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2 Executive summary

This study was initiated to explore in more detail, future fish supply and demand scenarios for Cambodia, the role of aquaculture and provide a basis for understanding future investment and strategies for its sustainable development. Inter-dependencies, trade, geo-political and macro-economic aspects within the Lower Mekong Basin and also within the wider regional space of neighbouring countries of Lao PDR, Vietnam and Thailand are important determinant factors influencing fish supply and demand. Recent trends and probable future are reviewed in the context of aquaculture expansion in Cambodia.

The approach involved four inter-linked steps; i) future scenario development, ii) modelling projected fish demand and supply for 2030 using the 'AsiaFish Model' iii) aquaculture system characterization and, iv) analysis of aquaculture pathway and investment options. The outputs from the first three steps provided the necessary information for investment and aquaculture pathway analysis. These outputs may be summarised as follows:

i) Scenario development involved an e-mail survey to determine key drivers of importance and uncertainty which was reviewed at a national level workshop to determine the four scenario narratives for 2030. The narratives focused on preservation of habitat, enforcement of Fisheries Law, aquaculture investment and hydropower development as key determinants of fish supply and relevant to this study the role of aquaculture as a source for projected production estimates.

ii) Application of the AsiaFish Model generated a reference scenario based on recent trends. The reference scenario provided the baseline template to model alternative scenarios (defined in (i) above) to generate alternative projections for the future and thus quantify production from aquaculture, as one of the source categories for fish supply, ranging from 106,000 tonnes to 281,000 tonnes by 2030

iii) Seven aquaculture systems were fully characterised in order to estimate input requirements and related outputs for any scaled up production target including varying distribution of production across the aquaculture systems. Software designed to constantly update projections is available to government and other public agencies.

Aquaculture pathway analysis reviewed the consequences of four dominant systems; cages (current situation) small holder low input, small holder high input and Small Medium Enterprise (SME) farmers according to different scenario-based estimates of production for 2030.

The results of this analysis highlight the importance of aquaculture for Cambodia's future fish supply and how growth is influenced by supply of fish from inland and marine capture sources, trade, technology development, private investment and adequate supply of essential inputs (mainly seed and feed). All pathways provide a good return on investment, indicating aquaculture can generate household and national income, business opportunity, employment, food and help lift rural households out of poverty.

The research provides the previously missing quantification of required inputs to achieve production targets and reveals to planners the implications for different expansion strategies. For example, focussing investment in small holder development especially low input would require an unrealistic number of farming households. Intensive systems using current production technologies require unsustainable supplies of wild seed and feed. Reviewing a potential optimal pathway to maximise social, economic and environmental benefits suggests a significant shift in production efficiencies of small holder low and high input systems to produce 46% of total supply, freshwater cage reduced to 20% (from current 51%), commercial SME farming remain constant at 23% and marine cages and others 11%. However key issues regarding competitiveness with LMB countries, shifting away from heavy reliance on wild and feed and seed sources and improving input supply value chains and investment still remain to be addressed even for an optimal pathway.

Regional perspectives and consequences for Cambodia are reviewed and incorporated into the recommendations for investment strategies, infrastructure development (e.g. hatchery and domestic feed manufacture), research and policy development.

3 Background

Fish is vital to the well-being and livelihoods to millions of people in the Lower Mekong Basin, many of whom are poor, relying on fish as a major source of protein, sometimes the only source. The diversity of aquaculture systems enable the poor to benefit directly and also offer a lucrative investment for the better off which in turn offers employment for the poor and can reduce fish prices thus providing greater access to the poor. Women may also gain from active participation in small holder fish farms, marketing and processing.

This contribution to national food security and income (including foreign exchange income for shrimp and catfish fillets) is well recognised by all countries of the Lower Mekong Basin, but particularly so in Cambodia. Economic growth coupled with a rising population in the region places an ever rising demand on food supply, and over the past two decades a significant proportion of the population are demanding better and more diverse diets. Fish supply from most natural sources is already fully exploited and production is likely to decline in many rivers, lakes and inshore coastal areas over the coming years.

In the foreseeable future aquaculture could not replace the large volumes of fish harvested from wild sources and even if it did different people to those deriving their livelihoods from wild fish would likely benefit. Population is expected to increase at 1.6% per annum over the next 20 years[1] to 19 million people which would mean to maintain current fish demand (mainly consumption) an additional supply of 200,000 tonnes at 40 kg per capita in 2030.

The requirement for additional supply is embedded in national planning strategy documents. The PRSP[2] for Cambodia states that “improved management and introduction of appropriate technologies for rice fish farming and aquaculture” and devotes a whole section to “Aquaculture Development”. Cambodia’s Fisheries Administration (FiA) has developed a Strategic Planning Framework (SPF) starting from 2009 for the next 10 years till 2019 projecting a 15% per year increase in aquaculture production from the 40,000 tonnes baseline in 2008 rising to a total of 185,000 tonnes by 2019.

The project described in this document reviews the consequences for aquaculture expansion by different pathways and potential scenario-based estimates of aquaculture production by the year 2030. Improved accuracy in these projections will be important to ensure the scale of investment and development effort meets the projected demand and supply.

To achieve these estimates the project was articulated around four objectives;

- Scenarios determined for future production and consumption of fish in LMB countries with specific emphasis on Cambodia
- Model projections of future fish supply and demand using scenarios identified in 1) above.
- Aquaculture development pathways that can respond to demand projections and supply constraints are identified
- Investment needs for aquaculture growth determined

[1] *US Census Bureau http://www.census.gov/ipc/www/idb/informationGateway.php and UN Statistics Division http://data.un.org/Data.aspx?q=cambodia&d=PopDiv&f=variableID%3A47%3BcrID%3A116*

[2] *Poverty Reduction Strategy Paper http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/CAMBODIAEXTN/0,,contentMDK:20174685~pagePK:1497618~piPK:217854~theSitePK:293856,00.html*

4 Methodology

The project was implemented through a partnership between The WorldFish Center, Fisheries Administration (FiA) and Inland Fisheries Research Development Institute (IFReDI) in consultation with a wide range of stakeholders in Cambodia, including farmers, provincial government fisheries and aquaculture officers, and Cambodian development partners from international agencies and civil society organizations. Key project activities involved consultations through a series of workshops, farm level surveys, email consultations and the development and modification of a fish supply and demand econometric model called AsiaFish model (a model previously developed by the WorldFish Center to analyse fish supply, demand and trade in Asia). The approach involved four inter-linked steps; i) scenario development, ii) modelling projected fish demand and supply for 2030 using 'AsiaFish Model', iii) aquaculture system characterization and, iv) aquaculture pathway and investment options (Figure 1).

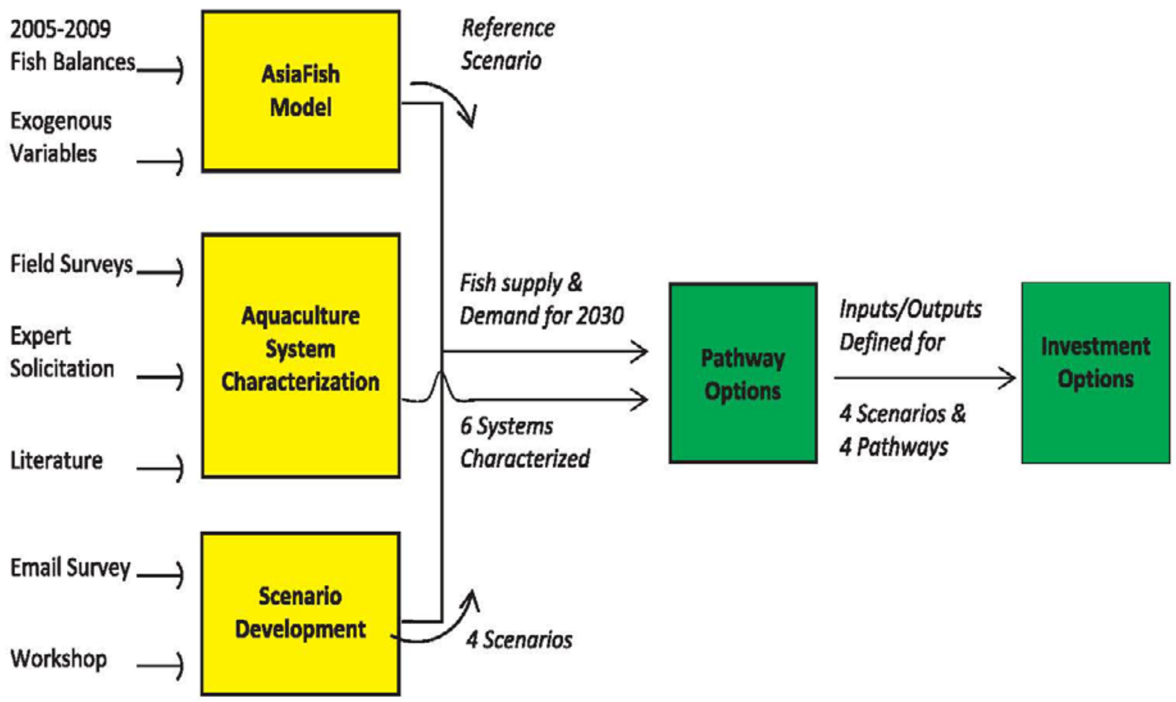


Figure 1: Schematic to show key steps, activities and outputs to determine future investment options for aquaculture in Lower Mekong Basin

Implementing activities concurrently, the project collected relevant data required to run the AsiaFish Model, characterize seven aquaculture systems commonly found in Cambodia, and through public consultations and working with stakeholders developed scenarios for future fish supply and demand. Projections for fish supply from aquaculture were then computed for quantification of input and outputs for all scenarios defined and specific pathway alternatives across the aquaculture systems (e.g. emphasis on developing small holder farms or alternatively emphasis on Small Medium Enterprises (SMEs). Once inputs and outputs are accurately defined across the aquaculture sub-systems for different projected supply volumes, details of investment requirement could be defined.

Key events to achieve component outputs necessary to develop aquaculture investment options for 2030 are tabulated below.

Date/period	Activity	Output
January - June 2010	Collect and input fish balance data 2005-2009 and exogenous data for AsiaFish model	Reference scenario for fish supply and demand
27 May 2010	Workshop to introduce the project and define aquaculture system categories	7 systems described but not fully parameterized
May-June 2010	Field Survey to 32 farms over 9 days by 4-6 enumerators	Aquaculture input/output data to fully
9 September 2010	Technical Review Workshop with leading technical experts in Cambodia	Finalise and agree on characterisation of aquaculture systems
November 2010	E-survey to identify the main drivers of change for fish supply and demand	Drivers categorized and ranked for impact and certainty
20 December 2010	Scenario narrative and aquaculture pathway development workshop	4 scenarios are fully described 4 pathway options identified.
7 January	Supply and demand analysis for scenarios using Asiafish Model	Model projections report for supply categories including freshwater and marine aquaculture
January - April	Analysis of input requirements for 6 aquaculture systems for four different scenarios and four different aquaculture pathways	Input/output data defined for a range of scenarios and pathways
6th May 2011	National Workshop on "Aquaculture Futures for 2030" and launching of Policy Brief "Fish supply and demand scenarios in Cambodia and perspectives on the future role of aquaculture"	9 presentations from 5 organisations generated discussion on future pathways and investment options to 72 participants from 7 representative organisations

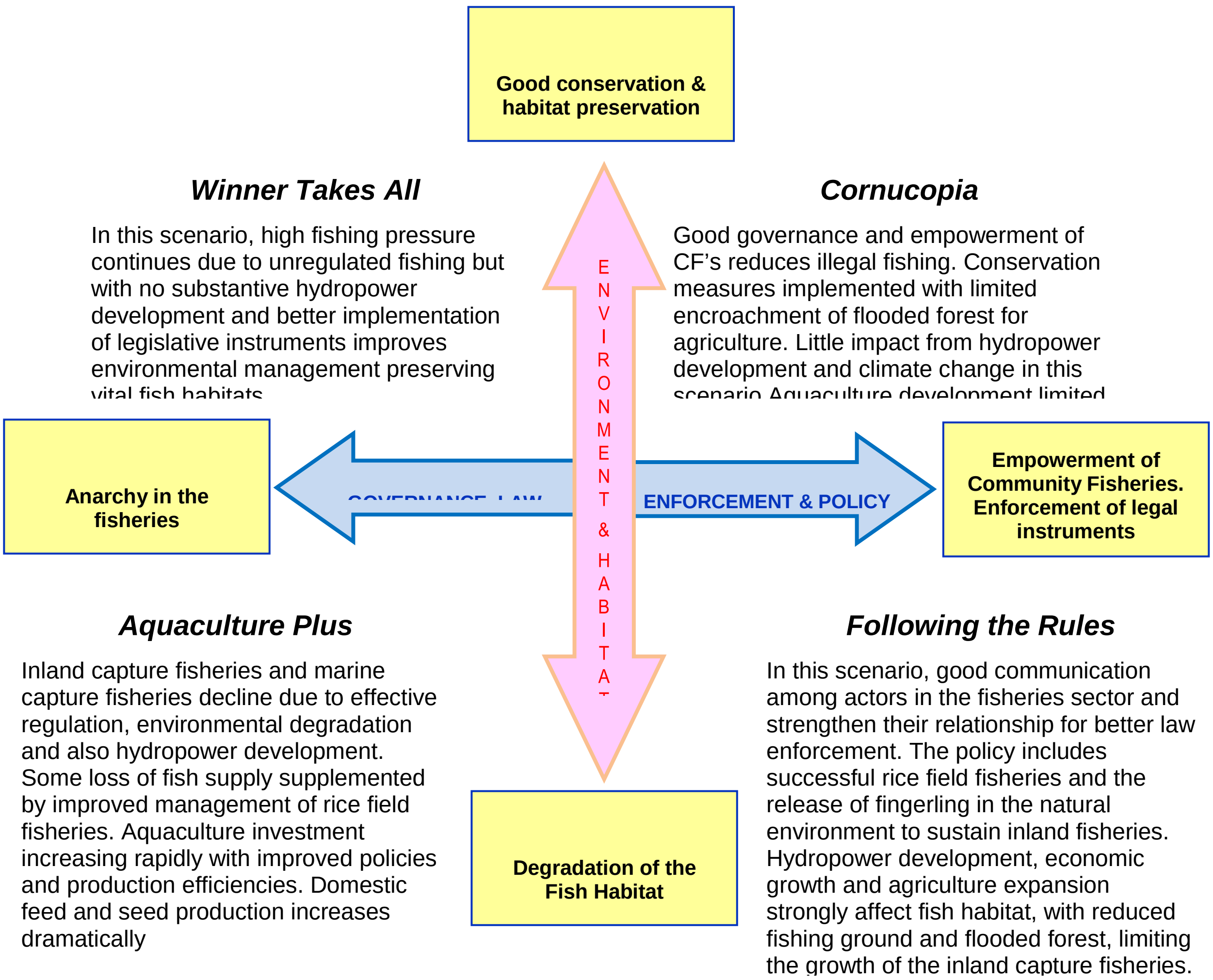
5 Fish supply and demand for 2030.

This section describes the outputs from the scenario development, application of the Asiafish Model to generate fish supply and demand projections by disaggregated output groups including marine and freshwater aquaculture and fully quantified system characterisations; necessary to analyse input requirements for different pathways (varied dominance of different systems) and their scenario based estimates of production projections.

5.1 Developing scenarios for aquaculture in 2030

Stakeholder consultations prepared four scenario narratives for fisheries and aquaculture in 2030. An e-mail survey identified key drivers of impact and their degree of uncertainty. Using the well established ‘Two-Axes’ method for scenario development, the drivers with high impact and high uncertainty were used to create scenario logic, the framework to develop four scenario narratives for fisheries and aquaculture in 2030 (Figure 2). Thereafter, a workshop was convened to describe in detail the scenario narratives and thus predict the most logical outcome in terms of output for different fish supply categories. Figure 2 shows the brief description of each scenario.

Figure 2: Scenario Logic for the future of Cambodia fisheries and aquaculture sectors in 2030.



5.2 AsiaFish Model for fish supply and demand analysis

To generate projections up to 2030 (the reference scenario), exogenous variables (e.g., population, incomes, foreign prices of fish, etc. as listed in table 2) and endogenous variables (fish supply and demand trends – production, consumption, export, import and processed fish from 2005-2009 (FiA statistics) were applied to run the model. For more detailed methodology, results and analysis on the AsiaFish Model for Cambodia can be found in Supply and demand Analysis for fish in Cambodia: An Application of the AsiaFish Model by Primo Rodriguez, WorldFish Center.

Table 2. Growth rates of the exogenous variables in the baseline scenario, % p.a.

Variable	Growth rate (%)	Remarks
Import prices	-0.38	Based on data from the FAO (2010) for the periods 2000-2002 and 2004-2007. Information for 2003 was excluded because the annual change in import prices was unusually large (212.68%) for this year.
Export prices	0.62	Based on data from FAO (2010) for the period 2000-2007.
Population	1.60	World Bank (2010)
Wage rate	3.04	Based on the inflation rate for 2000-2009. The information was sourced from the Asian Development Bank.
Food prices	4.31	Based on Asian Development Bank data from 2000 to 2009.
Non-food prices	1.26	Based on Asian Development Bank data from 2000 to 2009.
Nominal income	11.27	Based on the growth rate of Gross Domestic Product. The information was taken from the World Bank for the years 2000-2009.

In addition to the reference scenario which computes current trend variables, the storylines for four alternative scenarios were developed to estimate future fish supply from different fish group source categories. It is the fish supply 'culture' groups that this study takes forward for further analysis. However, of the four scenarios Cornucopia scenario was not taken into account due to unrealistic aquaculture sector growth and was replaced by the reference scenario from AsiaFish Model. The predicted volumes and specifically for aquaculture is presented for the Reference Scenario and three alternative scenarios below

Reference Scenario

Within the baseline scenario based on historical growth rate, the aggregate output of fresh fish is projected to rise by about 2.2% p.a. from 2007 to 2030 (Table 3). This implies that aggregate fish output in 2030 (933.2 thousand tons) will be about 66.7% higher than in its 2007 value (559.8 thousand tons). While the consumption and intermediate demand for fresh fish are projected to rise at about the same rate as production, exports of fresh fish are expected to fall at a rate of 6.4% p.a. Moreover, the relatively rapid increase in imports (12.2% p.a.) suggests that fish from abroad is expected to play a more important role in supporting domestic fish requirements in the future.

The outputs of all the different fish groups are expected to expand over simulation period. However, growth rates by fish group differ. The baseline scenario projects that the outputs of freshwater culture and marine culture will grow at 4.7% p.a. and 4.6% p.a., respectively. These are at least two times faster than the projected growth rates for capture fisheries and processed fish. As a result, the output of aquaculture fish is projected to be about three times higher in 2030 (106.4 thousand tons) compared to 2007 (35.3 thousand tons). The output of capture fisheries in 2030 (720.3 thousand tons) is only expected to be about 1.6 times higher than its counterpart in 2007 (458.5 thousand tons).

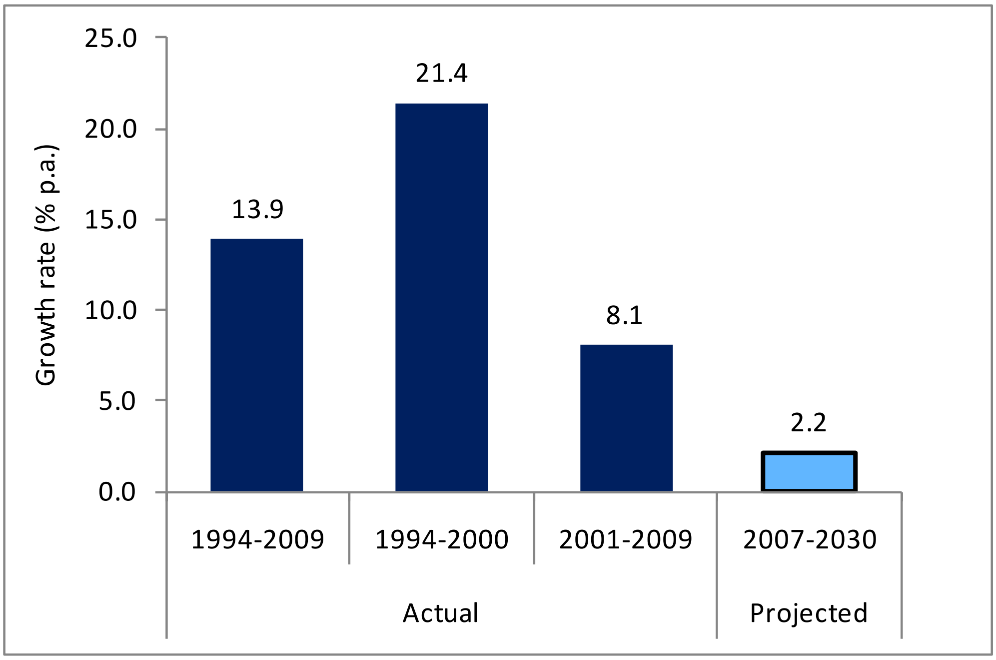
Table 3: Simulation results for the reference scenario

Item	Volumes (000 tons)		Average growth rate (% p.a.)
	2007	2030	
Aggregates			
Output	559.84	933.15	2.15
Imports	3.66	57.29	12.15
Exports	24.15	4.97	-6.37
Consumption	412.91	756.39	2.55
Intermediate demand	126.44	229.08	2.51
Outputs by fish group			
Marine capture	63.50	110.21	2.32
Inland capture	395.00	610.05	1.83
Freshwater culture	33.39	100.86	4.71
Marine culture	1.87	5.53	4.62
Processed fish	66.08	106.50	2.01

There are six important points worth noting from the simulation results for Reference Scenario

1. Domestic catch/output is expected to remain the dominant source of fish in the future. By 2030, imports are only projected to account for about 5.8% of total domestic supply (=output + imports). This means that about 94.2% of domestic supply will still be sourced domestically. However, the relatively rapid increase in total imports means the share of imports in total domestic supply will be more than 8 times larger than its counterpart in 2007 (0.7%);
2. The projected decline aggregate exports means that a larger proportion of domestic fish output will be destined towards the local market. Combined with rising fish imports, this result reflects the projected expansion in the domestic demand for fish in the next two decades.
3. Despite the relatively rapid growth of aquaculture, capture fisheries is expected to remain the dominant source of domestic fish in Cambodia. By 2030, the combined share of marine capture and inland capture fisheries in total fish output is projected to be about 77.2%, slightly lower than its 81.9% share in 2007. Furthermore, consumption of marine culture and freshwater culture fish in 2007 was about 38.9 thousand tons, or 9.4% of total fish consumption. By 2030, this is projected to rise to about 163.7 thousand tons or about 21.6% of total fish consumption.
4. With a population growth rate of about 1.6% p.a., the 2.6% annual growth of aggregate fish consumption suggests that per capita fish consumption is likely to increase at a pace of about 1.0% p.a.
5. The projected expansion of fish outputs suggests that the decline in fish exports is due to the expected growth pattern of fish prices. Projected growth rates for domestic fish prices are higher than the assumed growth rate of fish export prices. This implies that the incentive to export fish, i.e., from the viewpoint of the domestic producers, is expected to diminish over time. If there is sufficient basis, it is possible to assume higher growth rates for fish export prices.
6. Projected fish output growth is lower than its historical growth rate (Figure 3). While this suggests that the estimates in this paper should be treated as conservative, these are nonetheless consistent with declining historical growth rates of aggregate fish output.

Figure 3.. Historical and projected growth rates of aggregate fish output, 1996-2008, % p.a.



Source of basic data: Fisheries Administration (FIA) statistics and simulation results

Alternative Scenarios

Adjustments in the exogenous variable ‘productivity’ (set at zero for the reference scenario) were made in order to generate fish outputs from aquaculture close to the values specified in the scenario development expert consultation workshop. However, it is important to note that changes in productivity alter the market conditions for other groups. For example, the productivity of marine capture fisheries was calibrated to decline by 0.6% per annum (p.a.) under the Winner Takes All scenario. Ceteris paribus, this should make the output growth of marine capture fisheries 0.6 percentage points slower than its baseline growth rate. However, the observed output growth rate for marine capture fisheries in this scenario will be different for two reasons. First, changes in the productivity of marine capture fisheries will cause changes in market conditions for other fish groups. The induced changes in other fish markets, say on domestic prices, will have feedback effects on marine capture fisheries. Second, the market for marine capture fisheries will also be affected by the productivity changes introduced for the other fish groups. In short, all the productivity changes that were calibrated in the different scenarios account for the interaction among various fish markets.

By running the simulations using the Generalized Algebraic Modelling (GAMS) software projections for 2030 quantities by fish group, source (supply) and use (demand) are generated (Table 4)

Table 4: Simulation results for 2030

Item	2007	Reference	Winner Takes All	Aquaculture Plus	Following the Rules
Aggregates					
Output	559.84	933.15	1,005.12	846.08	1,416.71
Imports	3.66	57.29	60.92	58.26	67.76
Exports	24.15	4.97	4.86	4.47	14.89
Consumption	412.91	756.39	859.27	756.91	1,167.45

Intermediate demand	126.44	229.08	201.91	142.96	302.13
Outputs by fish group					
Marine capture	63.50	110.21	92.45	93.11	138.67
Inland capture	395.00	610.05	588.15	351.85	888.63
Freshwater culture	33.39	100.86	175.89	251.02	131.28
Marine culture	1.87	5.53	11.95	30.92	8.01
Processed fish	66.08	106.50	136.67	119.18	250.11

Scenario 2. Following the Rules

Aggregate output in this scenario is projected to be higher than the baseline, with an expansion in the outputs of all fish groups (Table 4). The explanation behind the increase in aggregate consumption rests with the slower growth of all fish prices. The latter is in turn a result of the productivity improvements in all fish groups which were used to achieve the output targets in this scenario. The projected increase in imports is due to higher consumption. In the case of exports however, the projected expansion is caused by the slower growth of domestic prices and higher fish outputs.

Scenario 3. Winner Takes All

This scenario indicates higher aggregate fish output, consumption and imports relative to baseline scenario. Aggregate output in the Winner Takes All scenario in 2030 (1,005.1 thousand tons) is projected to be 7.7% higher than the baseline value of 933.2 thousand tons (Table 4). The explanation for this result is trivial as the scenario calls for increases in the output of aquaculture and processed fish that are larger than the required decline in the output of capture fisheries

Aggregate consumption in 2030 is projected to be about 859.3 thousand tons, or 13.6% higher than the baseline scenario. This can be explained by the higher consumption of aquaculture and processed fish, which are due to the slower growth of domestic prices for these fish groups. As a result of the increase in aggregate consumption, per capita fish consumption is projected to rise to about 43.9 kg/person/year.

Scenario 4. Aquaculture Plus

Aquaculture Plus scenario indicates lower aggregate output and exports, accompanied by marginally higher consumption and imports (Table 4). This scenario generates a decline in aggregate output because it requires a more pronounced fall in the output in inland capture fisheries. Projected aggregate fish consumption in this scenario (756.9 thousand tons) is not very different from the baseline projection (756.4 thousand tons). This is due to the increase in the consumption of aquaculture fish, which offsets the contraction in the consumption of capture fish. Such an increase in consumption is attributable to the projected decline in the growth rates of domestic prices of aquaculture fish. Aggregate imports are projected to increase because of the increase in imports of aquaculture fish, due mostly to the increase in the domestic demand for these fish groups.

Uncertainties and gaps

The extraneous parameters (elasticities, etc) used in the model were adopted from previous applications of the AsiaFish model. The accuracy of the results is of course expected to be enhanced by attempts to estimate such parameters for Cambodia. The ability to generate such estimates depends on the availability of detailed fish data. Further work can also go into refining the disaggregation of the model though the explicit treatment of important fish species data in Cambodia.

The predictions relied upon storylines and their requisite outputs by fish group. More could be done to refine the model by improving estimates of exogenous variables for 2030.

Endogenous variables were based on the full balance sheet for 2007 and fish supply and uses for the years 2005 to 2009. Accuracy of model predictions could be improved with improved management of information systems for the fisheries and aquaculture sector across the country.

5.3 Aquaculture System Characterisation

Cambodia has a variety of aquaculture systems supplying various species of fish for household consumption, and to markets country-wide. Expert consultations and farm surveys identified the seven main fish culture systems in the country.

The seven aquaculture systems specific to Cambodia are:

- Smallholder - low input pond culture
- Smallholder – high input pond culture
- SME semi-intensive pond culture
- Freshwater cage culture
- Marine cage culture
- Rice-fish systems
- Extensive brackish water ponds [*The contribution to national output from brackish water ponds is negligible so this system was omitted from the analysis*]

These systems were characterized from a structural point of view, to quantify economic, technical variables and inputs requirements (full detailed descriptions of these systems is available in Technical Review document; "*Aquaculture Futures 2030; Fish supply and demand scenarios in Cambodia and perspectives on the future role of aquaculture*". Characterisation of the aquaculture systems enabled accurate quantification of inputs and outputs for different aquaculture pathways and scenario defined total fish supply projections from aquaculture.

Table 5 defines key parameters identified for each aquaculture system. The complete dataset was used to determine inputs required and outputs when scaled up to match 2030 fish supply targets from the scenarios analysis. The dataset does not represent averages of a sample but rather a pooling of knowledge from experts supported by farm field surveys to improve accuracy of the most typical quantification and characterisation of each aquaculture system.

Table 5 Characterisation of major Aquaculture Systems groups in Cambodia by key parameters

Aquaculture System	Small holder low input	Small holder high input			Small & Medium Enterprise			Fresh Water Cages			Marine Cages		Rice-Fish Culture
Parameter	Tilapia and carps poly-culture	Tilapia and carps poly-culture	Pangas& carps poly-culture	Pangas mono-culture	Hybrid Catfish	Pangas	Snake head	Pangas Poly-culture	Pangas	Snake head	Seabass	Grouper	Tilapia and carps
Average farm size pond (ha) & cages (m^3)	0.02	0.15	0.17	0.1	0.2	0.6	0.07	240	240	90	589	390	0.4
Fish yield (kg/ha/yr or kg/m3/yr for cage)	3,500	5,500	8,600	20,000	265,000[1]	51,000	87,000	35	35	94	12	7	400
Production (kg/farm/yr)	70	825	1,462	2,000	53,000	30,600	6,090	8,456	8,496	8,460	6,900	2,700	160
Home consumption (%)	75	5	3	0.4	0	0	1	0.5	0	0	0.5	0.6	30
Labour requirement (person days / contract workers per farm[2])	40	15 / 0.1	66	87	534 / 4.2	1,760 / 2	300 / 2	635 / 2.4	883 / 1.6	791 / 7	1,095 / 3	365 / 1	79
Average selling price (USD)	1.5	1.75	1.5	1.2	1.25	1.2	2.06	1.5	1.5	2.1	5	10	1.5[3]
Capital cost (USD/farm/yr)	175	900	508	1,000	1,733[4]	2,760	3,460	6,948	7,920	3,870	29,151	11,370	60
Operational cost: (USD/farm/year)	60	789	697	1,571	18,168	28,363	8,637	7,730	11,352	9,900	16,183	6,497	57
Net income (USD/farm/year and USD/ha/year (m^3 cages)	38[5]	522	1,235	792	17,044	8,356	3,416	4,942	1392	7,528	18,110	20,341	178
	1900	3,480	7,266	7,925	85,221	13,928	48,809	21	6	84	31	53	445

Note:

1. Catfish is 3 cycles per year ; 2. less than one for number of contract workers means part-time (1 year = 220 person days and 8 hours = 1 person day). 3. $2 for wild fish. 4. Ponds often leased. 5. Consumed fish (75%) included in financial analysis

6 Pathways analysis and potential impacts

Aquaculture systems from Table 2 may contribute in various ways to supplying future demand, but each has different economic, social and environmental costs and benefits. Four pathways for aquaculture growth represent different combinations of these systems, and were categorised: (1) Reference pathway, a continuation of current combination of systems, with cage culture systems continuing to dominate production of freshwater fish; (2) Small-holder, low input, pathway dominated by small-holder, low input farms; (3) Small-holder, high input pathway in which small holders still dominate production but the systems are higher yielding, implying improvements over present small holder aquaculture systems; and (4) Small and medium enterprise (SME) pathway in which the system of SMEs now found in peri-urban Phnom Penh grow and dominate production systems.

We could have restricted our analysis to one aquaculture systems distribution spread for each scenario but to broaden the analysis and identify of trends we adopted the following distribution spread for all scenarios.

Table 6: Relative proportion by percent of Aquaculture production systems projected for 2030 for selected pathways

System Type Pathway	Small holder Low input	Small holder high input	SME	Fresh Water cage	Marine cage	Rice-Fish
Reference	5.5	16.5	20	51.8	5.8	0.2
Small holder low input	35	20	10	23-25	5-11	2
Small holder high input	20	35	10	20-23	5-11	3-5
SME	15	20	35	16-18	5-11	3-5

Note: Marine cages variable as actual projections from AsiaFish Model available for this system

At this point we were able to combine the three main components for final analysis of consequences for different projections. Requisite input and related outputs were generated by scaling up all system parameters for each of the four projected aquaculture production scenario for four different pathways. For brevity in the report the detailed quantification of infrastructure (ponds, cages, equipment), system inputs (feed, seed, hatcheries, fertilisers) and gender disaggregated employment for each scenario and four pathways is recorded in the more detailed technical review series document published for this project. For this report we skip to the implications by analysing economic, social and environmental costs and benefits with special reference to one scenario ("Winner Takes All") and its four pathways (Table 7)

Social Impacts

Aquaculture growth can provide significant social benefits, such as food and income to households, as well as contributions to the nation’s food supply. More households benefit from small holder dominated pathways that involve less intensive systems. The small holder low input pathway could benefit over a million households (Table 7), an estimated one-third of total household if we consider approximately 2.8 million rural households by 2030. A huge increase in small scale pond farmers is unlikely.

The diversity of aquaculture systems avail to a wide range of livelihood groups including poor households. Pathways proposed may be regarded as pro-poor since 78% to 92% of benefiting households are small holder low input farmers i.e. poorest of the livelihood groups. Employment generated is calculated as time spent on own farms, occasional hired labour and contract workers for intensive systems. Pathways suggest aquaculture can provide Full Time Equivalent (FTE) or equivalent to almost quarter million people working full time.

Women's role is important for on-farm family labour representing 40% of FTE but due to the dominance of male hired labour, female FTE falls to 17% of the combined total of hired and on-farm labour. Aquaculture provides an opportunity to generate very high returns for labour, important for small scale farmers with multiple livelihood activities who are trying to maximise their returns on overall labour.

Average annual income increases with intensity of systems for pathways presented. Annual average incomes of $146 to $279 and food supply of 50kg per household would be important contributions to food security and family income. The key for households to achieve high incomes and potentially move out of poverty for good would be to graduate from low to high input production systems netting $500-1200 per annum (table 2)

Table 7. Indicators for 2009, Winner Takes All scenario and "best-bet" pathway

Social, economic and environmental indicators	2009	Reference pathway	Small holder low input pathway	Small holder high input pathway	SME pathway	"Best-bet" Pathway (see table 4)
Fish production (tonnes)	**50,000**	**187,840**	**187,840**	**187,840**	**187,840**	**187,840**
Social Indicators						
Employment (FTE) generated[1].	22,911	87,153	223,466	159,829	135,571	141,438
Female FTE (% of on-farm & % total on-farm + hired)	40 & 17	40 & 17	39 & 19	39 & 20	36 & 18	37 & 17
Labour productivity (kg/labour/yr)	2,182	2,155	841	1,175	1,326	1,328
Total Households (HH) benefiting	50,130	187,354	1,017,930	651,921	499,571	565,002
Total small holder HH benefit and % small holder of total HH	39,286 78%	147,589 78%	939,200 92%	536,686 82%	402,514 80%	483,017 85%
Total fish consumed (t/yr)	2,000	9,000	52,000	33,000	25,000	28,424
Income/household (US$/yr)	857	828	146	227	279	224
Fish consumption (Kg/household/yr)	47	47	51	50	50	50
Economic indicators						
Gross Revenue (US$ mn)	92	330	264	284	278	307
Net Income (US$ mn)	42	139	98	116	113	127
Infrastructure investment (US$ mn)	41	155	260	197	164	197
Operational investment (US$ mn)	47	177	149	154	155	170
Fish produced/$ invested (kg/$)	1.22	1.21	0.72	0.95	1.14	0.95
Profit/$ invested	1.04	0.89	0.37	0.58	0.67	0.64
Payback period (yrs)	0.95	1.11	2.65	1.71	1.49	1.55
Hatcheries (all domestic supply)	197	825	2,066	1,692	1,388	1577
Hatcheries (cap wild supply & annual import increment 5% / 10% p.a.)	NA	557 / 250	1,742 / 1,435	1,424 / 1,117	962 / 655	1,301 / 994
Environmental indicators						
Wild fish for feed demand ('000 t)	73	277	175	173	233	249
Total Seed required (million)	98	413	1033	846	694	788
Wild seed (million)	27	123	130	252	117	175

Note 1. FTE is Full Time Equivalent. Farm work calculated as hours per day, days per year and full time workers (8 hour = 1 day and 220 days = I year = 1 FTE

Economic Impacts

Comparison of economic, social and environmental indicators shows that if we wish to progress with growth first model (product at any cost) then we should continue with the current pathway whereby half of total production originates from cage culture. However, small holder low input pathway provides a more equitable distribution of benefits to many more families as direct beneficiaries and most probably indirect beneficiaries (local sales and barter for poor rural people). Small-holder models will require large number of ponds (approx. 1 million ponds), which requires substantial capital, and is probably unrealistic. Similarly compared to 2009, figure 4 shows significant increases in ponds and cages requirements for four pathways and four scenarios.

Economic indicators relate to farm investment and returns over one year only. Returns on investment would be high over several years with best returns for more intensive system pathways. However, ultimately growth of aquaculture will be mainly dependent on seed supply. Even with maintaining wild supplies at 2009 levels and increasing imported seed by 10% per annum a substantial increase in hatcheries for domestic supplies is required (additional 797 hatcheries to 197 in 2009 for best-bet pathway in Table 7).

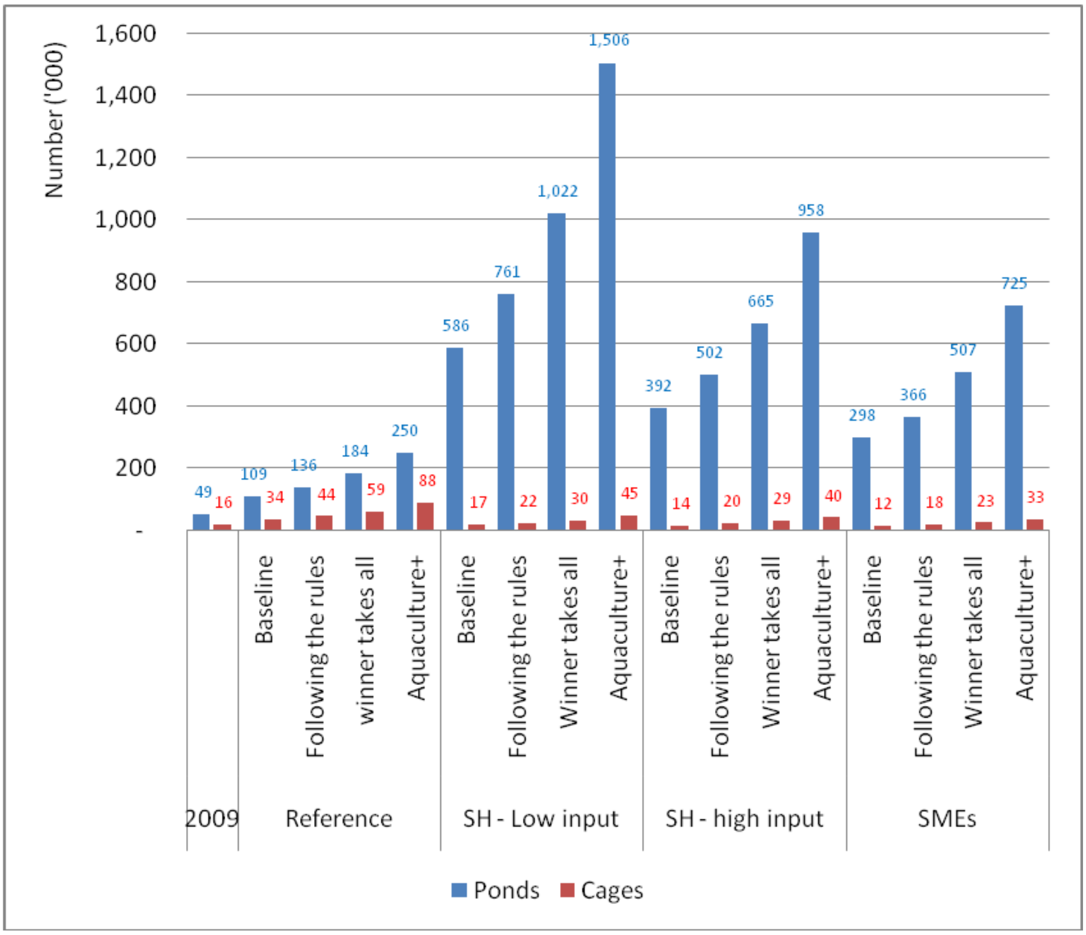


Figure 4: Number of production facilities (ponds and cages) by pathways across scenarios

Environmental Impacts

Environmental indicators show significant differences between the pathways but all show very high requirements for small-sized fish for feed (Fig. 5) and wild seed. The Winner Takes All scenario shown in Table 7 indicate that if we continue to use the existing system technology the demand for wild fish (277,000 tonnes) for feed would be excessively too high for aquaculture dominated by cage culture systems. For small holder pathways (which include cage culture and SME systems) an additional 100,000 tonnes of small sized fish would be required if the current production technology is used. Clearly different feeding strategies e.g. formulated feed would be necessary for the more intensive systems to maintain continued expansion of the sector. Similarly, current heavy reliance on rice bran as an input to low input systems will become inefficient if the small holder model is to grow, and more efficient feeding techniques will be required.

Wild seed requirement using the current production technology for the six systems characterised would be 6-9 times more than current seed sourced from the wild in order to achieve the projected production for this scenario. This is highly unlikely which means significant increase in hatchery-produced seed supply will be required to source additional seed required.

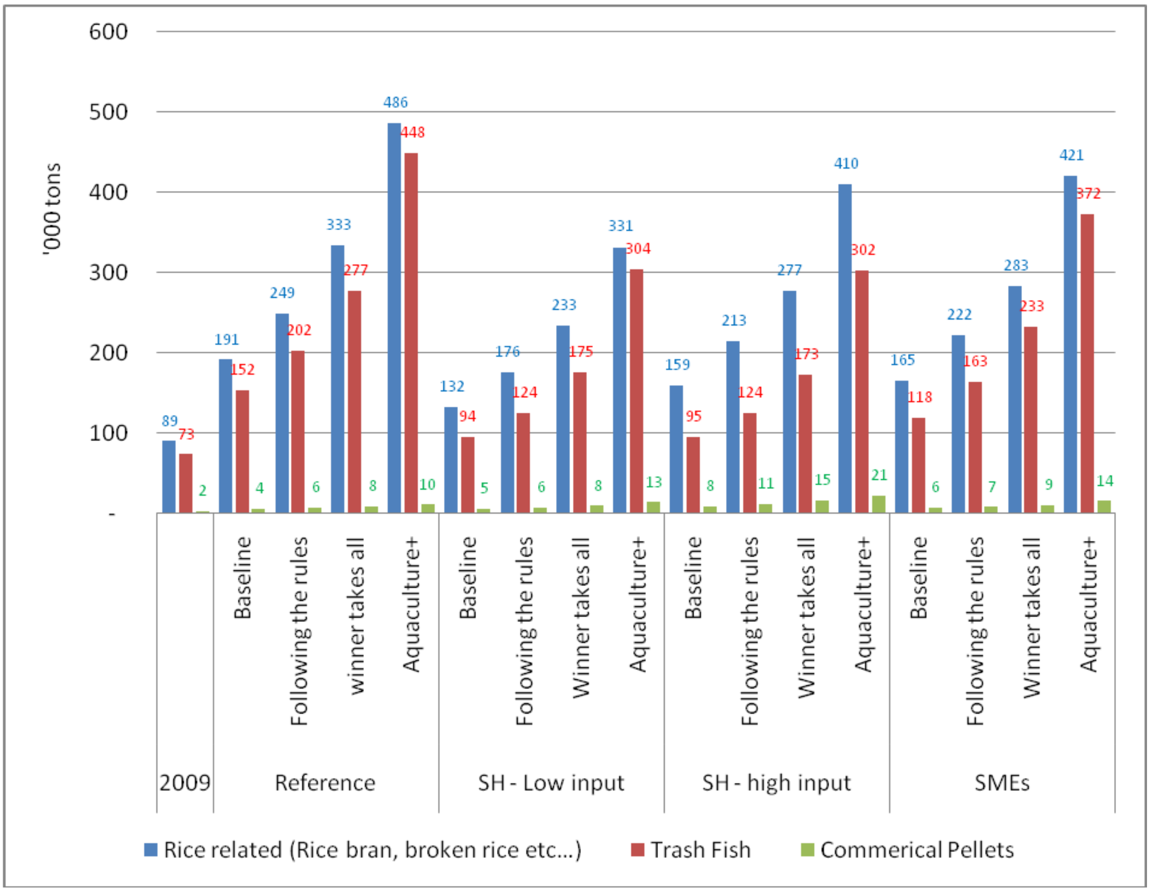


Figure 5: Fish feed requirement (tonnes) by pathways for four scenarios

Is there an optimal pathway?

Each pathway has advantages and disadvantages, raising the question of which is the optimal pathway? A best-bet share of output from the 6 systems is based on stakeholder consultation, reasonable annualised growth and indicators that occupy the 'middle ground' between pathways. Table 8 shows the percent share and production output for each system projected for 2030 and the indicators generated by this pathway are shown in Table 7 (to compare with other pathways). The ideal combination of systems suggested by participants of this study indicate that approximately half of total production would originate from more intensive systems, small scale low input systems increasing from 5% to 18% of total production volume and freshwater cage culture falling from 50% to 20% of total share.

Table 8: Current and Projected production estimates for 6 aquaculture systems by 2030

Year	System Parameter	SH Low input	SH High input	SME	Fresh water Cage	Marine Cage	Rice-fish culture
2009	Production estimate (t)	2,750	8,250	10,000	25,890	2,880	115
	Proportion of total [1] (%)	5.5	16.5	20.0	51.7	6.0	0.2
2030	Production estimate (t)	33,811	52,595	44,142	37,568	15,000	4,696
	Proportion of total (%)	18.0	28.0	23.5	20.0	8.0	2.5
	Annualized growth rate (% p.a.)	12.7	9.2	7.3	1.8	8.2	19.3

1. 'Others' make up 100%

The best-bet pathway may be articulated as follows (see table 7):- *For an investment of approximately $200 million and operational cost of $170 million the six culture systems produce 188,000 tonnes of fish annually of which 28,000 tonnes would be directly consumed by half million producers of who 85% would be relatively poor small holder farmers. Total net income generated is $127 million providing an additional $224 average annual income per household. However, with this improved combination of systems, new arrangements must be found for sourcing seed and improving feeding strategies to avoid heavy reliance on natural sources.*

Pathways dominated by one specific system point to perhaps unrealistically high input requirements for the twenty year period to 2030. However, the key to the future success of sustained growth of aquaculture will be not just getting the right combination of systems but also improved operational and production efficiencies, less reliance on wild seed and feed sources replaced by increased domestic supplies of feed, seed and services, and investment. Import of seed and feed will continue to be important which means improvements along the value chain must be made to reduce costs and improve product quality. This means that any pathway combination dominated or not by any system can only be successful if other important aspects challenging the industry are addressed.

7 Future investment needs

Cambodia needs aquaculture growth to supply the nation's future fish, but the scale of the challenge will require new investment, and new approaches to the management of the sector.

7.1 Finance

Finance is required for new ponds, cages and associated aquaculture infrastructure. Highest infrastructure costs are associated with the small holder models, with nearly US$260 million required to construct the large number of ponds required for the small-holder low input pathway under the reasonable "Winner takes all" scenario, and up to US$450 million in the highest "Aquaculture Plus" scenario. Current investment in aquaculture infrastructure is estimated at around US$41 million, indicating substantial new investment is necessary. In addition to capital investment in infrastructure, access to operational capital is required, with the Winner Takes All scenario requiring around US$149-177 million in operating capital annually.

Mobilisation of investment at the scale needed will be a challenge. Small holders have received investment in ponds from various donors and NGO's over the past few years, and SMEs and cage investment probably come from various private sources. Economic indicators show that capital investment can generate positive economic returns, to the country, and individual households, as well as social benefits, showing opportunities for profitable businesses. An organised initiative to attract investment to the sector is required, and a wider consultation initiated with Banks, investment funds, donors and other potential financers. Business models and investment approaches that work for small holders and SMEs require development.

7.2 Seed and feed

Significant investments will also be required to provide the fish seed for stocking of ponds and cages, and in feed for growing fish. Hatcheries will need to supply fish seed, considerably beyond current capacities. Present and projected commercial feed demand is quite small, but quantities of such feeds will need to grow to shift the aquaculture sector away from feeds such as small fish that will become limited in future. Again, investment opportunities exist in supply of both seed and feed that will provide for profitable business, and employment creation.

7.3 Markets

The analysis does not consider markets, but high demand is expected around urban centres in particular, but opportunities likely exist for more organised marketing in rural areas as well. Investment in marketing infrastructure and organisation of aquaculture farmers to access both urban and rural markets will be required, and further study is necessary of likely differences in supply and demand within the country.

7.4 Services

Farmers will need access to better technical, market and financial services to supply Cambodia's future fish. The analysis has not considered the investment necessary required in such services, but substantial improvements in access to services will be a key in moving forward along all pathways. Smallholder dominated pathways will require more investment in both technical and financial service delivery, in some places this will be challenging because of the scattered nature of small-scale farmers. Adoption of clustered approaches, and other organisational arrangements, should be investigated further. Improved cooperation among public, private and NGO partners will likely be necessary to reach the number of farmers required. Improving access to finance is a key and there is a need for dialogue with Banks and develop models that allow equitable access for small farmers as well as necessary finance for SME's. Investment away from cages in particular is required.

7.5 Knowledge gaps

Improving knowledge about a number of key issues through research can increase the impact of future investment in aquaculture. Research questions arising: (i) efficiency and yield improvements through better use of feeds, seed and management; (ii) better feeds and feed management, particularly shifting from use of small wild fish to feed fish, and use of alternative economical and environmentally sound resources; (iii) geographical priorities for development, such as in aquaculture in remote areas and identifying where households should best be targeted; (iv) investment models and financing partnerships that will work to provide the investment required, including ways of mobilising private finance for small holders; and (v) new ways of technical and financial service delivery to meet the challenge of servicing at scale, which will not be possible with traditional extension systems. There is also a need to improve the sector statistics and monitoring of progress towards achieving food security requirements.

7.6 Policy

Policy development will be needed to support the sectors growth. The review suggests the following issues need further attention: (i) policies that control growth of cages and discourage use small fish as feed; (ii) support to small holder high input and SME models; (iii) improving data collection/monitoring systems; (iv) investment promotion and public-private partnerships; (v) effective technical and finance servicing models, emphasising those required to reach small-scale farmers.

8 Regional Perspectives

This study focuses on trends in fish supply and demand and consequences for aquaculture in Cambodia. However, we recognise the importance of neighbouring countries and particularly their impact on the growth of Cambodian aquaculture, especially the dominance of Thailand and Vietnam in the region (2.4 million tonnes freshwater fish in 2009 (table 10)). Trade and macro-economic aspects in the Lower Mekong Basin are set within the wider sub-regional space of Vietnam, Lao PDR, Cambodia and Thailand, but it is important to note that from a geographical perspective the LMB comprises 97% of Laos PDR, 36% of Thailand (Northeast Plateau - *Issarn*) and 20% of Vietnam (part of Central Highlands and Mekong River Delta). Increased regional integration is inevitable, leading to cross border linkages and inter-dependencies of LMB countries for supplies, services and export from fisheries and aquaculture becoming very important factors in future trend analysis.

This section reviews likely trends in the LMB with specific emphasis on how these trends may affect fish supply and growth of aquaculture in Cambodia.

8.1 Status, recent history and trends

Lao PDR. Production from aquaculture dominates fish supply source in Lao PDR reporting 75,000 tonnes of a total of 105,000 tonnes for 2009. Small scale pond culture is the dominant system type with the remainder largely sourced from rain-fed/irrigate rice fields, rice-fish culture and cage culture. In recent years there has been increasing interest and development of per-urban commercial farming and intensive cage culture in large rivers but this has yet to be fully quantified. Annualized growth (% per annum) has been moderate at 5.7% between 2005 and 2009 (Table 10). However, production from aquaculture has exceeded LARReC projections made in 2004 (www.gms-eoc.org. 2005) and outstripped demand for population growth. Since capture fisheries has remained static over recent years growth in aquaculture is ensuring that fish supply in Lao PDR is maintaining demand from a growing population.

Vietnam. Fisheries and aquaculture are significant contributors to GDP, employment and export earnings. According to FAO yearbook (2008) the total value of aquaculture in 2008 is estimated to be almost $5 billion. The industry is dominated by brackish-water shrimp culture, semi-intensive and intensive freshwater catfish farming in cages and ponds. The well known integrated VAC system (V: Vegetables, A: Aquaculture and C: Livestock) common throughout small holder farmers in rural areas is also a significant contributor to total volume. The Vietnamese Pangasius industry has been tremendously successful rising to an estimated 1.25 million tonnes in 2008 (FAO 2010), mostly exporting to the US and EU markets. However, due to overproduction this has began to stagnate with some farms lying fallow. Globefish (2009) report that in 2008, 30% of Pangasius ponds were unused in An Giang and Dong Thap Provinces.

One feature of the industry relevant to aquaculture growth is the harvesting of marine-fish trash fish. It is estimated by FAO-FIGIS (2010) up to one-third of the 50-70% of total marine fish landings used for non-table fish consumption is used for direct feeding to fish or livestock. However, domestic trash fish is poor quality such that 90% of fish meal is imported which means future expansion for aquaculture will be affected by international market prices of fish meal. In recent years fish meal prices have been increasingly dramatically largely due to increased demand from China and static supplies from marine fisheries.

High demand has promoted widespread seed production in Vietnam although there are times of the year supply cannot match demand. Hatcheries are not evenly distributed which means some areas do not have easy access to seed and fingerlings and long transportation times reduces quality of the seed. According to FiA officials Cambodia imports most hybrid catfish seed from Vietnam and approximately 30% pangasid and carp seed down from an estimated 56% in 2004 (Haing and So 2007) as a result of hatchery development in Cambodia.

Thailand. Aquaculture in Thailand makes an important contribution to GDP, export earnings, plays a vital role in food security and rural income, and also generates employment for producers and many other related businesses. Emphasis is placed on aquaculture to fulfil demand as the capture fisheries declines but there are concerns low profit margins may constrain future growth of the sector. Lymer et al. (2010) report negative growth rates of -2.34 percent between 2006 and 2008 for total aquaculture production. FAO-FIGIS (2010) reports a slight increase over a longer period (table 10). Considering all data sources and time periods it is clear that aquaculture, including freshwater aquaculture, in Thailand is static.

Recent trends show that there has been a shift from green fertilised system towards intensive systems using expensive formulated feeds. Low profit margins due to the high price of formulated feed may be part of the reason for the decline in expansion. Investment in research to reduce costs of pellet-fed systems is a priority and could result in an important boost for Cambodian intensified systems shifting away from use of small wild fish as feed.

Table 10: Trends in fisheries and aquaculture production from 2005 to 2009

COUNTRY	YEAR 2005	2006	2007	2008	2009	Annualized growth (% p.a.)
Vietnam						
Fisheries	1,929,900	1,970,600	2,020,400	2,087,500	2,243,100	3.83
Aquaculture	1,467,300	1,693,727	2,123,400	2,498,120	2,589,800	15.26
Freshwater Aquaculture	961,100	1,157,045	1,530,300	1,989,300	1,956,000	19.44
Thailand						
Fisheries	2,814,295	2,698,803	2,304,951	1,873,432	1,741,662	-11.31
Aquaculture	1,304,231	1,354,297	1,370,456	1,330,861	1,396,020	1.71
Freshwater Aquaculture	506,331	498,378	489,218	485,060	484,469	-1.10
Lao PDR						
Fisheries	26,550	26,925	28,410	29,200	30,000	3.10
Aquaculture	60,000	60,000	63,250	64,300	75,000	5.74
Freshwater Aquaculture	60,000	60,000	63,250	64,300	75,000	5.74
Cambodia1						
Fisheries	384,000	482,500	458,500	431,000	465,000	4.90
Aquaculture	19,400	34,200	35,260	40,000	50,000	26.70
Freshwater Aquaculture	18,240	33,625	33,390	37,815	47,120	26.78

Source: FIGIS FAO 2010 except for Cambodia 1 (Data from Fisheries Administration)

As shown in table 10, the proportional contribution of freshwater aquaculture to total aquaculture production differs across the LMB countries with Lao PDR and Cambodia aquaculture dominated by fresh water production (Lao PDR 100% and Cambodia 94%). In contrast, Thailand and Vietnam have well developed shrimp culture industries such that freshwater fish production for Thailand accounts for just 35% of total output but much higher for Vietnam due to successful catfish industry at 76% of total output.

8.2 Future growth projection

Fish and rice are the staple food of people living in the lower Mekong basin. The fisheries and aquaculture production from the lower Mekong basin countries are domestically and internationally important, with Vietnam in particular and Thailand to a lesser extent supplying fish to markets well beyond the basin to global supply chains. The complex scenarios of fish production and trade and significant social, economic and ecological differences across the basin make analysis of fish demand and the future of aquaculture difficult to assess without more in-depth analysis. The scenario approach taken in Cambodia, and the associated modelling exercises, would ideally be extended to the other Mekong countries. In the absence of that analysis, we provide some initial projections below based on population analysis and literature review.

Using data on current populations, growth rates, consumption, and present aquaculture/fisheries production data, from each of the four lower Mekong basin countries Table 11 provides an initial assessment of the additional production that might be required from aquaculture, under two scenarios - fisheries supply constant and fisheries under a 20% decline from 2009. Whilst these show significant increased aquaculture production will be required in all countries, the data point to the relatively high growth required in Cambodia.

Table 11: Estimates of 2030 demand and aquaculture growth rate (%) with population increase in the four lower Mekong basin countries (note, these are countrywide estimates, not only LMB catchments)

	Production 2009 (tonnes)			Production 2030 (tonnes)				
	Fisheries	Aqua-culture	Total	Popul-ation. Growth rate % p.a.	Production 2030 (t)	Additional Aquaculture production if fisheries constant	Growth rate % p.a. fisheries constant	Growth rate if fisheries decline 20%
Laos	30,000	75,000	105,000	1.684	149,106	44,106	2.23	2.47
Thailand	1,741,662	1,396,020	3,137,682	0.566	3,532,512	394,830	1.19	2.05
Vietnam	2,243,100	2,589,800	4,832,900	1.077	6,052,113	1,219,213	1.85	2.40
Cambodia	465,000	50,000	515,000	1.698	733,446	218,446	8.33	9.88

Other analyses point to the need for further aquaculture production in the lower Mekong basin. The future of fisheries and aquaculture in LMB is reviewed in a recent publication commissioned as part of the UK's Government's Foresight Food and Farming Futures Project (van Brakel et al. 2010). This study suggests that by 2030 anywhere between 4.25 and 6.6 million tonnes of aquatic products will be needed for consumption by approximately 120 million people in the LMB, or 1.25 million to 3.6 million tonnes more than current estimated consumption of aquatic products of 2.6 million tonnes (36 kg /captit or 3.o millions (56kg/capita). Due to paucity of data for consumption we frame our analysis based on maintaining supply constant to population to show baseline annualised growth rates.

For Cambodia and Lao PDR, a plausible scenario will be a 'markets first' scenario where continued FDI will continue to convert natural forest and large-scale land concessions for crop plantations. This, together with a weak legislative and policy framework will likely result in deterioration of fisheries and aquatic biodiversity i.e. similar to our Aquaculture Plus scenario in this study. Also for Cambodia the Farming Futures Project concurs with our projections of possible of possibly minimal increases in capture fisheries output due to culture-based fisheries, also known as 'rice-field fisheries' in Cambodia. Another important consideration is that experts believe capture fisheries statistics are almost certainly underestimates, which is reflected in growth of capture fisheries for three of our four scenarios.

The Foresight Food and Farming Futures Project also predict that Vietnam will follow a 'Policy First' scenario with government taking strong action to achieve specific goals. For aquaculture, this will mean over the next 20 years production will level off between 2 to 3 million tonnes with 60% of production dominated by Pangasius.

Lao PDR aquaculture growth is expected to continue driven by decline from natural sources (Coates (2002) estimates 75% of all landings is from rivers), rapid urbanization and improved market access, improved technical know-how, supplies and services from Thailand and to some extent access to markets in Thailand. However, expansion of small holder aquaculture will be limited by insufficient fish seed supply and a relatively short growing season (most ponds are seasonal due to six-month long dry season). Commercial farms near Vientiane will eventually be limited by a decrease in farm-gate prices as supplies meet demand , high price of small sized fish used as feed (supply from inland sources in Lao PDR is negligible compared to Cambodia and Vietnam) and probable increase in land value.

8.3 Impacts and consequences for Cambodia

Recent trends indicate that aquaculture growth in Thailand has been on average static for past 5 years. Following Vietnam's spectacular increase in freshwater aquaculture production over the past decade up till 2008 this expansion has also significantly declined resulting in for both countries levelling total production at 2.5 to 3.0 million tonnes (freshwater aquaculture 2.3-2.5 million tonnes). This is in stark contrast with relatively nascent and rapidly expanding aquaculture industries of Cambodia, and to a lesser extent Lao PDR with a combined total of 125,000 tonnes for 2009. Key consequences for Cambodia may be:

- High price of formulated feed affects Thailand and Vietnam which means onward import for pellet-fed systems will become prohibitively expensive unless Cambodia farmers can improve production efficiencies beyond or at least equal to neighbouring counterparts
- However, research in those countries to 'solve' the feed issue problem may benefit Cambodia
- The higher demand for feed fish for the Vietnemese catfish industry may result in increasing prices of small sized fish used for feed in Cambodia. The outcome of this would be reduced competitiveness of Cambodian table fish
- Reduced supply of small fish from mainly marine capture fisheries in Thailand and Vietnam will further increase demand and raise price of small fish in Cambodia
- Possible increase in table fish supply (dumping) from Vietnam as markets become saturated with oversupply. However, the peaking of the industry in Vietnam and Thailand may provide a window of opportunity for Cambodian investors
- Oversupply of fingerlings may benefit Cambodian producers but legislative action is required to reduce informal value chain fees so that fish seed purchases prices for Cambodian farmers remain competitive.
- Niche markets for Cambodia to export high value species may open up as fish for feed prices increase. e.g. redtail catfish and wallago SCIENTIFIC NAMES

9 Conclusions and recommendations

9.1 Conclusions

Fish is a critically important part of the diet of Cambodian people. The future of inland fish capture fisheries as a sustainable source of fish in Cambodia, and elsewhere within the lower Mekong basin is uncertain. There is a lack of reliable quantitative data on fisheries (Hortle 2007) which has led to significant undervaluation of fish yields ad economic and nutritional importance (van Brakel et al 2010). Official catch data in the Mekong basin is reported to be grossly underestimated based on consumption studies supported by estimates of yield per unit area (Hortle 2007). This means that as catch statistics continue to improve accuracy of data (e.g. subsistence/artisanal inland fisheries data) increases in resource productivity may compensate and reduce annual impact of catch decline in published official catch data. Declines are widely predicted largely due to unregulated over-fishing and hydropower development. Baran 2005 and Hortle 2007 estimate that catches are close to the upper end of the possible range and more recent studies suggest dam development may result in 30-70% loss of capture fish in the basin (Baran 2010). However, recent investment in culture based fisheries and 'rice-field fisheries' in Cambodia is expected to increase fish production. The FiA strategic planning document, Strategic Planning Framework (FiA 2010) forecasts a growth rate of 15% per annum, incrementally contributing a greater proportion of total inland catch over the next 10 years.

Fish supply and demand projections generated in this study were based on official statistics published by FiA, data widely quoted and utilised by policy makers and development planners. Due to the uncertainty in data, therein lies arguably the weakness in these projections. However, to support modelled projections consultations were organised with national experts in three workshops to reach a consensus predicting that for 3 out of 4 scenarios, fish production from inland fisheries will increase over the next 20 years until 2030 but at a much slower rate compared to previous years. Growth of aquaculture is influenced by supply of fish from inland and marine capture sources. The study endorses the fact that aquaculture is a very significant contributor to national fish supply and household level livelihoods. However aquaculture cannot and should not be considered as a complete replacement for fish and other aquatic animals harvested from highly productive natural resources in the LMB. For Cambodia, scenario-based estimates range from combined production from freshwater and marine aquaculture of 106,000 to 281,000 tonnes by 2030. This means that according to the four scenario based estimates the proportion from aquaculture of total production (which largely originates from inland capture fisheries) ranges from 12% to 38% compared to 9% in 2009 (i.e. 50,000 tonnes of total output combined output of capture and aquaculture of 515,000 tonnes excluding processed fish). Therefore considering our scenario with highest aquaculture production and lowest production from natural sources, marine and inland fisheries would still contribute 62% of total output. Any strategy to maintain fish supply must involve investment in aquaculture, but essentially also preserve the productive capacity of marine and inland capture fisheries.

Each scenario generates for each pathway increasing quantities of inputs and outputs for aquaculture, and benefits in terms of households involved, and employment generated. Between pathways different social, environmental and economic implications arise. The current pathway, heavily reliant on freshwater cages, generates the highest average income to the lowest number of people (i.e. generates least employment and productivity per labour is highest). However this pathway strategy creates significant social and environmental impacts through very high and unsustainable demand on small-sized fish and wild seed. Alternatively if a strategy focuses on small holder low input (small ponds integrated into farming system dominated by rice), a 35% total share of production output (6% in 2009) will require an unrealistic number of ponds and smallholder farmers. Also due to inefficiency of seed use for this system, very high seed requirements indicate difficulties in meeting demand due to very high number of hatcheries required, excessive demand on wild sources and increase demand for expensive imported seed. To support this strategy significant mobilisation of extension resources to support a very high number of farmers would have to be considered. However, this strategy generates most employment including 40% women for non-hired labour and may be regarded as the most ‘pro-poor’ providing benefits to up to 92% of households engaged in aquaculture. Two other scenarios have similar characteristics to lesser or greater degrees. We may conclude therefore, even though there may be an optimal pathway occupying a ‘middle-ground’ between highs and lows of the 4 pathways and scenarios, the aquaculture industry needs to adopt alternative expansion strategies.

An optimal pathway was suggested by this study. This pathway projects 2030 total production of 187,840 tonnes with a shift to more efficient small holder systems (46% of total supply), fresh water cage reduced to 20% and commercial farms (SMEs) as today at 23% of total supply. Farm Infrastructure investment would be $200 million generating an annual net income of $127 million for half million households of which 85% are small holder farmers.

There are two major constraints which have been known for some time but this is the first study to quantify seed and feed requirement for future aquaculture growth. So et al. (2005) calculated that in 2004 54,593 tonnes (or 50%) of freshwater small-sized fish had to be directly used for feeding inland aquaculture and crocodile farming in Cambodia, representing 22% of the total inland fish catch in that year. By 2009, the amount had increased to 73,000 tonnes and for the 'Winner Takes All' scenario (187,840 tonnes by 2030) the range of small sized fish required for feed across four pathways would be lowest of 176,000 tonnes (small holder high input pathway) to the highest at 272,000 tonnes (current cage culture dominant pathway) consuming 25-40% of projected slightly higher inland and marine fisheries output in 2030.

So and Haing (2007) using data from 2004 report heavy reliance on imported (56%) and wild sources of fish seed (26%). Also it is worth noting that Thouk and Viseth (2004) cited in Viseth and Pengbun (2005) noted declines in cage culture production in some areas due to shortages of wild seed supply and small sized fish. This study shows how the supply of quality fish seed will become a more serious constraining factor for rapid aquaculture expansion unless reliance on wild seed supplies switches to a greater proportion of fish seed produced domestically in hatcheries, and value chain conditions are improved to increase imported seed supplies at a better quality and lower price.

All production systems require appropriate technological enhancement to improve efficiency of systems reducing operational costs, increasing competitiveness and reduce demand of input supplies. For example, small holder low input systems must improve efficiency of seed stock management (early survival, self recruiting species), system productivity (use of feed, farming systems integration, nutrient recycling) and harvesting strategies to optimise pond yield and capture better prices. The shift away from use of small fish as feed will require semi-intensive and intensive farmers to ‘raise their game’ and emulate production efficiencies found in Thailand and Vietnam (the latter for Pangasid farming)

Freshwater fish production in the Thailand and Vietnam is slowing down and may have levelled off. The next two years will provide a clearer indication of the pathway ahead. If Cambodian farmers improve production efficiencies and compete with imported table fish market prices, there may be benefits to support growth in Cambodia. Surplus seed supplies may decrease imported seed prices for Cambodian farmers, and the investment in research to provide cheaper pellet-based options may benefit growing industries in Cambodia and Lao PDR benefiting from high domestic demand. To avoid competitiveness for market price of same species, Cambodia and Lao PDR may also look for opportunities to capitalise on niche markets for high value or different indigenous species which may have other valuable qualities relating to climate change and nutritional benefits.

There are a number of researchable issues arising from the study:

- efficiency and yield improvements through better use of feeds, seed and management;
- better feeds and feed management, particularly shifting from use of small wild fish to feed fish, and use of alternative economical and environmentally sound resources;
- geographical priorities for development, such as in aquaculture in remote areas and identifying where households should best be targeted;
- investment models and financing partnerships that will work to provide the investment required, including ways of mobilising private finance for small holders; and
- new ways of technical and financial service delivery to meet the challenge of servicing at scale, which will not be possible with traditional extension systems.

FiA has also indicated that the research output provides a more quantitative basis for implementation of its future aquaculture strategy. A next step therefore would be to use the outputs as a basis for elaboration of a more detailed program and investment strategy for aquaculture.

Methods developed during this study in Cambodia provide the basis for better planning of aquaculture investments. They could also be usefully applied within the lower Mekong basin countries, to provide a better understanding of future aquaculture investments required elsewhere in the region.

9.2 Recommendations

Cambodia needs aquaculture growth to supply the nation's future fish, but new investment is required, as are new approaches to the management of the sector to achieve targets. Investment in aquaculture requires a continued and complementary investment in inland fisheries to sustain this important source of fish.

The research has shown that aquaculture growth that emphasise small holders and SME's create food and income for most people, but approaches that work at scale are necessary if impact on the nation's food security is to be achieved, Impacts at scale essentially means mobilising public and private investments, policy that is conducive to effective investment, improving services to aquaculture farmers, such as through better extension, and likely creating better partnerships and cooperation. This suggests a stronger role in future for FiA's multi-stakeholder working groups.

Whilst significant new investment in aquaculture will be required, the social, economic and environmental benefits could be substantial.

Key recommendations from this research:

- Cambodia needs to mobilize public and private finance to support future growth of aquaculture, and achieve impact on food security at the scale required
- Investment is required in improvements in aquaculture systems (scaling up) through better yielding and competitive small holder and SME systems. More farmers needed to be engaged (scaling out).
- Investment in seed supply (hatcheries), better feeds (alternatives to wild fish) and value chains (connecting to markets) require investment in research and infrastructure.

- Aquaculture's current reliance on wild fisheries as a source of seed and feed needs particular attention for future sustainable growth.
- Better financial, technical, market services are required to deliver the scaling up and scaling out of aquaculture required.
- The report and associated policy brief endorsed by the final workshop held on 6th May 2011provide FiA with the basis for development of a more comprehensive program with partners
- Address key researchable issues
- Apply the methods of scenario development and AsiaFish modelling established for a wider initiative within the lower Mekong basin.

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Joffre O. (2010). Scenario development for 2030 aquaculture future in Cambodia. WorldFish Project Report 2. 14p

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11 Appendixes

11.1 Appendix 1: AsiaFish simulation Results for baseline (Reference) scenario

Item	Volumes (000 tons)		Average annual growth rate (% p.a.)
	2007	2030	
Aggregates			
Output	559.84	933.15	2.15
Imports	3.66	57.29	12.15
Exports	24.15	4.97	-6.37
Consumption	412.91	756.39	2.55
Intermediate demand	126.44	229.08	2.51
Outputs by fish group			
Marine capture	63.50	110.21	2.32
Inland capture	395.00	610.05	1.83
Freshwater culture	33.39	100.86	4.71
Marine culture	1.87	5.53	4.62
Processed fish	66.08	106.50	2.01
Imports by fish group	0.00	0.00	
Freshwater culture	2.46	35.95	11.82
Marine culture	1.19	21.34	12.77
Exports by fish group			
Marine capture	10.17	3.25	-4.65
Inland capture	6.60	0.57	-9.70
Freshwater culture	0.03	0.01	-3.69
Marine culture	0.02	0.01	-5.07
Processed fish	7.33	1.14	-7.47
Consumption by fish group			
Marine capture	8.88	29.82	5.18
Inland capture	306.41	457.56	1.68
Freshwater culture	35.82	136.80	5.74
Marine culture	3.04	26.86	9.50
Processed fish	58.75	105.36	2.46
Intermediate demand by fish group			
Marine capture	44.45	77.15	2.32
Inland capture	81.99	151.93	2.60
Memo:			
Per capita fish consumption (kg/person/year)	30.39	38.65	1.01

11.2 Appendix 2: AsiaFish simulation results for 2030, thousand tonnes for baseline (Reference) and 3 alternative scenarios

Item	Baseline	Winner Takes All	Aquaculture Plus	Following the Rules
Aggregates				
Output	933.15	1,005.12	846.08	1,416.71
Imports	57.29	60.92	58.26	67.76
Exports	4.97	4.86	4.47	14.89
Consumption	756.39	859.27	756.91	1,167.45
Intermediate demand	229.08	201.91	142.96	302.13
Outputs by fish group				
Marine capture	110.21	92.45	93.11	138.67
Inland capture	610.05	588.15	351.85	888.63
Freshwater culture	100.86	175.89	251.02	131.28
Marine culture	5.53	11.95	30.92	8.01
Processed fish	106.50	136.67	119.18	250.11
Imports by fish group				
Freshwater culture	35.95	37.66	36.74	43.24
Marine culture	21.34	23.25	21.52	24.52
Exports by fish group				
Marine capture	3.25	2.53	2.58	7.99
Inland capture	0.57	0.52	0.20	1.09
Freshwater culture	0.01	0.05	0.16	0.02
Marine culture	0.01	0.03	0.39	0.01
Processed fish	1.14	1.72	1.13	5.78
Consumption by fish group				
Marine capture	29.82	25.21	25.36	33.62
Inland capture	457.56	450.44	273.87	682.48
Freshwater culture	136.80	213.50	287.60	174.50
Marine culture	26.86	35.17	52.04	32.52
Processed fish	105.36	134.95	118.05	244.34
Intermediate demand by fish group				
Marine capture	77.15	64.72	65.18	97.07
Inland capture	151.93	137.19	77.78	205.06
Memo:				
Per capita fish consumption (kg/person/year)	38.65	43.90	38.67	59.65