3. Contribution of commercial aquaculture to poverty alleviation and food security: an assessment framework

3.1 BASIC CONCEPTS AND BACKGROUND

In addition to economic growth, economic development includes other dimensions such as income distribution, education, health, environment, poverty alleviation, food security, and so on (Johnston and Mellor, 1961; Timmer, 1992). As poverty and food security are two major issues in the regions of sub-Saharan Africa (SSA) and Latin America (LA), we will develop a framework for quantitatively assessing the contribution of commercial aquaculture.

3.1.1 Poverty alleviation

Poverty is a concept that has many dimensions (Maxwell, 1999; UNDP, 2000). In brief, poverty means poor living conditions; its immediate cause is lack of real, financial and other resources; its many symptoms include inadequate provisions (in terms of both quantity and quality) of food, housing, nutrition, health, education, etc.

As poverty is the major culprit for long-term, chronic food security problems, one consequence of commercial aquaculture's contribution to poverty alleviation will be to improve long-term food security. Thus, our assessment framework will be specifically designed for evaluating commercial aquaculture's contribution to food security; indicators used to measure aquaculture's contribution to long-term food security will also be used to measure contributions to poverty alleviation.

3.1.2 Food security

Food security is also a multi-dimensional concept. While long-term, chronic food access problems are a result of persistent poverty, other aspects (such as food availability, food utilization, and transitory food insecurity) require a broader perspective and examination.

3.1.3 Food insecurity in sub-Saharan Africa and Latin America

Lack of food security has been a major issue in the SSA region; conditions are not likely to improve in the near future. During 1998–2000, more than 40 percent of SSA populations were undernourished (FAO, 2002). According to the USDA (2003, p. 12), "fifty-four percent of sub-Saharan Africa's population is estimated to be hungry in 2002. This share is not projected to change during the next decade".

The food security situation for the LA (and Caribbean) region is more promising. Between 1998 and 2000, the shares of undernourished population were around 25% and 10% for the Caribbean area and South America respectively (FAO, 2002). In addition "food security in this region is projected to improve over the next decade, thanks to increasing export earnings and, thus, increased import capacity" (USDA, 2003).

3.1.4 Aquaculture's contribution to food security

The existing and potential contributions of aquaculture to food security have been well recognized. Tidwell and Allan (2001) provided some statistics as to the contribution of fish products to food supply: around one billion people worldwide rely on fish as their primary source of animal protein; fish supplies 17 percent of animal protein in Africa; over 36 million people are employed directly through fishing and aquaculture; consumption of food fish has increased from 40 million tonnes in 1970 to 86 million tonnes in 1998 (FAO, 1999); and fish consumption is expected to reach 110 million tonnes by 2010 (FAO, 2001).

As pointed out by Tacon (2001, p. 63), aquaculture is "an important domestic provider of much needed high-quality animal protein and other essential nutrition (generally at affordable prices to the poorer segments of the community)".

Ahmed and Lorica (2002, p. 125) found "clear evidence of positive income and consumption effects of aquaculture on households" in Asia's experience.

From the perspective of fish farmers, Edwards (1999a, 1999b, 2000) summarized aquaculture's contribution to the livelihoods of the rural poor into "direct" and "indirect" benefits, with the former including the provision of high-quality food, (self) employment, and incomes; and the latter including food supply to local markets, employment opportunities for local communities, efficient resource utilization, and enhancement of farm sustainability through infrastructure construction and (farming) technology innovations.

Brummett and Williams (2000, p. 197) pointed out that high population growth, low elasticity of demand for fish and static fishery production make aquaculture an important supply source for fish products.

3.1.5 Research on aquaculture's contribution to food security

Although the roles of aquaculture in poverty alleviation and food security improvement have been well recognized, there are few systematic and quantitative evaluations of aquaculture's contribution in these two respects, especially from a macroeconomic perspective (Charles *et al.*, 1997).

As pointed out by Tacon (2001), "little or no hard statistical information exists concerning the scale and extent of rural or small-scale aquaculture development within most developing countries and LIFDCs or concerning the direct/indirect impact of these and the more commercial-scale farming activities and assistance projects on food security and poverty alleviation".

In evaluating the state of aquaculture economics related to the Latin American and Caribbean region, Agüero and González (1997, p. 31) pointed out that "the social impact of aquaculture is usually regarded in the existing literature in terms of employment, foreign exchange generation or food supply. However, references to these impacts are descriptive and based on assumed positive impacts (i.e. increased production is assumed to be associated directly to improved community employment and incomes; increased export earnings are assumed to mean increased community welfare, etc.). Therefore, positive impacts are extrapolated from assumed factors and rarely based on in-depth analysis".

In evaluating the state of aquaculture economics related to the Africa and the Middle East region, Stomal and Weigel (1997, p. 22) pointed out that "the absence of economists in the field of African and Middle Eastern aquaculture is felt most strongly in the field of macro-economics. Broadly speaking, two features seem to be missing: a production and marketing chain approach, and an accounting for the direct and indirect effects of aquaculture development upon the local economy".

Some of the difficulties in this line of research include the lack of data, especially for the SSA region, and the lack of a generally accepted methodology (Charles *et al.*, 1997).

Given this background, in the following we attempt to first develop a conceptual and then a data-amenable empirical framework for assessing the contribution of commercial aquaculture to food security.

3.2 ASSESSING THE CONTRIBUTION OF COMMERCIAL AQUACULTURE TO FOOD SECURITY

3.2.1 A conceptual framework

The concept of food security

"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

Food security is a multidimensional concept and needs to be examined from different perspectives (Maxwell, 1996). Several evaluation frameworks have been used to evaluate the performance of specific food security programs sponsored by governments or development agents (USAID, 1995; Riely *et al.*, 1999; Van Rooyen and Sigwele, 1998; Timmer, 1997; among others). Based on these experiences we will develop a framework for evaluating a specific sector's contribution to food security. Food security includes three major dimensions:

> *"(1) Availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports;*
> *(2) Access by households and individuals to adequate resources to acquire appropriate foods for a nutritious diet; and*
> *(3) Utilization of food through adequate diet, water, sanitation, and health care."*
> (USAID, 1995; USDA, 1996).

We will examine how commercial aquaculture can directly and indirectly contribute all these three dimensions of food security. It should be noted that these three dimensions are complementary yet not independent. For example, the improvement in food availability will tend to decrease food price and hence make food more accessible.

In general, factors that put food security in danger include chronic poverty, rapid population growth, declining per capita food output, poor infrastructure, ecological constraints, limited arable land, inappropriate policies, disease, poor water and sanitation, inadequate nutritional knowledge, civil war and ethnic conflicts, etc. (Riely *et al.* 1999; USAID, 1995). When evaluating commercial aquaculture's contribution to food security, we will consider how commercial aquaculture can enhance food security by reducing the elements that tend to cause food insecurity.

Contribution to economic growth as a general indicator

As economic growth (especially growth in agriculture) is one of the major elements for poverty alleviation and food security enhancement (Timmer, 1996; Lipton and Ravallion, 1994; Ravallion and Datt, 1996), the indicators for commercial aquaculture's contribution to economic growth discussed above can be taken as general indicators of its contribution to poverty alleviation and food security.

More specifically, commercial aquaculture can directly or indirectly contribute to all of the three major dimensions of food security, i.e. food availability, food access and food utilization.

Contribution to food availability

Two aspects of food availability are food quantity and quality. While food quantity provides a general, physical measure of the extent of food abundance or shortage, food quality is related to ultimate utility provided by food items to consumers.

Commercial aquaculture's contribution to food quantity includes its direct food supplies to domestic markets and its foreign exchange earnings that can be used for food imports. Food imports are vital for food security in many LA and SSA countries whose domestic food production usually cannot keep up with domestic population growth.

Commercial aquaculture's contribution to food quality depends on the characteristics of its products, which include nutrition contents, suitability to local taste, storability, etc. In general, aquatic products are an important source of high-quality animal protein for the LA and SSA countries (FAO, 1997; Tacon, 2004). Besides, aquatic food products generally suit the taste of the population in these countries.

Contribution to food access

Food availability is a necessary condition for food security, but not sufficient. Since households' own food supply may not be sufficient, households without sufficient resources for food purchases will be living in food insecurity, even when there is enough food available to feed all household members. Such a "paradox of plenty" is one example of food access problems.

The major aspect of food access is food affordability, which depends on food price and consumers' incomes.

Food supplies have major impacts on food prices – high food prices are usually caused by food shortage (Timmer, 1997; Haddad, 2000). Thus, aquatic food products supplied by commercial aquaculture to local markets will not only contribute to food availability, but also help food access by making aquatic products affordable to local households.

On the other hand, commercial aquaculture also contributes to food access by providing households with jobs and incomes. As discussed above, commercial aquaculture not only can provide wages (salaries) and jobs to its own employees, but it also stimulates income and job creation in the rest of the economy through its linkage impacts.

Besides affordability, food access is also "a function of the physical environment, social environment and policy environment, which determines how *effectively* households are able to utilize their resources to meet their food security objectives." (Riely *et al.*, 1999, p. 14, emphasis original). In this respect, commercial aquaculture's contribution stems from its investments in infrastructure, its impacts on community formation and its contribution to tax revenues.

Contribution to food utilization

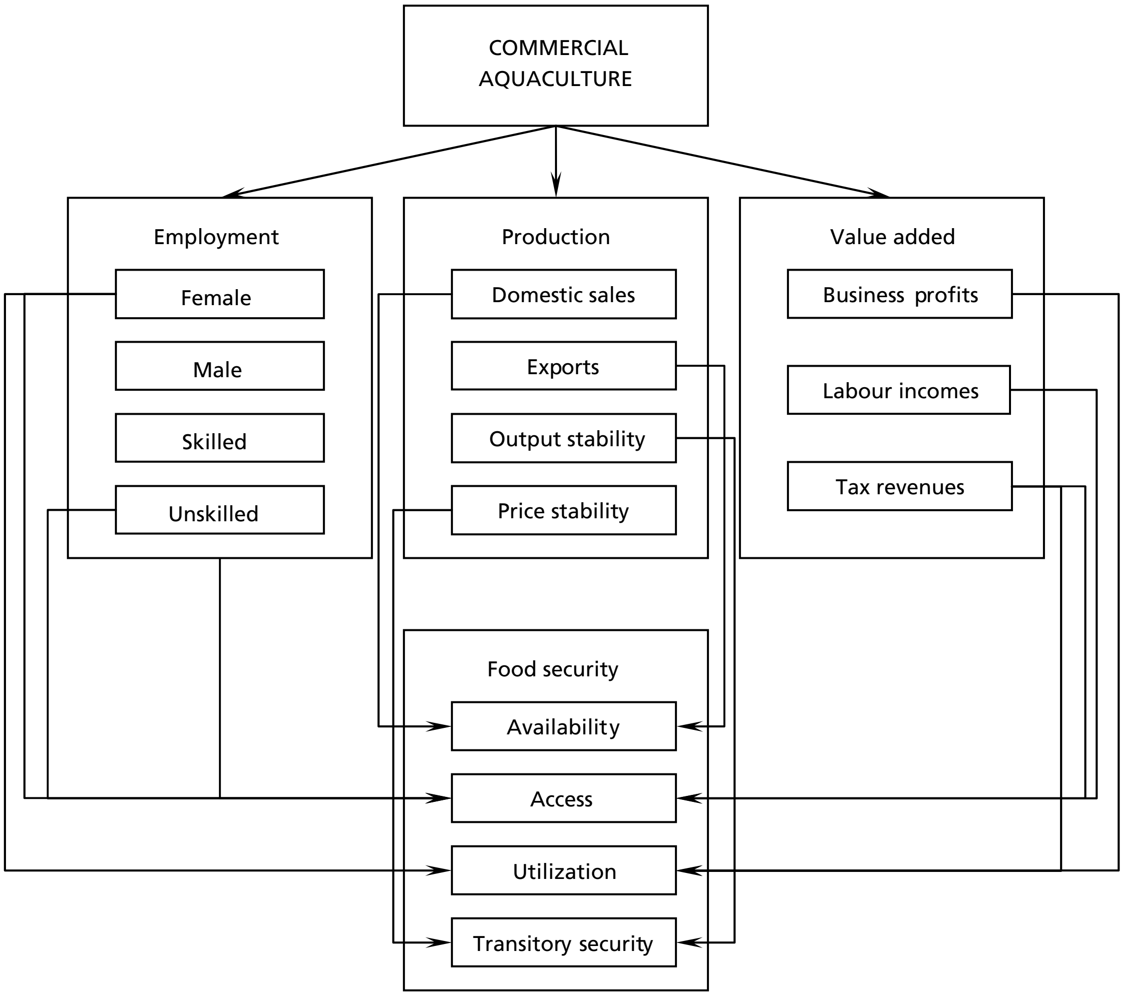
Food utilization is related to microdimensions of food security such as nutrition, food-preparing and sanitation knowledge, dietary habits, health conditions, etc. Commercial aquaculture can contribute to these issues indirectly. For example, commercial aquaculture's tax payments can help finance public health education and health care programmes, infrastructures for sanitation, etc. (Fan, Hazell and Thorat, 1999).

Contribution to short-term food security

In addition to long-term, chronic food security problems, food security is also threatened by transitional shocks such as natural disasters, diseases, food price shocks in domestic or world markets and so on.

By providing diversified aquatic products, commercial aquaculture can increase the stability of domestic food supplies and hence increase the country's resistance to transitory shocks that have negative impacts on food security. In addition, stable commercial aquaculture production will help secure the incomes and jobs of its employees and hence increase the resistance of their households against transitory food insecurity.

FIGURE 2
A conceptual framework for commercial aquaculture's contribution to food security



Summary

The conceptual framework for understanding the contribution of commercial aquaculture to food security is summarized in Figure 2.

3.2.2 Indicators

Indicators for commercial aquaculture's contribution to food availability

Protein and other nutrient supplies

Since aquatic products are an important source of (animal) protein, a rudimental measure of commercial aquaculture's contribution to food availability is its protein supply:

$$[7.1]\quad CPS = \sum_i p_i X_i \,,$$

where,

CPS = the protein supply of commercial aquaculture;
p_i = the protein content of a unit of commercial aquaculture product *i*;
X_i = the quantity of commercial aquaculture product *i*.

Data needed for calculating indicator [7.1] include the quantity (X_i) and protein content (p_i) of each commercial aquaculture product. Data on X_i are generally available from official statistical sources (such as FAO's FishStat). Data on p_i may be available from secondary resources.

Two extensions of indicator [7.1] are

[7.2] CPS / TPS
[7.3] CPS / APS

where,

TPS = total (actual or desired) protein supply for the entire economy;
APS = total (actual or desired) animal protein supply for the entire economy.

Indicators [7.2] and [7.3] measure the importance of commercial aquaculture as a source of protein in general and animal protein in particular. Data on *TPS* and *APS* are generally available from official statistical sources such as FAO's food balance sheets.

Similar to indicators [7.1]–[7.3], indicators for commercial aquaculture's contribution to other nutrient supplies can be constructed.

Direct and indirect food supplies

A portion of commercial aquaculture production may be exported and hence do not contribute to the domestic food supply directly. Yet, the foreign exchange earnings of commercial aquaculture's exports can indirectly contribute to the domestic food supply. Because of this complication, indicator [7.1] needs to be refined for countries that have non-trivial exports of commercial aquaculture products. We suggest the following two indicators.

[7.4] $CDPS = \sum_i p_i (X_i - Ex_i)$,

[7.5] $CIFS = NFE / FIM$,

where,

$CDPS$ = commercial aquaculture's direct protein supply;
Ex = commercial aquaculture's export quantity;
$CIFS$ = commercial aquaculture's indirect food supply;
NFE = commercial aquaculture's net foreign exchange earnings (defined in indicator [5]);
FIM = total value of food imports.

Indicator [7.4] measures the amount of protein that commercial aquaculture provides directly to domestic households. Despite its conceptual simplicity, one empirical difficulty in calculating indicator [7.4] is the lack of data on commercial aquaculture's exports. Although aquatic commodity export data are available from official statistics sources (e.g. FAO's FishStat or UN's Comtrade), these data may not be applicable directly here since they represent the total aquatic commodity exports that include both capture and culture products. Another problem is unmatched product categorizations for production data and export data. For example, the aquaculture production data in FishStat are categorized as "tilapia", "catfish", "shrimp", etc. Yet, the aquatic commodity trade data are categorized as "fillets", "freshwater fish", etc. Without matched data for production and export, indicator [7.4] cannot be calculated directly. One solution is to find out the export percentage for each commercial aquaculture product. Such information may be available from secondary sources. Otherwise, farm surveys may be necessary to obtain accurate data on the exports of commercial aquaculture products.

The rationale for indicator [7.5] deserves some explanation. *NFE* represents the net foreign exchange earnings of commercial aquaculture, which is equal to its foreign exchange revenues (from exports) minus its foreign exchange costs (for imported inputs). Even though the economy tends to have many other imported requirements besides food imports, indicator [7.5] measures commercial aquaculture's potential contribution to food imports if all of its net foreign exchange earnings are used for food imports. If data on the energy and nutrient contents of countries' food imports are available, we can calculate commercial aquaculture's indirect contribution to domestic food supply in terms of grain equivalents, calories, proteins, etc.

Note that, even though aquatic products *per se* may not be an important source for food energy (as compared to grain and root products) in the SSA and LA regions, commercial aquaculture can be a significant contributor to domestic food energy supply through its indirect food supplies.

Indicators for commercial aquaculture's contribution to food access

Labour income

Wages and salaries provided by commercial aquaculture directly and indirectly are important indicators of its contribution to food access.

[8.1.1] W^{ca}
[8.1.2] $W^{ca} * M_w$

[8.2.1] $w^{ca} = W^{ca} / E^{ca}$
[8.2.2] w^{ca} / w^{ag}

where,

W^{ca} = the total wage (salary) payments of commercial aquaculture to its employees;
M_w = the labour income multiplier defined in indicator [3.5];
E^{ca} = the total jobs provided by commercial aquaculture;
w^{ca} = the average wage (salary) income of commercial aquaculture employees;
w^{ag} = the average wage (salary) income of agriculture employees.

By measuring the labour incomes generated by commercial aquaculture directly or indirectly (through linkages), [8.1.1] and [8.1.2] serve as general indicators of contribution to food access. We assume the more labour income commercial aquaculture can generate, the greater its contribution to food access will be.

Indicators [8.1.1] and [8.1.2] deflated by food prices will reveal commercial aquaculture's "real" contribution to food access. This is especially important when the time series of the two indicators are used to assess commercial aquaculture's contribution to food access over time. For example, suppose commercial aquaculture's total labour income is US$10 million and US$15 million in 2003 and 2004 respectively; and the food price indices for the two years are respectively 1 and 2 (i.e. the food price has increased by 100% in 2004). Under this situation, even though commercial aquaculture provides a higher nominal labour income in 2004 than 2003, its real contribution to food accessibility in 2004, which is equal to US$7.5 million at 2003 prices, is nevertheless smaller because of inflation in food prices.

Indicator [8.2.1] measures the average wage rate in the commercial aquaculture sector; indicator [8.2.2] compares the average wage rate between commercial aquaculture and agriculture in general. A high wage rate of commercial aquaculture will make food more accessible to the families of its employees.

Employment

The jobs and wages (salaries) directly provided by commercial aquaculture are another important indicator of its contribution to food accessibility.

[8.3.1] E^{ca}

[8.3.2] E_j^{ca} / E^{ca}

[8.3.3] E_f^{ca} / E^{ca}

where,

E^{ca} = total jobs provided by commercial aquaculture;
E_j^{ca} = the number of commercial aquaculture's employees with educational level j;
j = no education; primary school graduate; secondary school graduate; etc.;
E_f^{ca} = the number of female employees hired by commercial aquaculture.

Indicator [8.3.1] measures the number of households whose food access will benefit from commercial aquaculture production.

Since populations with low skill levels are in general more likely to be food insecure, indicator [8.3.2] provides an in-depth measure of commercial aquaculture's contribution to food access. If a relatively large share of commercial aquaculture's employees belong to food-insecure-prone cohorts, its contribution to food access will be greater.

Indicator [8.3.3] measures the share of females in commercial aquaculture's labour force. Research has shown that households with female budget-planners tend to be more food secure – in general, female household heads demonstrate a stronger tendency to bring foods to the table rather than spending money in tobacco. Thus a large indicator [8.3.3] implies a greater contribution to food access.

Indicators for commercial aquaculture's contribution to short-term food security

From the perspective of food access, a measure of commercial aquaculture's contribution to short-term, transitory food security is the stability of its production, which will provide income and job security to its employees and hence enhance the food security of their households.

From the perspective of food supply, another measure of commercial aquaculture's contribution to short-term food security is the correlation between its food supply and the total domestic food supply and the price correlation between commercial aquaculture products and general food products. If the food supply of commercial aquaculture does not regularly move in the same direction as the total food supply, it plays a role in stabilizing the total food supply and hence contributes to transitory food security. Similarly, if the prices of commercial aquaculture products do not move regularly in the same direction as the general food price level, it contributes to food price stability, another dimension of short-term food security.

Variance

In general, the volatility of a variable can be measured by the deviations from its mean. Take commercial aquaculture's production as an example. Suppose $X_t = \overline{X}_t + \delta_{X_t}$, which implies that the actual production in time t (X_t) are determined by two factors: one is the mean $\overline{X}_t$ that represents the long-term trend of commercial aquaculture production; the other is a random variable δ_{X_t} that represents transitory shocks. The short-term volatility of X_t is caused by δ_{X_t} and can be measured by the following two indicators.

[9.1.1] $\sigma^2_{X_t} = \sum_t \frac{(X_t - \overline{X}_t)^2}{n}$

[9.1.2] $$\tilde{\sigma}^2_{X_t} = \sum_t \frac{(X_t / \overline{X}_t - 1)^2}{n}$$

where,

$\sigma^2_{X_t}$ = the magnitude variance of X_t;

$\tilde{\sigma}^2_{X_t}$ = the percentage variance of X_t;

X_t = the actual production or protein supply of commercial aquaculture in time t;

$\overline{X}_t$ = the mean production or protein supply of commercial aquaculture in time t;

Indicator [9.1.1] measures the average deviation of commercial aquaculture production from its underlying trend in a sample period whereas indicator [9.1.2] measures the average *percentage* deviation from trend. As opposed to indicator [9.1.1] measuring the magnitude of the fluctuations of commercial aquaculture production, indicator [9.1.2] measures the volatility *per se*. For example, the indicator [9.1.1] for agriculture tends to be always greater than that for commercial aquaculture. Yet it does not necessarily imply that commercial aquaculture production is more stable, but could merely reflect the large magnitude of agriculture production as compared to that of commercial aquaculture. Thus, by removing the scale element, indicator [9.1.2] provides a "weighted" measure of volatility.

Indicators [9.1.1] and [9.1.2] can be used to measure the volatility of commercial aquaculture's production, protein supply or other nutrient supplies. Measurements can be made for individual species or the total range of commercial aquaculture products.

While data for actual production X_t are available, the mean production $\overline{X}_t$ needs to be estimated. Suppose the time trend of X_t is linear; then the mean production $\overline{X}_t$ can be estimated by regressing the actual production X_t on time. Specifically, the regression model will be $X_t = a + bt + \delta_{X_t}$; the least-squares method can be used to estimate parameters a and b; thus, the estimation of $\overline{X}_t$ is equal to $a + bt$.

Similarly, price variability of aquaculture products can be measured by

[9.2.1] $$\sigma^2_{P_t} = \sum_t \frac{(P_t - \overline{P}_t)^2}{n}$$

[9.2.2] $$\tilde{\sigma}^2_{P_t} = \sum_t \frac{(P_t / \overline{P}_t - 1)^2}{n}$$

where,

P_t = the actual price of commercial aquaculture products;

$\overline{P}_t$ = the mean price of commercial aquaculture products;

$\sigma^2_{P_t}$ = the magnitude variance of P_t;

$\tilde{\sigma}^2_{X_t}$ = the percentage variance of P_t.

The interpretations of indicators [9.2.1] or [9.2.2] are similar to those of indicators [9.1.1] and [9.1.2].

Covariance and correlation

Another indicator of commercial aquaculture's contribution to short-term food security is its covariance and correlation with the total domestic food supply.

[9.3.1] $$\operatorname{cov}(x_t, y_t) = \sum_{t=1}^{n} \frac{(x_t - \bar{x})(y_t - \bar{y})}{n}$$

[9.3.2] $$\rho_{x,y} = \frac{\operatorname{cov}(x_t, y_t)}{\sigma_{x_t}\sigma_{y_t}}$$

where,

x = *CPS* (i.e. commercial aquaculture's total protein supply);
y = *TPS* (total protein supply for the entire economy);
$\rho_{x,y}$ or *APS* (total animal protein supply for the entire economy);
$\operatorname{cov}(x_t, y_t)$ = the covariance between x and y;
$\rho_{x,y}$ = the correlation between x and y.
σ_{x_t} = the standard deviation of x_t (as defined for indicator [9.1.1]);
σ_{y_t} = the standard deviation of y_t (as defined for indicator [9.1.1]);

Indicator [9.3.1] [i.e. $\operatorname{cov}(x_t, y_t)$] measures the extent to which x and y co-vary together. A positive indicator [9.3.1] implies that the protein supply of commercial aquaculture and the total domestic protein supply tend to deviate from their means in the same direction; a negative one implies that they tend to deviate in opposite directions. An indicator close to zero implies that there is no observable regularity between their deviations.

Indicator [9.3.2] (i.e. $\rho_{x,y}$) is a standardized covariance between x and y and measures their correlation. For example, suppose x-y covariance is greater than x-z covariance. This may not necessarily mean that x and y tend to deviate from their means in the same direction more often than x and z do, because the larger x-y covariance can also be a result of a larger variance for y than z. Therefore, by dividing the covariance between x and y by their respective variances, $\rho_{x,y}$ provides a measure of the likelihood of x and y deviating from their means in the same direction.

The value of $\rho_{x,y}$ ranges between -1 and 1. A value close to -1 indicates a strong negative correlation between commercial aquaculture's protein supply and the total protein supply, which implies a greater contribution of commercial aquaculture to short-term food security. The reason is straightforward. The negative correlation means that commercial aquaculture's protein supply tends to be above its trend when the below-trend total protein supply is threatening short-term food security. On the contrary, a $\rho_{x,y}$ close to 1 indicates a strong positive correlation between commercial aquaculture's protein supply and the total protein supply, which implies a small contribution of commercial aquaculture to short-term food security.

Also, commercial aquaculture's contribution to food price stability can be measured by the covariance or correlation between the prices of commercial aquaculture products and the general food price index.

[9.4.1] $$\operatorname{cov}(p_t^{ca}, p_t) = \sum_{t=1}^{n} \frac{(p_t^{ca} - \bar{p}_t^{ca})(p_t - \bar{p}_t)}{n}$$

[9.4.2] $$\rho_{p^{ca},p} = \frac{\operatorname{cov}(p_t^{ca}, p_t)}{\sigma_{p_t^{ca}}\sigma_{p_t}}$$

where,

p_t^{ca} = the price of commercial aquaculture products in time t;
p_t = the food price index in time t;
$\operatorname{cov}(p_t^{ca}, p_t)$ = the covariance between p_t^{ca} and p_t;
$\rho_{p^{ca},p}$ = the correlation between p_t^{ca} and p_t.