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# Aquaculture development and scenarios of change in fish trade and market access for the poor in Cambodia

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## Abstract

Aquaculture holds considerable potential to contribute to poverty alleviation, if it provides poor people with opportunities other than as primary producers. Integration of aquaculture into poverty reduction programmes provides means to diversify production systems and reduce food insecurity but also needs improved markets in locations where aquaculture can offer sustainable livelihoods to poor farming households. This study reviews the current constraints that poor people face in accessing markets in Cambodia and analyses its implications for pro-poor domestic aquaculture development. We use a Geographic Information System-based spatial Bayesian probability model to simulate market accessibility and estimate the numbers of poor people who could potentially benefit from improved market access under four different scenarios. Analysis of secondary data confirms that the potential for poor aquaculture producers to interact with urban markets in Cambodia is currently low. The potential of aquaculture to interact with rural markets is, however, high. It is concluded that the development of aquaculture has considerable potential to reduce the transaction costs in domestic fish trade by improved access of poor producers and consumers to rural markets in Cambodia. An aquaculture development strategy that improves rural market access could include benefits for up to 1 million poor aquatic resource users.

**Keywords:** aquaculture, market access, poverty, scenarios of change

## Introduction

### Aquaculture and poverty alleviation

Aquaculture and improved aquatic resource management hold considerable potential for alleviation of poverty if poor people are engaged through opportunities other than as primary producers. Poor people need access to appropriate and affordable low-risk aquaculture technologies, markets, access and control over common property resources and rights to participate effectively in aquaculture development planning. Benefits from aquaculture can be direct through target groups engaging in aquaculture production, indirect through secondary opportunities associated with aquaculture and inclusive through broader benefits from aquaculture that eventually reach target groups (Muir 1999). This study aims to identify current limitations to the development of pro-poor aquaculture in Cambodia and uses simulation of change in market access in order to emulate how such changes could affect opportunities for the development of pro-poor aquaculture in Cambodia in the foreseeable future. The current situation of fish supply and demand in Cambodia provides a baseline for simulation of differential market access by poor and better-off producers and consumers. The simulations provide estimates of the numbers of poor people who potentially could benefit from improved aquaculture value chains and market access.

Employment in aquaculture has important potential to contribute to poverty reduction in developing countries such as Cambodia and the Philippines, where labour supply is still abundant (Ahmed &

Lorica 2002; Irz, Stevenson, Tanoy, Villarante & Morissens 2007). Adoption of aquaculture by agricultural households has had positive income, consumption and employment effects in countries such as Bangladesh, China, India, Indonesia, Thailand and Vietnam. Incorporation of aquaculture into existing agricultural farming systems has also contributed to improved productivity and diversification of small-scale farms. In flood-prone ecosystems in Bangladesh, significant increases in farm and household income were reported following interventions that targeted aquaculture in order to increase on-farm production of resource poor households (Gupta, Mazid, Islam, Rahman & Hussain 1999). Compared with non-producing households and the national average consumption, the per capita consumption of fish in rural areas of Bangladesh was also noticeably higher for households adopting aquaculture (Dey, Bimbao, Yong, Regaspi, Kohinoor, Pongthana & Paraguas 2000). Phong, Udo, van Mensvoort, Bosma, Tri, Nhan and van der Zijpp (2008) concluded that Integrated Agriculture-Aquaculture systems in the Mekong Delta of Vietnam have provided an adequate response to threats and opportunities arising from rapid agricultural development, related market fluctuations and changes in policy. Poorer farmers tended towards diversification of their farming systems with aquaculture in order to avoid risks and safeguard their livelihood, while better-off farmers tended towards specialization and intensification of their farming practices. Similar opportunities potentially exist in Cambodia, given the importance of aquatic resources to the rural poor in the country and Cambodia's rapid integration into regional and global markets since the mid-1990s, which came accompanied by considerable demand volatility. The prices of fish and other food commodities have increased significantly since May 2007 (CDRI 2008). This has provided opportunities, but also obstacles for agriculture and wider economic development, and has undermined poverty reduction in Cambodia (Sovannarith 2009). Fishing communities are among those most severely affected. Fish catches and the average daily income of fishing households declined, while their daily expenditure increased. Fresh fish prices have increased relatively modestly, by about 20%, in comparison with rice, which doubled in price (CDRI 2008). In a survey held in June 2008 on the effects of high food prices among 2235 households in 14 villages in Cambodia, 98% of people in fishing villages indicated that they did not have enough money to buy food or cover essential expenses (Sophal 2009).

## Aquatic resources and poverty in Cambodia

The Cambodian poor still accounted for 30% of the population or 4 million people in 2008 (CDRI 2008). The highest incidence of poverty in Cambodia is found among households where agriculture is the primary source of income. In 2004, 90% of the poor lived in rural areas (Royal Government of Cambodia 2005). In rural Cambodia, poverty is closely linked to food insecurity. According to Sophal (2009), more than 1.5 million people in rural areas and more than 150 000 of the urban population are food insecure. Sixty-five per cent of rural households are either landless or land poor (owning one hectare or less). The majority of rural residents are net buyers of food. In the poorest two quintiles, food consumption amounts to 70% of the total household expenditure. Rice, fish and fish products, supplemented by seasonal fruits and vegetables, are the staple foods for these people. Capture fisheries contribute significantly to food security, nutrition and income generation. On a seasonal basis, fishing is a part-time activity for virtually all farming households. Per capita inland fisheries production amounts to 28.2 kg/year and ranks first worldwide (FAO 2003).

Cambodia's fisheries sector is undergoing major reforms towards a more poverty-focused approach. Despite this focus, Cambodia's National Poverty Reduction Strategy (Council for Social Development 2002) acknowledges that wild fish supplies will not be enough to meet the future demand of Cambodia's rapidly increasing population. Recent increases in the development of pond-based aquaculture are mainly a response to declining supplies of wild fish. Promotion of small-scale aquaculture and community-based fisheries are integral components of the country's strategy for equitable agricultural development that prioritizes poverty alleviation and food security. Aquaculture development through pond-based and rice-fish aquaculture has been receiving increasing attention because of its potentially important role in providing food security and rural income generation (Ministry of Planning, Royal Government of Combodia, United Nations World Food Programme & United Nations Development Program 2001).

Aquaculture is currently practiced in virtually all of Cambodia (Viseth & Pengbun 2005). Its contribution to food fish supply has increased by 28.6% from an estimated 20 675 tonnes in 2004 to 34 200 tonnes in 2006 (FAO 2009). Unofficial estimates, however, suggest that the aquaculture output in Cambodia currently could be as high as 80 000 tonnes

annually (Nam & Leap 2007). River catfish *Pangasianodon hypophthalmus* (Sauvage) is the most widely cultured species in ponds. It is cultured around Phnom Penh and major provincial towns in the country, where feed inputs are more readily available. Cage and pen culture are still the principal systems of inland aquaculture in provinces around the Great Lake (Tonle Sap), where it is especially developed in Kampong Chhnang province (Viseth & Pengbun 2005). These types of aquaculture have evolved from the activity of stocking surplus catch from the highly seasonal inland fishery in floating cages and bamboo fishpens, in order to keep the fish alive for sale in the off-season (DFID-SEA Aquatic Resources Management Programme 2000). The two major species cultured in cages, river catfish and giant snakehead *Channa micropeltes* (Cuvier), are high-value species. Cage culture is highly dependent on feed fish from the wild, and concerns have been raised over the impacts of expanding feed fish demand on the availability of fish for poorer consumers and on the environment (Phillips 2002; Sverdrup-Jensen 2002). The availability and price of feed fish vary during the year. Feed fish is readily available during December to March, when small fish are in abundance. During June to September, when the fishing season is closed, the availability of feed fish is low and the prices are high. According to Thuok and Viseth (2004) cited in Viseth and Pengbun (2005), the production of river catfish and giant snakehead in both ponds and cages has declined steadily due to the shortage of wild seed supply, shortage of feed fish and deterioration of water quality.

Small-scale aquaculture production may be the only option for poor farmers to derive direct benefits from aquaculture, especially in areas with limited access to capture fisheries resources. During the last decade, considerable effort has been dedicated to promote small-scale aquaculture in earthen ponds. The fish are fed on a variety of farm waste products that are cheap and easily available all year round. Rice-fish culture, an extensive form of aquaculture where fish are released into flooded rice paddies, has been introduced particularly in Prey Veng and Svay Rieng provinces, and more recently in Takeo province. Land-based pond aquaculture and rice-fish culture systems are most appropriate for poor farmers in inland rural areas, but many poor households do not own sufficient land to practice culture in a land-based system. For landless farmers, water-based systems such as cages, pens or enhanced fisheries in large communal water bodies may be the only option to culture fish, but this type of culture is usually beyond the reach of poor and marginal farmers as high investment levels are required (Edwards 1999; Friend & Funge-Smith 2002).

## Markets and fish trade in Cambodia

Our hypothesis is that benefits from aquaculture development to the poor in Cambodia will be mostly indirect through improved trade efficiencies and reduced transaction costs along the domestic fish marketing value chain. Freshwater fish are among Cambodia's most important traded commodities (Chea & McKenney 2003a). Fresh and processed fish are widely traded domestically, and exported in significant quantities to neighbouring countries, principally Thailand and Vietnam. Cambodia is a net exporter of fish and the sector has been targeted as important for export promotion. Nonetheless, the available statistics indicate that export revenues vary widely from month to month and between years. Revenues declined almost by half from USD 10 million in 2005 to USD 5.1 million in 2006 (source: CDRI). While export promotion is intended to spur 'pro-poor' trade, market integration and trade efficiencies also need to be improved domestically.

Fish trade in Cambodia is influenced by a complex set of factors. Currently, fish supply to domestic markets is stable, but the market prices of fish are variable and are influenced by imports from neighbouring countries and the availability of wild-caught fish. Cambodia has a small and fragmented internal market (Ward 2002). Domestic fish trade statistics are scant, but where available, confirm the wide variation in fresh fish prices between provinces and between seasons. Exports may deprive domestic users of fish, and shortages in supply may occur seasonally in areas with limited access to markets and capture fisheries resources. In rural areas located close to Phnom Penh, marketable fish may be diverted away to urban markets, reducing its local availability, whereas the costs of transportation to these markets become prohibitive in areas distant from Phnom Penh. Markets and distribution centres are characterized by inefficiencies, which increase costs. Traders and distributors complain about high distribution centre fees and lack of services. Only one distribution centre serves Phnom Penh for each major trade route and fish distribution facilities are absent in Poi Pet, the only official export border crossing with Thailand. Spoilage and weight loss along the marketing chain result in considerable value losses,

 

which are compounded by poor retail marketing practices such as displaying fish for sale without ice.

Analysis of the Tonle Sap fish trade offers valuable insights into the current market constraints associated with fish trade in Cambodia. The majority of traded fish in Cambodia originates from the Tonle Sap (Chea & McKenney 2003a, b). Marketing of this fish involves a number of transactions, of which sales from fishers to traders, from traders to retailers via distributors and from retailers to customers are the most important ones. Tied relations are the norm in this system. Distributors play a dominant role in the market structure. They are the financiers of fish trade and lend capital to traders to support fish purchases. Traders in turn re-lend some of this capital to fishers for gear purchases and other expenses. Under the terms of these loans, fishers are obliged to sell all fish to their creditor, the trader, and traders in turn must sell all fish through their distributor and pay the associated commission fees. The problem of credit dependency places fishers at a disadvantage. Most fishers are in debt to a trader and in a weak position for negotiating the sale of their catch. Pervasive fee charges along the trade route also reduce profit margins in fish exports. Many of these fees are charged without a legal basis (Chea & McKenney, 2003b). Seng (2006) reports that informal fees charged on fish exports via waterways to Vietnam are about twice as high as formal fees. Informal fees also tend to increase in relation to the distance between the landing site and the market. Fee charges absorb a large proportion of the potential earnings of exporters and add more than 50% to the costs of exporting fish. Hence, high transaction costs and tied trade relationships are the principal constraints to be addressed in order to secure benefits from fish trade to the rural poor in Cambodia.

## Methodology

### Materials

This study makes use of data on poverty headcount and spatial population distribution in Cambodia to simulate possible scenarios for pro-poor aquaculture market development. In the absence of data on poverty disaggregated by specific indicators, let alone aquaculture specific poverty indicators, the simulation is supported by anecdotal information about poverty and aquatic resource use in Cambodia. The IDRISI Andes© Geographic Information System is used to estimate the numbers of poor people who could potentially benefit from small-scale aquaculture development under four different scenarios of market access. A global population distribution model at 1 km resolution, known as LandScan™ (Oak Ridge National Laboratory, Oakridge, TN, USA), provides a proxy indicator of aquaculture development potential under these different market scenarios. The proxy is a distance decay function of population distribution and marketing constraints, expressed in 'distance to potential markets'. Commune-level population and poverty counts from the Cambodia poverty analysis in the year 2000, provided by the vulnerability analysis and mapping unit of the World Food Programme (WFP) Cambodia office are redistributed on the basis of this proxy. While the scenarios can hold true for rural market development in general, they are assumed particularly sensitive to the fisheries sector because trade constraints in the sector are exacerbated by distance and limited market access, characterized by high transaction costs and tied relationships and associated with a lack of storage and preservation facilities.

### Population distribution

LandScan is a population distribution model that combines four primary geospatial datasets that are key indicators of population distribution, namely land cover, roads, slope and night-time lights. The model is based on best available census counts and represents an ambient population distribution over a 24-h period. It does not represent residential population density but instead estimates the average number of people encountered per grid cell over 24 h. This feature emphasizes hotspots of economic activity, which is important to this study. The LandScan™ Global Population Database (2002) was used because the time lag between the 2002 release and population data from Cambodia's 1998 population census was considered to be sufficiently short to justify the use of the two datasets in conjunction. Moreover, the LandScan™ Global Population Database (2002) incorporates important refinements over earlier versions. The IDRISI regional data disaggregation tool was used to redistribute the commune-level population averages available from the census according to the LandScan model. This step provided a more realistic population distribution grid at a nominal 1 km resolution. The population counts were log-transformed (ln) in order to normalize them over a continuous scale for better visualization (Fig. 1a) and were then classified into discrete classes of

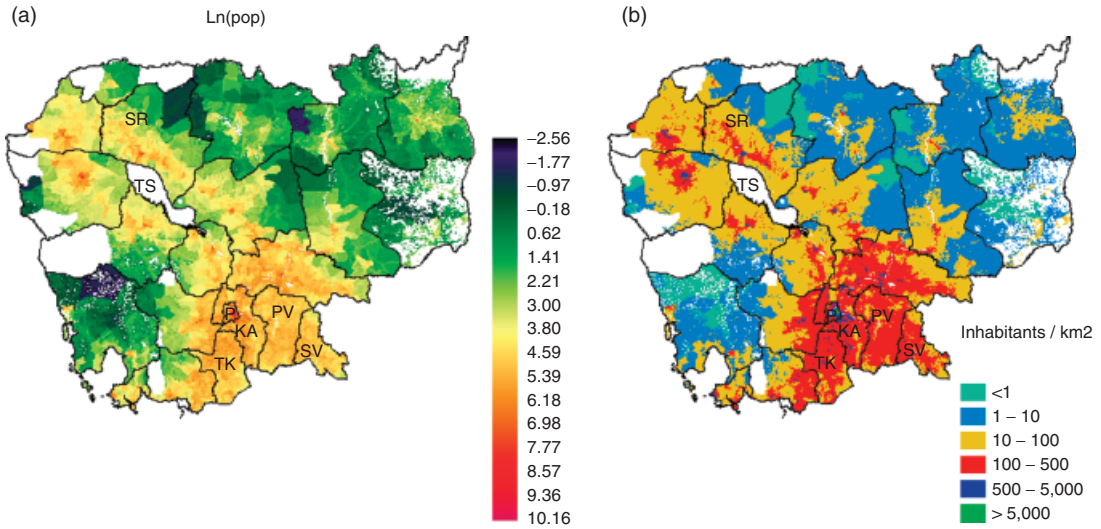


**Figure 1** (a) Natural logarithm of population density [ln (pop) km$^{-2}$]; (b) population density redistributed into discrete classes. KA, Kandal province; P, Phnom Penh (capital); PV, Prey Veng province; SR, Siem Reap province; SV, Svay Rieng province; TK, Takeo province; TS, Tonle Sap lake.

**Table 1** Population density (POPD) classification

| ln (pop) (Fig. 1a) | Inhabitants km$^{-2}$ (Fig. 1b) | POPD class |
|---|---|---|
| <0 | <1 | Remote |
| 0–2.30 | 1–10 | Sparsely populated |
| 2.30–4.61 | 10–100 | Rural low density |
| 4.61–6.21 | 100–500 | Rural high density |
| 6.21–8.52 | 500–5000 | Peri-urban |
| >8.52 | >5000 | Urban |

population density (Fig. 1b; Table 1). This grid was overlaid (multiplied) with the WFP commune-level poverty headcount expressed as a fraction of the population ranging between 0 (no poor) and 1 (100% poor). The result is a commune-level poverty distribution grid at 1 km resolution.

## Market access

A spatial Bayesian probability model was applied to the redistributed population counts in order to estimate the likelihood of access of poor people to either urban or rural markets. Bayesian probability theory establishes the probability that an entity belongs to any of a number of different classes or states. In this case, the two states were 'urban market access' ($P_u$) and 'rural market access' ($P_r$). The underlying assumption was that the probability of encountering more than 5000 people per km$^2$ at any given moment is an indicator of the presence of urban centres and markets. A probability of encountering 500–5000 people per km$^2$ is an indicator of peri-urban centres and was assumed to be equivalent to rural markets. The population density at any point of origin divided by its distance to these potential markets provided a proxy for the accessibility of markets from that point, expressed as the 'interaction potential' $V_i$ between that point and its nearest market. The method assumes a concentration of rural population in the proximity of rural towns and major urban centres, implying that rural population densities are higher in the vicinity of such centres than in areas distant from urban centres. The basis of this approach is the concept of social gravitation. Urban centres are regarded as physical masses, where the magnitude of attraction or interaction is proportional to the population size and inversely proportional to some form of spatial friction (Deichmann & Eklundh 1991), in this case market access.

For a given point $i$, the interaction potential $V_i$ of its population with any urban centre is therefore

$$V_i = \sum_{j=1}^{n} \mathrm{POPD}_j / (d_{ij})^b \qquad (1)$$

where $\mathrm{POPD}_j$ is the population density of market $j$ and $d_{ij}$ is the distance between points $i$ and $j$. The ex-

 

**Table 2** Market access from supply point $i$ ($V_i \geq 20$, exp. $b = 1$)

| $POPD_i$ (inhabitants km$^{-2}$) | Maximum distance $d_{ij}$ to market |
|---|---|
| <1 | No access |
| 1–10 | <0.5 km |
| 10–100 | 0.5–5 km |
| 100–500 | 5–25 km |
| 500–5000 | Rural market ($d_{ij} = 0$) |
| >5000 | Urban market ($d_{ij} = 0$) |

ponent $b$ is a distance weight that determines the structure of the distance decay. In this study, the population density at any point was assumed to be 'known'. Rather than being interested in $POPD_j$, which is already 'known' to be a market on the basis of population density, the population density $POPD_i$ at any potential supply point $i$ to market $j$ was used as an indicator of market access from that point as a function of the linear distance $d_{ij}$. The distance decay exponent $b$ was set to equal 1, representing the baseline situation of 'current' market access. Because there is no sharp boundary between access or no access to market $j$ fuzzy set logic was applied to assign any given supply point $i$ a probability between 0 and 1 of proximity to urban markets ($P_u$) and rural markets ($P_r$). The probability of market access from each point was modelled as a J-shaped membership function under the assumption that 0 (no market access) is only reached at infinity. The interaction potential $V_i$ between any point $i$ and market $j$ was calculated as a function of the linear distance $(d_{ij})^1$ for urban ($POPD_j > 5000$) and rural markets ($POPD_j$ in the range 500–5000) separately (Table 2). The membership function approached full market access ($P = 1$) at $V_i = 20$ and poor market access at $V_i = 5$.

The two models of interaction potential between urban (u) and rural (r) markets and their respective hinterland were used as conditional probability input images $P_u$ and $P_r$ in the Bayesian probability model. The output consists of posterior probabilities of urban vs. rural market access. $P_u \geq 0.5$ assumes urban market access and $P_u < 0.5$, $P_r > 0.5$ assumes rural market access. At equal posterior probabilities ($P = 0.5$) of access to urban markets u and rural markets r, it was assumed that access to urban markets is preferred over access to rural markets. 'No' market access is approached at $P_r < 0.5$.

### Differential market access of poor producers

The Bayesian probability analysis was repeated in order to simulate three alternative scenarios of access to markets. In order to simulate differential market access of poor people, the distance exponent $b$, which determines the structure of the distance decay, was adjusted according to three different assumptions about the effect that marketing constraints would have on their access. The first assumption was that market access is relatively more constrained for poor producers and consumers than for the better-off. Under this assumption, the distance exponent $b$ is set to 1.5 and the interaction potential $V_i$ becomes a function of $POPD_i/(d_{ij})^{1.5}$. The second assumption explored access to urban markets as a relatively higher constraint to poor producers and consumers, while access to rural markets would be less of a constraint. The assumption here was that rural markets are more numerous and widespread, and thus easier to access for poor and better-off people alike. The distance exponent $b$ was set to 1.5 for urban markets, and lowered to 0.75 for rural markets under this assumption. The third assumption was one of severe constraints resulting in high transaction costs to the poor, simulated by a distance exponent $b$ equalling 2. The absolute number of poor people (producers and consumers) with no access, rural market access or urban market access under the four different scenarios (including the baseline assumption of a linear distance decay with no differential access between the poor and the better-off) was estimated using the IDRISI extraction tool for summary statistics. On the basis of these estimates and empirical evidence on fish marketing in Cambodia, the implications of differential market access for pro-poor aquaculture development in Cambodia are discussed.

## Results

### Population and poverty distribution

The Cambodian National Institute of Statistics calculated the country's total national population at 12 132 172 in 1998. The sum of redistributed population counts for that year (Fig. 1a) results in a population of 10 881 878, thus representing an underestimate of about 10%. The highest urban population density is in the capital, Phnom Penh (P), and the highest rural population densities are found in provinces in the southeast of the country, in the vicinity of the capital. This appears to confirm the hypothesis that rural population tends to concentrate in the proximity of rural towns and major urban centres. The distribution of poor population reflects the overall population distribution over Cambodia, but poverty is particularly high

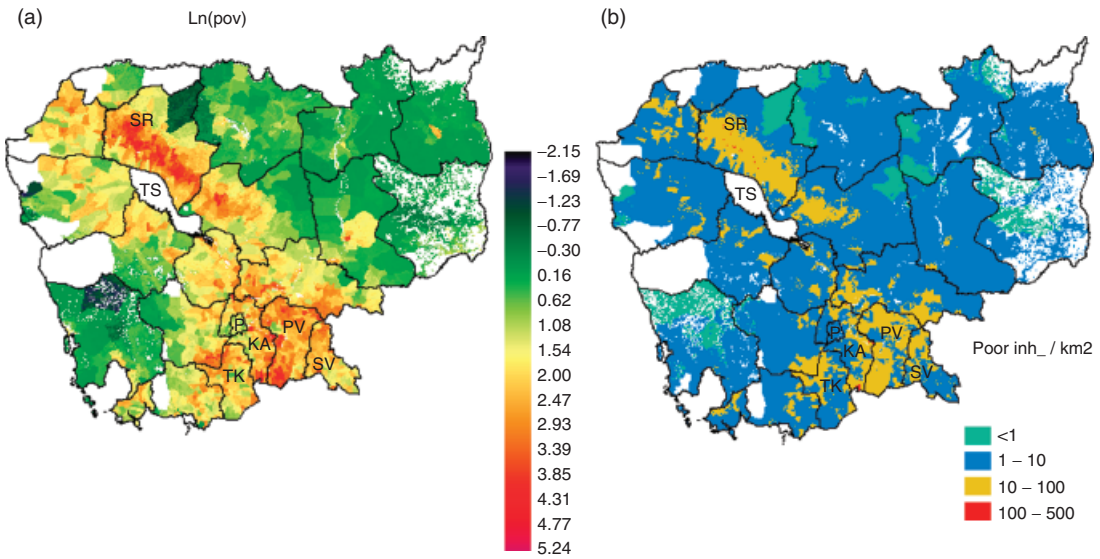


**Figure 2** (a) Natural logarithm of poverty density [ln (pov) km $^{-2}$]; (b) poverty density redistributed into discrete classes. KA, Kandal province; P, Phnom Penh (capital); PV, Prey Veng province; SR, Siem Reap province; SV, Svay Rieng province; TK, Takeo province; TS, Tonle Sap lake.

**Table 3** Area (%) of accessibility and number of poor (#) having 'no' access, rural market access or urban market access under different scenarios

| | 'No' access | | Rural ($V_r$) | | Urban ($V_u$) | |
|---|---|---|---|---|---|---|
| **Market accessibility** | **Area (%)** | **#poor** | **Area (%)** | **# poor** | **Area (%)** | **# poor** |
| (a) Exp. $b = 1$ | 43.8 | 1 17 865 | 53.2 | 7 95 160 | 3.0 | 25 181 |
| (b) Exp. $b = 1.5$ | 51.0 | 1 69 368 | 47.9 | 8 47 295 | 1.1 | 25 181 |
| (c) Exp. $b = 1.5$ ($V_u$) Exp. $b = 0.75$ ($V_r$) | 33.6 | 78 410 | 65.3 | 9 38 534 | 1.1 | 24 901 |
| (d) Exp. $b = 2$ | 56.5 | 2 16 430 | 42.9 | 8 12 262 | 0.6 | 13 152 |

The total land area of Cambodia is 176 515 km$^2$ (CIA 2010).

in Siem Reap province (SR) north of Tonle Sap lake (TS), with a second concentration of poor people in the south-eastern provinces, particularly Prey Veng province (PV) (Fig. 2a). Poverty in the south-eastern provinces is predominantly rural (Fig. 2b) but the context is one of high rural population density (Fig. 1b) and relatively close proximity to Phnom Penh (P). The Capital is relatively affluent, with a poverty headcount index of ca. 12% (Ministry of Planning, Royal Government of Combodia, United Nations World Food Programme & United Nations Development Program 2001).

## Market access

Under the baseline scenario (a), estimated as a function of linear distance, urban market access ($V_u$) is generally good in Kandal province (KA). This province lies well within the sphere of influence of the Capital, Phnom Penh (P). Isolated spots of good urban market access are found around some larger provincial centres in the rest of the country. Overall, urban market access is limited, with only 3% of the country having good access under the baseline scenario (Table 3; Fig. 3a). Under scenario (b), a higher overall distance constraint for poor producers and consumers results in a decrease in area of urban and rural market access (Fig. 3b). Under scenario (c), where rural market access is relatively less constrained for the poor than urban market access, some of the more remote areas in the northeast of the country shift from 'no' access to rural market access (Fig. 3c). Under this assumption, about two-thirds of

 

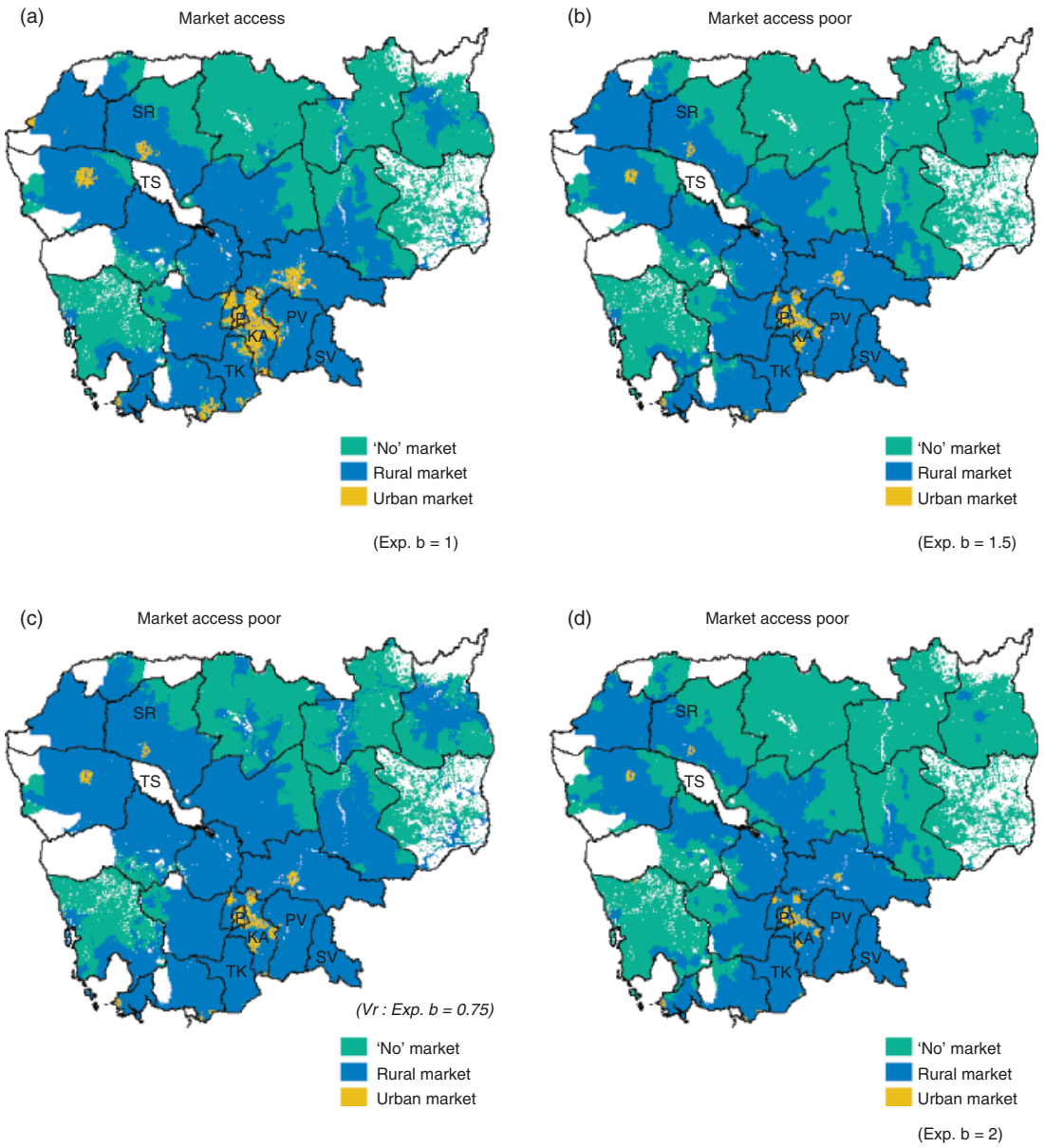


**Figure 3** (a) General market access as a function of linear distance $d_{ij}$ (exp. $b = 1$); (b) market access of the poor under a higher distance constraint (exp. $b = 1.5$); (c) access of the poor under a lower rural market access constraint (exp. $b = 0.75$) and (d) access of the poor under a severe distance constraint (exp. $b = 2$).

the country enjoys rural market access. Access to rural markets ($V_r$) remains broadly good in the south-eastern provinces and around Tonle Sap lake (TL) under all scenarios. Even under (d), the 'worst case' scenario (Fig. 3d), 43% of the country has rural market access (Table 3). Remote, thinly populated areas that are less likely to have any market access ($P_u < 0.5$, $P_r < 0.5$) are situated predominantly in the northeast of the country. More than half of the country has poor market access under scenarios (b) and (d) (Table 3).

Overall, the number of poor people who enjoy urban market access varies little and remains around 25 000 under the first three scenarios. Under scenario (d), the number of poor people who have urban market access decreases sharply to around 13 000. Rural market access ranges from almost 800 000 poor people under (a) no differential access to almost 940 000 under (c) the low constraint scenario. Taking into account the 10% underestimate in the population distribution model, up to 1 million poor people


 

would enjoy rural market access under the latter scenario, and around 86 000 poor people have 'no' market access. The number of poor people without market access increases to more than 210 000 under (d) the severe constraint scenario (Table 3).

## Discussion

Cambodia is situated in one of the most rapidly evolving regions of the world. Within this context of regional change, drivers of aquaculture market development are associated with global market integration, demographic growth and economic development trajectories of individual countries. Scenario analysis based on population distribution and poverty headcount can help predict future fish demand and priorities for aquaculture development. The baseline scenario suggests that the interaction potential of poor aquaculture producers and consumers with urban markets in Cambodia is currently low. Fish marketing in Cambodia traditionally has targeted larger urban markets and export supply, because fish destined for these markets have a higher market value. While urban market access is almost certainly much higher than the 3% area that the baseline scenario suggests, the scenarios of differential access of poor people to these markets support the notion that poor producers are at a disadvantage both in terms of the quality and in terms of the quantity of marketable fish that they can deliver to urban markets. They are severely constrained by high transaction costs and tied trade relationships. Poor consumers cannot afford to buy fish at a high market value. To put it simply, people who have access to urban markets are less likely to be poor. There are indications that urban markets, particularly in Phnom Penh, divert away most of the marketable fish from rural markets, reducing its local availability. Wholesale markets well outside urban areas but with good transport connections to urban markets play an important role in this. The scarce availability and high prices of fish in rural markets do not reflect the fish capture and consumption patterns of rural households. Naret, Viryak and Griffiths (2003) found that wild fish species encountered in those markets came primarily from rivers and lakes. A high proportion of wild fish is caught in rice fields and consumed within rural households instead of being sold. Despite this fact, most people purchase fish even when they live in rural areas (CDRI 2008). This underlines the need for rural market development. In contrast to their limited access to urban markets, the results suggest that rural market development could benefit high numbers of poor people, particularly in Cambodia's south-eastern provinces. The numbers of poor people who would have access to rural markets are high under all scenarios, including the baseline scenario. A scenario that improves rural market access, expressed in lower 'distance' to rural markets, is likely to create benefits for up to 1 million people who are heavily reliant on aquatic resources for their food security.

Aquaculture development is less likely to face the constraints of the high transaction costs and fragmented market access that are reported for capture fish trade. Because of its lower 'distance' constraints related to rural market access, aquaculture is therefore better placed to satisfy rural market demand. The operational costs and transaction costs of capture fisheries trade, including fees, tend to increase considerably with distance (Chea & McKenney 2003a, b; Seng 2006). Seng (2006) attributes the preference of traders for exporting fish caught in southern Kandal province to Vietnam despite relatively better fish prices in Phnom Penh to high transportation costs of fish to Phnom Penh. While poverty-targeted aquaculture has higher potential under improved rural market access, a number of factors currently constrain its development. In southern Cambodia for example, it has to compete against the supply of large quantities of cheap cultured fish from Vietnam (J. Pant, pers. comm.). The supply infrastructure and the availability of wild fish have an important influence on markets for aquaculture products. Inland fish still dominates fish supply in the capital, Phnom Penh. A monitoring survey carried out in early 2003 confirmed that indigenous inland fish, dominated by snakehead, comprised about 85% of fresh fish by weight sold at urban markets (Khay & Hortle 2005). The lack of refrigeration in traditional urban markets favours retailing of high-quality air-breathing fish, as they are able to survive with little water and can be transported and marketed alive. Introduced species such as Nile tilapia and silver carp *Hypophthalmichthys molitrix* (Valenciennes) made up 1% of sales. This may be an indicator that the urban market potential for such fish, typically promoted for rural aquaculture in ponds, is low (Guttman & Kunty 1997; Khay & Hortle 2005). The rural market demand for culture fish also appears to depend on how far natural stocks have declined in different situations (Edwards, Demaine, Innes-Taylor & Turongruang, 1996). Svay Rieng province, for exam-

 

**Table 4** Consumer price index (January 2007 = 100) for fresh fish in six representative provinces, Cambodia (based on fish price data, CDRI: Flash Reports April 2008–May 2010, http://www.cdri.org.kh/flashrep.htm)

| | Battambang | K. Speu | K. Cham | Kampot | Siem Reap | Svay Rieng |
|---|---|---|---|---|---|---|
| April 2010 | 222 | 200 | 151 | 291 | 108 | 158 |
| March 2010 | 213 | 196 | 144 | 282 | 108 | 145 |
| February 2010 | 213 | 189 | 148 | 291 | 108 | 158 |
| January 2010 | 199 | 200 | 131 | 255 | 120 | 145 |
| December 2009 | 199 | 185 | 128 | 236 | 108 | 158 |
| November 2009 | 189 | 163 | 148 | 264 | 120 | 121 |
| October 2009 | 227 | 207 | 128 | 273 | 145 | 158 |
| September 2009 | 255 | 185 | 154 | 291 | 145 | 158 |
| August 2009 | 241 | 163 | 134 | 273 | 169 | 158 |
| July 2009 | 232 | 178 | 128 | 291 | 169 | 145 |
| June 2009 | 217 | 163 | 131 | 255 | 157 | 145 |
| May 2009 | 194 | 163 | 101 | 273 | 145 | 158 |
| April 2009 | 170 | 163 | 128 | 273 | 120 | 145 |
| March 2009 | 170 | 148 | 102 | 291 | 102 | 145 |
| February 2009 | 161 | 170 | 131 | 273 | 102 | 145 |
| January 2009 | 161 | 156 | 128 | 273 | 102 | 133 |
| December 2008 | 165 | 215 | 157 | 273 | 120 | 103 |
| November 2008 | 284 | 163 | 138 | 273 | 145 | 158 |
| October 2008 | 284 | 178 | 151 | 273 | 145 | 152 |
| September 2008 | 312 | 207 | 180 | 282 | 157 | 158 |
| August 2008 | 340 | 178 | 177 | 273 | 181 | 212 |
| July 2008 | 202 | 215 | 177 | 273 | 145 | 212 |
| June 2008 | 200 | 178 | 135 | 273 | 145 | 170 |
| May 2008 | 200 | 178 | 184 | 273 | 145 | 158 |
| April 2008 | 200 | 185 | 157 | 273 | 145 | 152 |
| March 2008 | 196 | 215 | 131 | 236 | 120 | 170 |
| February 2008 | 184 | 222 | 131 | 236 | 120 | 145 |
| January 2008 | 189 | 207 | 125 | 218 | 145 | 121 |
| January 2007 | 100 | 100 | 100 | 100 | 100 | 100 |

ple, is a net exporter of capture fish during part of the year. Most fish in its district markets are larger and of a relatively high value. A substantial amount of this fish is redistributed to Phnom Penh and exported to Vietnam. Smaller markets sell a higher proportion of fish locally. The active trade of capture fish generates important cash income for poor farmers in the province (Guttman & Kunty 1997). The potential for aquaculture development in the provinces fringing the Tonle Sap might be low for similar reasons, as the capture fishery supported by the lake is still substantial. The available statistics appear to confirm the regional variation and recent increases in the prices of fresh fish. Particularly in Kampot province, southwest Cambodia, fish prices have almost tripled since January 2007. In April 2010, fresh fish prices in this province stood at 16 000 Riels per kilo (3.83 USD), 78% higher than that in Siem Reap province. Fresh fish prices in the latter province in that month were only 8% higher than that in January 2007 (Table 4).

The effects of changes in fish prices and demand on market access for the rural poor can be simulated using the methodology presented in this study. The effect of high consumer prices on market access for poor consumers, for example, can be simulated by adjusting to a higher distance exponent *b*, as done under scenario (d). The high fish prices in Kampot, on the other hand, do suggest that demand in that province currently exceeds supply, which could provide opportunities for producers who have access to this market. The simulation could be regionally differentiated accordingly by adopting a low distance coefficient, similar to scenario (c) for rural markets in and near Kampot.

## Conclusion

Aquaculture can provide both a means and an end to overcome the current market constraints in the Cambodian fisheries sector. Because of the decline in wild fish and growing market demand, aquaculture is likely to provide an increasingly important contri-

bution to domestic fish supplies in the foreseeable future (Viseth & Pengbun 2005). The development of local aquaculture capacity in or near areas where fish production falls short of demand would shorten the fish marketing value chain and reduce the transaction costs. Moreover, it would help buffer both fluctuations and regional variations in market prices as fish becomes more readily available during the lean season and in areas located far from capture fisheries resources. While the initial investment and input costs can be high, aquaculture development is likely to reduce the transaction costs in fish marketing because producers have greater control over production. This enables producers to respond better to changes in demand and be less dependent on tied trade relationships. Fish simply can be sold at the farm gate to wholesalers when the demand and prices are high or traded directly with local retailers in smaller quantities. Culture fish can also be kept alive till it is sold, or can even be marketed alive, which considerably reduces the need for preservation and avoids associated spoilage along the marketing chain.

A plausible scenario is that fish demand in Cambodia will increase considerably in the foreseeable future. The latest General Population Census and Cambodia Socio-Economic Survey was held in 2008 (National Institute of Statistics 2009). The provisional census results estimate the population of Cambodia at 13 388 910 in 2008. The projected population for the year 2025 is almost 19 million (U.S. Census Bureau 2009). Recently, an independent expert group concluded that aquaculture, including reservoir fisheries, will not be able to compensate for the expected decline of up to 70% in capture fisheries production in the region (MRC 2009). Despite that prediction, aquaculture must increase its contribution to fish supplies in order to satisfy future demand and feed Cambodia's burgeoning population. Initially, significant constraints need to be overcome, particularly the development of markets for aquaculture in a still predominantly rural subsistence economy. However, with the current regional market integration, throughout Southeast Asia, rural communities are increasingly participating in the cash economy (Bush 2004). Rural markets, despite being little developed, are more numerous, spatially diffuse and located at a shorter distance to the farm gate, thus reducing the transportation time and transaction costs. They also require relatively less volume of aquaculture produce, which in turn reduces the dependence on tied relations between producers, traders, distributors and retailers. Thus, aquaculture has the potential of initially increasing rural food fish self-sufficiency and to provide farm income diversification through rural market development. After its initial establishment, future consolidation of Cambodia's currently fragmented domestic market is likely to catalyse further aquaculture development as the gap between domestic supply and demand of fish widens.

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