Fish supply and demand scenarios in Cambodia and perspectives on the future role of aquaculture

MAIN MESSAGES:

- Aquaculture is essential for Cambodia's future fish supply.
- Growth of aquaculture 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)
- Scenarios for future fish demand-supply for 2030 suggest aquaculture will need to supply between 106,000 tonnes and 281,000 tonnes by 2030.
- Seven major Cambodian aquaculture systems currently supply the majority of farmed fish of which 50% of total production originates from one system, fresh water cage culture.
- Future farmed fish supply will come from a combination of aquaculture systems. Four pathways were analysed for the future – continuation of the current system, a small holders low input dominated approach; a small holder high input dominated approached; and one dominated by SMEs.
- Most optimal 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.
- 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.
- All pathways indicate that the key to success will be getting the sustainable combination of aquaculture systems, a shift away from heavy reliance on 'wild' feed and seed sources by significant investment in domestic seed and feed production, and depending on the success of domestically sourced supplies of seed and feed, improvement of input supply value chains.
- Research can contribute more efficient system productivity, enhance integration with agriculture, value chains, better feeds and to cope with this rapid growth and improved extension models.
- Growth will be influenced by regional fish supply and demand and status of aquaculture in the Lower Mekong Basin, and particularly in Vietnam and Thailand. Increased competitiveness for similar production systems, reduced reliance on wild and imported feed and seed and development of regionally com petitive aquaculture systems will be the key to successful expansion. New indigenous species and supply to niche markets in Thailand may also open opportunities for income generation of Cambodian aquaculture farmers.

IS THE GROWTH OF AQUACULTURE IN CAMBODIA IMPORTANT?

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 animal protein, sometimes the only source. Aquaculture - farming of fish and other aquatic animals - is becoming increasingly more important in supplying fish to people in the region. 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.

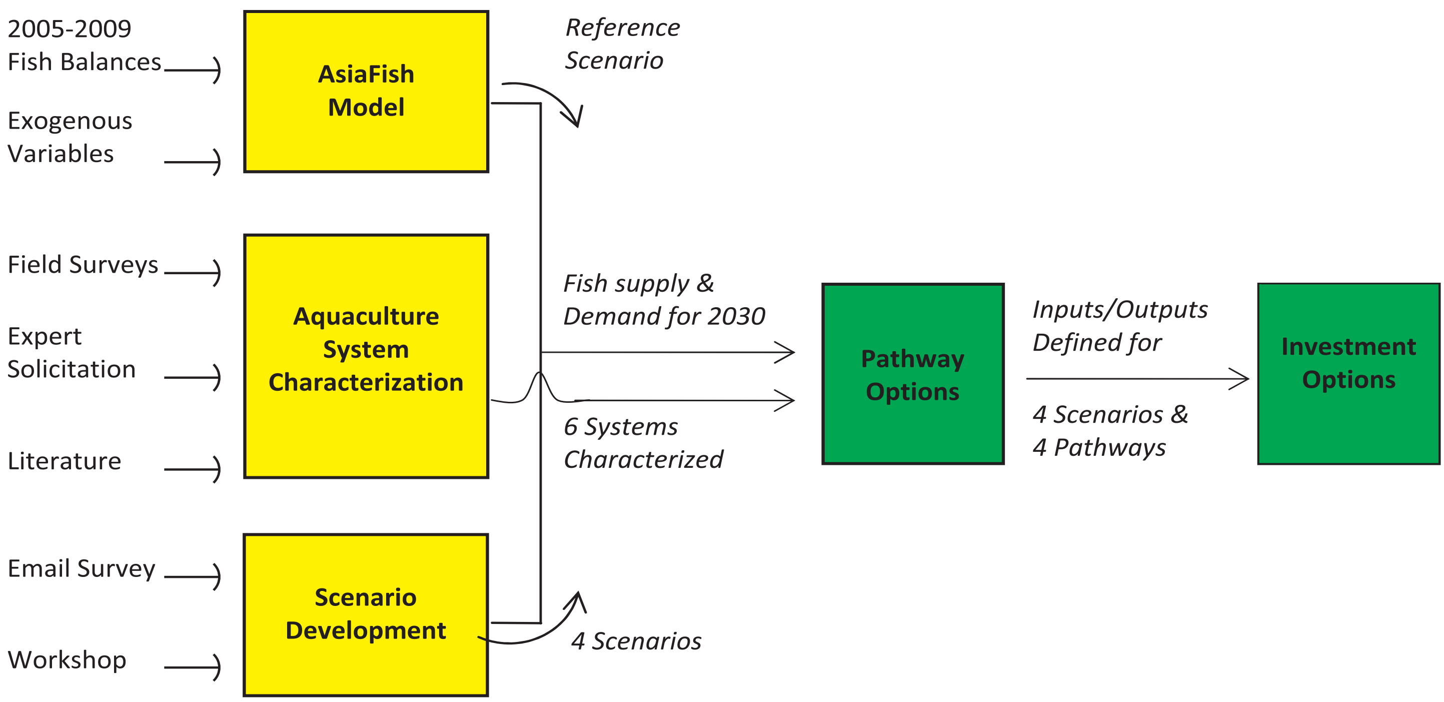
Aquaculture cannot replace the large volumes of fish harvested from wild sources, but will grow in importance, as demand for aquatic products increases. Population is expected to increase at 1.6% per annum in Cambodia over the next 20 years to 19 million people which would likely require substantial increased supplies of fish.

The supply of 'free' wild fish is under threat from overfishing, climate change, habitat modification and hydro power development which could mean less fish supplied from natural sources yet at the same time more demand. With aquaculture important for future fish supply, this study was initiated to explore in more detail future fish supply scenarios, the role of aquaculture, and provide a basis for understanding future investment and strategies for its sustainable development. The study was conducted by the Fisheries Administration (FiA), Inland Fisheries Research Development Institute (IFReDI) and the WorldFish Center co-funded by Australian Centre for International Agricultural Research (ACIAR), and the Ministry of Foreign Affairs, Japan.

HOW CAN WE LOOK INTO THE FUTURE?

Future fish supply and demand scenarios for 2030 were used to understand the choices and investment options for future aquaculture growth. The methodology 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 (Figure 1).

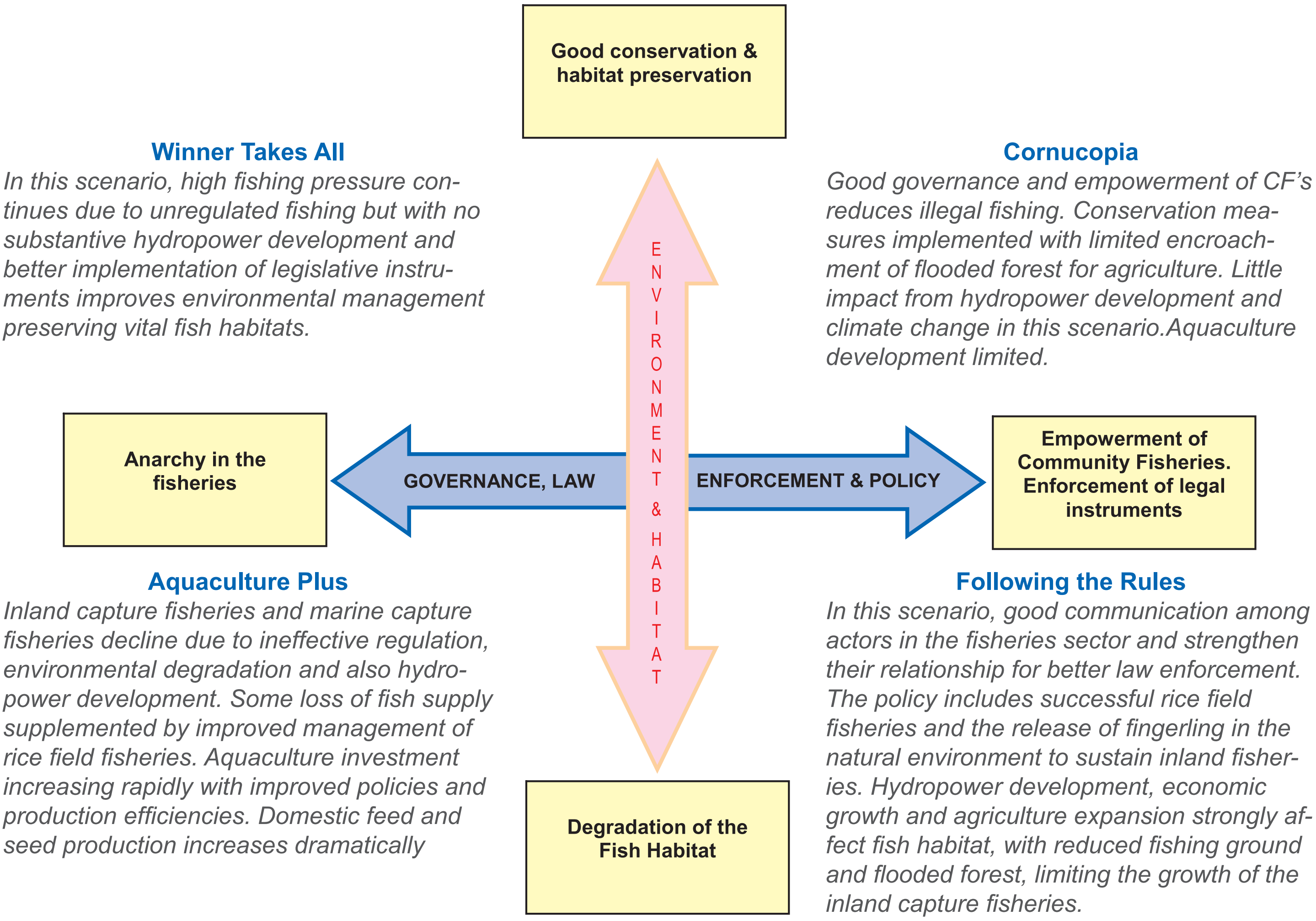
Figure 1: Schematic to show key steps, activities and outputs to determine future investment options for aquaculture in Lower Mekong Basin



SCENARIOS FOR FISH SUPPLY AND DEMAND 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.



ASIAFISH MODEL PREDICTS FISH SUPPLY AND DEMAND

Using the four scenarios as a starting point, projections were made on fish supply up to 2030, based on exogenous variables (e.g., population, incomes, foreign prices of fish, inflation, food and non-food prices) and endogenous variables (e.g. fish supply and demand trends – production, consumption, export, import and processed fish from 2005-2009 (FiA statistics)) were applied to run the model based on the most complete data set of all variables found for 2007.

The exogenous variables used in developing the reference scenario (established from current trend analysis) were amended according to scenarios defined and inputted into the AsiaFish Model to produce scenario-based outputs for import, export, consumption and production from fish supply "categories", inland and marine fisheries capture fisheries and marine and freshwater aquaculture (Table 1).

Simulation results for the Reference scenario, based on historical growth rate, project the aggregate output of fresh fish to continue to rise but at the much slower rate of 2.2% p.a. compared to 5.7% p.a. over the previous ten year period, 2000-2009. Aquaculture is projected to grow at least two to four times faster than capture fisheries and processed fish at 4-5% p.a. to 106,400 tonnes for the Reference scenario and 9% p.a. for the Aquaculture Plus scenario (281,000 tonnes) by 2030. Even so, the combined share of marine capture and inland capture fisheries still dominates supply in 2030 at 77% of total aggregate output, slightly lower than its 82% share in 2007. Also exports will contract and imports will increase at rate of 12% p.a. but this is still only 6% of total in 2030.

Except for "Cornucopia" alternative scenarios reveal higher outputs for aquaculture compared to the Reference scenario. To fulfil the objectives of this study to determine pathways and investment options for aquaculture growth Cornucopia was omitted from further analysis since this scenario projected low aquaculture output, and is considered rather unlikely given current trends.

Table 1: AsiaFish model simulations for 2030 ('000 tonnes)

Item	Reference	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

CHARACTERISING AQUACULTURE SYSTEMS

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 aquaculture systems in the country. These systems were characterized from a structural point of view, to quantify economic, technical variables and inputs requirements. Quantification of the aquaculture systems enabled us to determine scenario-based estimates of inputs and outputs for different aquaculture pathways. [The contribution to national output from brackish water ponds is negligible so this system was omitted from the analysis]

Table 2 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 2 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

With the three key components in place (AsiaFish model projections, 2030 scenarios defined and aquaculture systems described) as shown in figure 1, the next step considered the consequences for different aquaculture growth options and future investments.

PATHWAYS FOR AQUACULTURE GROWTH

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.

Key indicators associated with each pathway under one production supply target ('Winner Takes All' scenario 187,840 tonnes per annum in Table 1) are shown in Table 3 below. This scenario is favoured as the most likely especially in terms of aquaculture production.

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 3), 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 3 Indicators for 2009, Winner Takes All scenario pathways 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

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)

BOX 1 SUMMARISES PATHWAYS ANALYSED

Pathway 1, Reference pathway, provides most economic returns in terms of a model to invest and also average income per household, but least social benefits and highest risk of environmental impact.
Pathway 2, Small-holder low input pathway, requires the highest external investment and returns lowest economic indicators but provides by the far best social performance, addressing rural food security and income for the most households and is more environmentally friendly with least demand on wild fisheries for feed and seed.
Pathway 3, Small-holder high input pathway scales down the social indicators benefits and improves economic indicators found in pathway 2. Environmental indicators are as good as pathway 2.
Pathway 4, Small and medium enterprise pathway, exhibits second best economic indicators, second least social and environment performance.

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 3 and 4 show significant increases in ponds, cages and feed 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 700+ hatcheries for best-bet pathway in Table 3).

ENVIRONMENTAL IMPACTS

Environmental indicators show significant differences between the pathways but all show very high requirements for small-sized fish for feed and wild seed. The Winner Takes All scenario shown in Table 3 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.

Distributing catfish fingerlings in Phnom Penh

Figure 3: Number of production facilities (ponds and cages) by pathways for four scenarios

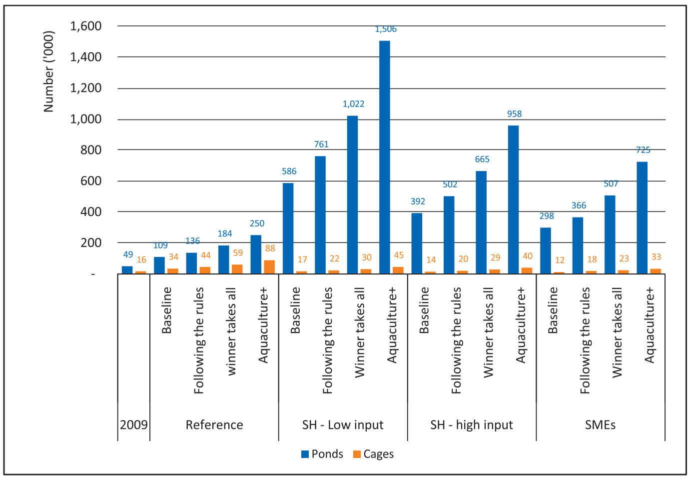
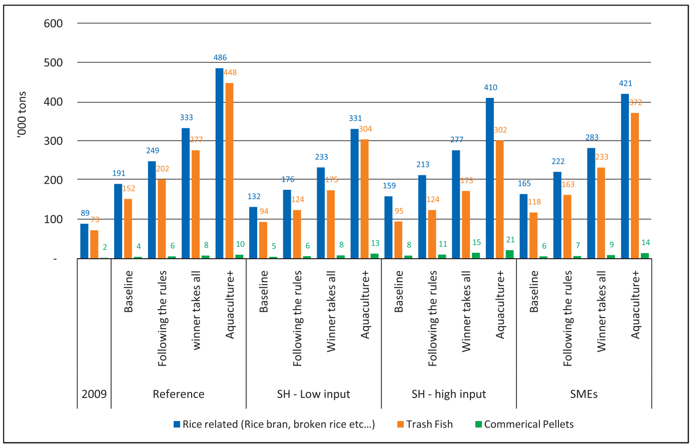


Figure 4: Fish feed requirement (tonnes) by pathways for four scenarios



WHAT IS THE OPTIMAL APPROACH?

Each pathway has advantages and disadvantages, raising the question of which is the optimal approach? 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 4 shows the percent share and production output for each system projected for 2030 and the indicators generated are shown in Table 3 (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 4: 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 3):- *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 still must be found for sourcing seed and improving feeding strategies to avoid heavy reliance on natural sources.*

In summary, pathways dominated by one specific system point to perhaps unrealistically high input requirements for the twenty year period to 2030. Therefore, the key to the future success of sustained growth of aquaculture will be getting the right combination of systems, 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.

INVESTING IN THE FUTURE

Cambodia needs aquaculture to grow 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

FINANCE

Finance is required for new ponds, cages and infrastructure to grow fish to meet future demand. 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. Higher production will require more investment; with current investment in infrastructure estimated at around US$41 million. 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 at the scales 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.

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.

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.

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 will be required to the present system, such as:

- Organisational capacity of farmers to access inputs and output markets, through clustering
- Improving extension and defining roles of government and private services. This level of industry development requires better services, and private sector models
- Access to better services essential to support all pathways – technical and financial
- Access to finance a key – there is a need for dialogue with Banks and develop models that can work for enterprises, and particularly non-cage models. Do not encourage more investment in cages

KNOWLEDGE GAPS

Improving knowledge about a number of key issues through research can increase the impact of future investment in aquaculture, particularly regarding:

- 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 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
- 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

POLICY

Policy development will be needed to support the sectors growth. The review suggests the following issues need further attention:

- Policies on cages and use of small fish as feed
- Support to small holder high input and SME models
- Improving data collection/monitoring systems
- Investment promotion and public-private partnerships
- Organizational assistance for small-scale farmers
- Improving extension services

REGIONAL PERSPECTIVES 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 leveling 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 production capacity in Vietnam will require Cambodian farmers to improve production system efficiency to remain competitive
- Feed requirements will intensify cross the Mekong basin, requiring research into lower cost pellet-based feeds which could benefit Cambodian SME farmers
- Seed supplies may become unpredictable and prices erratic. Cambodia must increase domestic fish seed supply output
- Export to Thailand into niche markets for high value species might offer opportunities.
- Growing demand for aquaculture products in Thailand may open opportunities for Cambodian export if costs are competitive, but export will place more pressures on domestic food supplies.

Small Holder Low Input in Ratanakiri Province

Small Holder High Input in Kandal Province

Sea Bass and Grouper Cages in Sihanouk Ville Province

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