Law, which promoted the conversion of uncultivated "wasteland" to fish ponds. In fact, there is little uncultivated land left in the Delta, so in practice many of the concessions granted to fish farm businesses included paddy land. The conversion of paddy land to fish ponds was actually accelerated by improvements to paddy lands: flood control schemes constructed in rice growing areas of the Delta in the late 1990s to intensify rice production made the land more suitable for pond farming.

Small and medium-sized commercial farms are more numerous than is generally recognized. In certain areas these farmers, attracted by the high returns possible from fish production, have circumvented regulations about conversion of paddy land to fish ponds. But, in other parts of the country such as Mon State, strict enforcement of these regulations has stifled the development of a smallholder fish farm sector. Insecure land tenure for smaller farms means that, unlike in most other Asia countries, aspiring fish farmers rarely rent privately owned land to construct fish ponds. Our survey of satellite images also identified more than 200,000 small 'backyard ponds' in the southern Delta. Although these were originally constructed to harvest rainwater, field visits confirm that they are increasingly used for growing fish, mainly for home consumption purposes.

Fish Farming Value Chain - non-farm (urban and rural) segments developing rapidly

There is a rapid proliferation and development of small and medium enterprises (SMEs) in off-farm segments of the supply chain, linked to the growth and geographic lengthening of the chain (e.g., in ice manufacture, rural transport - including increasing numbers and size of boats and trucks to move fish around the country, growing numbers of fish traders and rapid expansion of urban wholesale markets). There is also rapid development of small- scale processing of minced fish balls (*nga chit*) in Yangon.

A particularly interesting case of development is the sudden and rapid growth of buses transporting fish from Yangon to wholesale markets throughout the country. Before 2011, bus company numbers and vehicle imports were restricted, petrol was rationed, and buses were not used for fish transport. When these constraints were removed, bus lines multiplied and grew more competitive, bus companies took to moving fish to add an additional income stream, and the cost of transporting fish fell sharply. This has burgeoned to more than 200 tons of fresh farmed fish going from the Delta to Upper Myanmar on buses every day! This has all occurred in spite official regulations restricting the interstate transport of fish. We think this trade can continue to expand quickly and is beneficial for consumers and fish farmers. It also indicates potential to expand fish farming in other areas of the country if restrictions on paddy conversion were lifted.

Fish Farming Value Chain - upstream segments are developing rapidly

There is a rapid proliferation and development of SMEs in the off-farm segments of the supply chain linked to intensification of fish farming (e.g. pond digging services, hatcheries and nurseries, and feed mills and feed traders). We focus on two support segments that are very important in aquaculture development throughout Asia, but are somewhat constrained so far in Myanmar.

Feed segment – concentrated and costly

In most Asian countries, numerous fish feed manufacturing companies compete with one another to attract farm customers. Many of these companies also produce livestock feeds, and foreign direct investment in fish feed manufacture is common. None of this has happened yet in Myanmar. Rather, in Myanmar a handful of very large vertically integrated farms produce feed exclusively for their own use, and a very small number of domestic companies produce fish feed for sale to farmers. This latter group is dominated by just one firm, which provides feed on credit to farmers and buys back the harvested fish. production. Feed is the main operating cost for fish farmers. There is very little formal credit available to fish farmers. Large farms are able to access credit for buying feed from large fish traders at moderate (for Myanmar) interest rates of 3% per month. Smaller farmers are unable to access fish trader credit, and often borrow from informal lenders at 4-6% per month.

Seed segment - basic technology

Fish fingerling production started in government hatcheries. Hatchery technology spread to the private sector through informal partnerships between government staff and early fish farmers. The number of hatcheries in Myanmar is small, and the technology used is quite basic compared to neighboring countries. Many large vertically integrated farms produce seed in their own hatcheries and nurseries, with limited spillovers to other businesses. Nurseries (which buy small juvenile fish from hatcheries and raise them for several months, before selling them onto fish farms), have boomed in several locations. These are an important entry point into aquaculture for small landowners because they require relatively low levels of investment.

Policy Implications

There is a lot of pent up demand for farmed fish in Myanmar. The fish farming value chain is highly dynamic in some respects, but lags behind other countries in the region in many others. This unevenness reflects the effects of Myanmar's long isolation and recent, partial, economic transition. The sector has massive potential to grow and develop further by becoming more competitive, spatially diversified and smallholder-inclusive. To achieve this growth there needs to be:

- Fewer restrictions on land use (patchy "informal" relaxation of regulations has led to uneven development, high transaction costs and a risky investment climate).
- Better access to formal credit for fish farmers and other enterprises in the fish value chain (improving access to formal credit will also reduce the costs of informal borrowing, even for those who do not make use of it directly).
- Increased private investment and competition in the feed sector (to bring down cost to the farmer and improve quality).
- Greater development of 'hard' infrastructure (roads, electricity and water control to increase efficiencies all along the supply chain).
- Public investments in seed production technologies for promising species (building upon past successes in this area to encourage technological and product diversification for farmers).

- More development of 'soft' infrastructure (human capital, extension and veterinary services, to support more responsive public and private service provision for farmers in areas such as disease control).

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1. INTRODUCTION

Myanmar is a "rice fish culture", where rice provides the majority of energy in the diet, and fish provides a major share of micro-nutrients. Ensuring adequate availability of and access to fish supplies is therefore critical to ensuring food and nutrition security in a country where one out of every three children are stunted and one out of four are underweight (UNICEF, 2012).

Aquaculture (the farming of fish and other aquatic organisms) has grown rapidly in Myanmar over the last two decades, despite constraints posed by an apparently hostile policy environment that strongly favors the production of rice and tightly regulates the conversion of paddy land to alternative uses. Part of this growth has been driven 'from below', as farm households attracted by returns much higher than those possible from alternative agricultural activities have managed to circumvent official restrictions to enter production, but much expansion has taken place with state backing, by granting land concessions by companies and large farms, allowing the conversion of large areas of "wasteland" to ponds.

This growth has been accompanied by flourishing ancillary activities in up- and downstream value chains in locations with dense clusters of aquaculture operations, creating demand for labor and services. Aquaculture thus has an important role to play in supporting rural livelihoods by raising farm incomes and creating new non-farm employment opportunities, but a sector in which commercial smallholders account for a greater share of production could bring about a more balanced and inclusive pattern of economic growth.

There is a dearth of readily available and reliable information on the aquaculture sector in Myanmar. Official statistics appear to over-report production by a large margin, while the conventional wisdom paints a picture of a sluggish and unproductive sector comprised of giant farms producing largely for export. The present study addresses this information deficit, drawing on extensive fieldwork conducted in Lower Myanmar, where the vast majority of inland aquaculture operations are located, and data from an array of secondary sources. The research paints a more complex and picture of 'dual speed' development, in which all value chain segments of the inland aquaculture value chain have undergone a variety of transformations, both incremental and rapid, whilst simultaneously exhibiting a lack of diversity and underperformance. This pattern reflects the structural constraints associated with Myanmar's partial economic transition.

The remainder of this report presents these findings in detail. First, data from a range of existing sources are reviewed and triangulated. These include: gray literature; official statistics on fish production and international trade; food consumption data extracted from the 2010 national Integrated Household Living Conditions Assessment Survey; historical data on retail fish prices compiled by the Central Statistical Office; and analysis of satellite images from Google Earth. Second, results of field research on the aquaculture value chain in Lower Myanmar are elaborated. The second part of the report provides an overview of historical patterns and drivers of the sector's development, and describes the structure of the aquaculture value chain in Myanmar, the behavior of actors in it, the nature of transformations occurring in up, middle and downstream segments, and their implications. The report concludes with a summary of key findings, and offers policy recommendations for promoting equitable aquaculture growth that contributes to inclusive rural development and national food and nutrition security goals.

2. METHODS

This study presents data derived both from secondary sources and primary research. Official statistics on fish production and fish exports were collected from the Central Statistical Office (CSO) and Department of Fisheries (DOF). Monthly time series data on the prices of a variety of fish and fish products were obtained from the *Selected Monthly Economic Indicators*, also published by CSO. The food consumer price index, published in the same periodical, was used to deflate these figures to derive real (inflation adjusted) historical prices. Data on the consumption of fish and other foods were extracted and summarized from the Integrated Household Living Conditions Assessment Survey 2010, a nationally representative household survey dataset made available to the project by the United Nations Development Program (UNDP).

At the outset of the study, project researchers had little knowledge about the geographical distribution of aquaculture operations in Myanmar, beyond the broad region/state level trends evident from national statistics. These indicated that 90% of inland fish ponds were located in Lower Myanmar (the regions of Ayeyarwady, Yangon and Bago, which lie along the lower course and delta of the Ayeyarwady River) (DOF, 2014). At the outset of the research, a decision was made to focus exclusively on inland (freshwater) aquaculture, because fish grown in inland ponds account for close to 95% of Myanmar's reported aquaculture production (FAO, 2015a), and it was felt that attempting to include both coastal shrimp and inland fish aquaculture would dilute the research effort.

In order to effectively target field-based reconnaissance work, one of the project's first steps was to attempt to identify and catalogue all ponds utilized for inland aquaculture in Lower Myanmar by searching satellite images available via Google Earth Pro software.

Individual ponds and contiguous groups of ponds were identified manually by searching satellite images covering Ayeyarwady, Yangon, Bago and Mon systematically. All ponds or contiguous groups of ponds detected were tagged and assigned a unique geographical code. Boundaries were drawn around each pond or group of ponds using the software's " polygon" tool. The entire database of images was crosschecked several times by research team members to identify erroneous entries and missing ponds.[2] Ponds were subsequently mapped with Arc-GIS software, allowing their area to be calculated. Comparing historical satellite images taken at five year intervals made it possible to compare rates of change in pond area within several major pond clusters over the space of a decade.

Collection of primary data on the inland aquaculture value chain took place through a structured process of 'rapid reconnaissance'. Aquaculture development in Myanmar is highly geographically concentrated or 'clustered'. During the initial phases of research, the project team visited most of the major pond clusters in Ayeyarwady and Yangon regions, as identified from analysis of satellite images. These visits were used to produce a 'meso- scale' inventory of the 'lay of

[2] In order to ensure that only ponds utilized for commercial freshwater aquaculture were catalogued, the following categories of waterbody were excluded: ponds in densely inhabited areas, deemed likely to be used for religious or water storage purposes; ponds in coastal areas, deemed likely to be utilized for shrimp or crab farming; waterbodies with highly irregular shapes, deemed likely to be of natural origin; very small ponds, deemed unlikely to be used for commercially oriented aquaculture.

the land' at each segment of the value chain (i.e. the types, locations, and numbers of different kinds of enterprise, differentiated by scale), and to obtain estimates of changes in this structure occurring during the preceding five and ten years.

Based on exploratory visits conducted during the first phase of research, four 'supply side clusters' located in the townships of Kayan, Hlegu, Twantay (Yangon), and Maubin (Ayeyarwady) were selected as sites for more intensive fieldwork. These clusters are located along the arc of a broad semi-circle with a radius of approximately 50 km, which runs anti-clockwise from northeast to southwest around the city of Yangon. San Pya wholesale market in Yangon city is the initial destination of most of the fish produced in these clusters and, as the major demand side hub, was also selected for in depth study.

Interviews focusing on 'micro-scale' behavior (asset ownership and access, acquisition of production inputs, production or intermediation processes and sales arrangements) were subsequently conducted with enterprises of all of the types and scales identified during the meso-level scoping process. Interviews also explored additional contextual issues as appropriate, paying particular attention to the origins of aquaculture and related activities in each of the clusters visited, and the content and implementation of regulations governing land use. Elements covered in all in depth interviews are summarized as follows:

a) **Assets:** Ownership of, or conditions of access to, productive assets by the actor interviewed (e.g. land, machinery, vehicles, etc.)
b) **Behavior (buy):** The type and source of production inputs deployed (e.g. raw materials, feed, seed, labor, credit); source of acquisition (by actor type and geographical location); mechanisms for sourcing (e.g. transport, credit arrangements)
c) **Behavior (make):** The type of product produced or service provided by the actor; the seasonality and location of production/service provision; details of the production/intermediation process (e.g. farming methods, labor use)
d) **Behavior (sell):** The form and volume of product sold; timing of sales; type and location of buyer; sales arrangements (e.g. transport, credit, financial transactions).

Wherever possible, interviews were conducted 'one on one' in the privacy of informants' farms, homes and businesses. Public meetings were avoided, and interviews were never held in the presence of government or company employees, in order to ensure that interactions occurred in as unconstrained a setting as possible. The strategy throughout this stage of the research was to obtain data directly from the field, rather than from key informants in privileged positions (e.g., senior government officials and leading members of business associations), with a view to validating results with this group at a later date.

Table 1 provides a summary the types of enterprises and actors interviewed in up-, mid- and downstream value chain segments, totaling 251 interviews. The upstream segment of the chain is defined here as comprising all types of input production and distribution, midstream as comprising the farm and the provision of goods and services used to maintain farm equipment or harvest and transport fish from farm to buyer, and downstream as comprising all marketing, processing and distribution activities occurring post-farm.

Table 1 Summary of interviews, by value chain segment, actor type and number of interviews conducted

Upstream	#	Midstream	#	Downstream	#	Other	#
Nursery	23	Fish farm	87	Fish trader	35	Capture fish trader	4
Feed trader	19	Mechanic services	5	Transport services	10	Local official	3
Hatchery	14	Transport services	3	Market manager/worker	5	Government official	2
Seed trader	6	Worker	3	Other ancillary services	2	Landless household	1
Ice manufacturer	5	Labor broker	2	Fish processor (small)	2		
Rice mill	5	Other ancillary services	1				
Other ancillary services	4						
Ice trader	3						
Transport services	3						
Feed mill	3						
Chemical supplier	1						
Total	86		101		54		10
Grand total	251						

3. AQUACULTURE AND FOOD SECURITY IN MYANMAR: A REVIEW OF EXISTING EVIDENCE

3.1. Literature Review: The Conventional Wisdom on Myanmar's Aquaculture

Literature on aquaculture in Myanmar is sparse. A review conducted for this study identified a total of 15 English language publications; all of them gray literature, with the exception of a single peer reviewed article on fish genetics (Aung, 2010). Seven articles originated from a single magazine, 'Aquaculture Asia' (Win, 2004; Edwards, 2005; 2009a; 2009b; 2010; Aye et al., 2007; Ng, 2007). The search also identified three project or program scoping reports (FAO & NACA, 2003; Johnstone et al. 2012; Driel and Nauta, 2013) and four value chain studies (De Silva, 2008; CBI, 2012; Joffre and Aung, 2012; Joffre and Aung, 2014). Among the value chain studies, three dealt primarily with coastal aquaculture (shrimp and crab farming), highlighted for its export potential.

Publications describing the inland aquaculture sector offer up largely similar diagnostics of its key features. The sector is usually characterized in this literature as dominated by large farms, with small-scale forms of aquaculture almost non-existent (Driel and Nauta, 2013; Edwards et al. 2005; Johnstone et al. 2012; FAO & NACA, 2003). An apparent "absence of small multipurpose ponds near farming homesteads… dug in response to water shortages [and to] provide a domestic water source and refuge for wild fish" (Edwards, 2005, p6), is said to account for the observation that there are "very few small (less than 400 m2) fish pond operations" (FAO & NACA, 2003, p19).

The apparent lack of a small-scale farm sector is also attributed to stringent land use regulations which prevent the conversion of paddy land to fish ponds. For example, FAO & NACA (2003, p18) state that, "The strict control by the agriculture department regarding the conversion of rice lands into other uses (especially aquaculture) is one of the strongest restraints to more widespread development of aquaculture in freshwater areas". Edwards (2005, p7) also notes that, "Strict control over conversion of rice fields into other uses, is one of the major constraints to the more widespread development of aquaculture, especially by the major sector of the population, the small-scale rice farmer/fisher."

(Aye et al, 2007, p22) suggest the existence of a bifurcated sector, however, with "small farms, often family managed and owned catering to the local demands and large farms, often vertically integrated catering to the export markets". Johnstone et al. (2012, p19) state that large-scale farms in the delta are, "often oriented towards export markets", and development of the large farm sector is said to have "revolved around the development of export markets" (De Silva, 2008, p14).

Driel and Nauta (2013, p23) report that exchange rate fluctuations and underlying inefficiencies in production mean that, "Large-scale export-oriented enterprises have reverted to selling on domestic markets", thereby impacting competitiveness of smaller- scale commercial producers. Farming operations are said to be beset by low productivity with sub-optimal management practices, leading to inefficient use of inputs (Edwards, 2009a), resulting in with lengthy production cycles which render the long term economic viability of the sector questionable (Johnstone et al. 2012; Driel and Nauta, 2013). It is also contended that large-scale farms provide low levels of seasonal employment (Johnstone et al. 2012).

Table 2 Quotes summarizing the conventional wisdom on inland aquaculture in Myanmar

Theme	Example quote	Source
Large-scale farm dominated	"Aquaculture in the delta is dominated by large-scale production systems."	Johnstone et al. (2012, p19)
No small-scale producers	"The most striking feature of inland aquaculture in Myanmar is the almost complete absence of a small-scale aquaculture sector."	Edwards (2005, p5)
Export oriented sector	"Development of the large-scale farming system in Myanmar… revolved around the development of export markets."	De Silva (2008, p14)
Low productivity and technical efficiency	"Large-scale aquaculture production in Myanmar is characterized by low productivity… resources are not efficiently used."	Driel and Nauta (2013, p23)
Impossible to construct ponds on paddy land	"The authorities do not allow ponds to be built on land suitable for rice cultivation."	Edwards (2005, p7)

In short, according to this narrative, the prospects for aquaculture as a driver for rural development in the Delta region are weak: constrained by poor technical performance; an unfavorable policy environment; a rather sluggish domestic market; and offering few opportunities to small- and medium-scale producers or workers.

While there are elements of truth in some of these characterizations, they are, as will become apparent from results presented later in this report, often guilty of a high degree of oversimplification. This tendency is perhaps inevitable, given that most reports on aquaculture in Myanmar are the product of brief study tours or short term consultancies involving limited field work, and draw on the same small pool of literature reviewed in this section. This results in the repetition (sometimes almost verbatim) of conclusions drawn from earlier studies. In contrast, the intensive fieldwork on which this present study is based was conducted over a period of four months, and benefitted from an unusually high degree of unrestricted access by the research team to diverse actors across multiple geographical locations and throughout the aquaculture value chain.

3.1. Production Statistics

This section presents historical data on fish production in Myanmar, drawn from figures published by the Myanmar Department of Fisheries (DOF) and the Food and Agriculture Organization of the United Nations (FAO). FAO statistics are derived from Myanmar government figures so total levels of production reported by both sources are the same in all years, but FAO figures are more fully disaggregated than the national statistics.

Fish originate from three sources: marine capture fisheries, freshwater capture fisheries and aquaculture. The total reported output and share of production from each of these is presented in

Table 3. Marine capture fisheries and aquaculture are further subdivided into fish and shrimp.[3] According to these figures, aquaculture production in Myanmar increased more than nine times from 2000-2013, from a low base, to reach 926,000 t. However, aquaculture's share of total reported fisheries production only doubled over this period, to just under 20%, due to concurrent increases in the reported output of marine and freshwater capture fisheries. In 2013, shrimp, which is farmed in coastal areas (most importantly in Rakhine state), accounted for just 5.6% of total reported aquaculture production by volume. The presently limited contribution of shrimp production to Myanmar's aquaculture justifies this study's exclusive focus on inland aquaculture.

Table 3 Quantity and share of Myanmar fisheries production by source

Item	Year													
Production by source ('000 t)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Freshwater capture (fish)	*196*	*238*	*255*	*290*	*454*	*504*	*631*	*718*	*815*	*899*	*1002*	*1163*	*1247*	*1303*
Marine capture (fish)	873	926	1006	1031	1110	1206	1345	1486	1644	1828	2017	2123	2283	2431
Marine capture (shrimp)	23	23	22	22	21	20	28	30	33	37	41	43	47	49
Marine capture (total)	*896*	*949*	*1028*	*1052*	*1131*	*1227*	*1374*	*1516*	*1677*	*1865*	*2058*	*2166*	*2329*	*2480*
Aquaculture (fish)	94	116	184	233	371	437	526	556	626	705	777	764	831	874
Aquaculture (shrimp)	5	6	7	19	30	49	49	48	48	46	46	51	53	52
Aquaculture (total)	*99*	*121*	*190*	*252*	*400*	*485*	*575*	*605*	*675*	*751*	*823*	*815*	*883*	*926*
Total fisheries production	1191	1308	1473	1594	1985	2216	2580	2838	3166	3515	3883	4145	4459	4709
Share of production (%)														
Freshwater capture	16.5	18.2	17.3	18.2	22.9	22.7	24.5	25.3	25.7	25.6	25.8	28.1	28	27.7
Marine capture	75.2	72.5	69.8	66	57	55.4	53.2	53.4	53	53.1	53	52.3	52.2	52.7
Aquaculture	8.3	9.3	12.9	15.8	20.2	21.9	22.3	21.3	21.3	21.4	21.2	19.7	19.8	19.7
Shrimp (marine capture)	2.6	2.4	2.1	2	1.9	1.7	2.1	2	2	2	2	2	2	2
Shrimp (aquaculture)	5	4.5	3.4	7.5	7.4	10	8.5	8	7.2	6.1	5.6	6.3	6	5.6

Source: FAO, 2015a

Myanmar's reported aquaculture production stood at less than 100,000 t per annum before 2001, during which time it was dominated almost entirely by a single species, rohu (nga myit chin; Labeo rohita). Figure 1 depicts a boom in inland aquaculture occurring from 2000 onwards, during which time growth in output averaged 18.3% per year. Some diversification began to occur during this period in terms of the variety and quantity of other species farmed, but rohu continued to dominate the sector, accounting for approximately ⅔ of reported production. Reported production of tiger shrimp underwent a brief period of growth during the early 2000's, before stagnating; standing at around 50,000 t thereafter.

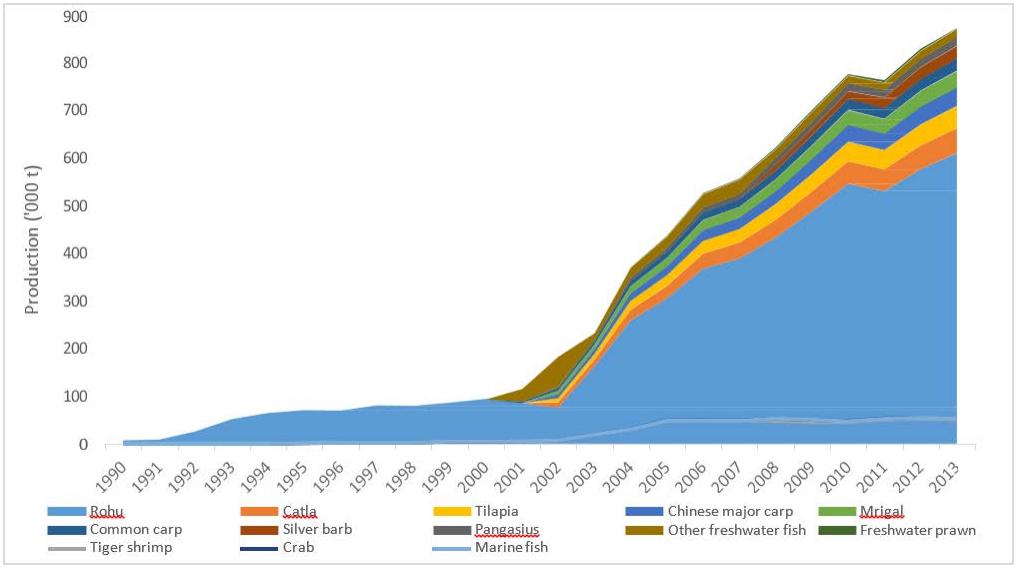
Data on the reported area under inland aquaculture production, the quantity of fish produced, and apparent yield (production/area) for Myanmar are presented in Table 4. Figures are provided in both local and metric units, for ease of interpretation.[4] The following trends are evident: Reported fish production more than doubled over the 11 years from 2004 to 2014, with an average

[3] 'Fish' here is used as a shorthand for all aquatic organisms other than tiger shrimp.

[4] 1 acre = 0.4 hectare; 1 viss = 1.6 kg

fitted annual growth rate of 8.7%. Pond area grew by 43% over this period, with areal expansion averaging 2.7% per year.

Figure 1 Myanmar aquaculture production by species, 1990-2013



Source: FAO, 2015a

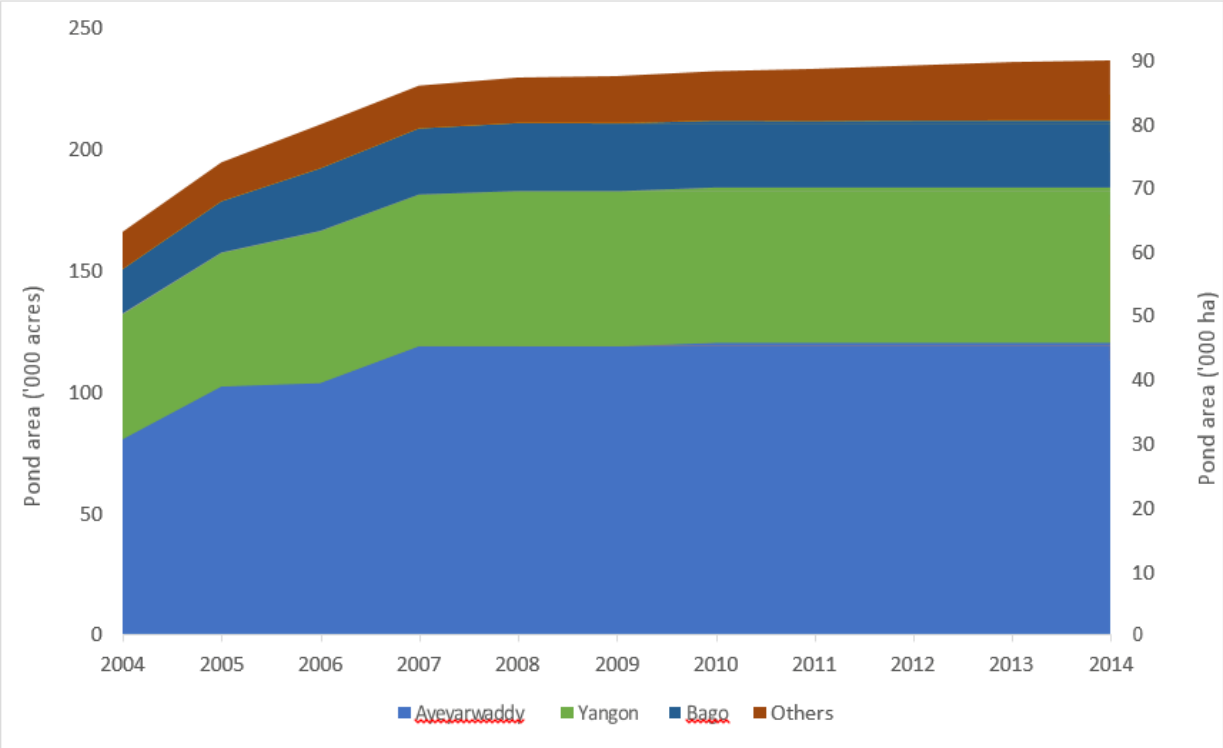
Reported annual areal expansion of ponds was rapid from 2004-2007 (10.6%), but almost static at <1% per annum from 2008 onwards. Annual growth of apparent yields was variable throughout the period, but associated very closely with annual changes in reported production from 2008 on after the reported growth of pond area plateaued. These figures would imply that yield increases (intensification), accounted for around two thirds of growth in the production of farmed fish over this period. Average apparent yields calculated using these figures are high, standing at 10.7 t/ha (2714 viss/acre) in 2014 (Table 4).

Table 4 Myanmar inland aquaculture production by quantity, farmed area and apparent yield

Item	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Annual Growth '04-'14
Production ('000 t)	400.4	485.2	574.9	616.4	687.7	775.3	858.8	830.5	899.0	929.4	964.3	-
Production (million viss)	250.2	303.3	359.3	385.2	429.8	484.5	536.7	519.1	561.9	580.9	602.7	-
Production growth rate (%)	-	21.2	18.5	7.2	11.6	12.7	10.8	-3.3	8.2	3.4	3.8	8.7
Pond area ('000 ha)	63.0	73.9	79.8	85.9	87.2	87.4	88.2	88.6	89.1	89.6	89.9	-
Pond area ('000 acres)	155.5	182.5	197.2	212.2	215.4	215.9	217.8	218.7	220.1	221.4	222.0	-
Pond area growth rate (%)	-	17.3	8.1	7.7	1.5	0.3	0.9	0.4	0.6	0.6	0.3	2.7
Apparent yield (t/ha)	6.4	6.6	7.2	7.2	7.9	8.9	9.7	9.4	10.1	10.4	10.7	-
Apparent yield (viss/acre)	1609	1662	1823	1815	1996	2244	2464	2373	2552	2624	2714	-
Apparent yield growth rate (%)	-	3.3	9.7	-0.4	9.9	12.4	9.8	-3.7	7.6	2.8	3.5	5.8

Source: DOF, 2014

Figure 2 Myanmar inland fishpond area



Source: DOF, 2014

Data on pond area as reported by DOF is broken down by location (state/region) in Figure 2. This illustrates the primacy of Ayeyarwady Region in inland aquaculture, with just over half of total pond area in 2014. The adjoining regions of Yangon and Bago accounted for 27% and 12% of reported pond area respectively in 2014. All other states and regions combined contributed just 10%. The relative shares of reported pond area among the three main producing regions remained relatively constant from 2004 to 2014. The location of 90% of inland fish ponds in the Ayeyarwady delta drove the decision to concentrate exclusively on farms in this area during fieldwork, with a particular focus on Ayeyarwady and Yangon regions, which account for almost 80% of Myanmar's inland fish ponds.

3.3. International Trade

Officially recorded exports of fish from inland aquaculture began in 2004, with a small quantity of rohu exported to Bangladesh. Nine years later, in 2012, total reported exports had reached 99,393 t, comprised predominantly of rohu (Table 5), worth a reported $110 million (DOF, 2012). Although these figures are significant, exports of fish from freshwater aquaculture never exceeded 14% of total reported farm output during these 11 years. This suggests that the characterization of Myanmar's aquaculture as export-driven has been overstated (Table 6).

Table 5 Quantity and share of freshwater aquaculture exports, 2004-2011

	2004		2005		2006		2007		2008		2009		2011		2012	
Product	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)	(t)	(%)
Rohu	45	100	30,015	74	31,630	77	59,207	83	66,084	84	69,766	86	85,194	87	85,290	86
Mrigal	0	0	2506	6	3612	9	4710	7	4286	5	5254	6	5929	6	6279	6
Catla	0	0	1633	4	1816	4	2141	3	3437	4	2662	3	2544	3	2965	3
Tilapia	0	0	575	1	1752	4	3541	5	2034	3	1474	2	838	1	1444	1
Pangasius	0	0	4336	11	1607	4	1467	2	1704	2	1357	2	435	1	1458	1
Common carp	0	0	691	2	797	2	668	1	804	1	882	1	974	1	1362	1
Pangasius fillet	0	0	424	1	56	<1	0	0	129	<1	124	<1	197	<1	333	<1
Pacu & others	0	0	195	<1	0	0	0	0	0	0	0	0	40	<1	262	<1
Total	45	100	40,376	100	41,270	100	71,735	100	78,477	100	81,519	100	96,151	100	99,393	100

Note: Trade data for 2010 is missing because it could not be accessed at the time of writing

Source: CSO, 2010; DOF, 2012

Table 6 Freshwater aquaculture exports as a share of quantity produced (%), 2004-2011

Product	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2011**	**2012**
Rohu	0.02	9.8	8.6	15.2	15.3	14.3	16.1	14.8
Mrigal	0.00	14.3	17.2	21.2	17.3	18.8	19.5	19.0
Catla	0.00	6.2	5.8	6.4	9.3	6.4	5.6	6.0
Tilapia	0.00	2.6	6.7	12.7	6.2	4.1	2.1	3.3
Pangasius	0.00	54.7	15.8	13.2	12.9	9.7	4.0	10.3
Common carp	0.00	5.3	5.0	4.0	4.3	4.2	4.3	5.5
Others	0.00	0.8	0.0	0.0	0.0	0.0	0.3	1.6
Total	0.01	10.2	8.7	14.3	14.0	12.9	14.0	13.3

Note: Trade data for 2010 is missing because it could not be accessed at the time of writing

Source: CSO, 2010; DOF, 2012; FAO, 2015a

Concentration or dispersion of trade can be estimated by calculating the proportion of a country's total imports and exports contributed by its top 10 (or five, or one) trading partners (Alamgir, 2008). Data on fish imports to Myanmar disaggregated by country are not available, but FAO (2015b), reports a figure of 6029 t for aggregate fish imports to Myanmar in 2011. This amounts to just 1.6% of total fish exports, meaning that exports alone provide a good indication of the degree of concentration of Myanmar's fish trade. The top five trade partners accounted for 91% of exports over the period 2004-2012, out of a total of 36 countries. This indicates a very high reliance on a small number of markets (Table 7).

Table 7 Cumulative volume and share of freshwater aquaculture exports 2005-2012, by importing country

Trade partner	Volume of	Share of trade
Kuwait	172,774	34
Saudi Arabia	94,034	18
Bangladesh	88,136	17
UAE	62,262	12
Singapore	44,886	9
Top 5 trade	*462,093*	*91*
Other trade	46,367	9
All trade	508,460	100

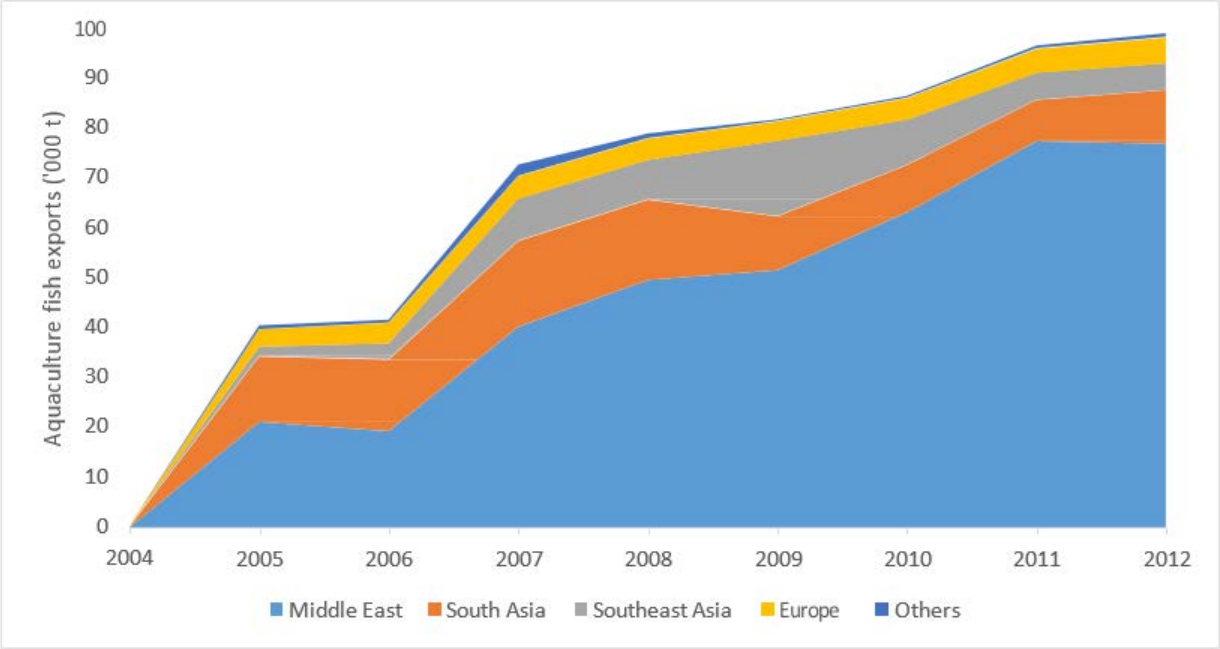
*Excludes missing data for the year 2010

Source: CSO, 2010; DOF, 2012

Myanmar's farmed fish exports are dominated by rohu, along with two other 'Indian major carp' species; mrigal (*nga gyin; Cirrhinus cirrhosis*) and catla (*nga gaung pwa; Catla catla*). Although widely consumed throughout their native range in South Asia and Myanmar, these fish are of limited popularity in other regions. Myanmar's main trading partners for these fish are thus countries in which there are large expatriate populations of people of South Asian origin, most importantly in the Middle East. Some fish is also traded directly to neighboring Bangladesh where it is consumed or re-exported. The fifth largest importing country, Singapore, is the main destination for goods transshipped from Myanmar, and also has a significant population of South Asian origin, as does neighboring Malaysia. Exports beyond these few key destinations are of limited significance (Figure 3).

Although the population of expatriate workers in the Gulf States numbers 11-12 million people (Kapiszewski, 2006; Winckler, 2010), not all are of South Asian origin, and this population has somewhat limited growth prospects. In contrast, the domestic market for farmed fish in Myanmar, with its population of 53 million, has strong long term growth prospects as urbanization, incomes and communications improve, and the productivity of freshwater and marine capture fisheries decline. In addition, domestic trade is less prone to instability (e.g. as a result of exchange rate fluctuations and occasional trade embargoes) than exports. The current dominance of rohu as Myanmar's main freshwater aquaculture product and its status as an 'ethnic niche' product in international markets suggests somewhat limited prospects for the long term growth of exports, unless significant product and market diversification occurs

Figure 3. Volume of freshwater aquaculture exports by importing region, 2004-2012



Source: CSO, 2010; DOF, 2012[5]

3.4. Fish Consumption

Consumers are the endpoint in any food value chain. Understanding consumer preferences and changing consumption behaviors is therefore key to understanding likely future demand for fish, as well as how changes in food supply may affect the food security of different sectors of the population.

Fish are a particularly rich source of high quality protein, a range of micronutrients (e.g. calcium, zinc, iron, vitamins) and fatty acids essential for human health and development. As such, they add diversity to diets dominated by starchy staples high in energy but low in micronutrients (Belton & Thilsted, 2014). Fish consumption thus makes an important contribution to food and nutrition security in many regions where large numbers of people are poor and undernourished. Other animal source foods (meats, milk and eggs) can play a similar role. The contribution of all animal source foods to nutrition security exceeds that of their intrinsic micronutrient content, because their consumption facilitates the absorption of micronutrients from portions of the diet of vegetable origin which would otherwise be inhibited (Leroy and Frongillo, 2007). Given the similar

[5] Missing data for 2010 are estimates

dietary function and nutritional significance of fish and other animal source foods, this sub-section and the one that follows present data allowing for comparison of both sets of products.

Myanmar is reported to possess one of the highest levels of fish and seafood consumption of any country in the world, ranked 10th out of 178 nations (FAO, 2015b). Reported apparent consumption stood at 55 kg per capita in 2011, exceeding that of any other Southeast Asian country other than Malaysia; around 20 kg per capita per year more than Cambodia, Vietnam and Philippines (the countries with the next highest levels of consumption in the region), and nearly three times the global average of 19 kg per capita (Table 8).

Table 8 Fish and seafood supply per capita in Southeast Asian countries and the world, 2011

Countries	Fish and seafood supply (kg/capita/year)
Malaysia	58.1
Myanmar	55.0
Cambodia	35.5
Viet Nam	33.2
Philippines	32.7
Indonesia	28.5
Thailand	22.4
*World average	18.9
Laos	16.6

Source: FAO, 2015b

The Integrated Household Living Conditions Assessment (IHLCA) is a nationally representative household survey for Myanmar, last conducted in 2010 under the auspices of the Ministry of National Planning and Economic Development and UNDP. The survey's purpose is to provide statistical data for determining living conditions in Myanmar (IHLCA, 2011a). As such, the survey instrument contains a detailed food consumption module with a seven day recall period, which records the details of 203 foods, of which 35 are fish and seafood or products derived from them.

The survey was conducted in two rounds of around two months each. The first took place between December 2009 and January 2010 (after the main rice harvest), and the second from May 2010 onwards (before the harvest) (IHLCA, 2011a). IHLCA thus captures part of, but not all, seasonal variation in food consumption. This dataset was used to estimate consumption of fish and other foods. The survey period does not cover the months of April and October, when the largest Buddhist festivals are held, so it is probable that the annual food consumption estimates derived are conservative.

Average frequency of consumption of both fish and meat is very high. Almost 100% of households surveyed consumed fish or fish products of some kind during the combined 14 day recall period of the two survey rounds. Even within the seven day recall period of each individual survey round, 97% of households consumed fish products and around 90% consumed meat (Table 9).

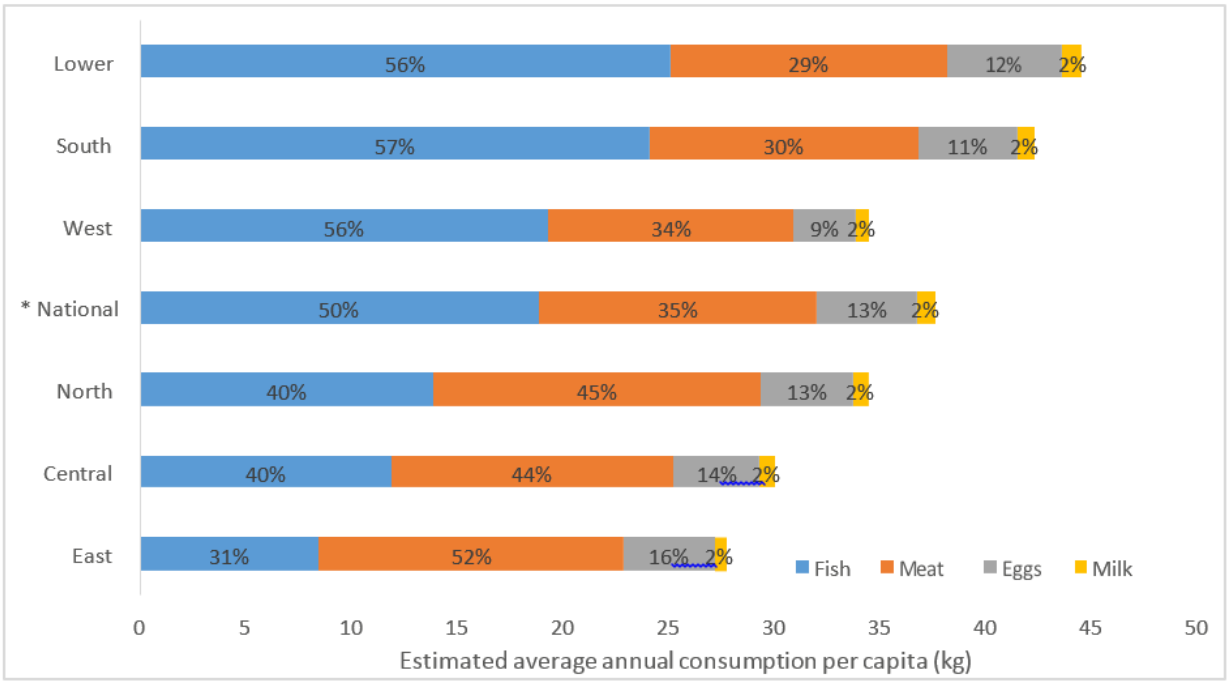
Table 9 Share of households consuming fish and meat by survey round

	Aquaculture	Freshwater capture	Marine capture	Dried/processed fish	All fish	Meat
Round 1 (Dec-Jan)	48.4	58.5	38.9	88.2	97.2	89.5
Round 2 (May-Jun)	52.2	51.3	36.7	90.7	97.3	92.1
Round 1 &2	67.0	72.9	52.6	96.3	99.3	97.7

Source: authors' calculations from IHLCA 2010 dataset)

Fish accounted for 50% of the animal source food consumed nationally, while meat provided just over one third (Figure 4). Eggs made up most of the remainder, with consumption of fresh milk extremely limited, at 2%. National average fish consumption for 2010 was estimated at 18.9 kg/capita. For reasons noted above, this may be something of an underestimate. Nevertheless, it is striking that it stands at well under half the 50.2 kg/capita fish supply reported in the FAO food balance sheet for 2010 (FAO, 2015b). The magnitude of this gap seems to imply that Myanmar's fish consumption as recorded in the FAO food balance sheet, along with the national fish production figures from which this number is calculated, are significantly inflated.

Figure 4 Myanmar estimated average annual consumption of animal source foods per capita, by location



Source: authors' calculations from IHLCA 2010 dataset

Myanmar is comprised of six geographical regions: South (Tanintharyi, Mon, Kayin); Lower (Ayeyarwady, Yangon, Bago); West (Rakhine, Chin); Central (Mandalay, Magway); North (Sagaing, Kachin); East (Shan, Kayah). Southern, Lower and Western Myanmar all have lengthy coastlines,

providing access to marine fisheries, and (in some places) rivers and deltaic environments utilized for lowland wet rice cultivation and freshwater capture fisheries. Aquaculture is heavily concentrated in Lower Myanmar. These three areas, had the highest estimated levels of fish consumption in the country, both relative and absolute, ranging from 56-57% of animal source food consumption, and 19.4-25.1 kg/capita/year.

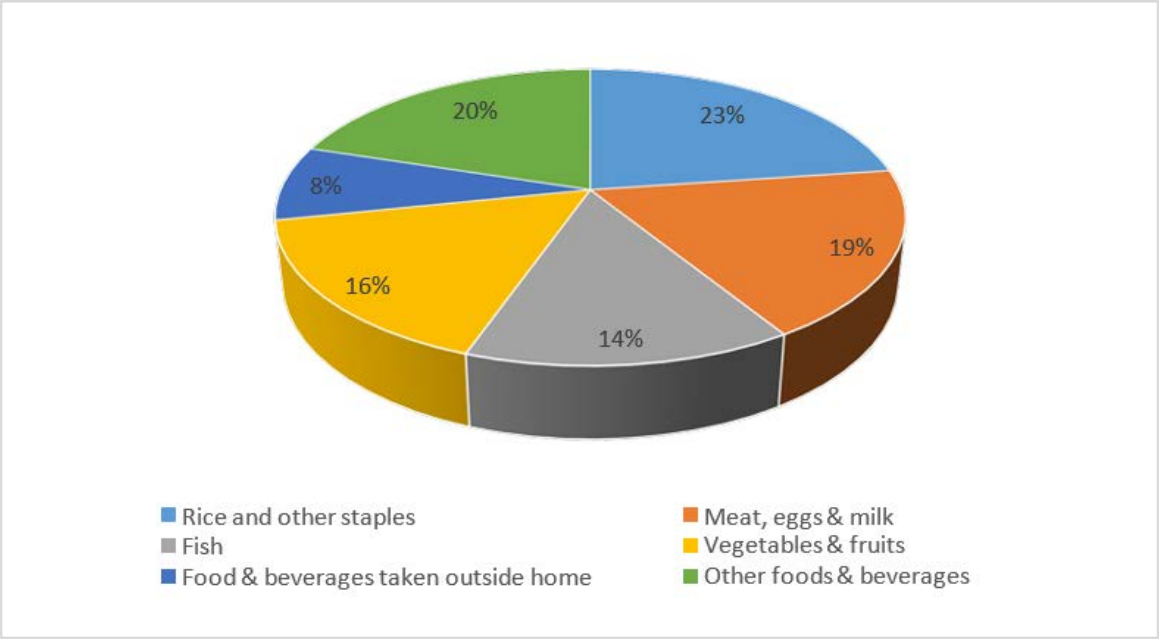
The estimated contribution of fish to the diet was smaller in the landlocked Central, North and Eastern areas that make up Upper Myanmar. These areas, where much of the environment is arid, hilly or mountainous, are distant from the main sources of fish production. Consumption of fish was lowest, although still significant, in eastern Myanmar, where average estimated consumption stood at 8.5 kg/capita/year, or 30% of all animal source food. Interestingly, while consumption of fish varied considerably with geography, consumption of meat, eggs and milk was relatively consistent across regions, with meat consumption ranging from a low of 11.6 kg/capita/year in Western Myanmar to 15.5 kg/capita/year in the North. This suggests that there is rather limited substitution between meat and fish, with fish consumption tending to occur *in addition to*, rather than in place of, meat.

The large share of staples in food budgets (and thus, total consumption expenditures), particularly among the poor, has long been a key justification for agricultural policies that aim to ensure national food security by limiting upward pressure on rice prices (Warr, 2013). However, all staple foods combined represented just 23% of total food consumption expenditure in Myanmar in 2010 (with rice alone accounting for just 19% of total food expenditure), whilst all animal source foods combined accounted for almost one third (Figure 5).

Among expenditures on animal source foods, average expenditures on fish and meat were almost equal, at just under 15% of the total food budget each (with eggs and milk combined accounting for about 3%). These observations fall within a similar range to the shares of food budgets allocated to cereals and non-staples in other Asian countries, contradicting the rationale of, "the near exclusive focus on cereal in general and rice in particular in the food security debate in Asia" (Reardon et al. 2014, p14). These figures also suggest strongly that the type of profound transformation occurring in diets and food systems throughout the rest of Asia is already well underway in Myanmar too. An important implication of this finding is that upward movements in the real price of fish and other animal source foods have potential to significantly increase overall food expenditures (thereby reducing effective incomes), or to reduce non-staple food consumption (with potentially adverse impacts on nutrition security). Falling real fish and meat prices would have the opposite effect.

The large share of expenditure on non-staple animal source foods relative to rice, evident in Figure 5, is consistent with Bennett's Law, which states that the share of cereals in total expenditure declines as incomes increase (Bennett, 1954). Further analysis confirms this, indicating that the share of staples in total food expenditures falls from an average of 26% for households in Quintile 1 (the poorest 20% of the population), to 20% among households in Quintile 5 (the wealthiest 20%)7. In contrast, the share of total food expenditure on animal source foods increases slightly across Quintiles 1 to 5, from 31% to 34%. However, even among households in the poorest quintile, the share of total expenditure devoted to animal source foods exceeds expenditure on staples, underlining the importance of the former for food security.

Figure 5 Share of national food expenditure by food group (%)



Source: Authors' calculations from IHLCA 2010 dataset

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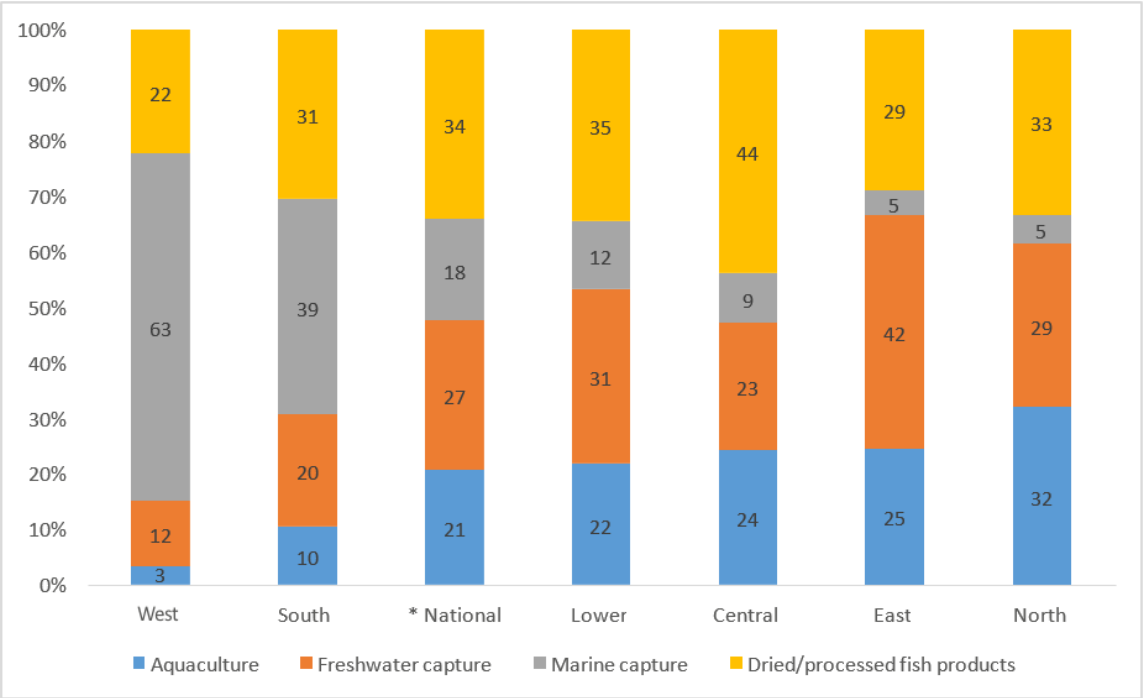
Focusing on the composition of fish consumption by source (marine and freshwater capture fisheries and aquaculture), and product type (fresh and processed), it is apparent that dried and other processed products account for the largest share of fish consumption nationally (34%). Among fish consumed in fresh form, freshwater capture fisheries account for the largest share (27% of total consumption), with aquaculture and marine capture fisheries contributing 21% and 18% respectively (Figure 6).

[6] Quintiles are defined based on consumption expenditure (food plus non-food), which is taken as a proxy for income.

Figure 6 Share of fish consumed by source and region



Source: Authors' calculations from IHLCA 2010 dataset

Processed fish products (mainly dried or fermented) are comprised of a mix of fish and shrimp from marine and inland capture fisheries. Fish from aquaculture are almost always sold in fresh form. Drying and fermenting have traditionally been used to preserve fish which would otherwise spoil quickly, smoothing seasonal gluts and shortages and facilitating trade over long distances in the absence of ice production and refrigeration.

Although the share of processed fish in total consumption seems extremely high, it does fall within approximately the same range reported in some areas of the Lower Mekong River Basin with similar aquatic ecologies (Hortle, 2007).

Consumption of aquaculture fish is lowest in West and South Myanmar, where marine capture fisheries dominate production. Interestingly, although absolute levels of consumption of fish from aquaculture (5.5 kg/capita) are highest in Lower Myanmar, where the vast majority is produced, its contribution to the diet is greatest in Upper Myanmar (central, northern and eastern areas), where it accounts for 23-32% of total fish consumption. This indicates the existence of considerable domestic trade in farmed fish, allowing the penetration of fresh fish produced in the delta far into Upper Myanmar. In fact, Upper Myanmar accounted for 47% of farmed fish consumption, with 43% occurring in Lower Myanmar, and just 10% in coastal areas (South and West Myanmar combined). This result highlights the scale and significance of intra-national trade in aquaculture products and its important implications for food and nutrition security in fish deficit areas of the country.

Fish consumption behaviors vary not only among different areas of the country, but between rural and urban zones, and across income groups (Table 10). Estimated average annual fish consumption per capita is almost the same in both rural and urban areas, at around 19 kg/year. This pattern is interesting because urbanization (and the higher incomes with which it is normally associated) is usually found to result in overall increases in fish consumption (c.f. Toufique and Belton, 2014).

Table 10 Average consumption of fish by source, location and expenditure quintile

Average consumption (kg/capita/year)	Aquaculture	Dried/ processed fish	Freshwater capture	Marine capture	All fish
National	3.9	6.4	5.1	3.5	18.9
Rural	3.5	6.5	5.5	3.3	18.7
Urban	5.0	6.3	4.0	4.1	19.4
Difference (U-R)/R (%)	41	-2	-27	25	3
Quintile 1	1.6	4.2	4.3	3.0	13.0
Quintile 2	3.2	5.8	4.6	3.0	16.6
Quintile 3	4.1	6.4	4.8	3.1	18.4
Quintile 4	4.9	7.3	5.3	3.8	21.2
Quintile 5	5.5	8.3	6.3	4.4	24.5
Difference (Q5-Q1)/Q1 (%)	253	98	47	45	88
Consumption increase per quintile (%)	34.4	17.3	9.5	10.1	16.2

Source: Author's calculations from IHLCA dataset 2010

However, aggregate consumption figures mask important differences in the source of fish consumed. Average consumption per capita of freshwater capture fish is 27% higher in rural areas than urban, probably reflecting the nature of the inland fishery, much of which is dispersed and small-scale, making the assembly of sufficiently large quantities to export to urban areas problematic, with the result that much of the catch is consumed locally.

Consumption of fish from marine capture and aquaculture is higher in urban areas than in rural (by 25% and 41% respectively). Dried and processed fish is consumed in almost equal quantities in rural and urban areas.

The apparent propensity of urban dwellers to consume farmed fish in greater quantities than their rural counterparts appears to indicate a high degree of substitutability with inland capture fish. This tendency is significant in terms of likely future demand patterns, given that progressively greater urbanization is likely to be a feature of Myanmar's geography as the country (which is currently in a stage of 'nascent urbanization', with around 30% of the population living in urban areas) integrates further into the global economy, and transitions away from a national economy dominated by the primary sector (World Bank, 2015a).

Total annual fish consumption per capita among the wealthiest 20% of the population is close to double that among poorest 20% (25kg versus 13kg). Disaggregating further, a similar pattern holds for dried/processed fish. Consumption of fish from both marine freshwater capture fisheries is more equitably distributed across income groups, with consumers belonging to the wealthiest quintile

eating, on average, less than 50% more than consumers in the poorest quintile. Inequality in consumption between rich and poor is greatest for aquaculture fish, average consumption per capita of which is around 3.4 times higher among members of the wealthiest quintile than among those in the poorest 20% of the population (5.5 kg versus 1.6 kg) (Table 10).

From this observation it can be inferred that the income elasticity of demand for aquaculture fish is higher than that for fish from other sources (i.e. an increase in income will result in a proportionately greater increase in expenditure on farmed fish than on fish from other sources). This is apparent from the final row of Table 10, which indicates that moving up one quintile will result, on average, in the consumption of 34% more aquaculture fish, as compared to 17%, 10% and 10% more dried/processed, freshwater capture and marine capture fish, respectively.

These findings have main two implications: First, as the economy grows and incomes rise, demand for farmed fish will increase faster than demand for fish from other sources. Second, the relatively unequal consumption of aquaculture fish across income groups, as compared to fish from other sources, reflects the low diversity and rather undifferentiated nature of Myanmar's fish farm sector (dominated as it is by a single species), equating to limited range of products and prices. Capture fisheries are characterized by much higher diversity of fish species and thus offer "something for everyone", including the poorest consumers. Consequently, there is scope for the development of a more diversified aquaculture sector that caters to a wider range of consumer demand. This possibility has precedents in many other countries in the region, where aquaculture supplies a wide variety of products, including those consumed by low income consumers (Toufique and Belton, 2014; Belton et al. 2009).

3.5 Fish Prices

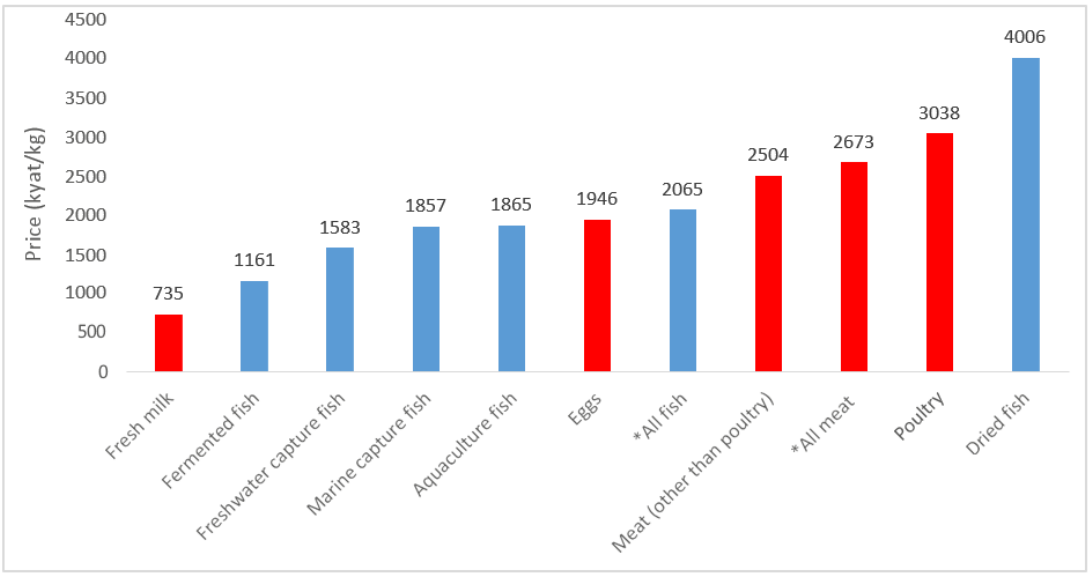
Fish represent a cheaper source of micronutrients than other animal source foods (Figure 7). The price of fresh fish was 35% lower on average than that of meat in 2010. Other than milk (consumption of which was negligible), fermented fish/shrimp products were by far the cheapest animal source food. Freshwater capture fish were moderately cheaper on average than marine capture fish, while fish from aquaculture were, on average, marginally more expensive than those from marine capture. This underlines the point that while farmed fish is cheaper than eggs and all meats, it may still be less accessible to the poorest consumers than fish from other sources. The unit price of dried fish is more than double that of fresh fish, but this price differential reflects water loss during the drying process, which makes it a concentrated source of nutrients, representing good value for money despite the high nominal price.

Fish prices vary widely across the country, reflecting transportation costs, differences in supply, and localized consumer preferences (Figure 8). In general, prices are lowest closest to the point of production, and highest in the areas most distant. Thus, the overall trend is for lower prices in West, Lower and South Myanmar, where the majority of capture fisheries and aquaculture production occurs. East Myanmar has both the lowest levels of fish consumption and the highest prices for fish in all categories.

The lowest prices for fish of all types are found in West Myanmar, comprised of Chin and Rakhine, the two states with the highest poverty incidence (IHLCA, 2011b). Although Rakhine has a large marine capture fishery, this cannot account for the low prices of farmed and freshwater capture

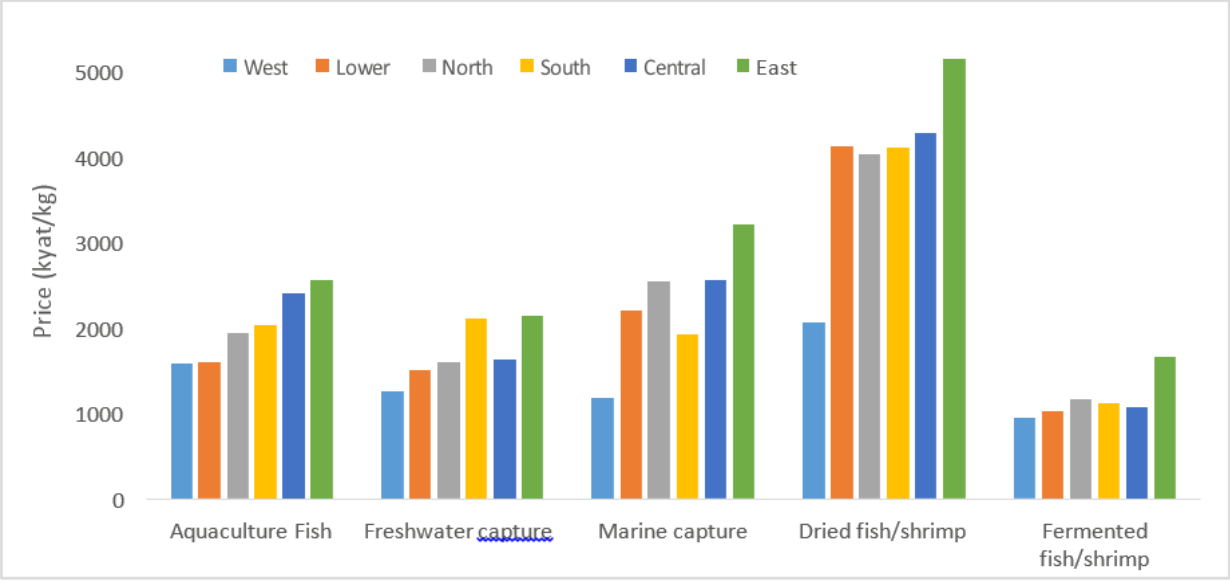
fish consumed there. This result can be attributed to a tendency to poor consumers to eat cheapest of fish available, from all sources.

Figure 7 National median prices of animal source foods



Source: Authors' calculations from IHLCA, 2010 dataset

Figure 8 Median prices of categories of fisheries product by geographical zone (kyat/kg)



Source: Authors' calculations from IHLCA, 2010 dataset

Historical commodity prices provide an indication of long term shifts in supply and demand. The Central Statistical Office collects prices of a basket of household goods, including 10 fisheries products, on a regular basis from retail markets around the country in order to construct the consumer price index (a measure of inflation). Prices of the three most important species harvested from the freshwater capture fishery, marine capture fishery and aquaculture are presented in Figure 9. These are: striped snakehead (nga yant; Channa striata); hilsa (nga thalauk; Tenualosa ilisha); and rohu, respectively. Prices for the period May 2008 to January 2015 are adjusted for inflation with the monthly consumer price index for food, using April 2008 as the base.

The real price of snakehead (freshwater capture) and hilsa (marine capture) increased by 2.9% and 5.2% per year on average over the period 2008-2014 respectively, whilst the real price of the main farmed fish, rohu, fell 0.5% per year. Among 10 common fisheries products analyzed, the real price of eight out of nine originating entirely or predominantly from capture fisheries increased faster than the rate of inflation (Table 11). Similar long term trends in real fish prices, as a result of declining capture fisheries productivity or production relative to demand and rapidly expanding aquaculture, have also been reported in neighboring Bangladesh (Toufique and Belton, 2014).

Table 11 Annual changes in the real price of animal source foods, 2008-2014

Origin	Freshwater capture						Marine capture			Aquaculture	Livestock farming		
Product	*Nga yant*	*Nga yant* (dried)	*Nga ku*	*Nga gyi*	*Pazun doke*	*Nga pi ye* (fish)	*Nga thalauk*	*Pazun kyawt*	*Nga pi ye* (shrimp)	*Nga Myitchin*	Pork	Chicken	Eggs
Annual price change (%)	2.94	4.45	1.20	1.67	3.19	1.43	5.20	3.77	-2.82%	-0.47%	0.91	-1.77	-1.94

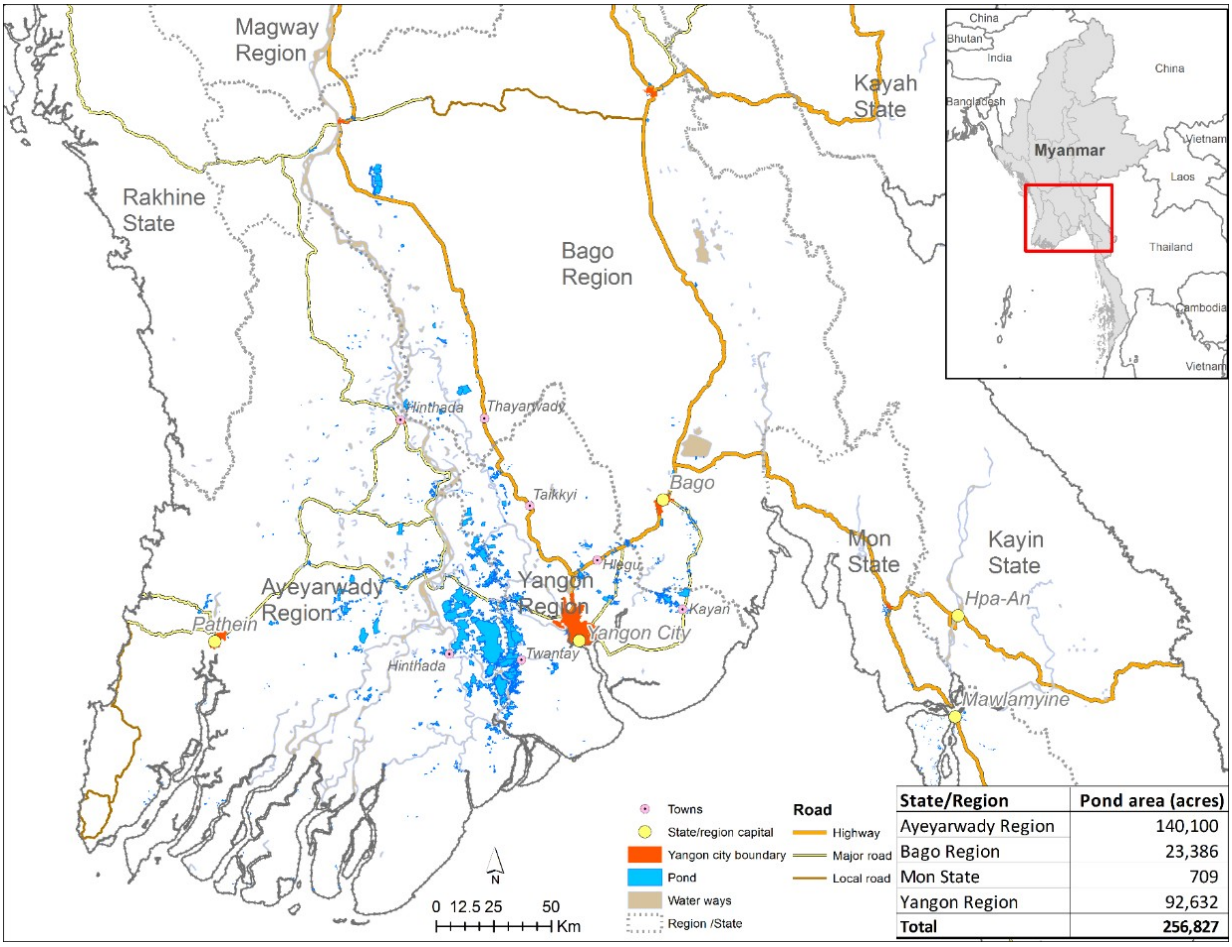
Source: CSO, various years

The real price of chicken meat and eggs which, like rohu, are produced in large volumes by a rapidly growing commercial farm sector, fell by an average of close to 2% per year over the same period. These figures indicate that aquaculture will have an increasingly important role to play in Myanmar's future fish supply, as the only fisheries subsector with potential to expand production sufficiently rapidly to avert real price increases.

3.6 Geospatial Analysis

Inland aquaculture in Myanmar has developed in a highly geographically clustered manner (Figure 10). The greatest concentrations of ponds are found in an area of floodplain located approximately 25-50 km west of Myanmar's largest city, Yangon (population 3.4 million), between the Ayeyarwady and Yangon rivers, along the borders to the two regions bearing the same names. These rivers are connected by the Twantay Canal, a large artificial waterway constructed for shipping during the British colonial period, which provides rapid access to Yangon (Cheng, 1968). The whole area is intersected by many smaller rivers, and canals constructed for water management and transport as part of efforts to control heavy seasonal flooding and bring the delta under agricultural cultivation. Most transport in this area is by boat, but it is also bisected by the Yangon-Pathein highway and a few smaller roads.

Figure 10 Fish ponds in Lower Myanmar



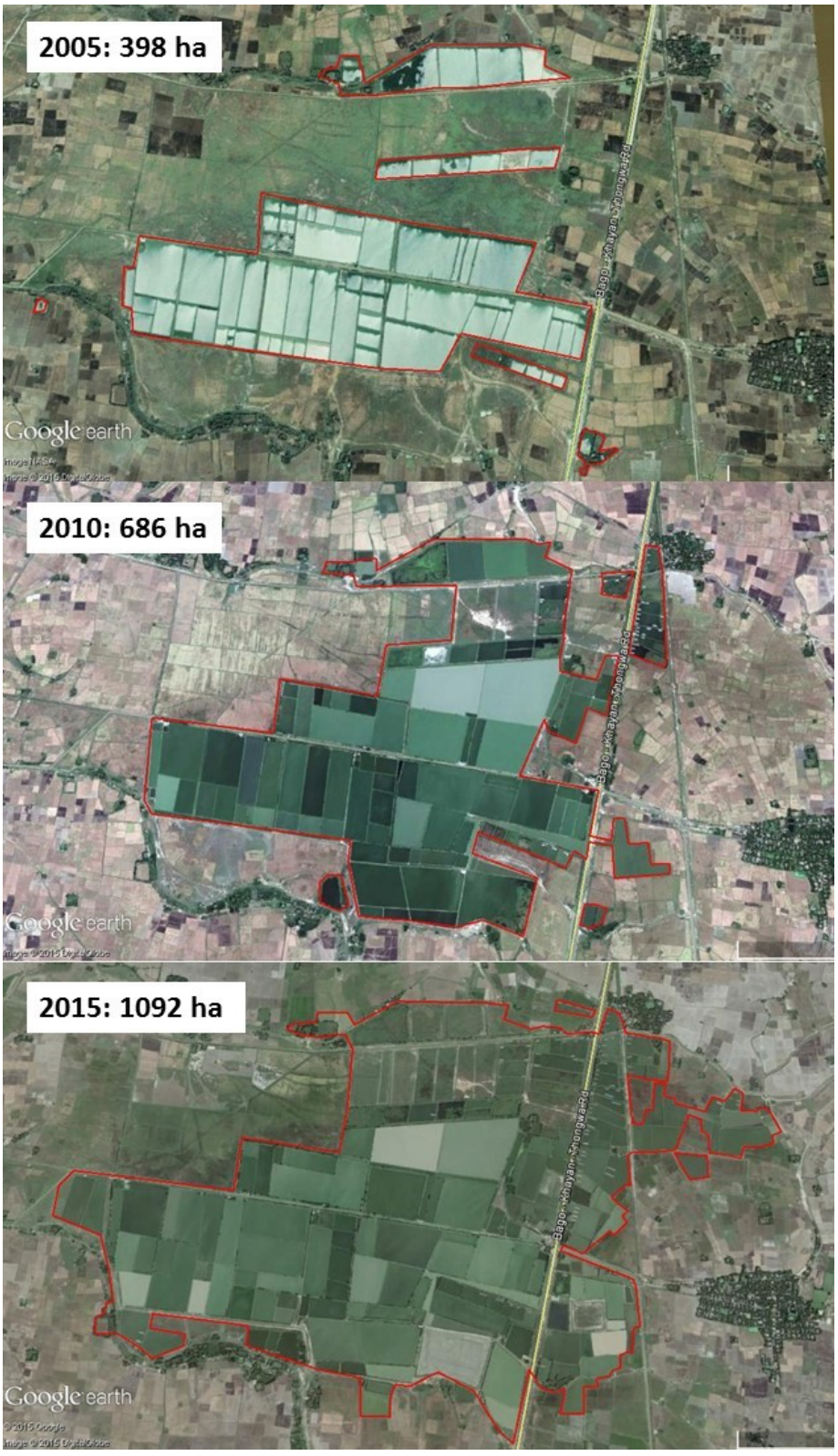
State/Region	Pond area (acres)
Ayeyarwady Region	140,100
Bago Region	23,386
Mon State	709
Yangon Region	92,632
Total	**256,827**

Aquaculture has also developed in peri-urban areas along the main highways leading out of Yangon, and to the east and north of Yangon city, north into Bago, and further west from the main aquaculture zone in Ayeyarwady. All these clusters are close to major rivers or canals, which provide water for transport and farming. Many of the fish farms immediately to the north of Yangon and in southern Bago are integrated with feedlot based poultry production. Almost all major pond clusters are located within a few hours travel time of the central 'demand hub' of Yangon, where the vast majority of the country's farmed fish are traded through the San Pya wholesale market, which stands on the Yangon River in the Southwest of the City. San Pya is connected to a dense road network, via which fish can be distributed throughout the city and beyond

Figure 11 illustrates the process used to estimate pond area. Analysis of satellite images facilitates comparison of estimated and officially reported pond area. There is a significant gap between these figures in Ayeyarwady and Yangon regions, where estimates exceed officially reported numbers by 24% and 55% respectively, a total of 60,000 acres (Table 12). In Bago and Mon, officially reported pond area exceeds that identified using Google Earth by 10% and 27%,

respectively (a difference of 2890 acres), suggesting that not all ponds were identified during analysis of satellite images. Total pond area for the four regions/states combined exceeds that officially reported by 29%. These findings imply that official statistics for fish production are inflated as a result of over reported yields, rather than over reported area.

Figure 11 Changes in fishpond area in part of Kayan pond cluster, Yangon region, 2005-2015



Source: Google Earth Pro

Table 12 Comparison of officially reported and estimated pond area

	Pond area (Official)		Pond area (Google Earth)		Difference
Region/State	Acre	Ha	Acre	Ha	(%)
Ayeyarwady	112,892	45,705	140,100	56,721	24
Yangon	59,864	24,236	92,632	37,503	55
Bago	26,014	10,532	23,386	9,468	-10
Mon	975	395	709	287	-27
Sub-total	199,745	80,868	256,827	103,978	29
Others	22,282	9,021	n/a	n/a	-
Total	222,027	89,889	n/a	n/a	-

Source: Authors' own calculations from DOF, 2014; Google Earth Pro

Ponds are highly geographically clustered, with just three townships out of 70 where ponds were identified. These three townships (Maubin, Twantay and Nyaungdon) alone account for 62% of total estimated pond area. Ponds take up an estimated 15-30% of land area in these three townships, but less than 2% of land area in another 60 townships, and just 1.3% of total land area in the surveyed 70 townships overall (see Annex 1 for details). Thus, while the effects of aquaculture on land use change can be significant locally, they are small when considered at scale.

In order to build up a picture of changes in pond area over time, the process of identifying ponds in selected clusters was repeated using historical satellite images taken at three intervals of five years (Figure 15). Table 13 presents the results of this analysis of pond area and numbers in five aquaculture clusters.[7]

Pond growth occurred at different rates in different locations. At one the longest established clusters, "Melbi Island" in Twantay Township (Yangon), ponds already occupied virtually all suitable land in 2003. However, expansion of ponds in "Nyaungdon Island" (the largest pond cluster in Myanmar, covering part of Nyaungdon and Maubin townships in Ayeyarwady) was much more rapid during this period, increasing 250%. Rapid growth also took place in Hlegu just north of Yangon city, where pond area increased more than 150% in 10 years. Other clusters in Yangon region grew by around 40%. Growth slowed in all clusters in the period after 2009. Officially reported pond area growth rates for the period 2004-2014 for Ayeyarwady and Yangon were 49% and 24% respectively (DOF, 2014). It thus seems that official documentation of pond expansion has failed to keep pace with changes occurring in Ayeyarwady and Yangon.

[7] Google Earth images are composites patched together from multiple sources, and older images are of sometimes variable quality. This made it impossible to analyze historical images of exactly the same age for all locations.

Table 13 Historical changes in pond area and characteristics in aquaculture clusters in Yangon and Ayeyarwady regions

Item	Pond area (acres)	Number of ponds	Average pond size (acres)	Integrated pond area (acres)	Number of integrated ponds	Average integrated pond size (acres)	Integrated ponds area / total pond area (%)
Kayan Cluster (Kayan Township, Yangon Region)							
2005	5115	2042	2.5	0	0	0	0
2010	6081	2103	2.9	556	137	4.1	9
2014	7170	2431	2.9	848	247	3.4	12
Change '05-'14 (%)	40	19	16	-	-	-	-
Hlegu Cluster (Hlegu Township, Yangon Region)							
2004	678	128	5.3	0	0	0	0
2009	1553	173	9	584	86	6.8	38
2014	1721	266	6.5	1281	176	7.3	74
Change '04-'14 (%)	154	108	23	-	-	-	-
"Melbi Island" Cluster (Twantay Township, Yangon Region)							
2003	7667	950	8.1	0	0	-	-
2011	7781	967	8	0	0	-	-
2014	7781	967	8	0	0	-	-
Change '03-'14 (%)	1	2	-1	-	-	-	-
"Nyaungdon Island" Cluster (Nyaungdon & Maubin Townships, Ayeyarwady Region)							
2003	9698	994	9.8	0	0	-	-
2010	27663	1509	18.3	0	0	-	-
2014	34192	1736	19.7	0	0	-	-
Change '03-'14 (%)	253	75	101	-	-	-	-
Latkyargyi Cluster (Maubin Township, Ayeyarwady Region)							
2003	2240	441	5.1	0	0	-	-
2014	3111	509	6.1	0	0	-	-
Change '03-'14 (%)	39	15	20	-	-	-	-

Source: Authors' analysis of satellite images from Google Earth

In general, pond numbers appear to have grown less rapidly than pond area, implying increasing average pond size over time. Average pond size in most clusters in 2014 ranged from 3-8 acres. Average pond size in three locations increased by approximately 20% over the decade. The largest ponds, and biggest increases in pond size were evident in Nyaungdon Island, where average pond size doubled from 9.8 to 19.7 acres between 2003 and 2014. Fish farms often consist of multiple ponds, meaning that pond area alone is not a reliable indicator of farm size. Thus, although these figures appear to suggest a tendency for average farm size to have increased, further research is required to confirm this trend.

Another point of note is the emergence of fish farms integrated with poultry production in Hlegu and Kayan clusters, to the north and east of Yangon. In these farms, broiler or layer chickens

are housed over fish ponds, with manure and spilled chicken feed providing "free" pond inputs, which reduce the costs of fish production. This technology was absent from both clusters at the start of the decade, but subsequently underwent rapid growth, particularly in Hlegu, where three quarters of total pond area was integrated with poultry in 2014.

Analysis of satellite images also identified large numbers of very small ponds, usually located close to homesteads, with sizes ranging from around 0.02 ha to 0.2 ha but falling mainly toward the lower end of this distribution (Figure 12). Groundtruthing revealed these 'homestead ponds' to be constructed mainly for the purpose of harvesting rainwater for household use, particularly in areas with saline groundwater. Similar findings are also reported by Okamoto (2008). Groundtruthing also revealed that some of these ponds are purposely stocked with fish, primarily for subsistence consumption.

As homestead ponds were too small and too numerous to count individually, their numbers were estimated as follows: Locations in southern Ayeyarwady and Yangon regions with high concentrations of such ponds were identified and their boundaries defined in Google Earth Pro. Satellite images of these areas were overlaid with a 100 km^2 grid, comprised of a smaller 10 X 10 grids of 1 km^2 squares. Five 1 km^2 quadrants were selected at fixed positions on each 100 km^2 grid, and all homestead ponds within these quadrants were identified visually and counted. The average number of homestead ponds per km^2 in the five quadrants was then multiplied by the total area in km^2 lying within the boundaries of the area where these quadrants were located, to give a figure for the number of ponds in each. On this basis there are estimated to be a total of approximately 210,000 homestead ponds.

Figure 12 Homestead ponds close to Kayan town, with inset close up

Source: Google Earth

3.7 Synthesis: An Emerging Picture of Aquaculture and Food Security

The conventional wisdom on inland aquaculture in Myanmar, evident from a review of literature on the subject, depicts an export-dominated value chain comprised of large farms, with few, if any, small-scale producers. This sector is characterized by low productivity and poor technical efficiency, and its development is severely constrained by laws prohibiting the conversion of paddy land to ponds; in short, aquaculture in Myanmar appears to be underperforming, and its prospects for meeting domestic food security and rural development needs seem limited at present.

Official figures paint a very different picture, indicating that from 2000-2014, aquaculture in Myanmar underwent a dramatic boom, during which production volumes increased more than nine times, to reach close to 1 million t. From 2004-2014, recorded pond area increased by 67,000 acres, despite ostensibly rigid legislation aimed at preventing it from doing so, and apparent yields grew by 69% to reach an impressive 10.7 t/ha. No more than 14% of farmed fish was exported in any year during this period for which data was available. Myanmar's reported annual consumption of fish and seafood increased rapidly, to reach 55.0 kg per capita; one of the highest rates in the world. This is not the profile of a country with a sluggish, backward and inefficient export-oriented aquaculture sector that the conventional wisdom suggests.

However, triangulation with alternative sources of data on fish consumption, and analysis of satellite images suggests that both the 'conventional wisdom' and the 'national statistics' scenarios are exaggerated (one unduly gloomy, the other excessively positive), with the reality lying somewhere between the two. This apparent mismatch reflects both the dearth of rigorous research on Myanmar's aquaculture sector to date (the vast majority of English language literature on the sector being the output of brief study tours or short consultancies), and the generally poor quality of official agricultural data in the country (Haggblade et al. 2014).

Estimates of annual fish consumption per capita derived from the IHLCA dataset are less than half those reported in FAO's food balance sheets (18.9 kg/capita versus 50.5 kg/capita in 2010). Consumption estimates reported in FAO's food balance sheets are derived from government statistics on national production and trade. This implies that officially reported production levels are also likely overstated by a large margin.

Analysis of satellite images suggests that records of pond area are significantly under reported for both Ayeyarwady and Yangon regions. This interpretation is supported by analysis of historical changes in pond area, which suggest much faster areal growth rates in most pond clusters than indicated by official statistics. This observation has two implications: 1) restrictions on the conversion of land to ponds may not always be as great an impediment to pond construction as generally believed; 2) farm productivity has increased less rapidly than apparent yields calculated from official statistics would suggest.

The 'conventional wisdom' emphasizes a sector dominated by large farms, with little if any small-scale production. Farm size is not reported in official statistics, and analysis of satellite images alone does not allow for estimation of average farm size because farm boundaries cannot be identified. Estimated average pond sizes in selected commercial aquaculture clusters range between 3 and 20 acres. There are also an estimated 210,000 'homestead ponds', spread throughout southern Ayeyarwady and Yangon. This latter finding is contrary to accounts stating that ponds of this kind do not exist in Myanmar, and suggests the need to pay closer attention the potential of these resources for aquaculture. In sum, triangulation of multiple secondary data sources paints a picture

is which is more dynamic than that suggested by the 'conventional wisdom', but rather less spectacular than official statistics would imply, and considerably more complex than indicated by either.

Table 14. Alternative estimate of Myanmar's total fish production, based on consumption and exports[8]

a) Estimated consumption per capita by source and product type (kg/year)		**b) Estimated consumption per capita adjusted for processing losses and recategorized by source (kg/year)**	
Marine capture	3.5	Marine capture	11.5
Freshwater capture	5.1	Freshwater capture	9.2
Aquaculture	3.9	Aquaculture	4.1
Dried & processed products	6.5	Total	24.8
c) Apparent national production consumed domestically, by source (t)		**d) Officially reported exports, by source and product type, 2010-11 (t)**	
Marine capture	595,266	Freshwater fish (culture)	97,244
Freshwater capture	478,990	Freshwater fish (capture)	2643
Aquaculture	214,685	Marine fish	173,157
Total	482,872	Freshwater prawn	281
-	-	Marine shrimp	18,862
-	-	Fish & seafood (exported live)	20,342
-	-	Fish & seafood (dried & frozen)	61,364
		Total	373,893
e) Officially reported exports adjusted for processing losses and recategorized by source (t)		**f) Total apparent production (t)**	
Marine capture	327,884	Marine capture	923,150
Freshwater capture	45,351	Freshwater capture	524,341
Aquaculture	109,637	Aquaculture	324,322
Total	482,872	Total	1,771,813
g) Officially reported production by source, 2009-2010 (t)		**h) Difference between officially reported and estimated production (%)**	
Marine capture	2,060,780	**Marine capture**	**123**
Freshwater capture	1,002,430	**Freshwater capture**	**91**
Aquaculture	858,760	**Aquaculture**	**164**
Total	3,921,970	**Total**	**121**

Explanatory notes

a) Author's estimates for 2010, derived from IHLCA 2010 dataset.

b) Dried and other processed products were allocated by most probable source of production (i.e. marine capture, etc.) and converted to live weight equivalents using conversion factors from Hortle (2007) to obtain total apparent production of fish consumed domestically. See Annex 2 for details.

c) The total quantity of apparent national production consumed domestically is derived by multiplying adjusted estimated consumption per capita by national population of 51.93 million in 2010 (World Bank, 2015).

d) Net volumes of exports for 2010-11 by source/product categories listed in DOF (2012).

e) Officially reported product categories reallocated by probable source, and adjusted to live weight equivalents to account for processing waste using conversion factors from FAO (2015b) and Hortle (2007). See Annex 2 for details.

f) Derived by adding adjusted domestic consumption (c) with adjusted exports (e).

g) Official production statistics reported in DOF (2014).

h) Officially reported production, minus estimated production, divided by estimated production.

In an attempt to attain further clarity, an alternative estimate of Myanmar's total fish production based on consumption and trade of fish, is presented in Table 14. The estimate is derived by combining apparent domestic consumption (calculated from IHLCA 2010), with exports for 2010-11 (as reported by DOF, 2012), both adjusted to live weight equivalents (to take into account weight losses during processing). For reasons discussed above, it is likely that apparent domestic consumption is somewhat underestimated, and there are complex reasons as to why exports from Myanmar (particularly border trade), might be misreported, in either direction (Kubo, 2012). It must therefore be emphasized that this calculation is imperfect, and figures derived from it should be treated as a rough guide only.

These caveats notwithstanding, the magnitude of the gap between officially reported and estimated production is striking, standing at 121% for all fisheries products combined, and 164% for aquaculture. In the case of aquaculture this would imply total production in 2010 of just 324,000 t,

[8] Calculations on which these estimates are based are presented in more detail in Annex 2

rather than the 859,000 t officially reported, making the country a less significant player in global aquaculture than is currently understood. There are precedents for over-reporting on a comparable scale in other agricultural sectors in Myanmar. The United States Department of Agriculture (USDA) estimates, for instance, that officially reported rice production is 90% too high (Haggblade et al. 2013). Another important implication of this finding would be that exports of aquaculture products account for one third of total production of farmed fish.

4. AQUACULTURE VALUE CHAINS IN MYANMAR: EVIDENCE FROM THE FIELD

The second half of this report summarizes key findings from a 'rapid reconnaissance' study (Reardon et al. 2012) of the aquaculture value chain in Lower Myanmar, conducted from September to December 2014, with several follow up visits during the first half of 2015.

This analysis is intended to serve as the basis for the design of a more detailed in-depth study of the aquaculture value chain, facilitating accurate measurement of quantitative indicators of its structure, conduct and performance (e.g. farm sizes and yields, the distribution of costs and value added between different enterprise types, and the degree of concentration within each segment of the chain). The present study takes the form of a qualitative sectoral overview, but does not to provide detailed estimates of, for instance, yields, margins, or enterprise budgets. These will be derived from the follow up study.

Rapid reconnaissance findings presented in following subsections have two broad purposes. The first is to describe the aquaculture value chain in Myanmar terms of: 1) its structure (the types of enterprises operating at different scales and locations), and temporal changes in this structure and their drivers; 2) the conduct of the actors within the chain (their behavior, in terms of inputs accessed and transformed and outputs sold), and;

its overall performance, in terms of efficiency and inclusiveness. This is an important exercise because the existing literature on aquaculture on Myanmar is limited in scope and quality, and no other comprehensive description of the farmed fish value chain exists. The second purpose of the report is: 1) to identify implications of ongoing transformations occurring within the value chain for its performance, in terms of contributions to national food security and prospects for stimulating inclusive rural development, growth and employment; and 2) based on these findings, to identify potential policy interventions to steer development in optimal directions.

The following subsections provide an introduction to the main components of Myanmar's aquaculture value chain, and then focus in detail on the 'meso' structure of its up-, mid- and downstream segments, and the 'micro' behavior of the main enterprise types operating in each of these. A final sub-section synthesizes key points from this analysis, drawing attention to the processes of value chain transformation identified, their implications for rural development, future fish supply and potential policy initiatives.

4.1 Overview of Sectoral Structure

For the purposes of this analysis, the value chain is divided into three segments; upstream, midstream and downstream. Upstream is defined here as comprising all enterprises involved in the production and distribution of inputs utilized by the midstream segment.

The most important of these are 'seed' (a generic term which applies to all juvenile fish used in aquaculture) and feed. Fish seed is produced in hatcheries, and grown on in nurseries until it reaches sizes suitable for stocking 'growout' ponds where fish are raised to harvestable size. Feed consists of byproducts from agro-industrial processing (most importantly rice bran and peanut oilcake from milling) as well as manufactured pelleted feeds formulated to meet fishes' nutritional requirements. The midstream segment is comprised of farms, where these inputs are combined using labor to produce fish of marketable size. The downstream segment, as defined here, involves

all activities relating to the marketing, processing and distribution of fish produced by the midstream segment of the chain.

4.2 Upstream: Input Supply

4.2.1 Hatcheries

Origins and structure

The first hatcheries in Myanmar were established by the Department of Fisheries (DOF) during the mid-1970s. The technical knowledge required to do so was reported to have originated from trainings received by DOF staff in India. The earliest fish farmers in Kayan, to the east of Yangon (who were already raising wild fish in enclosed deep water rice fields) began to purchase seed produced at DOF stations close to Yangon. The first private hatchery was established in Kayan around 1985, through collaboration between a fish farmer from the area and a DOF officer. Members of the extended family of the first hatchery operator subsequently established hatcheries of their own in the area, leading to the development of Myanmar's first hatchery cluster in Kayan.

Myanmar's second hatchery cluster developed in Twantay after 1990, when the owner of a large farm began to produce seed on an experimental basis, also using knowledge acquired from staff at a local DOF station. In 1995, another large pond farmer in Twantay successfully established a hatchery with the support of a senior DOF official. Similar informal consultancies and partnerships, facilitating the transfer of technical knowledge between government technicians and entrepreneurial farmers, have also been an important feature of the early stages of development of commercial hatchery sectors in Vietnam, Thailand and India (Belton, 2012; Padiyar et al, 2014).

The development and uptake of technologies for the artificial reproduction of fish seed during this period was a fundamental prerequisite for the subsequent emergence of aquaculture as a significant economic activity. As noted by a classic text from this period, with reference to the development of aquaculture in Asia: "The progress of carp culture in recent years is almost entirely due to the development of induced breeding techniques" (Jhingran and Pullin, 1985, p43).

Since this time the number of commercial hatcheries has grown steadily. Many of the more recent hatcheries were established by, in partnership with, or with support from, technicians who learned their trade in early hatcheries in Kayan and elsewhere. At present, there are five hatcheries in Kayan, along with similar numbers in Twantay, and in Latkyargyi village tract in Maubin (a hatchery cluster that emerged after 2000). Individual hatcheries are also found in almost all locations with large concentrations of ponds in Yangon, Ayeyarwady and Bago regions. Some hatcheries operate as standalone businesses, while others have been established by the operators of large growout farms primarily for the purpose of providing seed for own use, with the excess sold commercially. Some large farms operate hatcheries exclusively for their own use. This may explain what appears to be a rather low total number of commercial hatcheries (i.e. those producing primarily for sale) relative to the size of the farm sector.

DOF operates a total of 27 fish hatcheries nationally, with at least one facility located in most states and regions. Their total combined seed production amounted to 549 million in 2013-14 (DOF, 2014), most of which was used for stocking natural waterbodies to enhance open water

fisheries. Government hatcheries thus make a limited contribution to seed supply for aquaculture in the delta area, which is well served by private seed producers.

This pattern is similar that found in other countries in the region, where the private sector overwhelmingly dominates fish seed supply for aquaculture. It is likely that the role of public hatcheries in supplying seed for aquaculture is more significant in states and regions which are distant from the main centers of seed production in the delta, but the overall contribution to national seed supply for aquaculture is small.

Production technology

The main fish species produced by hatcheries in Myanmar are Indian major carps (rohu, catla and mrigal), pangasius catfish (nga dan; Pangasianodon hypophthalmus), and pacu (nga mote; Colossoma brachypomum). Many hatcheries experience difficulty in producing mrigal seed, and informants estimated that 80% of the mrigal juveniles used in aquaculture are of wild origin, captured from the Ayeyarwady river system several days after hatching. The ecological impacts of this practice are unknown. There are no monosex tilapia hatcheries operational at present, although two are reported to be under development. A number of private hatcheries, including seven around Twantay, produce giant freshwater prawn. For reasons that are not fully understood, survival rates during hatching are extremely low and production of prawn post larvae is unable to meet demand.9

Fish hatchery production runs for approximately four months from May to August, during early and mid-monsoon. There are two main hatchery technologies used in Myanmar. The most widespread is the traditional 'hapa-based' system for spawning carps, in which brood (parent fish) that have been primed for reproduction by hormone injection are placed in hapas (fine mesh enclosures) in ponds at a ratio of two males to one female. The fish spawn in the hapas, and fertilized eggs are removed and placed in other hapas in the pond until they hatch.

In the more advanced system, which is adopted by only a small number of hatcheries, brood fish are manually stripped of eggs and milt following hormone injection[10], and these are mixed by hand, before placing in funnel shaped incubator nets suspended in concrete tanks for hatching. Designs similar to the latter are the norm in carp and pangasius hatcheries throughout much of Asia. Both types of hatchery are effective in producing seed, but the former appears more land and labor intensive, while the latter is more capital intensive, and can produce a greater number of hatchlings (newly hatched fish) per unit area. Brood fish are sourced from wild stocks or from farms in areas surrounding the hatchery, and there is no system in place for the maintenance or improvement of genetic lines.

[9] Freshwater prawn in Myanmar is usually grown in polyculture with carps in ponds. This practice is quite common, particularly among smaller farmers in some areas, but production is limited by insufficient seed supply

[10] The hormones used to induce spawning are imported, and are sourced through DOF, or from livestock input suppliers.

Worker tending brood spawning hapas at a "traditional" hatchery

Preparing to remove brood and fertilized eggs from spawning hapas

Collecting fertilized rohu eggs from a spawning hapa

Checking hatchlings in incubation tanks at a modern "Chinese style" hatchery

Organization of production, labor, production capacity and marketing

Most hatchlings produced in commercial hatcheries, are sold directly to nurseries in the surrounding area, or to large growout farms with the capacity to complete the entire nursery cycle. All commercial hatcheries also retain a portion of the hatchlings they produce for nursing to larger sizes and subsequent sale to growout farms.

Hatcheries are specialized enterprises, the operation of which requires considerable technical expertise. Most hatcheries employ a skilled technician responsible for the critical task of spawning brood fish, and in some cases, the hatchery operator performs this function personally. In addition, most hatcheries employ four to eight permanent staff (usually paid around $100/month) to tend brood fish, maintain the hatchery and assist with spawning. Depending on the size of the hatchery, as many as 30 workers are hired on a daily basis during peak production season, mainly for harvesting and packing hatchlings. Most hatchery workers are men, as were all the hatchery owners encountered.

The hatcheries visited reported producing between 30 million and 700 million hatchlings per year. Rohu fingerlings sold for approximately $3 per 100,000 during middle of the 2015 production season. All commercial hatcheries visited also produced several million additional fingerlings each year for sale and/or (if also operating a farm) for own use. Most hatcheries reported that their production capacity had grown significantly since they were established (often increasing two to three fold), indicating that expansion of hatchery production capacity has occurred through simultaneous growth in both the number and scale of enterprises.

Most sales of hatchlings do not involve an intermediary. Hatchlings are normally produced to order for buyers who collect them from the hatchery and transport them to the point of use in oxygenated water-filled plastic bags. In contrast, sales of fingerlings produced at hatcheries are usually mediated through traders, in the manner described below for nurseries. Some hatcheries provide credit to reliable customers, but the majority of transactions are settled immediately.

4.2.2 Nurseries

Origins and structure

Commercial nurseries (aquaculture enterprises specialized in rearing hatchery produced seed to 'fingerling' size, for sale to growout farms) are present in virtually every village where there are clusters of growout ponds. They are especially highly concentrated in locations where there are multiple commercial hatcheries. The most important nursery clusters are found in Kayan (where there are an estimated 3000 acres of nursery ponds) and village tracts along the border of Twantay and Maubin townships. In Laykyargyi village tract, which falls within this area, informants estimated that numbers of entrants into nursing had increased by 5-10 times over the last decade, and that nursery pond acreage had grown threefold. In one particular village, 80% of households with land were reported to operate a nursery, up from only 10% in 2005.

Several explanations were given for the rapid growth in nursery numbers in this area: 1) Nurseries are potentially more profitable than alternative forms of agriculture, generating an estimated 5-10 times more income than mangoes or paddy; 2) nurseries have a more rapid production cycle and revenue turnover than alternative types of agriculture or aquaculture, and it is possible to make a return within as little as two months; 3) production is less risky than for

alternative types of agriculture/aquaculture: it was reportedly rare to ever lose money when nursing; 4) there has been an increase in demand for fingerlings due to growth in the area of growout ponds, and the market price of fingerlings is currently high; 5) there has been an increase in fingerling demand due to changing production technologies, and growout farmers now have a preference for stocking larger fingerlings. Although most commercial growout farms incorporate nursery ponds for nursing seed to larger sizes, they require small fingerlings as inputs, in addition to which, most large farms cannot produce sufficient numbers of large fingerlings to meet their own needs; 6) the investment requirement to establish and operate a nursery is much lower than that for growout ponds, making it relatively easy to enter production; 7) many banana and mango orchards destroyed during Cyclone Nargis in 2008 were replaced with nurseries rather than by replanting.

Most commercial nurseries range from 1-5 acres in size (although nurseries in Kayan tend to be somewhat larger). Having lower investment costs and much more rapid rates of turnover than growout farms, nurseries serve as an entry point into aquaculture for rural households who lack the capacity to invest in food fish production. Some larger nurseries, particularly those in Kayan, retain a portion of the fingerlings they nurse to stock growout ponds of their own.

Hatcheries, nurseries and growout farms tend to co-locate in clusters due to agglomeration economies. As a result of clustering, costs of transporting seed between enterprises are minimized; laborers perform functions required by all types of enterprise (e.g. fish harvesting, pond construction, fingerling transport), and specialized services (e.g. fingerling transport boats) are available; information can easily travel between enterprises; small individual producers (nurseries, hatcheries) can easily find customers (seed traders, nurseries, growout farms); and traders can easily assemble bulk orders for distant markets from multiple small differentiated suppliers (nurseries, offering a range of choices in terms of species and sizes of fingerlings).

Many commercial growout farms buy fingerlings from nurseries, typically sized between 1- 6 inches, and nurse them for several months before stocking in growout ponds at large sizes (6-12 inches) to ensure higher survival rates and reduce the duration of production cycles. The typical areal ratio of nursery ponds to growout ponds on farm was reported to be 1:5. The main advantages gained by farms from nursing seed themselves (rather than buying fingerlings at the desired size) are reduced production costs, and the ability to ensure that seed of the desired quantity and size is available in a timely manner. There are many variations in on-farm nursing practice depending on the number of nursery ponds available and the production strategy of the farm.

Production and marketing

Commercial nurseries are usually comprised of at least two ponds, but may have many more. Hatchlings are usually purchased directly from nearby hatcheries during early-mid monsoon, and stocked at high density. Fish are harvested at monthly intervals. During the early stages of nursing they are 'thinned out' by dividing and restocking across previously empty ponds. During the later stages of nursing, fish are graded by size during each harvest and stocked accordingly to ensure that each pond contains fish of uniform size. The process of regularly grading fish by hand is labor intensive. Fingerlings are fed mainly with rice bran and peanut oilcake. Mixed carp species are usually nursed together, and pangasius are nursed separately. Fingerlings can be sold at any size from 1 inch upwards, depending on customer demand and the production strategy of the nursery.

Harvesting a nursery pond

Harvesting fingerlings for grading

Rohu fingerlings ready for delivery to farm

Specially modified fingerling transport boat with oxygenated 'live well'

In the vicinity of major aquaculture clusters fish seed is easily accessible to farms of all scales, including homestead ponds. Large farms in areas more distant from these centers are also able to access seed by ordering in bulk through traders. However, it seems likely that limited access to fish seed may still represent a constraint to small producers in more remote places, although this could not be confirmed as of the time of writing due to the geographical focus of rapid reconnaissance in more dynamic areas.

In areas outside of the main seed clusters, most fingerlings produced by commercial nurseries are sold to local growout farms, and transactions are often direct from nursery to farm without an intermediary. In larger hatchery and nursery clusters, most fingerlings are distributed through traders, often to distant locations, that individual nurseries would otherwise face difficulties making contact with and delivering to independently. A variety of payment arrangements exist. Some nursery operators will accept delayed payment from traders, while others will only accept payment cash at the time of sale. Similarly, fingerling traders may choose to extend or withhold credit for farms depending on their relationships and resources.

Fingerlings are transported using boats that have been specially modified so that the hull becomes a 'live well', and covered with netting to prevent fingerlings jumping out. Water is sprayed into the hull from suspended pipes to maintain high levels of oxygenation, and excess water is discharged automatically. The largest fingerling boats can carry 300,000 three inch fingerlings, but most have a smaller capacity. Most boats are owned by fingerling traders or hatcheries, but rental services also exist. There were reported to be 30-40 such boats in Latkyargyi and around 15 in Melbi Island, Twantay. Large numbers were also observed in Kayan. In all these locations, numbers of fingerling transport boats were reported to have increased two to three times over the last 10 years. Fingerlings can be transported by boat over long distances because the delta is well connected by a system of waterways that serve as an alternative to the road network. Small trucks and motorbikes are used to transport fingerlings packed in oxygenated bags by road where transport by water is not feasible.

4.2.3 Feed

Sources and production of feed

Feed is an extremely important input for aquaculture, accounting for the majority of variable costs. The type, quantity and quality of feeds used, and the efficiency with which they are applied are key factors influencing fish growth rates, duration of production cycle, water quality in ponds, yields and profitability. The main feeds used in aquaculture in Myanmar are byproducts from agro-processing. The most important of these are rice bran (a byproduct of rice milling, obtained by polishing grains to produce white rice), and peanut oilcake (a residue derived from milling peanuts to produce edible oil). Many other agro-processing byproducts are also utilized as supplementary feeds. These include, but are not limited to, sesame, sunflower and other oilcakes, wheat bran, broken rice, processing wastes from pulses and cassava, and waste from breweries and noodle factories (Ng et al., 2007). Rice bran, oilcakes and other agricultural processing residues are also important ingredients in manufactured pelleted fish feeds.

The ability of agro-processors to sell waste byproducts has significant implications for the efficiency and profitability of their operations. According to interviewees, rice bran accounts for approximately 10% by weight of unhusked paddy, and 6.5% of gross rice mill income. Ng et al

(2007) report a slightly lower fraction of rice bran derived from rice milling in Myanmar, at 7%. USDA (2014) estimates that paddy production in Myanmar in 2013 reached 17.3 million tons. This would amount to between 1.2 to 1.7 million tons of rice bran. Rice bran traders interviewed reported that prices had been buoyant over the long run as a result of growing demand from aquaculture.

The Bayintnaung Commodity Exchange Center, located close to the Yangon River in the west of Yangon city, is Myanmar's largest wholesale market for agricultural commodities. Large traders of agricultural byproducts located there estimated that the size of the national market for fish feeds and feed ingredients was as large as the total market for all other animal feeds combined. Figures from the Ministry of Livestock and Fisheries cited in Favre and Myint (2009), indicate that aquaculture accounts for 73% of national annual demand for rice bran (1,401,000 t) and 47% of national demand for oilcakes (601,000 t). The growth of aquaculture is thus highly dependent on these other agricultural sectors and their allied processing industries, whilst also making an important contribution to their viability, as sales of these byproducts provide an important revenue stream for mills.

We estimate that greater than 80% of aquaculture production in Myanmar is reliant on the use of agricultural byproducts and wastes as feeds (or fertilizers, in the case of integrated poultry-fish farming), with the remainder using commercially manufactured pelleted feeds.[11] The degree of penetration of manufactured feeds in Myanmar is considerably lower than in other Asian countries, including Bangladesh and India (Mamun-Ur-Rashid et al. 2013; Padiyar, 2014). A key informant estimated that Myanmar's total aqua-feed production capacity had grown quickly, from 200 t/day in 2000, to 500 t/day in 2005, to 1000 t/day in 2010, but the share of farm production utilizing pelleted feeds remained relatively small because the total size of the sector also grew substantially over this period.

Supply and distribution of pelleted feeds is dominated by a single domestically owned company, Htoo Thit. Three other domestically owned private companies were confirmed as producing and distributing pelleted feeds, but their market shares appear rather small. Another two feed mills were identified as producing feeds exclusively for the use of the large vertically integrated farming operations. The Ministry of Livestock and Fisheries was reported to own three feed mills, all of which were said to be inactive. The fish feed manufacturing sector in Myanmar appears largely separate from, and less competitive than, the poultry/livestock feed industry, in which around seven major companies, several of which are part foreign owned, operate. This apparent lack of co-development in fish and livestock feed manufacturing is rather unusual when compared to other countries in the region.

Seventy percent of the feed produced by Htoo Thit is floating feed, and it is the only producer of floating feed in Myanmar at present.[12] The company was reported to produce an 18% and 25% crude protein (CP) sinking feed, and a 25% and 28% CP floating feed, and to manufacture a number of other specialist feeds to order (e.g. frog feed, seabass feed, soft shelled crab feed). The main ingredients utilized by the company for feed production were reported to be rice bran, peanut

[11] Unlike agro-processing byproducts, commercially manufactured pelleted feeds are formulated to provide a nutritionally complete diet for the fish being farmed.

[12] As the name suggests, floating feeds float when placed in water. Using floating feed means that fish can be observed while they are feeding, making it possible to avoid the application of excess feed and maximize feed use efficiency. However, floating feeds require more energy to produce than sinking feeds, and are more expensive.

oilcake, sesame meal, fish meal, and soy cake. All of these are sourced domestically, with the exception of soy cake, which is imported mainly from India. Fish meal comes mainly from Tanintharyi region, where there are several fish meal plants in operation (DOF, 2012).

Feed costs and use

Rice bran is much cheaper than peanut oilcake. The two feeds cost $0.15-0.18/kg and $0.60-0.80/kg respectively. However, peanut oilcake has a much higher protein content than rice bran - 42% (Favre and Myint, 2009) and 10-15% respectively – and is thus converted to fish biomass more efficiently, resulting in faster rates of growth than would be possible if feeding rice bran alone. The feed conversion ratio (FCR) of rice bran was widely reported by farmers as 3.4, whereas the FCR of peanut oilcake was reported as 2.[13] Farmers combine the two inputs in the attempt to optimize fish growth whilst minimizing production costs. The most common reported combination of feeds was 10 sacks of rice bran (unit weight 27 kg) to 1 sack of peanut oilcake (unit weight 32 kg), a weight for weight ratio of 8.4. Farmers reported the most commonly available floating feed with 25% CP to have an FCR of 1.6, and to cost approximately $0.62-0.64/kg.

Manufactured pelleted fish feeds in Myanmar are expensive. Informal enquiries with international experts suggest that prices for commercially manufactured floating feeds with comparable characteristics are between 10% and 30% higher in Myanmar than in other countries in the region.

A foreign-owned company which had imported floating fish feeds from Vietnam on a trial basis and marketed them at competitive prices reported that it had proven economically viable to do so, even after factoring in transportation costs and customs duties. The same informant stated that fish feed prices in Myanmar are among the most expensive in the world, and ascribed this to a combination of lack of competition and high production costs, but considered the former reason to be the more significant factor in determining prices.

Feed marketing and distribution

The market for fish feed supports a vibrant interstate trade in agricultural byproducts. Farmers access agro-processing byproducts through a variety of channels. These tend to vary with the scale of production and purchasing power of the farm. Large farms source bulk orders of rice bran direct from rice mills (mainly in Ayeyarwady, Yangon and Bago)[14], oilcakes from oilseed mills (located mainly in the Central Dry Zone), and brewery, pulse, and other processing wastes from factories located in the industrial zones around Yangon. Depending on circumstances, farmers may pay advances to mills to guarantee large orders, and mills may extend credit to farms on a short term basis, but the majority of transactions are settled at or shortly after the time of sale, either by bank transfer or in cash. Farms of all sizes may also source feed directly from rice or oil mills, where these are to be found close to pond clusters.[15]

[13] FCR is a ratio of the quantity of feed used during production to the quantity of fish harvested. For example, an FCR of 2 implies that 2kg of feed is required to produce 1kg of fish.

[14] 1097 of Myanmar's 1362 rice mills, and 84% of its rice milling capacity are located in these three regions, (MoIA, 2015).

[15] Rice mills span a range of scales, from large and medium sized mills, usually located in rural towns, to more

Oilcakes and maize on display at an animal feed trader's shop

Delivering a boatload of pelleted feeds in Kayan

Worker on a large farm feeding fish from a platform

Fish eating floating pellets

According to Favre and Myint (2009), medium size oil mills generally sell oilcakes to local wholesale markets, or to commodity exchange centers in Mandalay or Yangon (the largest and second largest wholesale markets for oilcakes in Myanmar, respectively). Large mills (which produce higher quality oilcakes than medium sized mills) sell the majority of the oilcake they produce directly to feed mills, but also sell oilcakes to traders from wholesale markets. Oilcakes are sold at the oil mill gate and payment is usually made in cash at the time of transaction, or a few days later (Favre and Myint, 2009). Informants noted that modern large and medium-scale rice mills produce higher yields of better quality rice bran than small village based milling operations. Many rice mills were reported to have upgraded their machinery within the last five years using imported Chinese equipment, suggesting ongoing processes of transformation occurring within the rice-milling sector.

Fish farmers operating at a range of scales also access agricultural byproducts through traders. Large traders interviewed at Bayintnaung Commodity Exchange Center purchased a wide variety of feed ingredients direct from mills for resale to fish and animal feed factories, as well as to large farms and smaller traders in located fish producing areas. The

highest concentration of smaller feed traders is found in Twantay town (an urban center located adjacent to the large pond cluster immediately west of Yangon), where approximately 15 shops stock agricultural byproducts for sale as aqua-feeds. These traders tend to serve smaller commercial farms and nurseries. Rice bran traders are more numerous and more geographically dispersed than traders of oilcake, perhaps reflecting the larger numbers of rice mills as compared to oil mills, and their wider geographical distribution. Large farms will sometimes also act as brokers, selling agricultural byproducts to neighboring farms at a markup.

Htoo Thit (Myanmar's largest pelleted fish feed manufacturer) operates a quasi-contract farming system, under which farmers receiving feed on credit from the company's dealerships are required to sell through wholesalers trading fish for the company, with outstanding feed costs deducted at the time of sale. Land use certificates must be provided as collateral for these loans. Farmers who buy feed from the company without taking credit are not bound to sell their products back to it. At least one other company (a large farm which has achieved complete vertical integration) has recently begun to operate a similar system for client farmers in the area surrounding its operations.

Many large farms own transport (boats and/or trucks) which can be used for collecting feed. Those that do not may make use of boat/truck rental services to collect feeds, or accept deliveries from mills, traders and feed dealerships. If the farmer organizes transport, they will also arrange labor for unloading (using their own permanent workers and/or casual laborers). If mills, traders or feed dealerships arrange delivery, workers for loading and unloading may be supplied by the seller, with the costs of doing so added to, or implicit in, the costs of the order. As large volumes of feed are required, and feed purchases are made regularly, transport and unloading of feed creates significant demand for labor in areas with large concentrations of ponds.

Other inputs

A wide range of other inputs and services are required to facilitate fish production. These include a variety of fixed or quasi-fixed inputs (e.g. buildings, poultry houses, pumps, generators, trucks and boats), variable inputs (e.g. lime, salt, medicines, ice), transport (truck and boat rentals) and other specialized services (e.g. mechanical repairs, earth moving equipment rentals). Demand for these inputs and services has resulted in the proliferation of up- and midstream value chain actors

performing increasingly specialized functions in key growth hubs, most notably the towns of Twantay and Kayan. The number of businesses providing these goods and services has grown rapidly over the space of a decade (see Table 15 for an example).

Table 15 Changes in numbers of selected enterprises in Twantay town, 2004-2014

Enterprise type	Remarks
Fish feed shops	• The number of feed shops in Twantay town has increased from 5 to 15. The fastest increase occurred between 2004 and 2009
Fish feed brokers	• There were conflicting opinions on the number of feed brokers, and the trend in their number over time. A few informants reported that numbers had decreased because of an increasing tendency for farms to source feed directly from mills
Fish feed mills	• One operational fish feed mill is located close to Twantay town, but only produces feeds for use on its own farms. Previously the company sold feeds to other farms, but has since stopped doing so
Ice factories	• There has been a steady increase in the number of ice mills in the town, up 2- 3 times, from 2-3 in 2004, to 3-4 in 2009, to 6-7 in 2014
Fish traders	• There has been a fairly consistent rate of increase in fish trader numbers, from 3, to 4, to 6 between 2004 and 2014
Excavator hire	• Mechanical excavators for pond construction first appeared after 2009. There were 3 available for rental in Twantay in 2014
Fingerling transport boats	• The number of fingerling transport boats available increased by 50%, from 10 in 2004 to 15 in 2014, with most of the growth occurring between 2004 and 2009.
Trucks for hire	• There has been a gradual increase in number of enterprises offering truck rental services, up from 2-3 in 2004, to 3-5 in 2014. The number of trucks available for hire has increased in step, from ~5 to ~12
Boats for hire	• The number of boats available for hire appears to have increased, perhaps doubling over the period, to 150 or more.
Pump/generator repair shop	• There is an upward trend in the number of mechanics shops, perhaps accelerating after 2009, and doubling in 10 years, to at least 10.

Source: own field data

Over the last decade, workshops located in aquaculture clusters have begun to manufacture fiberglass boats and fiberglass water pump casings, and to produce specially modified boats adapted for the live transport of fingerlings. Imported Chinese water pumps, engines and generators are now widely available from hardware suppliers at very low prices (for instance, diesel powered water pumps can be purchased for $80, generators for $90, and combined generator and pump sets for $165). Retailers of these items located in pond clusters reported selling them in large and increasing volumes. The number of workshops and mechanics repairing engines and other machinery has also increased rapidly.

In comparison to other Asian countries, businesses selling antibiotics and other chemical theraputants to treat fish disease appear to be relatively few in number, despite disease being the most common problem reported by farmers. It is possible that the high average size of ponds makes it difficult to administer chemical treatments effectively. This is positive in as far as antibiotic use appears limited, and drugs do not account for a significant share of production costs (as they often do elsewhere), but means that farmers are unable to manage disease effectively.

Boat for transporting harvested fish for hire

Locally manufactured fiberglass boats

Hardware shop selling imported pumps, generators and boat accessories

Mechanic's workshop providing services to farmers and boat owners

In Twantay, DOF staff were reported to provide informal veterinary consultancy services for a fee, but informants reported that few, if any, formal extension or veterinary services were provided by DOF. Customers purchasing Htoo Thit feed on a contract basis were reported to receive farm visits by company technicians but, rather than providing extension advice, the main purpose of these visits appeared to be to allow the company to monitor customers and to ensure that only its own feeds were being used.

4.3 Midstream: The Farm Sector

4.3.1 Origins and development of the farm sector

Aquaculture started to emerge from the mid-1960s onwards, as farmers in the townships of Kayan and Twantay (to the northeast and west of Yangon respectively) began to raise wild fish in enclosed deep water rice fields, where they were grown without feed. In Kayan, wetland species such as walking catfish (nga ku; Clarias spp.) were deliberately stocked in these water bodies. Beveridge and Little (2002) refer to this nascent stage of aquaculture development as 'proto-aquaculture'[16]. In Twantay, farmers began to construct small ponds and stock wild seed of riverine carp species such as mrigal using rice bran as feed, after observing fish ponds established close to Twantay by DOF personnel. During the 1970s, a small number of hatcheries operated by the DOF began to produce carp seed, which early farmers in both areas quickly began to purchase. Use of peanut oilcake as an additional supplementary feed began later, in around 1985.

Early pond farmers were able to make use of existing market channels for wild fish harvested from the inland capture fishery, and found a ready market for carp species that they produced, which had a high market value at that time. The price of the main feed, rice bran, was extremely low, making aquaculture highly profitable for many early entrants.

Some of these farmers were able to able to expand their operations rapidly by reinvesting profits and using credit provided by large fish traders in Yangon and gold shops (another important source of informal finance) to buy submerged paddy fields with low productivity from neighboring households.

The sector suffered a temporary setback during the late mid to late 1980s as expansion of the area under ponds caused aquaculture to become more visible. This resulted in a crackdown by the socialist government on fish pond operators who were in breach of tightly enforced controls mandating paddy production. These restrictions were particularly heavily enforced in Kayan, where some pond operators were arrested and detained for up to two months, and some ponds were destroyed. This caused a number of pond operators from Kayan to relocate operations to Twantay, to where the first Kayan hatcheries had already begun to sell fingerlings.

Aquaculture began to expand again rapidly in the period post-1988 as the command and control of agricultural production was relaxed somewhat. According to Edwards (2005), the Aquaculture Law, passed in 1989, legalized ponds which had been constructed previously and

[16] Similar transitions from 'proto-aquaculture' utilizing wild fish seed to more actively managed pond-based forms of husbandry using hatchery produced seed have taken place in countries throughout Asia, including Viet Nam, Bangladesh and India.

allowed pond construction to take place on uncultivated "wasteland". The development of aquaculture was actively promoted by the military in some areas during the early 1990s. The end of armed conflict with the Karen National Union in western Yangon and eastern Ayeyarwady regions around this time contributed to the expansion of aquaculture by enhancing the security and predictability of investments in ponds[17]. The cessation of hostilities would also have had the effect of making regular contact and formation of close relationships between early entrants into aquaculture (many of whom were of Karen ethnicity) and government staff easier, facilitating access to and transfer of technical expertise and fish seed.

As the area under aquaculture expanded, the land frontier in pioneering areas began to close, and the most successful farmers from early aquaculture clusters began to acquire land for pond construction in new areas with adequate water supply and transport links. Residents of these 'frontier' areas also began construct ponds in increasing numbers, leading to the formation of new pond clusters. This pattern of pond expansion through the opening up of 'new' land at the edge of a widening frontier has continued until the present day. The 'first mover' advantage conferred to successful early entrants enabled some of these individuals and their families to accumulate very large aquaculture landholdings spread across multiple sites, aided by the development of close ties to officials in the state bureaucracy that accompanied their rise as wealthy producers[18]. Although the land frontier for pond construction has long since closed in the most mature aquaculture clusters in areas such as Twantay, total pond acreage has continued to increase rapidly over the last decade through the conversion of paddy and uncultivated wetlands in pond clusters still in the process of formation.[19]

4.3.2 Farm size

The distribution of farm sizes is the principle indicator of aquaculture's inclusiveness for smaller producers. Conventional wisdom on aquaculture in Myanmar suggests the existence of a sector dominated by very large export-oriented farms, with little scope for the development of small-scale aquaculture. It is not possible to estimate the mean or median size of commercial fish farms in Myanmar (with any degree of precision) based on available data or information collected during rapid reconnaissance. However, multiple visits to the field in numerous locations do provide the basis for making some general observations about the structure of the sector in terms of farm size.

In terms of the volume of fish produced, it seems clear that aquaculture is dominated by large-scale operations. However, large farms in Myanmar span a wide range in terms of size and organization of production, and thus require some differentiation. A small number of very large

[17] Secretary No. 2, General Tin Oo, a very high ranking army officer, who later died in a helicopter crash, was reportedly personally involved in promoting aquaculture in the Twantay area. It might be argued that supporting the development of aquaculture in what had previously been a conflict zone was part of a deliberate strategy, similar to that pursued through expansion of agricultural enterprises in former conflict zones elsewhere in the country, "to govern land and populations to produce regulated, legible, militarized territory" (Woods, 2011, p747).

[18] For example, the combined aquaculture holdings of the relatives of one of these pioneers were reported to cover 4800 acres, spread across Kayan, Bago, Twantay and Maubin townships, while the family of another entrant from this period was reported to operate 2000 acres of ponds in Twantay and Maubin.

[19] Analysis of satellite images presented in Table 13 of this report indicates that there was almost no expansion of pond area in the "Melbi Island" pond cluster in Twantay Township between 2003 and 2014, whereas pond area grew rapidly in other locations (e.g. "Nyaungdon Island").

vertically integrated farms operated by companies occupy the upper end of the size spectrum. A few of these have achieved almost complete vertical integration; including hatchery, nursery, feed mill, growout, transport (boats and trucks), ice plants, and cold storage/export. At least two companies also market feed, and buy back harvested fish from customers for onward sale, on a contractual or quasi-contractual basis. Some of these companies have investments in other agro-industrial enterprises, including marine fishing, brewing, rubber, rice mills, food processing and dairy farming.

The largest of these farms is reportedly 7000 acres in size, and another is more than 3000 acres. Some very large, partially vertically integrated farms of around 1000 acres are operated by individuals or families, often from among the earliest investors in the sector. Most farms operating at this scale have their own hatchery facilities, and some also engage in related business activities such as land speculation or renting out earthmoving machinery for pond construction. One of these enterprises is a joint venture, partly funded by foreign direct investment from China. The status of others is unknown in this regard, but most appear to be founded with domestic capital, although some of the owners are of naturalized ethnic Chinese origin.

Large farms at the next 'tier' down the scale are sized in the low hundreds of acres. Although they are also relatively few in terms of absolute numbers, farms of this size are found in most locations with significant concentrations of ponds, and represent a large share of total pond area. Some of these farms operate hatcheries for their own use, and some also sell feeds such as rice bran to smaller farmers in the vicinity. Virtually all farms in this size range own transport (usually boats), but may need to make use of additional hired transport for harvesting. In one village visited, three farms in this size bracket, all belonging to members of the same family, accounted for 90% of total pond area, and similar patterns were observed elsewhere. Based on these observations, it seems that the farm sector is highly concentrated, with a cumulatively low number of farms sized in the hundreds and thousands of acres together accounting for the majority of production.

Although this finding supports the conventional view of a large-scale dominated sector, it should be emphasized that in almost all major pond clusters, the most numerous category of farms range from approximately 5-50 acres in size. The mean area of agricultural holdings operated in Ayeyarwady, Yangon and Bago (the majority of which are paddy farms) ranges from approximately 6 to 10 acres (MoAI, 2013). Three quarters of agricultural holdings are sized below 10 acres, and 99.5% below 50 acres (Table 16). Fish farms at the smaller end of the scale thus fall across a distribution ranging from that of average agricultural landholdings, to several times larger than the average paddy farm.

Table 16. Distribution of agricultural landholdings by area

Agricultural landholding size (acres)	Relative % of holdings	Cumulative % of holdings
>3.00	24.5	24.5
3.00-9.99	50.1	74.6
10.00-19.99	18.6	93.2
20.00-49.99	6.3	99.5
≥50.00	0.5	100

Source: MoAI, 2013

The distribution of aquaculture farm sizes in Myanmar thus appears to be somewhat similar to that in rubber cultivation, in which 42% of farm area is accounted for by farms under 20 acres (comprising 90% of all farms), and 35% is occupied by just 1.2% of farms over 100 acres in size (Table 17). This 'top heavy' size distribution among aquaculture operations is unusual. Although average aquaculture farm size throughout Asia often exceeds average paddy farm size, in most countries production is dominated by commercially oriented family farms falling within the size bracket labelled 'smallholder' in Table 17 (Belton, 2013).

Table 17. Landholding categories for rubber cultivation

Landholding category	Smallholder	Medium	Large	Very large
Area (acres)	<20	20-100	100-500	>500
Share in farm numbers (%)	90	8.8	1	0.2
Share of farm area (%)	41.9	23.3	13.7	21.1

Source: Ye et al., 2014

All farms falling with the range of sizes referred to above are strongly commercially oriented, with almost all harvested fish sold. However, as noted earlier, we estimate there to be approximately 210,000 homestead ponds located throughout the southern half of the Ayeyarwady delta, at an average density of 12 per km2. These range in size from approximately 0.02-0.2 ha (0.05-0.5 acres), but are skewed heavily toward the bottom end of the scale. This finding is unexpected, given the widespread belief that there is little or no very small-scale 'backyard' or 'homestead' aquaculture in Myanmar.

Interviews in Thongwa, a township east of Yangon with a particularly high concentration of homestead ponds (20/km2) indicated, that over the past 10 years, these ponds (which were originally excavated to provide drinking water for farm households in areas with saline groundwater) have increasingly been stocked with hatchery seed, to provide fish for subsistence consumption as a replacement for once abundant wild fish captured from rice fields. It is likely that this also occurs in other townships with good access to fish seed, but further research is required to determine whether fish are deliberately stocked in ponds of this type in areas located far from the main seed production hubs.

Owners of homestead ponds reported not wishing to intensify production by stocking fish at higher densities and applying greater quantities of feed because the primary purpose of the ponds was to provide household drinking water. However, one farmer interviewed who had installed a deep tubewell to provide drinking water, had been able to significantly increase production in his pond by stocking pangasius catfish, providing feed and selling the harvested fish to the market. This indicates potential to increase the productivity of these resources if drinking water needs can be met.

Large fish pond on an 800 acre farm

Medium sized integrated poultry-fish farm of around 20 acres

Two acre nursery pond

Small homestead pond stocked with fish

4.3.3 Land access and tenure

Land provides the basis for all agricultural production, and is a source of common property resources (e.g. fuel, wild foods, building materials, fodder) that make important contributions to sustaining rural livelihoods, particularly among the poorest. Landholdings in rural Myanmar are strongly positively correlated with households' food and nutrition security status (Rammohan and Pritchard, 2014). Smallholder farmers in many areas have been displaced from their land by the granting of large-scale land concessions (Oberndorf, 2012), and despite recent reforms, land rights and governance processes in Myanmar remain weak and/or ambiguous, and land tenure is often insecure (Srinivas and Hlaing, 2015). Issues around land use, access, and tenure are thus of fundamental importance in shaping the future direction of Myanmar's rural development.

Land use regulation

With respect to aquaculture, one the characteristics of the sector most frequently emphasized in the literature is the difficulty experienced by prospective fish farmers in general, and prospective small-scale fish farmers in particular, in obtaining permission to convert agricultural land to aquaculture ponds. This view is captured in the oft repeated statement that, "it is possible for one group or individual to obtain permission to construct a 1,000 ha fish farm but impossible for 1,000 small-scale farmers to get permission to build 1,000 individual 1 ha ponds on their rice farms" (Edwards, 2005, p 7).

Under Myanmar's constitution, the Union (state) is the ultimate owner of all land. There are two broad legal land categories, 'agricultural' and 'non-agricultural', each comprised of several sub-categories. Occupants of agricultural land (i.e. farmers) may be viewed as tenants of the state, on whom an annual land use tax is levied as rent. Agricultural land can only legally be used for the purpose of agriculture, and farmers are bound to abide by tenancy conditions, major infringements of which can result in the state taking back the land or imposing fines and, previously, sometimes extended to imprisonment of the tenant. In the past, a tenant's failure to cultivate the land allocated to them, to grow the crop stipulated, or to provide the government with the full mandated quota of a stipulated crop, constituted an infringement of tenancy, as did the sub-letting, sale or other transfer of allocated land by the tenant (UN-Habitat/UNHRC, 2010; Thein, 2014).

Discussions with informants suggest that although in the past a failure to cultivate allocated land, grow stipulated crops or meet production quotas sometimes resulted in land confiscations or arrests, the informal or semi-formal transfer of land was a regular occurrence which was seldom penalized. The Farmland Law (2012) formalized transferrable private land use rights (Oberndorf, 2012), in effect regularizing the existing informal market in agricultural land[20].

Failure to cultivate agricultural land can still result in its confiscation. However, farmers have had freedom to choose which crops they plant since 1993, with the exception of rice, which must be cultivated on all designated paddy land (an official sub-category of agricultural land) (UN-

[20] Previously, individual permanent agricultural land use rights were registered using a document referred to as 'Form 105' (UN-Habitat/UNHRC, 2010). Since the Farmland Law was enacted, the equivalent document, which provides for permanent agricultural land use and exchange rights, has been referred to as 'Form 7' (MoAI, 2012).

Habitat/UNHRC, 2010). The system mandating compulsory sale of crops was abolished in 2003 as Myanmar deepened its transition toward a market economy (Okamoto, 2005).

Aquaculture is not legally designated as a form of agriculture, so the conversion of agricultural land to ponds can, in principle, result in its confiscation from the farmer, although no cases in which this had occurred recently were encountered during the fieldwork. In order to convert agricultural land to aquaculture in a legally compliant manner, it is necessary to apply to the State/Regional Peace and Development Council for permission to change the title of the land. A successful application to change land titling will result in the issue of an official document called 'La Na 39' (UN-Habitat/UNHRC, 2010).

The process of applying for La Na 39 is complex. Any request for a change in land use must be initiated at the village tract level21, and must go through successive tiers in the state structure, eventually to be endorsed or approved at the union (national) level, after undergoing factual verification by the Settlement and land Records Department (SLRD), within the Ministry of Agriculture and Irrigation, at the township and district levels[22]. The township-level General Administrative Department (GAD), within the Ministry of Homeland Affairs, is responsible for processing such applications. Thus, land rights transfer or land-use change is a lengthy process, requiring considerable time and frequent visits to various government offices located in entirely different line ministries (Srivinas and Hlaing, 2015, p8). (The steps of the application procedure are set out in full in Annex 3, p118).

Informants reported that navigating this complex process entails the payment of substantial "unofficial" fees. The size of these varies widely from case to case, depending on factors such as the nature of applicants' relationship with the officials involved, the location and type of land to be converted, and the speed with which the application is to be completed. Obtaining specific details of these transactions was difficult, but one informant, who provided a detailed account of his experience of the process, suggested that the full costs of obtaining La Na 39 could be as much as one hundred times greater than the official fees for doing so[23].

It is easy to imagine that these factors (cost, time, inconvenience and need for connections with officials in the state bureaucracy) might undermine capacity of many smaller prospective fish farmers to obtain permission to take up aquaculture. However, in many pond clusters it was widely reported that the assent of the village administrator was sufficient to allow a person wishing to convert a small area of agricultural land into ponds to do so. This observation suggests that the law pertaining to land use may be less rigidly applied than is widely assumed, at least in areas where there are already high concentrations of aquaculture. As a result, few of the farmers interviewed who operated an area of ponds of less than 10-15 acres had chosen to apply for La Na 39.

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[21] The administrative division below township level.

[22] MOAI recently changed the name of SLRD to the Department of Agricultural Land Management and Statistics. The inclusion of the term "management" in the Department's title raises the possibility that it may begin to play a more interventionist role in the management of agricultural land. This may represent some cause for concern, based on kinds of agricultural land management scenario that have occurred in the past.

[23] In the case in question, this reportedly cost $1500 per acre, as opposed to the $15/acre officially required, although it should be emphasized that other informants quoted considerably lower figures.

A pond license, issued by DOF, is also a legal requirement for the cultivation of fish. Pond licenses are reported to be granted as a formality to any individual in possession of a pond and evidence of land use rights (Form 105, etc.), irrespective of whether they have applied for or possess La Na 39. Having a pond license entails payment of a small annual fee to DOF, which is one of the means by which the department generates revenues.

As reported by informants, permission to convert paddy land to aquaculture can only be granted legally if the land is of very poor quality (i.e. producing extremely low yields, usually as a result of being deeply flooded). Paddy land of this type is referred to as category 'R3'. Having paddy land officially recognized as of R3 quality is thus usually part of the La Na 39 application process. Informants suggested that it was sometimes, though not always, possible for farmers to have the better quality paddy land downgraded to R3 status by providing financial incentives to officials, making it possible to convert it to ponds either with or without La Na 39.

Village administrators act as 'gatekeepers' as their consent is required before ponds can be constructed. According to informants, village administrators benefit financially from giving permission to convert land and, in areas with high concentrations of ponds, they are frequently involved in aquaculture themselves, often having been among the first villagers to have taken up activity. This local political economy accounts for part of the reason why widespread breaches of the procedural laws on land use are apparently possible.

From the perspective of most farmers, the only discernible benefit of obtaining La Na 39 is that it affords the bearer some protection in the case of disputes over land use rights, and provides entitlement to compensation in the event that the land is confiscated by the state. Thus, most pond operators have little incentive to apply unless their farm is sufficiently large that their lack of La Na 39 might come to the attention of the authorities, subjecting them to the possibility of fines, other penalties, or rent seeking behavior, or if they have reason to fear that their land use rights might be challenged (as might be the case if the land in question were obtained under less than transparent circumstances).

As a result, the majority of informants in most pond clusters estimated that La Na 39 had been issued for around only half of total pond acreage, with some putting the figure as low as 10%. Large producers often stated that they had applied for La Na 39 for only part of the area farmed in order to minimize the costs entailed, while others reported having begun the application process, but deliberately failed to pursue it further once the application had been lodged. Thus, at least in certain areas where pond clusters are already well developed, the need to obtain permission for land use conversion does not appear to pose as large an impediment to the expansion of small and medium scale aquaculture as is widely believed.

This observation should not be taken to imply that current land use regulations do not act as a break on the expansion of aquaculture. Separate research conducted in Mon State by the authors of this report suggests that significant potential for the expansion of aquaculture there is severely constrained by rigid enforcement of the law. It is also likely, though this could not be confirmed during rapid reconnaissance, that a regulatory climate similar to that in Mon prevails in many other locations outside the main pond clusters. In addition, even where land can be converted to ponds with relative ease, the cost of doing so may be increased considerably by the need to apply for La Na 39, and if permission to change land use title is not sought, tenure security is potentially weakened and pond operators may be subject to fines or the extraction of rents.

Furthermore, as the adoption of modern land mapping and monitoring technologies makes accurate information on land use easily accessible, it is possible that increasing regulatory management oversight of agricultural land will occur. As noted above, the recent renaming of SLRD hints at a possible expanded remit for more active management of agricultural land. Such a scenario might make it harder to convert land to new fish ponds, especially for smallholders, and might also result in greater pressure on existing operators of fish ponds constructed on illegally converted agricultural land. Effective policy safeguards are thus required to avoid unintended consequences arising from initiatives aimed at ensuring greater transparency and accountability with respect to land use.

In most, though not all, pond clusters where rapid reconnaissance was conducted, the majority of pond operators had initiated aquaculture on land to which they or their family members already possessed permanent use rights (Form 105/Form 7), usually as a result of inheritance, marriage or, in some cases, having cleared and registered uncultivated land[24]. Almost all large-scale pond operators, as well as some smaller ones, had expanded the area under production by buying up additional land close to their original farms, or in more distant townships or regions with lower land prices or other favorable conditions.

In Maubin (Ayeyarwady), at least two thirds of pond acreage in several villages was reportedly owned by large farmers originating from the earliest pond cluster in Twantay, who had purchased land from paddy farmers unable to support their production costs and/or living expenses. Similar patterns of land acquisition and pond ownership were reported in other pond clusters. The apparent ease with which many pond farmers had apparently been able to buy agricultural land may be the result of the very low incomes historically associated with paddy cultivation. Low levels of agricultural productivity and events such as severe floods and cyclones played some part in this. However, policies (no longer implemented) that strictly regulated paddy production targets, sales and prices, leaving many farm households deeply indebted (Okamoto, 2008), are the most likely cause of distress sales of land[25]. In addition, land prices are reported to have risen sharply in all pond clusters, as suitable land for aquaculture has become less available, providing incentives for indebted farmers to dispose of unprofitable agricultural land.

Some wealthy pond farmers were reported to have acquired land from paddy farmers who defaulted on private loans provided by the former to the latter. Members of households having sold land to aquaculture producers tended either to become labor on fish farms, or to invest in non-farm businesses (for instance, informants in one village where large numbers of residents engaged in trading fish seed attributed this to particularly high levels of landlessness there that resulted from widespread sales of land to fish producers.) Migrating to take up work in the non-farm sector, usually in Yangon, appeared to be the most common livelihood strategy among the adult children of newly landless households. Thus, large scale forms of aquaculture appear to have been implicated in the concentration of access to land and associated processes of 'depeasantization'.

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[24] The main exception to this tendency was found in Hlegu, where most integrated poultry-fish farm operators were investors or tenants originating from Shan State.

[25] Paddy farmers were obligated to sell a quota of rice to government depots at a procurement price 40-60% below the prevailing free market price (Okamoto, 2005). Those unable to meet their quotas were subject to arrest and the confiscation of their land (Thein, 2014)

In neighboring Thailand and Bangladesh, it is common for land used for aquaculture to be accessed through lease agreements between private individuals, and serves as a means by which small landowners are able to enter production (Belton, 2013; Belton et al, 2014). In the pond clusters studied in Myanmar such arrangements, though reported, were rare, and occurred mainly in cases where pond farmers had amassed financial losses too great for them to bear subsequent operating costs, but not so large as to necessitate sale of the land on which their ponds were constructed. Some informants reported leasing in land for aquaculture from state institutions, including various government departments, prisons and the military, all of which own large tracts of agricultural land and also engage in aquaculture directly (one key informant estimated that 5% of all pond area was owned directly by the state or concerns associated with the ruling Union Solidarity and Development Party). It may be surmised that the limited development of a private land rental markets is linked to the continuing ambiguity pertaining to private property rights, although it is also likely that purchasing land use rights is seen as a better investment than renting.

Land confiscation

Numerous informants reported that land confiscation had occurred throughout Maubin and Nyaungdon townships in Ayeyarwady region during the early 2000's. A large government flood control and irrigation scheme was completed in the late 1990s with the intention of facilitating the intensification of rice cultivation in the area but, in doing so, simultaneously improved conditions for aquaculture. Informants reported that a number of companies and individuals with close ties to the military government had acquired thousands of acres of land as concessions following completion of the scheme. This included both uncultivated "wasteland" and land already worked by paddy farmers. In one village visited, 180 out of 300 households were reported to have lost all or part of their agricultural holdings in this way.

Paddy and wetlands in the most favorable locations within these land concessions were converted to ponds. In most instances, these were leased out to large pond farmers rather than operated directly by the companies concerned. Some large pond farmers also used uncertainty created by the acquisitions to convince paddy farmers close to the areas affected to sell their land use rights at low prices. Most of the land awarded as concessions was not developed for intensive paddy cultivation as intended, and some was leased back to its original owners or other small farmers by the companies that had acquired it[26]. Use rights to land in parts of some concessions were sold on to other companies.

Procedures to enable complaints over land confiscation to be lodged with government were initiated in 2011 (Srivinas and Hlaing, 2015). Informants reported that since this time some affected paddy farmers had begun efforts to reclaim confiscated land or obtain compensation. In some instances, farmers were able to lodge successful claims, but there are many unresolved cases,

[26] Okamoto (2009, p242), reports that the large scale reclamation of land in deep water areas of Ayeyarwady and Yangon divisions in the late 1990s was "an extreme example of the inefficient expansion of sown [paddy] acreage". According to the author, "the government invited private companies to reclaim the land by providing privileged access to fuel and machinery at subsidized prices and by allowing half of the rice produced to be exported. These companies (mostly construction and export firms with no experience of cultivation) were supposed to reclaim 3000-5000 acres on average. However, no companies actually exported rice because the program was not economically viable to begin with, and most of the participating companies sought the 'privileges' such as cheap fuels and machineries rather than the potential income from rice cultivation and export". Given the widespread failure of these schemes, aquaculture would have provided an attractive alternative use for the land.

which were often complicated by changes in use taking place after concessions were granted. Many other farmers have not launched appeals however, fearing the consequences of bringing cases against powerful individuals, remaining skeptical of the likelihood of successful actions, or being uninformed of the procedures for launching appeals. Launching appeals was reported to be difficult for the claimants involved, in part because they required frequent costly travel to distant government offices. Interestingly, one key informant claimed that 70,000 acres of ponds were not currently in production because of challenges being made by former users of land that had been purchased or confiscated, although it was not possible to verify this figure independently.

The descriptions given by informants of the loss of their lands to concessions are consistent with published accounts. Srivinas and Hlaing (2015, p6), report that during the military government of the State Law and Order Restoration Council (SLORC), "land leases were granted to private and public companies, chiefly those affiliated to the military", with the objective of boosting intensive agricultural and agro-industrial activities through the development of so called 'wasteland', or 'vacant, fallow and virgin lands"'[27]. In practice, it has been difficult to find suitable large tracts of fallow or unoccupied land, making it necessary for the government to acquire (requisition) fallow and privately used land, by "ousting traditional occupants and users, without adequate compensation" Srivinas and Hlaing (2015, p25). As a result, "In numerous instances, land was forcibly acquired to make it available to investors as part of the wasteland development policy" Srivinas and Hlaing (2015, p6). Oberndorf (2012) has also noted that, "even when smallholder farmers have legal land tenure documents, their land is still often appropriated".

With reference to the Ayeyarwady region, Thein (2014, p23), notes that "the large-scale concession of lands" has been a "major driver of land grabbing", and that Ayeyarwady is the site of the biggest area of large-scale land concessions in Myanmar. These land concessions have often been ineffective in achieving their stated intent. Oberndorf (2012, p13) sates that,

> "Projects have often not been developed according to the original purpose, have had few if any benefits for local communities and project developers have been known to redistribute land allocated for other purposes to other parties. Land acquired for State sponsored projects sometimes ends up lying fallow, in violation of the terms and conditions of the project."

Srivinas and Hlaing (2015, p28) also report that, "many concessions awarded since 1991 may not be performing or contributing to national economic development", whilst FSWG (2012) finds that land developed and cultivated by companies granted land amounts to just 36% and 20%, respectively, of the total area allocated.

It is also important to note that so called "wastelands" that have been converted to aquaculture are usually wetlands. This has serious environmental implications because wetlands are often 'biodiversity hotspots', conversion of which to aquaculture, agriculture, or other uses destroys valuable habitat. Because wetlands often function as common property resources, their enclosure as

[27] These objectives are still enshrined in 2012's Vacant, Fallow, Virgin Lands Management Law (2012), which is "virtually identical" to the Prescribing Duties and Rights of the Central Committee for the Management of Cultivable Land, Fallow Land and Waste Land (1991) (Oberndorf, 2012, p22).

a result of conversion to other uses also results in the loss of access to ecosystem services (foods, fodder, fuel etc.), which are often of greatest significance in the livelihoods of the poorest.

A recent report compiled by a local NGO, Share Mercy, provides an extremely detailed account of the resolution of a land confiscation case with striking similarities to those described above. In the late 1990s a senior military commander formed a company with a successful businessman and a fishery lessee, to confiscate 41,900 acres of land in Kangyidaung Township, central Ayeyarwady region. This concession included areas of fallow land, cultivated paddy land, pasture and natural waterbodies. The company constructed 1200 acres of fish ponds, a biofertilizer plant, rice mills, offices and staff living quarters. Management of paddy land within the concession was reallocated in 50-200 acre blocks to local administrative officials, large paddy growers, and groups of neighbors or relatives who received seeds, fuel and fertilizers on credit, as well as cash loans, which they were required to repay to the company in harvested paddy (Share Mercy, 2015).

The venture only operated for two years. Many plot operators were unable to repay their debts to the company, and some of these handed over land that they had been recruited to work to their relatives, or borrowed from moneylenders, who subsequently colluded with officials to change the registered identity of indebted plot holders into their own names. The land was not returned to its original owners following the company's liquidation, and partners in the company as well as some of those it employed or recruited as tenants were able to appropriate land for themselves, either continuing to work it, or leasing out or selling on to third parties (Share Mercy, 2015).

In 2012, following a Land and Land Related Disputes Investigation by the Union Parliament, it was ruled that permanent landholder rights to the confiscated land should be granted to those cultivating it, but the ruling was ambiguous as to whether this applied to those farmers who had worked the land before its confiscation, or to those who subsequently gained possession. Although much of the land confiscated was redistributed at this time, many households, including those possessing tax receipts and other documentation proving that they had had use rights to confiscated land, received only part, or none, of the area they had originally worked (Share Mercy, 2015).

In light of this account, it seems probable that similar processes of land confiscation and redistribution involving senior military officials, members of the local state bureaucracy (including at the lowest levels) and influential businesspeople (in this case, large fish farm operators), account for much of the highly concentrated pattern of aquaculture landholdings observed during rapid reconnaissance. It is noteworthy that from 2003 to 2014, the fastest rates of growth and greatest absolute areal expansion among the pond clusters analyzed in the first half of this paper occurred in 'Nyaungdon Island' (Table 13, p35); an area in Ayeyarwady region, spanning Maubin and Nyaungdon townships. At around 20 acres, average pond size in this area is also more than twice that in any of the other pond clusters analyzed. This location was also the site of much more extensive land confiscation than was reported in other pond clusters.

According to estimates in Table 12 (p34), official statistics underreport the area of ponds in Ayeyarwady and Yangon by 24% and 55% respectively. One possible explanation might be that ponds constructed on confiscated land have not been officially reported in full. If correct, these observations suggest that a significant part of the growth in the area under aquaculture in Myanmar over the last decade has been linked, directly or indirectly, to land confiscation. It is also possible that official statistics on pond area are deliberately underreported in order to avoid greater scrutiny

of, and direct intervention in, the conversion of paddy land to aquaculture by the authorities at Union level (an outcome which, it may be speculated, would be undesirable to officials at lower levels, for whom issuing permissions to convert land to aquaculture may be represent a significant source of rents).

4.3.4 Water

Water is a key input for aquaculture, and must be available in sufficient volumes, and be of sufficient quality, for production to take place successfully. Optimal environments for pond based aquaculture are usually low lying lands located close to permanent water sources (e.g. irrigation canals, rivers or other waterbodies), allowing for filling, 'topping up', or exchange of water to be achieved without heavy expense on fuel for pumping. Heavy soils that retain water well and minimize nutrient leaching are ideal. Although most of the commonly farmed freshwater fish can tolerate low levels of salinity, growth is best in areas that are not severely affected by saline intrusion. Ideally, ponds should also be located in areas protected from frequent heavy flooding that could allow fish to escape.

Ideal environmental conditions for pond based aquaculture are thus almost identical to those optimal for the production of lowland rice. The development of aquaculture has therefore been closely linked to the development of flood control and irrigation schemes designed to support agricultural expansion in the delta. Water control schemes have also proven important role in the development of aquaculture because they provide access routes to and from farms in the form of canal networks and roads constructed on bunds (such as the main road linking Twantay and Maubin), along which feed and seed can enter and harvested fish can leave.

4.3.5 Labor

This section reviews issues pertaining to labor in aquaculture. Myanmar is characterized by high levels of landlessness and historically low wage rates. These factors mean that the availability of off-farm labor opportunities and the rates at which they are remunerated are crucial determinants of rural welfare. However, the ratio of land to labor is high, and as Myanmar's economic transition continues the value of real wages is likely to become an increasingly important factor in determining the economic viability of agriculture, and will shape the agricultural sector by driving adoption of more labor saving technologies, including alternative crops and mechanization. Migration flows – international, rural-urban and rural-rural - will also play important roles in determining labor supply and wage rates. In this context, the demand for and productivity of labor in aquaculture and related activities, as compared to alternative forms of agriculture and non-farm employment, have important implications for the prospects of rural workers and future agricultural development.

Farm labor in aquaculture can be recruited on a temporary or permanent basis. Temporary labor is required mainly for harvesting fish, grading fingerlings, unloading feed delivered to the farm, and pond construction/repair. Teams of temporary workers are usually hired through local labor brokers, and large groups of loosely organized casual laborers were found in all pond clusters visited. Harvesting requires large teams of workers to net ponds, weigh fish, transfer them to boats or trucks and ice them prior to transport. Netting ponds is reported to be dangerous work, as large, fast moving fish jumping at head or chest height sometimes collide with workers, causing injuries and, in some cases, death. Netting, grading and restocking fingerlings in nursery ponds on growout farms is also labor intensive work. Teams, usually numbering around 10 individuals, are employed to unload feed from boats or trucks and carry it to the pond side.

Water control infrastructure, Maubin township

Workers harvesting a pond

Packing harvested fish in ice in the hull of a transport boat

Small homestead pond stocked with fish

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In the past, all ponds were constructed using manual labor. Manual workers continue to perform this function, but are increasingly being replaced by mechanical earthmoving equipment that is considerably cheaper (the cost of pond excavation using a mechanical backhoe was reported at $300/acre, as opposed to $600/acre using human labor). Rental services for mechanical earthmovers were reported to have developed rapidly in all clusters visited within the last three years. This appears to reflect a tightening of the labor market, but may also be related to relaxation of import controls and lowering of taxation on imported vehicles occurring since 2011.

Harvesting fish for transport to market is a labor intensive process. A 30 acre pond will take a team of 30 day laborers 10 days to harvest completely; equivalent to 10 person days of labor per acre. In contrast, a group of 12 laborers can harvest 3 acres of paddy per day, equivalent to four person days per acre. Most land preparation for paddy cultivation in the areas visited during the survey was mechanized, with plowing usually completed by farmers using their own power tillers. Most rice is planted by broadcasting, there is limited weeding or pesticide or fertilizer application during most paddy production, and threshing is mechanized, also requiring little labor. In contrast, even a moderately sized pond requires the fulltime labor of one to two people to manage it, plus additional temporary workers for grading and restocking fish during on-farm nursing, and unloading and portering feed. On the basis of this rough comparison, it is probable that demand for labor created by aquaculture per unit area of land in Myanmar is considerably higher than that in paddy cultivation.

In most cases, temporary laborers are long term residents of the pond clusters where they work, not inward migrants. An exception to this tendency was found in peri-urban Hlegu, just to the north of Yangon, where large groups of migrants from Ayeyarwady and Bago live in makeshift housing erected on roadside land, and perform a variety of farm and non-farm casual labor.

Women and men were both observed to engage in all kinds of day labor associated with the farm segment of the aquaculture value chain in large numbers in all locations visited, although the tendency was for greater numbers of men to be employed in pond harvesting. Wage rates for temporary workers are usually gender differentiated, falling in the region of

$4/day for men and $3/day women in late 2014 in most locations. Field visits during the first half of 2015 suggested that wage rates had jumped by at least 20% since 2014, suggesting an escalation of real wages taking place, at least in some fish producing areas.

A number of farms reported experiencing labor shortages. One informant stated that the strengthening position of workers had raised the cost of hiring permanent labor, making it necessary

to hire temporary workers for jobs such as unloading feed, which had once been performed by a larger permanent workforce. Another cited the same reason for reducing the number of pond guards employed on-farm, from four to two.

Large farms are often spread across multiple sites, meaning that owners may be absent for much of the time, making regular or occasional supervisory visits, depending on circumstances. Larger farms may also employ supervisors or managers to oversee the work of permanent laborers, employed for activities such as feeding fish, day-to-day maintenance and guarding, as well as that of casual workers. Operators of small and medium scale commercial farms tend to play more actives role in daily on site management, but medium sized farms usually also employ additional permanent labor to carry out manual work. Family management and labor inputs are supplied by both men and women household members in small and medium sized operations, although it appears to be the norm for male household heads to assume a leading role in farm management in most cases. It was not ascertained to what extent this division of labor affects household decision making over the use of returns from the farm.

Residents of pond clusters, where opportunities for casual labor were readily available, rarely opted to engage in permanent farm work, preferring the greater relative freedom and better remuneration of daily labor. As a result, the majority of permanent workers on fish farms originated from outside pond clusters, mostly from remote townships in Ayeyarwady and Bago regions, where there were reported to be few employment opportunities other than occasional causal agricultural work.

Permanent workers are usually provided with on-site accommodation, and the most common arrangement is to hire husband and wife teams. One family is usually employed to manage each growout pond (or, in the case of integrated poultry-fish farms, each chicken house). Very large ponds may require more workers. Wages for a single permanent male fish farm worker are estimated at approximately $2.50/day. Members of families hired as permanent workers are not paid individually, and the male household head generally receives a lump sum of around $100/month ($3.30/day), with additional bonuses paid as an incentive for meeting production targets in some cases. This arrangement effectively undervalues women's work. Resurreccion and Sajor (2010) report similar practices on Thai shrimp farms, where there is a tendency for both employers and live-in migrant workers themselves to describe to women who support their husbands in tending ponds as "not a real worker"; a status which is used to legitimize their lack of remuneration.

Widespread outmigration was reported from pond clusters in Twantay and Maubin, particularly among landless residents, including members of families who had sold agricultural land to fish pond operators. The main destination for these migrants was the industrial zones around Yangon city, where they sought employment in garment factories and other industries. Informants linked this outflow of labor to rising wage rates and occasional labor shortages within pond clusters. However, the high value of fish as compared to rice[28] means that the productivity of labor in aquaculture is likely to be higher than that in agriculture, and thus more likely than rice to remain profitable in the event that the rural labor supply contracts further.

[28] In December 2014, 1 kg of rohu retailed at around $2.50, and 1kg coarse rice retailed for around $0.50.

These observations suggest that the rural economy is increasingly well integrated with that in urban areas, with outmigration for employment in the urban industrial sector resulting in a tightening of the labor market in the dynamic agricultural zones surrounding Yangon. This in turn has created opportunities for in-migration among landless workers from more remote areas, where more limited off-farm employment opportunities exist. If this flow of migrants occurs on a sufficiently large scale it should eventually begin to drive up wages in more distant hinterland areas.

4.3.6 Credit/capital

The costs of investing in aquaculture can be substantial. Fixed or quasi-fixed inputs may include land purchase or rental, pond construction, housing for workers, poultry sheds, boats, trucks or other means of transport, water pumps, generators and transformers. Variable inputs include labor, feed, seed, chemicals, fuel, and ice. Expenditure on feed alone (which accounts for an estimated 75-80% of operating costs), may run to $2000-2500 per acre/year, with labor and seed accounting for the bulk of the remainder. The ease and terms with which startup and operating capital for aquaculture can be accessed thus have important implications for the sector's inclusiveness.

Small farms and nurseries are usually financed from a combination of own savings, informal loans from relatives (both with and without interest) and informal moneylenders (at between 3-6% per month, depending on terms), and (once running), reinvestment of profits. In Thongwa township, households with homestead ponds reported receiving fingerlings on credit from traders during the month of June, and repaying the costs in July using agricultural loans disbursed by the Myanmar Agriculture Development Bank (MADB). This behavior indicates that these farmers prioritized fish production, but had it not been for the complementary timing of agricultural loan dispersal they might have been prevented from stocking fish by a lack of funds.

The most frequently cited source of credit among larger farmers was output tied loans provided by large fish traders based at San Pya wholesale market. These loans are used to fund both the expansion of operations (buying land and constructing ponds), and operating costs (principally feed), and obligate the farmer to sell fish through the trader who provided the loan. The trader deducts a commission of 3-4% for brokering the sale of the farmer's fish, along with monthly interest ranging from 3-5% depending on the anticipated duration of the loan and whether or not it is secured, with a rate of 3% being most common. Loans which are secured usually use land ownership documents belonging to the farmer as collateral.

Farms tend to borrow regularly in order to minimize interest payments, taking only as much as is needed to pay for their feed requirements for each month. Long-term borrowing to fund feed purchases is rare, but may occur when big farms stockpile large quantities of agricultural byproducts when their market value is low. Other sources of credit used by large farms include gold shops, which serve as pawn brokers (gold is an extremely important form of savings in Myanmar), and other informal private moneylenders.

Formal credit provision for agriculture is limited. Only 1-3% of the volume of formal bank loans is extended to the agricultural sector. Agricultural producers are serviced by the Myanmar Agricultural Development Bank, which now provides loans to around a third of the farming population (OECD, 2014). Access to loans for aquaculture from the Myanmar Livestock and Fisheries Development Bank (MLFDB) is more limited, as indicated by informants who ranked

banks as the least important source of credit after fish traders, informal moneylenders, relatives, and feed traders.

Although MLFDB provides credit at low rates of interest (13% per annum), it was said by informants only to issue loans to farmers with more than 50 acres of ponds. These loans must be secured with land, and informants reported that it was only possible to borrow up to one third of the value of the land owned, and that the bank tended to value land at below market rates. It was not clear whether borrowers were required by the bank to possess La Na 39 for ponds used as collateral, but this seems likely, possibly serving as a further impediment given the relatively low share of farms know to have this document. One informant reported that, in the past, some finance for pond expansion had been provided by son of a senior government official, also the owner of a major fishery company, who obtained a large loan from MLFDB and informally re-lent to pond owners in Twantay at a profit.

Feed traders and mills selling rice bran, peanut oilcake and other agricultural byproducts usually extend credit to farmers on a very short term basis only. Myanmar's largest manufacturer of pelleted feed, Htoo Htit, operates a quasi-contract farming system, under which customers who have obtained feed on credit (at a 2% monthly interest rate) are obliged to sell harvested fish through the company's trading arm. This arrangement makes pelleted feed available to smaller and medium sized farms, as well as to some larger operations, but reportedly places restrictions upon the management decisions that can be made by the farmer, as the company stipulates that alternative sources of feed cannot be used by its customers (for example, customers of the company reported being blocked from constructing poultry houses over fish ponds). This sanction can be enforced because the company is able to withhold payment after fish are harvested.

One interviewee from a foreign feed company which has made investments in the poultry sector in Myanmar and has also explored the possibility of marketing fish feeds, reported that it was unfeasible for the company to extend credit to fish farms due to the lengthy duration of production cycles. Another informant reported that foreign fish feed companies were wary of investing in Myanmar dues to fears over their ability to recover credit extended to farmers. This may suggest that development of a more competitive feed sector is constrained by foreign investors' access to capital and concerns over the strength of the legal frameworks in place.

Much of the growth in integrated poultry-fish production to the north of Yangon has been fueled by the inflow of capital from ethnic Chinese investors from Shan State with trading, mining and agricultural businesses, seeking to diversify their asset portfolios. Marine fishing boat owners have also invested in aquaculture for the similar reasons, as have some fish traders or their family members, perhaps having accumulated these assets from fish farmers who defaulted on loans in some cases.

International migration for work is less common in the main aquaculture regions (Ayeyarwady, Yangon and Bago) than in states/regions which border neighboring countries to the east, and the investment of international remittances in pond farming in the delta area is thus rather limited. This may also reflect the high capital threshold in growout farming. Investment of international remittances in smaller non-farm businesses related to aquaculture (e.g. fingerling or food fish trading) was somewhat more frequently observed.

In sum, 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. One informant reported that fish traders themselves obtained operating capital through informal loans from wealthy individuals closely connected to the military. Although credit and output markets for many large fish producers are 'interlocked', the

conditions do not appear particularly exploitative. Although monthly interest rates of 3% and upwards may appear high, they fall within the same range reported by Okamoto (2008) for loans of operating capital taken by wholesalers and collectors of green gram, and below the usual rates for smaller loans taken from informal lenders, and should not therefore be considered excessive in the Myanmar context.

More than one interviewee stated that average rates of interest paid on advance payments from fish traders fallen in recent years, from 5% in 2010 to 3%, possibly indicating increasing liquidity in domestic credit markets emerging with ongoing reform of the banking sector. This observation is supported by findings from ARDWG (2015), who report that average interest rates paid on small loans from informal lenders have fallen from 5% (secured) and 10% (unsecured) to 3-4% and 7-8% in recent years, and ascribe this to the effect on rural financial markets of the diversification and increased flow of formal and semi-formal (microcredit) loans.

Although loans from fish traders are often secured with land use certificates (e.g., La Na 39 or Form 105), meaning that land can be foreclosed in the face of a serious default, the conditions are flexible (allowing for regular borrowing to cover monthly feed costs, repayment upon harvest, and rescheduling of payments in case of unforeseen circumstances) and beneficial to both lender and borrower.

In addition to the interest they charge, fish traders benefit from the commission that they take from brokering sales of fish. This provides an incentive for big traders to work with producers capable of supplying the largest volumes of fish, but means that this source of finance is not generally accessible to smaller producers, as monitoring them would impose relatively high transactions costs on large fish traders. Reardon et al (2012) find that it is now extremely rare for traders of rice and potatoes to advance tied output credit to producers in Asia. However, a recent survey of rural credit in Myanmar (ARDWG, 2015) finds that output tied loans persist between producers and traders of maize, jaggery and, to some extent, rubber, though not paddy. The scale of the investment costs involved in aquaculture (which could exceed $1 million per annum for a farm of several hundred acres), may go some way to explaining the persistence of these arrangements in the case of aquaculture in Myanmar, but ARDWG's findings also point to the influence of severely underdeveloped formal credit markets.

Thus, whilst large fish farmers do not generally appear credit constrained, it is likely that many small and medium sized farms are, to varying degrees. Some of the smallest commercial pond operators interviewed reported being unable to access credit from any source, and being averse to the risk of doing so even in the event that it were available, for fear of losing their remaining assets in case of default. Stocking and feeding practices and financial returns on these farms were found to be suboptimal as a result. The high cost of credit increases the risk of productive investments (both on-farm and in supporting value chains), and lowers potential rates of return, and may thus act as a disincentive to investment in the sector by smaller producers and SMEs.

4.3.7 Technology

Aquaculture technologies can be categorized as extensive, semi-intensive, and intensive, based on feed use (Edwards, 1993). Extensive technologies make no use of external feed inputs, relying entirely on the natural productivity of the pond (sometimes stimulated by supplemental fertilization) to provide nutrition for stocked organisms. Productivity (yield/unit area) in extensive systems is very low. The 'trap and hold' coastal shrimp farms found in Rakhine State are a good example of extensive aquaculture as practiced in Myanmar, as are homestead ponds receiving no external inputs of feeds.

In semi-intensive systems, fish derive nutrients from both natural feeds produced in the pond (phytoplankton and zooplankton) and external inputs of supplemental feed. Most of Myanmar's inland aquaculture is semi-intensive, as fish derive nutrients from a mix of plankton (natural feed) and supplementary feed inputs such as rice bran and peanut oilcake. Semi-intensive systems can span a broad spectrum in terms of productivity, depending on the level of input use and species farmed. Yields from semi-intensive carp dominated polyculture in Myanmar appear to vary widely, depending in on the level of inputs provided. Edwards (2009a) reports yields to average 4.5 t/ha for large farms, up to a maximum of more than 15 t/ha.

Yields reported by farmers interviewed in the present study ranged from as little as 1 t/ha, to a maximum of 10 t/ha, with a mean of 3.7 t/ha. This level of productivity is surprisingly low, falling well below yields reported in Andhra Pradesh, India (the location which most closely resembles Myanmar in terms of the carp farming technologies deployed), where average yields of 9 t/ha are reported (Padiyar et al. 2014). Stocking density (the number of fish stocked per unit area) reported by farms in Myanmar was also variable, ranging from 1000 to 3500/acre (0.25-0.85/m2) The upper end of this spectrum corresponds to that commonly employed in Andhra Pradesh, while the lower end is similar to that in Andhra in the 1980s, before the industry developed (Padiyar et al. 2014). It should be stressed that these results are preliminary, and not based on systematic collection of detailed production data. Nevertheless, it is noteworthy that these low levels of production are within the range that might be expected based on estimates of apparent production and pond area provided in the first half of this report.

Intensive aquaculture systems are those in which all fish nutrition is derived from external feed inputs, most commonly in the form of formulated pelleted diets. Although intensive aquaculture technologies are commonplace elsewhere in Asia, examples from Myanmar are limited to a very small number of specialized marine fin fish and white shrimp (Litopenaeus vannamei) farms, and a few farms producing pangasius and pacu using only pelleted diets. However, these latter species are usually raised in polyculture with carps, which derive part of their nutrition from natural feed.

All semi-intensive aquaculture systems in Myanmar are polycultures, meaning that multiple species occupying different ecological niches are stocked to maximize the utilization of natural feed in the pond. Rohu is the dominant species, accounting for at least half for stocked biomass in most cases, and often as much as 80%. Other commonly stocked species include mrigal and catla, pangasius and pacu. Free-breeding feral tilapia (Oreochromis spp.) appear to be present in most carp ponds, but since the destruction of the country's only commercial tilapia hatcheries during Cyclone Nargis, hatchery produced monosex tilapia seed are no longer stocked. Giant freshwater prawn is

sometimes produced in polyculture with carps, particularly in smaller farms in Ayeyarwady region, but seed is presently difficult to obtain due to disease problems in the hatchery sector.

Several species that make important contributions to aquaculture in other countries in the region - e.g. walking catfish, barramundi (kakatit; Lates calcarifer), climbing perch (nga pyayma; Anabas testudinidae), stinging catfish (nga gyee; Heteropneustes fossilis), and striped snakehead – are either absent from aquaculture in Myanmar, or produced on an experimental basis, or in very small quantities. It is possible that this is a reflection of the continued productivity of Myanmar's inland capture fisheries, meaning that these species remain more abundant (and thus cheaper) than elsewhere in the region. Nevertheless, price data published by CSO (various years) indicates that the retail value of most of the species listed above is approximately 20-60% higher than that of rohu, and that real prices are rising over time, suggesting potential to expand farmed production using technologies already developed in neighboring countries.

Three major variants on the main semi-intensive carp polyculture technological blueprint can be identified. In the most traditional of these, the main feeds used are rice bran, peanut oilcake and other agro-processing byproducts. Animal manure or inorganic fertilizers are usually also added to pond water in these semi-intensive systems to promote production of natural feed (plankton), though fertilization rates appear sub-optimal (Edwards, 2009a). Another variant of this production technology involves using commercially manufactured pelleted feeds (either floating or sinking) for all or part of the production cycle. Use of manufactured pelleted fish feeds appears to be increasing gradually, facilitating shorter production cycles for some farmers, but remains somewhat limited at present, likely accounting for a maximum of 20% of total production.

The third variant on semi-intensive polyculture involves direct integration of feedlot poultry production (broiler or layer chickens or, occasionally, ducks) with fish production. Poultry droppings and spilt feed provide low cost pond inputs, sometimes supplemented with additional feed if the numbers of poultry raised provide insufficient fertilization. Fish in these systems provide an additional crop that lowers the risks associated with poultry production, providing a buffer against fluctuating poultry prices by lowering the point at which it is possible to break even. Clusters of integrated poultry-fish farms, which require high levels of investment, have developed rapidly over the last decade in peri-urban areas along major roads to the north of Yangon, and are operated mainly by ethnic Chinese farmers who cooperate closely to share information, thereby reducing risks and costs.

Although aquaculture is dominated by semi-intensive farming systems that utilize agricultural byproducts or wastes as feeds, productivity gains have been achieved over the past decade principally as a result of the practice of stocking increasingly large fingerlings, at sizes of up to 12 inches. This has had the effect of shortening production cycles by a third or more, as well as increasing yield per acre/cycle in some instances. Based on farmer interviews, we speculate that productivity increases may be responsible for at least a third of the output growth that occurred over the past 10 years.

4.4 Downstream: Postharvest Activities

4.4.1 Market structure and actor behavior

Central wholesale markets

Most fish ponds in Myanmar lie within a 50 km radius of the capital, Yangon. Myanmar's largest fish wholesale market, San Pya, is located in Yangon, on the river which marks the city's western boundary and provides the main transport link to pond clusters located in the zone around the city. The vast majority of farmed fish produced in this zone is traded through San Pya. San Pya was established in 1991, and is administered by the Markets Department of the Yangon City Development Committee (YCDC). The market operates daily, from late night until mid-morning.

A second fish wholesale market, Shwe Padauk, opened in Yangon in October 2014, further north than San Pya, on the Yangon River. Shwe Padauk was privately constructed on land belonging to YCDC, and it is envisaged that it will partially replace San Pya market, which is located in a congested residential area. However, at present only a relatively small fraction of the fish traded in Yangon passes through Shwe Padauk. Both markets trade fish from aquaculture and capture fisheries. Informants estimated that farmed fish accounts for 65- 70% of the fish traded at San Pya, and around half traded at Shwe Padauk. Fish that passes through the two markets is distributed throughout the Yangon area, to the country beyond, and abroad.

From farm to market

Farmers can sell fish to Yangon in one of two ways: 1) through local collectors; and 2) directly to traders at San Pya or Shwe Padauk. Collectors are present in all major aquaculture clusters. They can provide harvesting services or purchase fish already harvested, and may either buy fish to resell to larger traders in Yangon or earn a commission through brokering sales on farmers' behalf. Collectors tend to provide this to service smaller farms, because large traders in Yangon will only arrange collection of fish from farms if the quantity harvested exceeds 10,000 viss (16 t; the capacity of a small collecting boat). Some small producers choose to sell direct to wholesalers in Yangon using their own or hired transport, receiving a better price than if selling through collectors, but incurring transport costs.

Most of the farmed fish traded through Yangon markets is sold without the involvement of an intermediary. Farmers who have taken advances from fish traders are bound to sell all their fish through those traders. Those who are not indebted to traders are free to choose to whom they wish to sell, but often opt to work with one or a small number of trusted individuals. Farmers usually inform the trader several days in advance of the harvest to set a date agreeable to both parties, and receive payment from traders at the time of sale or after a delay of a few days.

When fish is harvested, it is packed in crushed ice in the hulls of collecting boats or in unrefrigerated trucks. Boats are the main form of transport because many ponds are accessible only by canal, and account for as much as 80% of the volume of fish deliveries to San Pya. Refrigerated trucks are also occasionally used to transport fish to market, particularly by the largest farms. Workers collecting parking fees from trucks delivering fish to San Pya reported that the number of trucks making deliveries to the market had doubled within the past 10 years.

Yangon traders and larger farms own boats and/or trucks for transportation purposes, and transport rental services are widely available from vehicle owners located close to wholesale markets and in aquaculture clusters. Traders may supply ice, deducting the costs from the sales price, farmers with their own transport may collect their own ice prior to harvest, or owners of rented vehicles may supply it as part of their service. Ice is sourced from ice plants located in Hlaing Tharyar industrial zone, or from plants in towns close to major aquaculture clusters. There are a total of 106 ice plants in Yangon region (DOF, 2014), and 15 businesses at San Pya that specialize in crushing ice blocks.

Wholesale

The five largest fish trading business at San Pya operate riverside landing sites for boats, referred to as "jetties". A sixth jetty, located just outside the market, is owned the son of a senior military figure and leased out to other operators. The jetties were originally state owned, but were privatized by the SLORC government in 1989. Although the jetties were established to allow fish from marine and freshwater capture fisheries to be brought to market, aquaculture fish now make up the bulk of landings at three of them. In addition to

providing a landing site for fish, jetty operators act as traders, earning a commission for brokering sales. They also receive deliveries of farmed fish by road, which are sold in the same manner. Four of the jetties and the trading businesses associated with them belong to individual- or family-owned companies, but one is run by a shareholder-owned company that also operates Myanmar's largest fish farm. Some other jetty operators also own fish ponds, and all were reported to own fleets of marine fishing boats[29].

There is a single jetty for receiving aquaculture fish located at the newly established Shwe Padauk market, which is owned by the fish trading wing of the Htoo Htit fish feed company. The company is reported to have purchased a large block of the spaces allocated to traders in the market.

In addition to the jetties, there are three market buildings occupied by wholesale traders at San Pya, divided into a total of 142 licensed stalls. Only wholesalers officially licensed to do so by YCDC operate inside these buildings. The largest wholesalers may own more than one license, while the majority own either a single license or share the license and physical space that goes with it with other wholesalers. Each license is reportedly worth MMK 80 million (approximately $70,000) at present. According to unpublished figures made available by YCDC, excluding jetties, there were 310 licensed wholesalers operating at San Pya in 2014, of which 152 specialized in trading aquaculture fish. Most of these traders are men. The total number of traders in the market was reported to have increased by around 40% between 2004 and 2014, as had the number of aquaculture fish traders.

According to informants, three categories of licensed wholesaler can be identified at San Pya, based scale of operations and behavior31. Approximately 60 "large" and 90 "medium" traders

[29] In addition to the jetties at San Pya and Shwe Padauk, there are seven others located slightly further north within the city along the Yangon River, where only marine capture fish are landed. This group of jetties is reported to serve 2000 marine fishing boats. Most of them are operated by companies established by groups of fishing boat owners. At least one jetty is owned by a fish exporting company. More than half the fish landed at these jetties is reported to be exported, particularly to China. Unlike the jetties at San Pya, these businesses operate on a monthly tender basis, under which the buyer offering the highest price for a particular species at auction gains the right to buy an agreed quantity of that species over the course of the following month.

advance output-tied loans to farmers and/or fishing boat owners that (as well as earning interest) serve to secure access to large volumes fish. The main difference separating the two groups is the amount of operating capital they have access to and the volume of transactions they are capable of handling. Smaller licensed traders, of which there are around 150, do not advance loans to producers, buying fish from jetties and larger traders for resale, rather than taking a commission for brokering sales. None of these licensed wholesalers have access to jetties of their own. They receive fish delivered by truck or landed by boat at four public landing areas operated by Myanmar Port Authority, which levies a toll on the boats using them.

San Pya operates as a spot market in which traders set a price for their fish depending on the volumes available in the market and levels of demand, adjusting the price over the course of the trading day in line with fluctuations in both, while buyers choose freely between different sellers on the basis of the product selection and price offered.

Traders hire unskilled workers on a casual basis for jobs such as pushing carts, carrying baskets, unloading ice and packing fish. There are two types of casual labor at San Pya: 1) those managed by the Ministry of Labor; and 2) those working directly for wholesalers.

There were reportedly 400 Ministry of Labor affiliated laborers in 2014; up from 200 in 2009 and 80 in 2004. An additional 1500 workers are employed directly by wholesalers, for similar purposes. These workers, who are almost all men, originate mainly from Yangon and Ayeyarwaddy. Wages for a night shift are around $8. Many wholesale traders employ at least one clerk to keep track of transactions. These are sometimes, though not always, traders' family members, and can be either women or men.

Unpublished figures made available by YCDC indicate that 80 traders operated at the new Shwe Paduak market during early 2015, of which 19 specialized in sales of farmed fish[30]. Traders of aquaculture fish dealt with a larger volume of sales on average than those trading fish from capture fisheries, averaging a turnover of 2700 viss/day (4.3 t/day), as opposed to an average of 1350 viss (2.2 t/day) for all traders at the market. Based on these figures, the extrapolated annual volume of trade at Shwe Padauk during its first year of operation will be approximately 40 million viss (63,000 t).

It has not been possible to determine a reliable estimate of the volume of fish traded through San Pya on the basis of research conducted thus far, as figures made available appeared questionable, and a systematic survey of traders was not attempted. Estimates of the total volumes of farmed fish traded through San Pya provided by key informants seemed low considering its status as the primary wholesale market for aquaculture products, falling within the range of 100,000-200,000 t per annum.

Many small and unlicensed wholesalers operate from buildings around the outskirts of San Pya and along the side streets leading to it. When the market was first established, there were no wholesalers located outside. One informant estimated there to be 150 in 2014, up from 55 in 2009, and 35 in 2004. Some unlicensed marine fish traders have relocated to Shwe Padauk market since

[30] There are a total of 360 3X6 m lots available in the market, which is currently trading at well below capacity.

field work was conducted, so numbers at San Pya may now be significantly reduced. An additional group of unlicensed traders without fixed business premises act as brokers, buying fish from licensed wholesalers and dispatching to other states and regions. Their numbers were estimated to have increased from 5 in 2004 and 10 in 2005, to 30 in 2014.

Fish being traded at night at a jetty in San Pya wholesale market

Small-scale processing of farmed rohu to produce nga chit

Packing fish in Styrofoam boxes for dispatch to Upper Myanmar by express bus

Retailer in Mon State selling farmed rohu delivered by road from San Pya

There are four major categories of buyer from wholesale markets in Yangon: 1) wholesalers in distant urban markets; 2) retailers and semi-wholesalers located in and around Yangon; 3) cold storages/processors/exporters in Yangon; 4) small-scale processors based around at San Pya (these are by far the smallest group in terms of the volume of trade they account for). Details of the behavior of each of these groups are outlined below.

Regional wholesale markets

Long distance trade between San Pya and regional wholesale markets is usually conducted by telephone, with certain wholesalers specializing in dealing to markets in specific geographical locations. Some traders in regional wholesale markets work with family members based in Yangon to assemble and dispatch orders, while others receive fish through brokers at San Pya working on a commission basis, and some deal directly with wholesalers. Larger buyers may send their own transport to collect fish from San Pya (particularly if they also have fish to sell in Yangon), while others rely on the sender to make delivery arrangements. Payment for these orders is usually made by bank transfer. Informants estimated that 40-50% of the fish traded at San Pya was destined for domestic markets outside Yangon.

The customer base in regional wholesale markets is comprised of retailers and semi-wholesalers (large retailers who sell part of their stock to other smaller retailers) from wet markets and smaller rur-urban centers in the surrounding area. Semi-wholesalers from these locations often travel to the nearest urban wholesale market to assemble orders on behalf of groups of small retailers.

Retail

There are several domestic supermarkets and modern chain restaurants each operating multiple outlets in Yangon, but at present these cater primarily to middleclass consumers, and there are currently very few of these stores outside the city, where the retail sector continues to be comprised almost exclusively of wet markets.

A sizable majority of retail fish traders are women. Retailers and semi-wholesalers from Yangon and the region surrounding it (e.g. towns in southern Bago), visit Yangon wholesale markets daily to buy fish, often using transport rented collectively with other traders from their area to do so. Larger semi-wholesalers may have their own transport. At San Pya, these customers move from wholesaler to wholesaler, selecting fish in the combinations they require. Retailers and semi-wholesalers in regional wet markets outside of Yangon operate in a similar manner; purchasing fish from wholesale traders in spot transactions based on the selection and price of fish offered, and making payment in cash immediately, or taking very short term credit (usually one or two days), or some combination of cash and short term credit

Retailers in wet markets can be divided into those who trade from a licensed stall, and those who have no fixed location from which to trade. Licensed stalls are usually constructed of wood and elevated from the ground, and are accessed by purchasing a license from the authority controlling the market, or by renting space from an existing license holder. Unlicensed retailers normally vend produce within or close to the market from a plastic sheet, tarpaulin or basket laid on the ground. The former type of retailer usually trades quantities of up to 100 viss (160 kg) per day, whilst the latter may sell from less than 10 viss to 50 viss or more. In rural markets the smallest unlicensed retailers often sell freshwater fish caught by their family members or neighbors. A typical market will

include considerable numbers both types of trader (perhaps totaling 50 or more in a busy market), with unlicensed traders usually in the majority. Retailers selling large farmed carps sell intestines and swim bladders obtained when cleaning fish to commercial buyers, who use them, respectively, for the production of edible oil, and for drying for export to China.

Cold storage, processing and export

There are numerous cold storage facilities located around Yangon, particularly in its industrial zones, where large wholesale traders and exporters rent space to store stock. There is one cold storage facility located at San Pya, operated by a military-linked business group, which sources and freezes fish for processors and exporters. Cold stores in other locations perform similar functions. Many processors and some exporters have cold storage facilities integrated into their operations, and some businesses combine all three functions.

There were 77 seafood processing factories in Yangon Division in 2014 (Table 18), of which 57 were reported to process fish for human consumption (the remainder specializing mainly in processing shrimp or producing fish meal). Two hundred and eighty nine companies are recorded as having exported fish and seafood products from Myanmar by sea in 2012, and 211 as having exported fish by overland border trade. The majority of these businesses were small, exporting less than 500 t/year, with only four reported to have exported above 10,000 t (DOF, 2012).

Table 18. Numbers of seafood processors in Myanmar by state/region in 2012

Region/State	Number of seafood processors
Yangon	77
Tanintharyi	18
Ayeyarwady	6
Mon	7
Rakhine	5
Shan	1
Total	114

Source: DOF, 2012

The number of facilities processing fish sourced from aquaculture could not be ascertained, and there appeared to be few, if any, which specialized exclusively in processing farmed fish. Factories were reported to process farmed fish mainly when there were insufficient supplies of fish from marine capture fisheries, particularly during monsoon when rough weather hampers fishing. It was commonly reported by informants that supplies of fish from marine capture fisheries had become scarcer than in the past, making securing sufficient raw material difficult for processors, and suggesting potential for more diversified aquaculture production to utilize this capacity.

Most farmed fish undergo little, if any, value addition at present, with processing activities limited mainly to freezing and packing whole fish. A minor exception is the production of pangasius fillets, which seems to have increased slightly in recent years, but with only 333 t exported in 2012 (DOF, 2012), this remains relatively insignificant. Informants at San Pya estimated that somewhere in the range of 20-30% of the farmed fish traded at the market was exported abroad.

Small-scale processing

In addition to industrial scale processing operations, there are also a large number of small businesses located at San Pya and Shwe Padauk markets which produce nga chit – a paste made of ground fresh fish flesh, which is a popular ingredient in curries and many other dishes. Traditionally nga chit was made with bronze featherback (nga phel; Notopterus notopterus), a fish sourced from freshwater capture fisheries. However, this species is increasingly rare and expensive, and small farmed rohu are now the main raw material used by processors at San Pya to make nga chit31.

Byproducts from nga chit production include fish skins (fried and sold as snacks), fish heads (sold into retail markets for making soup), and swim bladders (dried and exported to China). Fish frames (bones with attached scraps of meat) are sold as feed for African walking catfish farms. The production of walking catfish was initiated after the growth in nga chit production to utilize this supply of byproducts, and there are reportedly now 100 ponds close to Yangon using nga chit processing waste as the main input.

Almost all the nga chit producers at San Pya originate from a single village, close to the market on the opposite side of the Yangon River. The number of businesses producing nga chit at San Pya was reported to have grown rapidly, from none in 2004, to 14-15 in 2009, to more than 50 in 2014, employing, according to one informant, as many as 1500 workers, most of them women, earning up to $10 day for the semi-skilled processing work. This rapid growth was said to have taken place in response to demand from Nay Pyi Taw and elsewhere in Upper Myanmar.

The operator of one nga chit business reported producing 180-200 viss (288-320 kg) per day in 2014, up from 90-100 viss (144-160 kg) three years ago, and 10-30 viss (16-48 kg) five years ago. The informant had recently begun to pack and brand his product. Businesses producing nga chit at San Pya are unlicensed, and can be fined MMK 100,000 for operating in the market. There was a recent drive to move them to the new Shwe Padauk wholesale market, but only a small number have been willing to relocate because their business contacts are at San Pya.

4.4.2 Transport and distribution

Distribution of fish from San Pya to other areas of the country takes place primarily by road, by truck and public express bus. Transport workers at San Pya reported that a total of 12 twelve-wheel trucks made long distance deliveries of fish to Nay Pyi Taw and Mandalay on a daily basis (six to each destination), with additional trucks of a similar size making deliveries to other states and regions. Ten years previously, out of state deliveries were made by six wheel vehicles with approximately two thirds of the capacity of those operating at present - 6000 viss (9.6 t), versus 10,000 viss (16 t). Five years ago, only one truck delivered fish to Nay Pyi Taw each day.

Trucks sending fish along these routes carry dry goods on their North-South journey and typically deliver fish to four to five customers on the return journey, dropping off at several markets along the way. Vehicle owners come both from Yangon and other parts of the country. Owner-operators of a further 50 small (six wheel) trucks were reported to offer delivery services from San Pya to cold storages and processors located in industrial zones in and around Yangon, and to the Aung Mingalar Bus Terminal.

[31] Nga chit made from rohu costs around $8/kg, whereas that made using featherback costs around $15/kg.

Fish deliveries from Yangon to the rest of the country by express bus began in 2011. Most of the fish transported by bus originate from aquaculture. Fish dispatched by express bus are packed with ice in Styrofoam boxes, and delivered to the receiving bus company by six wheel truck, along with a manifest listing the contents. Before the new government took office, there were strict controls on opening new bus lines because of the system of fuel rationing in place. The number of bus companies, routes and buses running increased rapidly after this restriction was abolished. Currently, there are more than 200 highway bus lines operating out of Aung Mingalar Bus Terminal, and 500-600 buses leaving daily for different destinations. Five years ago, there were only 300 buses running per day.

Restrictions on imports of new vehicles were also relaxed after new government took office, allowing for the use of modern Scania buses, which are more comfortable, and run faster than those previously used. The emergence of bigger bus companies using modern vehicles led smaller companies with older buses to begin carrying fish and other freight in order to remain competitive, resulting in declining transport service fees. At present, typical transportation charges for fish are around $5 per Styrofoam box, down from $8 in 2011. Completion of Yangon-Mandalay Expressway in 2011, which reduced journey times significantly, was also an important factor in increasing the transport of fresh fish to the north of the country.

Although transport of fish by bus has increased dramatically within the last four years, vehicle licenses issued for passenger buses do not permit them to carry goods, and their ability to do so is based on what respondents described as "mutual understanding" with the authorities (a euphemism for rent seeking).

Before 1990, the delivery of fish outside of Yangon was not legal, the food security of the then capital city being prioritized over that of the rest of the country. After this time, 53 licenses were granted enabling wholesalers to export fish to other parts of the country. License conditions stipulate the amount of fish that can be traded to particular destinations, and license holders are required to report the quantities they deliver and to obtain a letter of permission from DOF for every delivery, allowing them to transport a specified category of good on a specific route.

These restrictions are ineffective. Registered traders deliver quantities of fish in excess of their allowable quotas, and unregistered traders deliver fish interstate illegally. One informant indicated that in the event that trucks carrying fish without permission were stopped, the matter could be settled for a small "unofficial fine" of $1.50. However, another noted that unauthorized interstate deliveries of fish could be confiscated and sold at auction if found during inspections by DOF at toll gates entering destination cities, making it important for traders to maintain "good relations" with its officials.

4.5 Synthesis: Transformation in Myanmar's Inland Aquaculture Value Chain

This subsection synthesizes and interprets research findings presented in the second half of this report with respect to the changing structure of the inland aquaculture value chain in Myanmar, the behavior of actors within it, and the implications of these characteristics for rural development and food security. Upstream input supply chains, the midstream farm sector, and domestic and international trade downstream all occupy intermediate stages of development, displaying evidence of dynamism and potential for further growth, as well as the effects of distortions which act as a break on the achievement of technically, economically and socially optimal performance. This distinct mix

of features is born of Myanmar's unique political economic history and its role in shaping the country's ongoing economic transition; setting boundaries on conditions under which production, distribution and consumption of farmed fish occur. Each value chain segment is addressed in turn, in keeping with the overall analytical structure of the study.

4.5.1 Upstream transformation

In structural terms, most of the input supply chains studied are long or moderate in geographical length, but intermediationally short (Reardon et al., 2012). Rice bran and seed (fingerlings) are traded over quite long distances across the delta, and oilcakes are sourced from Upper Myanmar. Feed inputs produced as byproducts of agro-processing pass through few, if any, hands between producer and consumer. This does not necessarily reflect the effects disintermediation (coordination among buyers and sellers to "cut out the middleman"), although improving communications and bank transfer capabilities may have made some contribution in this direction. Rather, this characteristic reflects the scale of large farm enterprises, which enables them to procure byproducts directly from distant mills, nurse hatchlings ordered direct from hatcheries, or internalize seed production entirely by establishing hatcheries as part of vertically integrated operations. Inputs accessed by small producers (who lack the capacity to buy in bulk), tend to pass a greater number of intermediaries, but even here, the links in the chain are not particularly numerous (e.g. from mill, to large trader in wholesale market, to small trader in a farming area, to farm; or, from hatchery, to nursery, to fingerling trader, to farm).

The fish feed manufacturing sector is uncompetitive, and the costs of formulated fish feeds are among the highest in Asia. A small number of very large farms are supplied by aqua- feed mills integrated into their business operations. A single company dominates sales of manufactured feeds to small and medium scale commercial farms, to which it extends feed on credit on a quasi-contractual basis. One domestic competitor has recently entered the market operating a similar model, but has yet to gain significant market share. Although these marketing arrangements enable smaller producers to access production finance relatively cheaply in an otherwise credit constrained market, they also impose stringent conditions on credit recipients.

Feed companies tend to interface directly with customers through employees of branch offices rather than through networks of affiliated feed dealers, as is common in other countries. For instance, in Bangladesh feed is marketed on behalf of producing companies by thousands of affiliated dealers who compete with one another to attract new customers, to whom they often extend self-financed credit at low rates of interest (Mamun-Ur-Rashid et al. 2013). Lack of access to formal credit for SMEs may explain why prospective entrants into the feed market in Myanmar (e.g. foreign feed manufacturers) are unable to adopt similar business models for distribution. This situation is compounded by the overall investment climate which, although improving, is still ranked as one of the worst in the world (e.g. World Bank 2014; OECD, 2014). This poses a range of problems for prospective investors related to, among other issues, foreign exchange regulations, and concerns about the adequacy of the legal framework for dispute resolution.

As a result, the commercial aqua-feed sector is far less diverse than in other countries in Asia (e.g. Thailand, Vietnam, Bangladesh, India), where there is intense competition for customers between multiple domestic and foreign owned producers. In addition, the size of the market for aqua-feeds in Myanmar is presently smaller than in other major producing countries in the region. This reflects total levels of production which (as indicated the first half of this report) stand at less

than half what is officially reported, and limited diversification into species other than carps, (e.g. tilapia, catfishes, carnivorous species) for which the use of formulated diets would be necessary or more advantageous.

The relative lack of capital intensification (greater use of feed and other inputs), may also reflect Myanmar's relative abundance of land, which has facilitated the continual opening up of new frontiers for pond expansion. The most capital intensive technology identified (in terms of investment per unit area land) - integrated poultry-fish production - occurs largely in peri-urban areas where land prices are far higher than in the zones where land intensive traditional pond technologies predominate. Never-the-less, land prices have risen sharply across the board since 2011. This factor, if combined with access to appropriate production inputs (e.g. different fish species, pelleted feeds supplied on more favorable terms, credit), could ultimately catalyze a shift toward more land-sparing capital intensive production technologies.

Sales of agro-processing byproducts account for a significant share of gross revenues in rice and oilseed milling, meaning that backward production linkages from aquaculture contribute to the viability these enterprises. This may have implications for the retail value of polished rice and edible oils, given that processing costs account for a significant share of the marketing margin of these commodities. Modernization and consolidation, which has occurred within both milling sectors over the last decade, has been positive for aquaculture, resulting in the availability of larger quantities of higher quality byproducts for use as feeds.

The seed sector shows little diversification in terms of species produced, although pacu is a fairly recent addition to the range of widely available species. The capacity to artificially reproduce seed of alternative high value 'niche' species (e.g. snakehead, climbing perch, barramundi) rests principally with a small number of hatcheries operated by vertically integrated farming and processing operations. At present, neither the seed of these species, nor knowledge of how to reproduce it in the hatchery has diffused widely, resulting in limited positive externalities for the sector as a whole.

Nursing fish seed represents one of the main pathways by which small landholders can enter aquaculture directly. The clustering of nursing operations close to groups of hatcheries is a result of agglomeration economies related to the sale and transport of fingerlings and availability of specialized services (e.g. construction and rental of fingerling transport boats), coupled with demand for progressively larger fingerlings (the main technological change by which some intensification has been achieved within the farm sector).

Seed clusters and clusters of other high value specialized input and service provision for aquaculture act as drivers of local economic growth, creating high levels of demand for labor, knowledge, and technological spillovers among producers and service providers, and higher incomes for the actors involved than are possible from most alternative agricultural and non-farm activities. Input supply chains exhibit some dynamism and are undergoing change which is often incremental but sometimes, particularly in the nursing segment, quite rapid. However, dominance by large, partially or fully vertically integrated farms/firms – both terms of in farm size distribution and in their command over parts of upstream and downstream segments of the chain - may dampen more rapid technological change driven by competition among commercial smallholders.

The positive effects of the inland aquaculture value chain on rural growth would likely be greater in a sector comprised mainly of commercial smallholders, creating higher densities of backward and forward production linkages (e.g. through reliance on nurseries, local traders and transport rental services) and consumption linkages (by spending incomes on locally produced goods and services, instead of repatriating profits to urban centers). The reasons for the structural pattern of large farm dominance evident in Myanmar are explored in detail in the following sub - section.

4.5.2 Midstream transformation

The political economy of Myanmar's land governance is crucial to understanding the nature of its aquaculture sector, in which farm size distribution more closely resembles that of rubber plantations than of paddy farms, (the latter scenario being more typical in most other Asian countries). Early growth in Myanmar's nascent aquaculture sector stalled in the early 1980's as a result of the interventions by the socialist state aimed at guaranteeing national self-sufficiency in paddy production. Aquaculture began to expand rapidly again after 1989, following the decision of the SLORC regime to regularize existing farms and promote aquaculture by encouraging pond construction on "wasteland".

Piecing together fragmentary reports from the field and information from secondary sources, it appears that this policy shift paved the way for coalitions of senior military officials and their affiliates, successful fish producers from the earliest pond clusters and administrators at lower levels of the state bureaucracy, acting with varying degrees of coordination, to establish and expand fish farming operations via two processes: 1) formation of companies to acquire confiscated land for pond construction; and 2) market- based transfer of land from paddy cultivators to successful fish producers. This latter process of land concentration was able to occur rapidly, in part because paddy farmers were often heavily indebted as a result of policies mandating the requisition of paddy by the state and sale at below market prices. The formation of a 'top heavy' farm sector dominated by large enterprises has been further compounded by two related factors with distorting effects.

First, the state continues to mandate rice production on paddy land (also the most suitable type of land for aquaculture), and categorizes aquaculture as a non-agricultural land use, making obtaining the change in land use titling required to construct ponds in a legally compliant manner complex and expensive. Although in practice it has proven possible for farmers in many areas with high concentrations of ponds to circumvent these regulations (in part because many local administrators themselves are involved in aquaculture or benefit financially from allowing it to take place), these restrictions increase the expense, risk and difficulty of adopting aquaculture, particularly for smaller farmers with limited social, political and financial capital.

Resulting uncertainty over the tenure of land used for aquaculture has stifled the development of private land rental markets (an important feature of aquaculture clusters elsewhere in Asia), further diminishing the possibility of smaller landowners entering production. Never-the-less, the existence of small and medium scale commercial fish farms in all pond clusters speaks to the attractiveness of the activity even in the face of significant constraints, and to the potential for further expansion of this smallholder-led sector under more favorable conditions.

Second, aquaculture is a capital intensive activity with a longer production cycle than most forms of agriculture. High investment costs make access to credit an important condition for entering and sustaining production. The availability of formal credit in general, and of formal

agricultural credit in particular, has been extremely limited in Myanmar historically, and the rates of interest paid on informal loans are consequently extremely high. Output- tied advances provided by large fish traders (who earn commissions on sales of fish) are a major source of finance for aquaculture, but are provided only to producers operating at a scale capable of supplying large volumes of raw material. Consequently, while large producers are not generally credit constrained, many smaller farmers are - a situation common to SMEs in all sectors in Myanmar (Kyaw, 2008) - forcing them to borrow from other informal lenders at high rates, and potentially inhibiting investments in more capital intensive forms of production.

At the 'micro' level, changes in producer behavior have mainly taken the form of incremental productivity increases achieved by reducing the length of production cycles by stocking larger fingerlings, as well as limited adoption of pelleted feeds. The most striking example of rapid technical change observed during the study has been the shift from traditional production technologies based on supplemental feeds to more capital intensive integrated poultry-fish systems. This change has occurred extremely quickly in peri-urban pond clusters to the north of Yangon, where average farm sizes are moderate, and development has been driven by well capitalized ethnic Chinese investors from Shan State, and availability of formulated poultry feeds on credit[32].

Aquaculture has contributed to the transformation of rural labor markets through two interlinked processes. First, the outflow of households from aquaculture clusters close to Yangon, in response to the pull of increasing opportunities in urban industries and the push of landlessness resulting from the processes outlined above. Second, the inflow of landless rural migrants from more remote areas of Ayeyarwady and Bago with limited off- farm employment opportunities. The latter process is a response to two sets of inflationary pressures on wages occurring in pond clusters: 1) labor shortages created by the outflow of residents to urban areas; and 2) the generation of new employment opportunities as a result of the labor intensive nature of aquaculture, which has higher labor requirements than the paddy cultivation it replaces.

A continuing trend toward higher wages in Yangon and the dynamic rural zone that surrounds it should further reduce the profitability of paddy cultivation relative to aquaculture because labor accounts for a smaller share of variable costs in aquaculture than in paddy cultivation, and because the labor productivity of aquaculture is higher than that of rice farming. In this climate, diversification away from paddy cultivation into higher value activities such as aquaculture is necessary if rural areas are to continue to remain a source of viable livelihoods for their inhabitants.

4.5.3 Downstream transformation

Downstream segments of the aquaculture value chain are intermediationally short or moderate, and geographically moderate or long. Large farms engage in output tied credit arrangements with large traders or, in a few cases, are vertically integrated with marketing and/or processing and export operations. As a result, fish produced by large farms reaches primary wholesale markets in Yangon without any intermediation, while smaller operations are more likely to rely on collectors to deliver fish. However, the close proximity of production to the main demand

[32] There are more competing feed companies active in the poultry feed sector than in aquaculture, and production cycles are much shorter, meaning that credit can be recouped more quickly by feed suppliers. Both these factors contribute to better availability of credit for poultry feed than aqua-feed.

hub of Yangon and good water transport linkages mean that even fish from smaller farms rarely passes more than one intermediary before reaching primary wholesale, and there is little indication that the degree of intermediation between farms and Yangon wholesale markets has changed significantly in recent years.

The primary wholesale segment of the value chain is concentrated in two Yangon markets, San Pya and Shwe Padauk, (the former accounting for the major share of trade). The largest of the trading businesses in these markets operate jetties (private riverside landing facilities). Two very large vertically integrated aquaculture enterprises operate, respectively, one of the three jetties specializing in sales of aquaculture fish at San Pya, and the only jetty at the recently opened Shwe Padauk market. It is possible that this latter development signals a nascent tendency towards greater concentration in wholesale.

However, fish are also traded directly through a further 150 large traders at San Pya, of which around half specialize in farmed fish. This is a sufficiently large number to ensure competitive pricing, and trader numbers appear to have grown in step with increasing supplies of farmed fish.

The biggest transformation downstream (and by far the most dramatic meso-scale change observed in the entire aquaculture value chain), is the massive increase in volumes of fish flowing out of Yangon to the rest of the country since the relaxation of restrictions on bus transport and improvements to transport infrastructure in 2011. Even in 2010, when IHLCA was conducted, the domestic market was relatively well integrated, with close to 60% of domestic farmed fish consumption occurring outside the main zone of production in Lower Myanmar. It is highly probable that this fraction has increased significantly since, with upcountry markets absorbing much of the increase in supply which has occurred over this period.

Although domestic retail is in the process of modernization, with supermarkets and chain restaurants beginning to gain market share in large urban centers, they are not yet major drivers of structural change, and traditional retail (wet markets) continue to be the main outlets at which consumers purchase fish. The expanding domestic market is the primary driver of aquaculture growth, though exports may account for as much as a third of production (more than is apparent from the analysis of official statistics, but less than is suggested by the conventional wisdom).

Freshwater aquaculture exports (comprised mainly of rohu) undergo little, if any value addition or product differentiation and are concentrated primarily in a small number of countries with large populations of South Asian ethnic origin. In its current form, other than absorbing surplus supply, processing and export exerts limited influence on the farm sector, although it has potential to act as a transformative force in future, particularly if increasingly scarce marine capture fishery stocks strengthen demand for raw materials from aquaculture.

5. POLICY IMPLICATIONS AND RECOMMENDATIONS

5.1 Rationale for Policy Recommendations

This study has produced the most comprehensive assessment ever conducted of the inland aquaculture value chain in Myanmar and its role in national food security, based on extensive fieldwork and the triangulation of multiple secondary data sources. The study's most important findings with respect to policy are summarized below, providing the rationale for recommendations advanced in the following sub-section

Fish is of fundamental importance to food and nutrition security in Myanmar, representing a (perhaps *the*) major source of micronutrients in the diet. **It is the cheapest form of animal protein, accounting for 50% of animal source food intakes, and occupies a share of food expenditure nearly as large as that of rice**, the staple food on which all of Myanmar's food security policy has historically focused. **The contribution of farmed fish to fish consumption is greatest in the fish deficit areas of Upper Myanmar**, far from areas of Lower and Coastal Myanmar where most fish is produced, highlighting the importance of aquaculture for food security at the national level.

However, **at present aquaculture supplies only 21% of total fish intakes, and farmed products are often inaccessible to the poorest consumers**, being priced higher than small fish species and fermented products from inland and marine capture fisheries. **This is an effect of limited diversity in the farm sector, which is oriented to the production of large carps** (in particular rohu), meaning that cheaper varieties of aquaculture fish are not as readily available to low income consumers as they are in many other Asian countries. **The long term demand prospects for aquaculture are buoyant**, because capture fisheries supply appears to be contracting, and because better-off and urban consumers have a greater propensity to consume farmed fish relative to fish from other sources, in a national context where urbanization and the formation of a middle class are occurring rapidly.

Triangulation of secondary data sources indicates that **official statistics on aquaculture production (and fisheries more broadly) are flawed**. Estimates of apparent production suggest that **production figures for aquaculture are inflated by as much as 160%**, and fisheries as a whole by 120%. Even allowing for a wide margin of error in the method of calculation, these estimates indicate that aquaculture yields have been consistently over reported. At the same time, analysis of **satellite images suggests that pond area has been underreported by 30%**. Geospatial analysis also indicates that fears that pond construction will displace rice cultivation to any significant degree are unfounded: **aquaculture occupies just 1.3% of land in townships where ponds were identified**.

These findings highlight the need for more rigorous data collection in order to inform evidence based policy making.

Aquaculture value chains in Myanmar occupy an intermediate stage of development displaying, in all segments, a mix of both incremental and dynamic change in structure and actor behavior, which coexists with relative underdevelopment, uncompetitiveness and low diversity, as compared to other Asian countries. **This 'dual speed' pattern of development is linked to the**

legacy Myanmar's unique political economic history and its influence on the country's lengthy transition toward a more open and globally integrated market economy.

This history has resulted in the formation of an aquaculture sector dominated by large firms and farms exhibiting varying degrees of vertical integration; backwards into input supply (where they lead the production and distribution of manufactured feeds), and forwards into domestic trade, processing and export. **Aquaculture development in other Asian countries has been driven primarily by commercial smallholders and SMEs, and displays greater diversity in all value chain segments**. This indicates that the pattern of development in Myanmar should not be considered the outcome of advantages of scale and efficiency among large enterprises. Rather, it reflects the specific nature of conditions under which to two key factors of production; land and capital (as outlined in detail in the previous section), are accessed. However, **despite serious constraints, small- and medium-scale commercial aquaculture producers in Myanmar are more numerous than is generally recognized**, and have the capacity to act as a driving force for technical and economic change and diversification (as evidenced by the rapid adoption and growth of capital intensive forms of integrated poultry-fish culture, and the boom in nursing operations).

Aquaculture is labor intensive in comparison to paddy cultivation, and has contributed to rising real rural wages. At this stage in Myanmar's development, a primary goal of economic policy should be to drive up rural wages further to reduce poverty quickly. The expansion of high value, labor intensive agricultural activities such as aquaculture, which also create numerous non-farm employment opportunities up- and downstream, is one of the principle means by which this can be achieved.

In sum, **aquaculture in Myanmar currently makes important contributions to food and nutrition security and rural growth**. However, because of the 'top heavy' structure of the sector (and the legacy of the conditions under which it was formed), aquaculture has also created widening inequalities and undesirable social and environmental outcomes in some locations. **More diverse production driven by commercial smallholders and SMEs in supporting value chains has potential to deliver greater and more inclusive rural growth** through the formation of denser networks of production and consumption linkages, **and to make bigger contributions to national food and nutrition security** by increasing the range and volume of products accessible to poorer consumers. **There is considerable potential for the development of such a sector if structural constraints are reduced**. The massive growth in trade of fish from Lower to Upper Myanmar is a clear example of the type of positive transformational change that can occur when regulations that distort the functioning of the market are removed.

On the basis of this analysis, **the following section advances policy recommendations, aimed at creating conditions for the development of a more diverse, inclusive and competitive sector**. These aim, first and foremost, to promote inland aquaculture capable of fulfilling immediate and future domestic demand for fish in support of national food and nutrition security goals, with the understanding that establishing the conditions for this to occur will also support export oriented activities. Although this study has focused largely on Ayeyarwady and Yangon, the **implementation of these recommendations at the national scale would also support the development of a less geographically concentrated sector**, stimulating growth in other areas of the country where suitable environmental conditions for aquaculture exist.

5.2 Policy Recommendations

Policy recommendations arising from the analysis presented above are organized around five themes: legal frameworks governing land use; finance and enabling environment; infrastructure; technical interventions and institutional development, and; environment. Some recommendations span macro and meso scales, having national reach and implications that extend beyond aquaculture, while others are sector-wide in scope, or are specific to particular value chain segments.

5.2.1 Legal frameworks governing land use

Restrictions on land use represent the single largest constraint to development of the farm segment of the inland aquaculture value chain, particularly in areas outside of existing pond clusters. The prohibition on conversion of paddy land to other uses is misplaced given that rice now represents a minor cost component in food budgets, even among the poorest, and aquaculture occupies a tiny fraction of cultivable land nationally.

The need to apply for land use titling change of in order to convert agricultural land to ponds in a legally compliant manner is similarly restrictive. Accordingly, the removal of these controls is a priority. **Holders of use rights to agricultural land should be allowed complete freedom of choice in crop cultivation**. Redesignating aquaculture as a form of agriculture (in relation to land management issues only), might offer one means of overcoming land use titling restrictions.

Insecure tenure and legal ambiguities have inhibited the development of private land rental markets that could support smallholder access to land for aquaculture, and place those who have constructed ponds without following due process at risk from a more interventionist future role for the state in land management. Retroactively **regularizing the status of ponds already constructed would remove this source of uncertainty**. However, to do so indiscriminately would risk undermining the compensation claims of former landowners whose property has been subject to confiscation. In these instances, **efforts to return confiscated land to its original owners or to provide adequate financial compensation should be intensified**. Given that land confiscation is one of the main causes of the distorted structure of the farm sector that these recommendations seek to address, **stricter criteria should be applied to any decisions to grant large land concessions for aquaculture**, including requirements to provide detailed business plans demonstrating economic viability, and the submission of social and environmental impact assessments, to be assessed by an independent body.

An interim measure would be to waive the requirement for farms sized 10 acres or less to obtain apply for La Na 39, formalizing what is already a *de facto* norm in some locations and guaranteeing future security of tenure in a pro-smallholder manner. **A stepped system of land taxation and pond licensing fees represents an additional option for rebalancing the sector in favor of smallholders**, by minimizing charges levied on smaller pond farms and taxing larger operations at higher rates, proportional to farm area.

5.2.2 Finance and enabling environment

Limited access to finance is the greatest constraint to aquaculture development after land use restrictions. Myanmar has the least developed banking sector in Asia, although this situation is beginning to improve gradually. Large farms are not generally severely credit constrained, but smaller commercial producers and SMEs involved in input supply, transport and marketing must borrow from informal lenders at high rates of interest, and are sometimes unable to access credit

from any source. **This results in underinvestment, suboptimal use of inputs, and diminished capacity to seize new opportunities**. These observations indicate that **there is the need to continue and accelerate ongoing macro- scale reforms to finance and banking**. It is beyond the scope of this study to address these in detail, but a number of investment policy reviews offer detailed recommendations on this issue (e.g. OECD, 2013).

With respect to sector specific finance mechanisms, **the capacity of MLFDB to provide larger volumes of credit to a wider customer base should be expanded, and its approach to loan dispersal should be reformed to make it more responsive to the practical needs of aquaculture producers**. This should include an explicit remit to serve the needs of commercial small and medium scale producers. Measures to achieve this goal could include: removing restrictions on the size of farms to which loans can be extended; allowing for multiple loan withdrawals over the course of a production cycle; scheduling repayments in line with the duration of the production cycle; reducing the degree of collateralization required; providing loan facilities with a window of more than one year; supplying credit to non-farm SMEs in aquaculture value chains, and; training bank staff on aquaculture to support more effective decision making. Institutions such as Thailand's Bank of Agricultural Credit and Cooperatives, which provides dedicated financial products and services tailored to farmer needs for a large proportion of the country's small- and medium-scale fish commercial producers provide an example of how such approaches might be implemented.

Microcredit delivered by non-governmental organizations (NGOs) or microfinance institutions (MFIs) is the most appropriate means of reaching very small producers. Delivery of credit to this group should be packaged with extension services to increase adoption of aquaculture in underutilized homestead ponds, which have seldom been targeted by development organizations to date. Efforts to enhance productivity and returns from homestead ponds should also include value chain development approaches to ensure the availability of seed in remoter areas, and promotion of the culture of nutrient rich small indigenous fish species to meet household nutrition security needs.

The feed manufacturing sector is currently uncompetitive. **Foreign and domestic investment in aqua-feed production should be encouraged to improve the sector's performance**, leading to lower prices, higher product quality, and more widespread adoption of formulated feeds with resultant productivity gains. Experience from other countries in the region shows that feed manufacturers are at the forefront of promoting new innovations in order to gain market share (e.g. distribution of high quality monosex tilapia seed with feeds, promotion of new farming technologies such as cage culture, provision of a range of embedded extension services). Incentives for investments in feed production could include tax holidays, and reductions of duties on imported feed ingredients such as soy cake and capital goods such as milling machinery. **These measures need to be accompanied by improvements in access to formal finance that will enable feed dealerships and distributors to deliver feeds to customers on credit**.

Express bus services are extremely important for the transport for fish throughout the country, but are not licensed to carry freight. In addition, **fish cannot legally be transported interstate without written consent from DOF, and can only legally be distributed to markets outside of Yangon by a limited pool of licensed traders**. These restrictions are ineffective, and serve only to promote rent seeking behavior and increase marketing costs which are ultimately passed on to the consumer. **All restrictions on domestic trade in and transport of fish should be removed.**

5.2.3 Infrastructure

Energy represents a significant cost in all value chain segments. On the farm, costs associated with pumping water and generating electricity using diesel fuel are substantial, causing producers to minimize water exchange in ponds, leading to poor water quality and high levels of disease and mortality. Energy costs are particularly high in integrated poultry-fish operations, where lighting and ventilation for hen houses is required. **Improving the extent of rural electrification would reduce farm production costs and improve husbandry practices**.

Energy also accounts for major share of costs upstream in milling (both agro-processing and manufacture of pelleted fish feeds), and downstream in ice production and cold storage. The extent of rural electrification is extremely limited and even in urban industrial zones power supply is erratic, resulting in widespread dependence on diesel powered generators which are costly to operate. **Improving urban power supply would substantially increase the efficiency of up- and downstream enterprises**, reducing input and marketing costs, and resulting in efficiencies and savings that could be passed on to both producer and consumer.

The domestic market for fish has proven extremely responsive to the liberalization of regulations governing transport, and improvements in transport infrastructure. **Additional investments in transport infrastructure would further enhance market connectivity and reduce transport times**, particularly for roads linking urban and rur- urban centers in Upper, Eastern and Western Myanmar. The highly clustered geographical distribution of ponds is closely related to the location of transport links. **Improving access to remoter parts of Ayeyarwaddy Region by road and waterway would open up new areas for pond expansion**, and result in a more even spatial pattern of aquaculture development.

Commercialization of production in the large numbers of small homestead ponds that exist through the southern delta is currently constrained by the need to limit feed use, in order to retain their primary function as sources of drinking water in areas with saline groundwater. **Improving household access to potable water in these areas would remove the key constraint to more intensive utilization of homestead ponds for aquaculture**, whilst also improving rural health and sanitation.

5.2.4 Technical interventions and institutional development

By far most effective investments in the aquaculture sector by DOF have been in the sphere of fish seed production. These were instrumental in catalyzing the sector's early development. Knowledge transfer between government employees and hatcheries occurred through informal consultancies and partnerships. **Investments in developing and disseminating seed production technologies for promising candidate species should represent a priority for DOF**. These efforts could seek to replicate and formalize diffusion pathways that have proven successful in the past, through the provision of fee- based consultancy services to hatcheries. **DOF should continue its role in providing seed to farms in remoter areas of the country not currently adequately served by the private sector**, and should seek to develop its long term capacity to maintain and supply high quality germplasm of key species to the private sector.

This study identifies a clear need for the adoption of improved methodologies for the **collection of fisheries data** to generate more accurate information that adequately reflects changing conditions within the sector and delivers stronger evidence on which to base policy decisions. **This**

could include greater use of modern techniques for capturing and analyzing geospatial data and revised methods for estimating production yields based on representative sampling of farms. Donor investments and collaboration between government and institutions such as the Food and Agriculture Organization of the United Nations (FAO) could support these efforts.

Giant freshwater prawn is high value crop, suitable for production by small farmers, with strong domestic and international demand and good prospects for export to the European Union (the main international market), following its recent removal of restrictions on the export of aquaculture products from Myanmar. However, production is currently severely constrained by high levels of mortality during the hatchery stage. Efforts to break the bottleneck in freshwater prawn production are already ongoing with donor support. **Research to overcome the technical problems that prevent production of prawn seed should represent a priority investment** given the substantial opportunities that exist.

Fish diseases and parasites are by far the most common technical problems identified by farmers, reflecting the very limited availability of veterinary services (either public or private). **Services that offer timely information on the diagnosis and treatment of disease are needed urgently.** These could be provided through interventions such as the development of simple interactive diagnostic tools (e.g. phone apps), and the development of public-private partnerships (e.g. sponsorship of government-led training events by veterinary pharmaceutical companies). Other Asian countries are well served by private aquatic veterinary services, and the entry of these companies into Myanmar should be encouraged. **Expansion of higher education in aquaculture and aquatic veterinary sciences through the development of strongly practically orientated university courses would increase the pool of skilled workers available to the public and private sectors**, and build long term capacity of both to deliver effective extension.

5.2.5 Environment

Ponds construction has occurred on wetlands in many areas of Ayeyarwaddy region. Although these are officially regarded as "vacant", "fallow" or "wastelands", they often are rich in biodiversity, and perform an important function in the provision of ecosystem services that are of critical importance in the livelihoods of large numbers of landless people. The importance of wetlands should be fully recognized, and their conversion to ponds or other agricultural uses should be regulated in order to maintain the biodiversity and ecosystem services they support. **Independently evaluated environmental and social impact assessments should form part of any applications to convert large areas of wetland to ponds.**

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ANNEX 1

Table A1. Fish pond area by township and state/region

Estimated fishpond area by region/state and township

Region/State	Township	Fish pond area (acres)	Township area (acres)	Share of ponds in township area
Ayeyarwady	Maubin	72,737	347,388	20.9
Yangon	Twantay	53,624	178,385	30.1
Ayeyarwady	Nyaungdon	33,677	222,605	15.1
Ayeyarwady	Pantanaw	15,580	329,131	4.7
Yangon	Htantabin	10,370	148,288	7.0
Bago	Thegon	9,147	192,190	4.8
Yangon	Taikkyi	7,405	435,783	1.7
Yangon	Kayan	7,212	157,580	4.6
Bago	Letpadan	4,511	363,711	1.2
Yangon	Kawhmu	4,206	152,002	2.8
Yangon	Hlegu	4,157	373,425	1.1
Ayeyarwady	Wakema	3,069	291,045	1.1
Yangon	Dagon Myothit (East)	3,027	33,925	8.9
Ayeyarwady	Danubyu	2,515	185,877	1.4
Bago	Bago	2,332	720,547	0.3
Ayeyarwady	Dedaye	2,202	222,032	1.0
Bago	Thayarwady	2,108	257,399	0.8
Ayeyarwady	Kangyidaunt	1,546	195,372	0.8
Ayeyarwady	Kyaiklat	1,530	153,277	1.0
Bago	Minhla	1,121	167,525	0.7
Bago	Kawa	1,116	289,091	0.4
Ayeyarwady	Zalun	1,112	154,979	0.7
Ayeyarwady	Einme	1,083	184,538	0.6
Yangon	Mingaladon	1,036	31,799	3.3
Ayeyarwady	Thabaung	957	521,751	0.2
Bago	Thanatpin	894	234,323	0.4
Ayeyarwady	Pathein	790	380,605	0.2
Yangon	Hmawbi	750	116,431	0.6
Yangon	Dala	724	56,758	1.3
Ayeyarwady	Ingapu	505	414,363	0.1
Bago	Padaung	416	619,385	0.1
Ayeyarwady	Hinthada	375	249,680	0.2
Ayeyarwady	Kyaunggon	367	168,537	0.2
Bago	Nattalin	332	334,864	0.1
Mon	Mawlamyine	327	34,529	0.9

Region/State	Township	Fish pond area (acres)	Township area (acres)	Share of ponds in township area
Ayeyarwady	Bogale	323	500,345	0.1
Ayeyarwady	Labutta	303	615,925	0.0
Ayeyarwady	Pyapon	300	350,935	0.1
Ayeyarwady	Yegyi	300	320,581	0.1
Ayeyarwady	Kyonpyaw	262	203,515	0.1
Bago	Taungoo	247	427,101	0.1
Ayeyarwady	Mawlamyinegyun	243	300,912	0.1
Bago	Kyauktaga	218	704,110	0.0
Bago	Pyay	187	193,878	0.1
Bago	Oktwin	164	355,119	0.0
Ayeyarwady	Lemyethna	156	248,168	0.1
Bago	Waw	148	235,942	0.1
Mon	Paung	146	241,913	0.1
Bago	Paungde	125	230,989	0.1
Bago	Okpho	121	259,664	0.0
Mon	Thaton	117	306,746	0.0
Bago	Daik-U	94	318,013	0.0
Ayeyarwady	Myanaung	73	379,090	0.0
Yangon	Dagon Myothit (Seikkan)	69	19,075	0.4
Mon	Chaungzon	68	100,436	0.1
Ayeyarwady	Ngapudaw	61	793,150	0.0
Bago	Monyo	39	162,201	0.0
Ayeyarwady	Myaungmya	38	283,301	0.0
Bago	Paukkhaung	36	473,525	0.0
Mon	Kyaikmaraw	28	327,738	0.0
Bago	Shwedaung	25	172,282	0.0
Yangon	Seikgyikanaungto	21	2,991	0.7
Yangon	Kungyangon	14	147,314	0.0
Mon	Ye	13	676,474	0.0
Yangon	Kyeemyindaing	11	1,102	1.0
Bago	Gyobingauk	6	190,048	0.0
Mon	Bilin	6	494,957	0.0
Yangon	Kyauktan	5	198,521	0.0
Mon	Mudon	4	181,423	0.0
Total		256,827	19,336,604	1.3

ANNEX 2

Table A2a: Allocation of fish products listed in IHLCA by probable source

Allocation of fish products by source and processing conversion factors

Aquaculture[1]		**Freshwater capture[1]**		**Marine capture**		**Dried, fermented and other processed products**	
Burmese	English	Burmese	English	Burmese	English	Burmese	English
Nga myit chin	Rohu	Nga yant	Snakehead	Nga shwe	Pike conger eel	Fish meat[2]	-
Nga gyin	Mrigal	Nga khu	Walking catfish	Nga pokethin	Croaker	**Dried products (freshwater)**	
Nga ton	Pangasius	Nga gyee	Stinging catfish	Sardine (All kinds)	-	Nga yant chauk	Snakehead
Nga moke	Pacu	Nga pyayma	Climbing perch	Pazun Kyawt	Shrimp	Other dried small river fishes	-
		Other small river fishes	-	Squid and the like	-	Other dried medium river fishes	-
		Other medium river fishes	-	Other small sea fishes	-	**Dried products (marine)**	
		Other large river fishes	-	Other medium sea fishes	-	Nga kunshut chauk	Seer fish
		Pazun Doke	Giant freshwater prawn	Other large sea fishes	-	Ar bye chauk	Bombay duck
				Nga thalauk	Hilsa	Other dried small sea fishes	-
				Kakatit	Sea bass	Other dried medium sea fishes	-
						Dried prawns	-
						Dried prawn powder	-
						Fermented products	
						Shrimp paste	-
						Nga pi yae	-
						Nga pi kaung	-
						Fish/shrimp sauce	-

Notes: [1] Marketed and consumed fresh; [2] Minced fresh fish (*nga chit*) used in fish cakes, can be made of fish originating from freshwater/marine capture or aquaculture

Table A2b: Allocation of processed food categories from IHLCA 2010 by probable origin, and conversion to live weight equivalents. Conversion factors from Hortle (2007)

Product category	Source assumption	Consumption (kg/capita/year	Conversio n factor	Estimated live weight equivalent (kg/capita/year)
Dried freshwater fish	Freshwater capture	0.9	3.5	3.2
Dried marine fish	Marine capture	1.1	3.5	4.0
Total dried prawn	Marine capture	0.4	3.5	1.4
Fish/shrimp sauce	Marine capture	1.0	0.5	0.5
Shrimp paste	Marine capture	1.3	0.88	1.2
Fermented fish	50% freshwater capture, 50% marine capture	2.0	0.75	1.5
Fish meat	33% freshwater capture, 33% marine capture, 33% aquaculture	0.4	2	0.7
Processed products consolidated by source				
Marine processed products WWE				8.0
Freshwater processed products WWE				4.1
Aquaculture processed products WWE				0.2
Total processed products WWE				12.4

Table A2c: Allocation of marine shrimp, freshwater prawn and exported products listed as 'Other (live)' by DOF 2012, by probable origin.

	Quantity allocated by probable origin (t)			
Product category	Aquaculture	Marine capture	Freshwater capture	**Assumptions**
Crab	1500	9942	-	FAO (2015a) reports 1500 t of crab produced by aquaculture in 2010. Assume that 100% is exported, with the remainder from marine capture fisheries.
Eel	-	-	8132	All 3 eel species listed in DOF (2012) as exported are from freshwater capture fisheries
Other live exports	-	10710	-	All live exports listed in DOF (2012) except for eels & farmed crab originate from marine capture fisheries
Shrimp	10186	8677	-	In 2010, 46% of shrimp production was from marine capture and 54% of shrimp production was from aquaculture (FAO, 2015a). Total reported exports of 18862 from DOF (2012) allocated to each source in these proportions
Prawn	281	-	-	100% of freshwater prawn exports assumed to come from aquaculture as production reported as 2881 t reported to be produced by aquaculture by FAO (2015a), and no separate figures for production from capture fisheries exist

Table A2d: Allocation of exported products listed as 'Other (dried or frozen)' by DOF 2012 by probable origin, and conversion to live weight equivalents. Conversion factors from FAO (2015c), Hortle (2007).

Dried (marine capture)				Dried (freshwater capture)				Frozen (marine capture)				Frozen				Excluded
Product	Exports (t)	CF*	LWE* (t)	Product	Exports (t)	CF	LWE (t)	Product	Exports (t)	CF	LWE (t)	Product	Exports (t)	CF	LWE (t)	Product types
Dried Anchovy	405.1	3.5	1417.9	Dried Snake Skin Gourami	3259.8	1.5	4889.7	Soft Shell Crab	1987.9	1	1987.9	Vannamei cooked	147.6	2.8	413.3	Fish bones
Dried Baby Lon Meat	19.5	3.5	68.3	Dried small fish	8443.8	3.5	29553.5	Babylon (Frozen)	101.2	1	101.2	Vannamei sushi	1.6	2.8	4.4	Shrimp shell
Dried Big Eye Ilisha	59.9	3.5	209.8	Dried Kiski	21.2	3.5	74.3	Babylon Meat	125.0	6	750.1	Pangash meat	4.2	1.5	6.3	Shrimp liquid
Dried Clam	0.0	3.5	0.0	Dried Star Baime	5.7	3.5	19.8	Blue Swimming Crab	52.9	1	52.9	Vannamei meat	1.1	2.8	3.0	Fish maws
Dried Cuttlefish	3.2	3.5	11.2	Dried Shol	4.3	3.5	15.1	Boiled Slipper Lobster	1.1	1	1.1		154.5		427.0	Fish heads
Dried False Travellv	21.8	3.5	76.1	Dried Tenaira	1.1	3.5	3.9	Boiled Spanner Crab	80.3	1	80.3					Shells
Dried Fish	542.6	3.5	1899.2	Dried Bowal	0.7	3.5	2.5	Breaded Prawn Cutlet	234.1	2.8	655.4					Shrimp shell dust
Dried Gwe Pa Zun	0.8	3.5	2.8	Dried Puti	0.9	3.5	3.1	Clam	47.3	1	47.3					Seaweed
Dried Hard Tail Scad	2.0	3.5	6.9	Dried Pabda	0.3	3.5	0.9	Clam Cooked	0.6	6	3.3					Fish skin
Dried Lizard Fish	0.1	3.5	0.2	Fish Paste	3.9	3.5	13.6	Clam Meat	67.8	6	406.7					Fish roe
Dried Long Fin Majarro	21.6	3.5	75.6					Crab	3.2	1	3.2					Prawn cones
Dried Lotia	141.6	3.5	495.7					Crab Meat	2.3	6	13.8					Techioleus Gigas
Dried Octopus	4.8	3.5	16.7					Cuttle Fish	1983.4	1	1983.4					
Dried Pony Fish	128.4	3.5	449.4					Dead Small Crab	156.6	1	156.6					
Dried Prawn	2615.0	3.5	9152.7					Flat Head Lobster	6.0	1	6.0					
Dried Ribbon Fish	39.4	3.5	137.9					Hilsa Meat	0.9	1.5	1.4					
Dried salted jellyfish	1101.9	3.5	3856.6					Lobster	133.2	1	133.2					
Dried Sardine	94.0	3.5	329.1					Mud Crab	14.5	1	14.5					
Dried Sea Cucumber	36.9	3.5	129.0					Octopus	16.5	1	16.5					
Dried Seasoned Thread Fin Bream	0.3	3.5	0.9					Pink Cooked	58.4	1	58.4					
Dried Squid	202.4	3.5	708.4					Pink Filo Pastry	2.1	2.8	6.0					

Dried (marine capture)				Dried (freshwater capture)				Frozen (marine capture)				Frozen (aquaculture)				Excluded Product types
Product	Exports (t)	CF*	LWE* (t)	Product	Exports (t)	CF	LWE (t)	Product	Exports (t)	CF	LWE (t)	Product	Exports (t)	CF	LWE (t)	
Dried Sting Ray Meat	3.1	3.5	10.7					Red Crab	20.5	1	20.5					
Dried Sting Ray	112.2	3.5	392.6					Sand Crab	432.2	1	432.2					
Dried Strlng ray	45.1	3.5	157.8					Slipper Lobster	1.2	1	1.2					
Dried Thread Fin Bream	0.1	3.5	0.3					Spanish Mackerel Meat	79.0	1.5	118.5					
Dried Toungue sole	60.7	3.5	212.5					Spanner Crab	366.7	1	366.7					
Dried Trump Whiting	0.4	3.5	1.3					Squid	1707.2	1	1707.2					
Dried White Croaker	16.4	3.5	57.3					Squid Cooked	4.3	1	4.3					
Dried White Croaker	1.8	3.5	6.3					Squid Fillet	127.7	2.3	293.7					
Dried White Pomfret	1.7	3.5	6.0					Squid Head	51.1	5	255.6					
Dried Yellow Croaker	1.6	3.5	5.6					Surimi	2645.1	4.3	11373.9					
Dried Small Squid	2531.3	3.5	8859.7					Thread Fin Bream Meat	1.0	1.5	1.5					
Fish Meal	22449.2	3.5	78572.2					Three Spot Crab	62.1	1	62.1					
Fish Paste	3.9	0.88	3.4					Tiger cooked	145.0	2.8	406.1					
Salted black pomfret	4.6	1.5	6.8					Tiger Sushi	1.6	2.8	4.5					
Salted Fish	3079.0	1.5	4618.6													
Salted Hilsa	3.5	1.5	5.3													
Salted Platu	468.4	1.5	702.6													
Salted Spanish Mackerel	702.5	1.5	1053.7													
Salted Spotted Croaker	48.2	1.5	72.2													
Total	34,980.7		113,810		11,741.7		34,576.3		10,720.9		21,530.4		154.5		427.0	

Notes: *CF = conversion factor; *LWE = live weight equivalent

ANNEX 3

Step by step guide to the process of applying to for La Na 39

To change the title of the land from 'agricultural land' into 'non-agricultural land' it is necessary to get the permission for land use from the State / Division Peace and Development Council, according to the 1953 Land Nationalization Act, Article 39. If the construction of village is on Agricultural Land we must take the following steps to change the land use:

1. Chairman of VPDC [Village Tract Peace and Development Councils] submits the application Form LR103 to Township Land Records Department in order to get a certified map.

2. Chairman of VPDC submits the application form to Township Peace and Development Council/General Administration Department with:

   (1) Certified Map

   (2) Site Plan and Layout Plan

   (3) Promise Letter i.e. [in the case that the purpose of obtaining non-agricultural land use status is to construct a house] a contract indicating that the shelter will be completed within 6 months.

3. Township Peace and Development Council/G.A. Department will process the case file. In Myanmar the Township Officer of G.A. Department also acts as the Chairman of Township Peace and Development Council (TPDC).

4. The application form is received and registered by the Office of TPDC.

5. The Chairman of TPDC opens the case file and takes necessary actions according to the Directions of Central Land Committee. During the process, the Township Land Records Officer enquires about the land and his report is attached in the case file.

6. The Township Peace and Development Council then submit the case file, passing it through the District Peace and Development Council to the State/Division Peace and Development Council (DPDC).

7. Finally, the State/Division Peace and Development Council has authority to give permission for the change in land use.

Source: UN-Habitat/UNHCR (2010)

ANNEX 4

Glossary of technical terms related to aquaculture

Term	Definition
Aquaculture	The farming of fish and other aquatic organisms under controlled conditions
Backyard ponds	Small ponds constructed close to rural houses to collect water for mainly domestic uses, sometimes also stocked with fish
Broodfish/Broodstock	Sexually mature fish used in aquaculture for breeding purposes
Exotic fish species	Non-native species of fish introduced for the purposes of aquaculture
Feed conversion ratio	The ratio of the quantity of feed used during production to the quantity of fish harvested
Fingerling	Juvenile fish of a size suitable for use in aquaculture (usually several inches in size, or roughly the length of a finger)
Floating feed	A pelleted fish feed which floats in water
Formulated fish feed	Fish feed manufactured using ingredients that satisfy nutrient requirements for fish growth
Freshwater capture fisheries	Naturally occurring fish stocks harvested from the freshwater aquatic environment, and the human activities that support their harvest
Growout	Stage of production during which juvenile fish are raised to marketable size
Hatchery	Specialized enterprise producing juvenile fish under artificially controlled conditions
Hatchling	Very recently hatched juvenile fish
Homestead ponds	See 'backyard ponds'
Indigenous fish species	Species of fish endemic to a specific geographical area
Inland aquaculture	Aquaculture occurring in a freshwater environment
Marine capture fisheries	Naturally occurring fish stocks harvested from the marine environment, and the human activities that support their harvest
Milt	Fish sperm
Monosex tilapia	Tilapia treated with methyl-testosterone to produce all male seed that grow rapidly
Nursery	Intermediate stage of fish production during which very young fish are raised to sizes suitable for stocking in 'growout' farms
Pelleted fish feed	Fish feeds formed into small compressed pellets using mechanical equipment
Seed	Any juvenile fish used as an input for aquaculture
Sinking feed	A pelleted fish feed which sinks in water