

Genesis of the workshop

The projected global demand for fish and fish products is expected to increase over the next decade. Because many capture fisheries are at their limits of production and the energy requirements to run the world's fisheries are increasing in spite of technological improvements in fishing, satisfying this demand will rely on increased production from aquaculture. Aquaculture is now one of the fastest-growing food-producing sectors, but it is being criticized for creating adverse environmental impacts. In order to maintain the growth of aquaculture and protect the environment, accurate environmental accounting of food production will be necessary to help policy-makers make informed decisions that will ensure aquaculture develops in a responsible manner.

The international community recognizes the need to address the environmental impacts of development. The Convention on Biological Diversity (CBD) and the FAO Code of Conduct for Responsible Fisheries (CCRF) are key international instruments that have called for development to address environmental concerns and strive to protect natural biological diversity. In acknowledging the adverse environmental impacts from the food production sector, the First Session of the FAO Committee on Fisheries' Sub-Committee on Aquaculture held in Beijing, China, from 18 to 22 April 2002, recommended future work be devoted to "undertaking comparative analyses on the environmental cost of aquatic food production in relation to other terrestrial food production sectors". The Sub-Committee specifically asked the FAO Fisheries and Aquaculture Department to undertake such a study and analysis.

The workshop reported here (Annex 1) is a first step to address that request. Its purpose was to provide FAO with information that could be used to advise Members on how to make development decisions that take into account the environmental costs of food production. These decisions will help determine where public and private sector investments will help optimize national food production in terms of economic viability, environmental sustainability and social acceptability. FAO's ultimate aim would be to minimize adverse costs and impacts of food production systems through facilitating informed decisions at the national level.

To that end, a group of experts in aquaculture development, ecology, environmental economics, environmental impact analysis, energy analysis and livestock farming (Annex 2) were brought together to advise FAO on appropriate and accurate accounting approaches for comparing environmental costs of aquaculture and other terrestrial food production sectors; to evaluate the strengths and weaknesses of these accounting systems; and to advise FAO on options for moving forward in this important area. While the workshop recognized that social aspects of environmental impacts are extremely important and should be considered in analyses and in decision-making, this area was not addressed in sufficient detail to provide meaningful statements. Similarly, traditional economic impact analysis was not discussed in detail, despite clearly having application in cost-benefit analysis.

Food production: intensification and environmental impacts

Aquaculture may be the fastest growing food-producing sector but others are increasing as well. Consumption of animal products in the developing world rose from 15 kg per capita in 1982 to 28 kg per capita in 2002 and is expected to reach 37 kg by 2030 (Gerber *et al.*, 2007; Soto, Salazar and Alfaro, 2007; FAO, 2004); this is nearly twice as high as predicted consumption of food from aquatic sources. Food production has in general outpaced human population growth over the last few decades but the distribution of this increased production is still inequitable (FAO, 2002).

A key driver of the increase in food production is intensification of farming systems, often characterized by increased inputs, effluents and energy demands (Prein, 2007). However, more traditional farming systems that use large amounts of land may also pose serious risks to the environment, native biodiversity and local communities. Evaluation of these risks has been attempted, but assessment has not generally included comprehensive analysis of costs to the environment, and there have been very few studies done comparing different food production sectors.

Yet all development has impacts. Progress has been made in mitigating some of them, but there is a long way to go. Production of feed has been identified as one of the most significant environmental and economic costs in both the aquaculture and livestock sectors. While farmed aquatic animals are generally more efficient converters of feed energy than are ruminants, many farmed aquatic animals are fed diets with fishmeal and fish oil. This has led to criticism of the aquaculture sector for using fish to feed fish and for causing environmental problems. Reducing the fishmeal and fish oil component in aquaculture feeds is a high priority for intensive systems; in salmon feeds, for example, some current formulations rely much less on wild fishmeal than did diets of a decade ago with a reduction from 60 to 35 percent (Tacon, 2005). The energy needs of fish farming may thus be reduced along with the dependence on fish products in the feed. However the global growth of aquaculture and the increasing use of formulated feeds present a challenge as there is a net increase in total demand for fishmeal and fish oil.

The important role of the environment in providing ecosystem services is becoming better understood, sometimes with surprising results. For example, while mangroves provide valuable feeding and nursery areas for many coastal fisheries, their value in protecting coastal communities from storm damage may in fact be greater (Barbier, 2007).

Because development agencies may need to consider a range of development or resource management scenarios, the analytical process upon which these scenarios are based should include *comparison* of the costs of all potential options. Comparative environmental cost assessment is therefore not only an important and potentially fertile area for study, it is also an area where research results will be extremely useful to decision-makers, the industry and the public. Nevertheless, misconceptions concerning food production and its impacts persist. These misconceptions, as well as the general lack of knowledge concerning food production and the environment, can only be eliminated through policies that are informed by science-based studies.

Workshop findings

The present workshop represented a scoping exercise which identified broad issues that need to be addressed in environmental cost analysis. Further action will be needed to move the analyses forward in order to promote food production systems that are economically viable, environmentally sustainable and socially acceptable.

THE NEED FOR A LEVEL PLAYING FIELD

The main conclusion of the workshop was that it is necessary to include environmental costs in any analysis of the sustainability of any food-producing sector. This message is certainly not new. The concept of “sustainable development” was explicitly identified 20 years ago in the Brundtland Report (UNGA, 1987); however, sustainability has been difficult to achieve or simply ignored. Fortunately, the tools available to address the issue are better now; unfortunately, policy- and decision-makers may still avoid using them if the result is politically unpalatable. There is thus a need to present a balanced picture of the environmental costs of *all* food-producing sectors and to formulate environmental policies that deal with the impacts of all sectors. Such a balanced view will require a multidisciplinary team of ecologists, economists, social scientists and policy-makers working with the appropriate food production sectors. The ultimate goal should be to balance all development sectors, e.g. tourism, municipal development and capture fisheries.

So long as this balanced picture of environmental costs is absent, policy does not reflect farming realities, the prices of food products cannot reflect the real costs of their production, especially for ecosystems and communities, and both the public and government receive very mixed messages. Inconsistencies become common. For example, the recent explosion of aquaculture has led in some cases to overregulation, while other sectors with a longer history of production have negative impacts that have traditionally been accepted (Brooks, 2007; Gowing and Ocampo-Thomason, 2007; Soto, Salazar and Alfaro, 2007).

IS THERE OVERREGULATION OF AQUACULTURE?

The workshop identified two main reasons why aquaculture may be subject to more regulation than other sectors, at least in some parts of the world. First, aquaculture is relatively new, and growing rapidly. That growth impinges on established uses of land and water: hotels, farms, housing developments, industry etc. may already be established near water bodies where aquaculture is proposed or already being developed. These previously established activities have already been accepted by society; adding aquaculture to the picture invites additional scrutiny and criticism. People have become accustomed to and may even prefer seeing lighted city streets or rolling pastures, but cages in the sea may not be so palatable. Such preferences can easily affect government policy.

Second, farming and other terrestrial development often use private land with well-defined boundaries and access rights. The aquaculture ventures that are most often criticized or heavily regulated are marine and coastal operations located on common property where boundaries and access rights are less well defined and impacts more difficult to contain.

There may also be misconceptions regarding the science on which regulations are based. For example, use of certain pesticides is highly restricted in the United Kingdom of Great Britain and Northern Ireland, but these pesticides have been shown to have

minimal effects in that country (Gowing and Ocampo-Thomason, 2007). Nutrient inputs are also regulated in waters of the Pacific Ocean around Chile and also around the Canada/United States of America border. However, some studies have shown the specific nutrients being regulated to have little adverse impact in these environments (Brooks, 2007; Soto, Salazar and Alfaro, 2007). Thus, the industry may feel that regulation does not always address the real causes of environmental perturbations.

Despite these controversies, there is no question that environmental effects have been identified and all food-producing sectors need to mitigate them. Industry needs to be aware that the costs of avoiding or pre-treating hazards are often much lower than the penalties for non-compliance or the costs of cleanup or rehabilitation (e.g. mangrove replanting; Brooks, 2007; Soto, Salazar and Alfaro, 2007).

EFFECTS OF ECONOMIC AND TECHNOLOGICAL GROWTH AND PUBLIC PERCEPTION

The workshop discussed whether economic growth is a prerequisite to managing environmental issues and mitigating adverse impacts (Brugère, Soto and Bartley, 2007). The relationship between economic growth (national income) and environmental degradation or some of its components (e.g. pesticide use) can be expressed mathematically and suggest that pollution associated with production activities decrease after a certain level of income has been reached. The relationship is complicated, however, and is affected by technological progress, relative energy prices and the presence of adequate and well-functioning institutions (Brugère, Soto and Bartley, 2007).

Another aspect complicating analyses of environmental costs is that food production systems keep changing; intensification and the use of genetically modified plants and animals are good examples. Change in the industry means that government and public perception and acceptance of farmed products are changing too. The rise in popularity of organic products, the controversy over the health and environmental effects of farmed salmon in some developed countries, the reluctance to use genetically modified fish in aquaculture, and the increased value being placed on native biodiversity are all examples of attitudes that are anything but static. In developed countries, cost may not be the most important factor: although consumers often express a preference for inexpensive food products, the rise in demand for organic products indicates that some people are willing to pay more for a product they perceive to be more environmentally or socially friendly. Therefore, there should be periodic reassessment of models and analyses that compare trade-offs between environmental impacts, consumer preferences and production efficiencies.

THE NEED FOR COMMUNICATION

The pace of technological and social change implies that good policies on the environmental costs of food production can only come about where there is good communication. Misconceptions concerning the impact of certain effluents, the overregulation of a sector because it is the most recent, the failure to appreciate the cost-savings of early prevention of adverse impacts, the failure to place adequate value on biodiversity and ecosystem services, and the changing nature of food production are all issues that demand the sharing of information. That information will need to be packaged for three key groups: policy-makers, farmers (including aquaculturists) and consumers. A key component of that information will be provided by the methods for economic and environmental analysis discussed in the following section.

COMPARISON OF THE EXISTING METHODS FOR ASSESSING ENVIRONMENTAL COSTS OF FOOD PRODUCTION

The workshop identified numerous problems that arise when one attempts to compare environmental costs of different food production sectors. These problems stem from:

- the many differences between terrestrial and aquatic environments;
- differences in patterns of ownership, e.g. terrestrial areas are often privately owned while aquatic areas are often common property;
- the huge diversity of farmed products;
- the need to choose a functional unit for comparison, e.g. kg of protein, energy, contribution to daily nutrient or energy requirements;
- the difficulty of translating impacts into monetary units;
- the diversity in farming systems within a given sector, e.g. feed-lot to free range livestock, and small-scale extensive to super-intensive aquaculture;
- the influence of management practices on environmental impacts and costs of production; and
- differences in terminology between sectors and disciplines, e.g. “sustainability” and “cost” have different meanings for ecologists and economists, while “water productivity” would be defined differently by fisheries biologists and water management engineers.

Nevertheless, valid comparisons can be useful to address local development and zoning concerns, global issues of sustainability and trade, and consumer preferences for inexpensive food produced in an environmentally sustainable manner. The workshop developed a general framework for assessing the environmental costs of food production (Annex 3). Although few comparisons have been reported, they can be done when the systems are well defined and data are available (Brooks, 2007; Brummet, 2007; Gowing and Ocampo-Thomason, 2007). Biophysical methods have a history of use and corresponding data on energy equivalents of certain activities that can be linked to methods such as Life Cycle Analysis (LCA) (Mungkung, 2007; Tyedmers and Pelletier, 2007) and material and energy flow analyses (Prein, 2007; Haberl and Weisz, 2007) to allow comparisons of different impacts or costs.

A wide range of methods has been developed in order to assess environmental costs of development (Table 1). Each has its own strengths and weaknesses. Because environmental valuation is often omitted in analyses of any of the food sectors, many of the “external costs” referred to earlier are presently not well accounted for in these methods (Barbier, 2007). In order to be useful to FAO and decision-makers, methods to assess environmental costs must not only include these externalities but should also be scientifically-based, comparable across different sectors, expandable to different scales, practical to implement and able to produce results that are easily understood and interpreted. Satisfying all these criteria will be difficult; trade-offs and combinations of methods will need to be made.

The workshop concluded that none of the existing methods captures all of environmental impacts and costs of food production. With the possible exception of Environmental Impact Assessment (EIA) and Cost-Benefit Analysis (CBA), few decisions can be made using a single method. However, many of the methods can and should be used together, and various combinations may be fruitful. For example, LCA and Material Flows Accounting (MFA) can first identify key sources of pollution, then environmental valuation and CBA can be applied to the specific environment or commodity to determine which development path to take.

Existing legislation often specifically mandates the use of EIA. Although EIA is better than nothing (and in many cases there really is no assessment at all) it may be inappropriate or incomplete in some circumstances. Risk assessment (RA, see Brooks, 2007) is another method that may also provide incomplete analyses. These two methods used alone usually do not include environmental valuation criteria, and it would be preferable to complement them with other methods that include multiple criteria and environmental valuation. There are some issues common to all methods: the need for accurate information, the problem of assigning values to un-marketed goods such as environmental goods and ecosystem services, and the problem of biased analysis.

TABLE 1
Comparison of methods for environmental cost analysis

Method	Linkages to other methods	Key attributes	Strengths	Weaknesses	Scientific rigour	Standardization of methods	Ease of application and communicability
Environmental Impact Assessment (EIA)	CBA, RA	Project-based, descriptive, site-specific	Public planning and transparent process; based on multiple criteria and can be used in sensitivity analysis; identifies hazards and impacts; allows redesign of project to reduce impacts.	Does not quantify trade-offs or effects; does not provide a single performance indicator for comparisons; problems with how to interpret data	Variable (very high to low); lots of uncertainty due to lack of data; often time-constrained due to development deadlines	High (e.g. Europe) but may vary across sectors, regions and in national legislation	Good; often figures prominently in decision-making
Risk Assessment or Analysis (RA)	Should underpin all other methods for hazard identification and understanding; widely used in toxicity analysis	Tool for understanding environmental processes	Contributes to better understanding of environmental flows and impacts; attempts to be quantitative but can also be qualitative; identifies hazards and impacts.	Relies on qualitative judgements and estimates due to knowledge gaps; limited comparative use (some risks apply to some sectors, others not)	Variable at present; quantitative measures need to be developed (environmental indicators)	High for procedural aspects	Good; formalized in legislation as decision-making tool
Material Flows Accounting (MFA), Mass balance, and Input/Output models (IO)	A first step towards more complete assessments using EIA, RA, energy analysis	Examines input and output of key materials; accounts for biological flows associated with economic activities; applicable to systems at many scales	Quantifies levels of inputs and outputs; can produce comparable information over time and space; used to improve ecological efficiency; well-known tool with standard protocols.	Does not reflect environmental effects; snapshot picture of flows at a specific point in time and place.	High	High	Very good
Energy analysis (EA)	Could be incorporated into MFA and used complementarily with CBA	Examines fossil fuel energy used in food production	Produces a single measure, which is a proxy for the other components of the sector, for comparison; good history of analysis and data; comparable at all levels.	Presents an incomplete picture of the sector; relevance is questioned because energy (fuel) has a market value that will change; does not account for the environmental effects of fuel consumption.	High	High	Good; few decisions are made on EA alone
Human Appropriation of Net Primary Productivity (HANPP)	Can be used with MAF, EA, EF	An indicator of environmental effects based on changes in ecological flows of trophic energy caused by land use	Aggregates information into a single statistic for comparison, e.g. land use change; can examine economic causes for change; ecologically focused indicator; comparable at different scales, regions and across time	Not well developed for aquatic environments; does not describe impacts and does not address specific local ecological changes; limited expertise for HANPP analysis; in some cases analysis of secondary or tertiary productivity would be more informative	High	Medium	Easy to communicate; difficult to interpret

Method	Linkages to other methods	Key attributes	Strengths	Weaknesses	Scientific rigour	Standardization of methods	Ease of application and communicability
Ecological Footprint (EF)	LCA could be used as an input (aggregation of multiple units used in LCA); could also be used to present MFA results	Method to aggregate impacts into a single statistic to address eco-efficiency of human activities; converts all impacts to a measure of area needed to support a given activity	Provides a single indicator for comparison; can be applied to many levels and scales (e.g. a footprint for an individual to one for a national economy); provides accumulative/aggregated effects	Does not include all flows. Applications to food production systems are not obvious; method does not deal well with water; does not provide specific information about impacts or effects; does not address specific effects in specific environments; aggregated statistic treats all environments as homogenous and equal	Low	Low	Easy to communicate, but statistic is often misused or can be mis-interpreted; application is constrained by knowledge gaps on environmental differences among habitats
Life Cycle Analysis (LCA)	MFA, EA, for more elaborate EIA	Examines a range of impacts of food production systems; production-oriented environmental impact assessment, with an earth-to-earth (or cradle to grave) perspective, multiple criteria analysis; quantifies potential contribution to global impacts	Allows hazards to be identified and prioritized; can build on previous work/products/processes/ alternatives and different scenarios; basic method to develop eco-labelling criteria to support purchasing decisions for consumers (ISO 14020 series); can provide policy-relevant insights	Large data requirements; some studies use different functional units; results address global impacts at expense of local impacts; some indicators may not be appropriate for specific cases; results are not directly applicable unless conducted for the specific comparison; some standard impact categories may not be relevant to food product systems, thus need to develop new ones	High	Very high, e.g. ISO 14040-14043; streamlining LCA will reduce data requirements and facilitate comparisons; specific impact categories associated with food production not well standardized;	Can "streamline LCA" for specific comparisons; communication on multiple criteria may be difficult;
Cost benefit analysis, including environmental costs (CBA)	EIA, RA, EA, EFA, LCA, MFA	Uses valuation techniques, for non-marketable goods, e.g. contingent valuation, willingness to pay, hedonic pricing are techniques used in CBA to compare net result of activities of different sectors	Can compare production systems; can be very inclusive of many types of information, including non-marketable goods; long history and familiarity with concept; decision-makers need and want to know this information; C/B ratio and Net Present Value provide aggregate measures of the relative performance of various production systems	Environmental values hard to determine; ecological function changes hard to predict; often environment is not included; normally long term sustainability issues not addressed; discount rates are arbitrary and may be political; loses information during aggregation	High	Standardized in theory, but often not in practice	Results easily communicated and understood; including valuation of environmental goods and services and non-marketable goods makes application difficult

The workshop noted that application or interpretation of the results of any of these methods could be affected by development context. A developer who is responsible for cost analysis certainly has a stake in the results of the analysis. However, bias is spread between all parties (including academics industry and conservation groups) – which is why methods and their environmental, social, and economic results need to be reviewed by a multidisciplinary team.

IDENTIFYING THE MOST IMPORTANT IMPACTS

The methods provide a basic framework for analysis and impact assessment. An initial step in the framework is the identification of the hazards or adverse impacts for the sectors where valuation of environmental damage is to be compared. Those hazards or impacts need to be described in terms of probability and consequences. It is clearly important to choose impacts that will provide the most useful comparative analysis. Impacts can be classified using the following criteria (Brooks, 2007):

- amount of adequate data to address the issue;
- probability of the hazard or impact occurring;
- consequences if it does occur; and
- level of confidence in the analysis, i.e. level of uncertainty.

Using these criteria, a suite of potential hazards can be narrowed down for comparative analysis. This is similar to standard procedures in risk analysis.

KIND AND MAGNITUDE OF ENVIRONMENTAL COST

Environmental impacts produce consequences or effects that can be translated into costs when they result in a loss of welfare (Table 2). This allows for their incorporation into the analysis of the financial benefits or losses of the activity they are related to. Environmental economists classify such costs as follows (Knowler, 2007):

- private costs (cost of the damage to the activity itself, e.g. damage to production);
- external costs (primarily to the environment, including abatement costs, costs of adapting to external costs, residual damages after control measures are in place);
- user costs (damaging for future uses); and
- rehabilitation costs.

TABLE 2.

Terminology

Term	Definition	Example
Impact	The force of the impression of one thing on another	Amount of Nitrogen discharged from a farming system
Consequence or effect	Something produced by a cause or necessarily following from a set of conditions	Decrease in fish diversity caused by increased Nitrogen levels in the watershed
Environmental cost ¹	Loss or penalty incurred especially in gaining something. Environmental costs are those losses resulting from environmental damage	Decrease in Total Economic Value (Brugère, 2007) of the local water body as a result of change in fish abundance (change would include decrease value of any fishery, i.e. direct value, and any decrease in the indirect value, e.g. aesthetics, ecosystem service, or culturally important species)
Sustainability	Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. ² Definition has been modified to stress that economic and social factors are now key elements of the concept	

Source: from Merriam-Webster Online³ except where noted

¹ Theoretically, this should be “societal costs”, i.e. costs to the society (or people) as only people can value things or experience a loss in welfare and well being through environmental degradation; it can be understood as the costs resulting from environmental damage

² UNGA, 1987

³ <http://www.m-w.com>

In comparative environmental cost analysis it is important to define the scale and scope of the system analyzed, including outstanding issues and the overall purpose of the analysis. Results of analyses need to be placed in the proper perspective, i.e. the results need to be stated in terms of real changes to the environment, so that the consequences of different comparisons can be estimated (Knowler, 2007). Simply reporting the presence of X kg of Y nutrient in Z environment is meaningless unless the environmental consequences of the inputs are specified (Brooks, 2007). Analyses need also to include information on the consequences to the environment and a valuation of the resulting loss of ecosystem products and services – a complicated task that is rarely undertaken.

CHOOSING UNITS FOR COMPARISON

Comparative analysis requires normalization of the unit of assessment (Brummet, 2007; Mungkung and Gheewala, 2007) as well as the scope of the consequences to be contemplated. For example, LCA usually examines global consequences and therefore may be unsuited to determining impacts on a specific ecosystem. Analyses have often reported production as simple kilograms of product, but a kilogram of shrimp has very different nutritional and monetary values from a kilogram of chicken and corn. Some candidate units that these data could be converted to include edible output, crude protein or digestible energy equivalents (Brummet, 2007; Mungkung and Gheewala, 2007).

However, farming is above all a business that produces food to generate *money*. Farming systems that produce a high value product may be able to produce less while meeting economic objectives (thereby using less inputs); they may also be able to meet production objectives using intensive systems with minimal effluents, thereby having less environmental impact than extensive systems grown over a large area to produce a large amount of low value product. When comparing such sectors, conversion of product and costs into monetary units may be advisable. It is also important to keep in mind the overall objectives of the farming system, especially when comparisons of environmental costs are being made. For example, farming can increase food security, but the money it also generates can buy more food as well.

TRADE-OFFS AND FAIR COMPARISONS

Many things cannot be usefully (or fairly) compared because of the differences in the commodity or the environment in which it is produced. Thus comparing the environmental costs of producing beef from a feedlot in Chile with production of tilapia in Thailand would be pointless for national policy-makers, but might be relevant for consumers who wish to know which production system has a greater influence on climate change.

In comparing aquaculture and livestock, the feed used by both sectors has a strong influence on their environmental costs. For example, the environmental costs of salmon farming become high when the costs of catching fish and processing them into fishmeal and fish oil are included, because wild populations of fish are reduced and energy expended in catching and processing them. Similarly, the water and fertilizer requirements for beef production are high when the costs of producing feed are included because the water is lost to other uses or ecosystem services, and production of fertilizer expends energy.

Comparisons should facilitate the kinds of real choices policy-makers and the consumer need to make. Decisions at the national and local levels will justifiably be based on societal needs, priorities and preferences (CBD, 1994). There will usually be trade-offs between economic gains and environmental costs and therefore a need for multicriteria decision analysis methods that prioritize benefits and costs (Mungkung and Gheewala, 2007). In such analyses, methods that include a suite of characters (e.g.

LCA, MFA) rather than aggregated single measures or indices (e.g. ecological footprint and CBA) will generate more accurate comparisons.

INFORMATION AND COMMUNICATION NEEDS

Comparative analyses will require extensive information on farm production and effluent, material flows, prices, biodiversity affected by farming, ecosystem products and services and economics. Some of this basic information is available free of charge over the internet or by request, for example the FAO databases on livestock, fisheries and aquaculture production, land use, and food balance sheets. FishBase⁴ contains information on most of the world's fishes. Other information is available for a fee, e.g. Ecoinvent⁵ or satellite data. Information on local biodiversity or production on private farms is often non-existent or difficult to access; for example, information on illegal farming practices such as the use of banned drugs is crucial to impact analysis, but by its very nature is difficult to obtain. There is usually a wealth of useful information in government files or in older literature that is often forgotten or not published in popular or scientific media; some comparisons could be made through specific desk studies using this grey literature.

A distinction must be made between simple lack of data and the uncertainties that are either contained within the data that do exist or inherent in the task of making predictions about far-flung biological effects. An example of the former would be information gaps on the carrying capacity of coastal ecosystems, or levels of effluent from various types of farms. An example of the latter is in the basic values of environmental goods and services. This is partly due to differences of opinion on how to assign values to intangibles such as endangered species and ecosystem services; nevertheless, data are accumulating to indicate that these services are very valuable (Barbier, 2007). Information from biophysical analysis does exist and there are additional sources of information that can be used in evaluating impacts and costs. More fundamental uncertainty would surround the long-term ecosystem consequences of environmental impacts, the area of uncertainty judged by the workshop to be the most serious.

It should be recognized that a "complete" set of all the relevant scientific information will never be available and that comparative analyses may need to be done with the best at hand. We already have general knowledge of production systems, their probable outputs and possible effects (Brummet, 2007) and should not let the incompleteness of such information stand in the way of analyses of food production sectors.

After analyses have been completed, results will need to be communicated to a variety of groups. These include:

- policy-makers (to establish environmental regulations, environmental impact mitigation measures, and for zoning of aquaculture/agriculture);
- farmers (to help plan production, understand and comply with environmental regulations, and implement good management practices); and
- consumers (to help make informed choices on food production and drive appropriate policy and farming practices).

Each of the above groups has different backgrounds, mindsets and agendas, so the language and vehicles used to communicate research results will be different for each.

⁴ <http://www.fishbase.org>

⁵ <http://www.ecoinvent.ch>

A potential role for FAO

It is only recently that FAO in general, the Fisheries and Aquaculture Department and the Animal Production and Health Division⁶ in particular, has begun to analyse the environmental costs of food production. While environmental impacts continue to be studied and separate work has been started on aquaculture economics, the actual valuation of environmental goods and services, and the merging of these fields to present a comprehensive picture of an industry or to allow comparisons among sectors, has not been undertaken. It is abundantly clear from the above summary of workshop findings that work in this multidisciplinary and multisectoral field would help make food production more sustainable; it is also clear that it will not be easy.

FAO is well positioned to provide advice on many aspects of this emerging field. Participants of the workshop recommended that FAO assist in advising members about the known impacts of all food production systems and facilitate access to methods, information, analyses and policy that would help minimize adverse impacts. Some specific examples of potential FAO actions include:

- **Facilitate the development of analytical methods.** While methods exist for environmental impact assessment and environmental economics, these disciplines have not been merged to allow environmental cost comparisons between sectors. The methods listed in Table 1 can be used together with specific data sets to make such comparisons. FAO can help promote the use of these combinations of methods and help decision-makers incorporate outputs of the analyses into national policies.
- **Improve awareness and use of the methods of environmental valuation on the part of researchers outside the field of environmental economics.**
- **Establish a framework for data collection and build standardized databases while promoting access to those that exist.** FAO could be a repository of relevant information that is standardized to facilitate assessment and comparison of environmental costs. As a first step, the workshop recommended that FAO collect relevant and existing bibliographic information and data sources and make the information widely available.
- **Provide guidance on incorporating environmental cost analysis into the ecolabelling of fishery and aquaculture products.** FAO has ongoing work on labelling of fishery and aquaculture products, including guidelines on marine fishery products (FAO, 2005). This work should be extended to include environmental costs.
- **Demonstrate recommended methods by using existing data from higher profile activities.** FAO Fisheries and Aquaculture, Agriculture and other interested Departments could develop case studies and compile a multidisciplinary team to carry them out. This would also include evaluation of methods and comparison of results using different methods. Such studies will require economic and human resources but will have the added benefit of improving capacity and expertise within FAO.
- **Develop technical guidelines on environmental cost analysis and comparisons in support of the CCRF.** Such guidelines could focus on the aquaculture sector

⁶ Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. and De Haan, C. 2006. Livestock's long shadow – Environmental issues and options. FAO, Rome.

with its diversity of species and farming systems, but could also extend to comparisons with other food production sectors including capture fisheries.

- **Improve policy to include environmental costs of food production.** Current policy often does not take into account the full costs of food production. FAO could help expand the policy discussion to include environmental valuation, social impact and environmental impact assessment. Policy or legislation could be modified to extend required analysis beyond simple environmental impact assessments by linking EIA with other economic methods.
- **Provide leadership by encouraging governments and industry to think and act holistically.** Beyond the farm and local watershed there is a lack of awareness and knowledge of impacts and associated costs that accumulate on a regional or international level.
- **Improve communication and awareness of the value of environmental cost analysis.** The value of ecosystem goods and services and other externalities are often not considered in evaluation of food production sector.
- **Continue to stress the value of good management practices in terrestrial and aquatic farming systems.** Impacts of individual farms will depend on farm management practices. Proper farm management will be one of the single most effective measures to reduce environmental impacts and costs. Incorrect application of therapeutics, overfeeding, careless waste-disposal and improper containment of animals or fish will increase adverse impacts regardless of the system being used.

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Annex 1 – Agenda

24 APRIL				
Evening	Arrival of experts and registration			
25 APRIL				
08:30	Registration			
09:00	Session 1	Opening		
		Welcome by Vancouver Aquarium	Heather Holden	
		Welcome by World Fisheries Trust	Brian Harvey/ Penelope Poole	
		Welcome by FAO	Devin Bartley	
		Objectives of workshop	Devin Bartley	
10:00	Coffee			
10:30	Session 2	Environmental costs and development		
10:30		FAO Fisheries perspective	Devin Bartley	
11:00		Agriculture, Livestock and Sustainable Development	Pierre Gerber	
11:30		Environmental economics	Cécile Brugère	
12:00	Session 3	Impacts and valuation		
12:00		Environmental economic approaches for the comparative evaluation of aquaculture and other food production systems	Duncan Knowler	
12:30	Lunch			
14:00	Session 3 cont.	Impacts and valuation		
14:30		Valuation of Ecosystem Services Supporting Aquatic and Other Land-Based Food Systems	Edward Barbier	
15:00		Use of Life Cycle Assessment (LCA) to compare the environmental impacts of fisheries, aquaculture and agri-food products	Tam Mungkung	
15:30		The potential use of the MEFA framework to evaluate the environmental costs of agricultural production systems, and possible applications to aquaculture	Helmut Haberl	
15:30	Coffee			
16:30	Session 4	Case studies		
16:30		High input farming: Salmon and cattle farming	Kenneth Brooks and Doris Soto	
17:00		Livestock	Francisco Salazar	
17:30		Low input farming: carp and poultry farming	Mark Prein	
18:00	Close			
26 APRIL				
09:00	Session 5	Case studies		
09:00		Exploratory analysis of the comparative environmental costs of shrimp farming and rice farming in coastal areas	Patricia Ocampo-Thomason/John Gowing	
09:30		Comparative Analysis of the Environmental Costs of Fish Farming and Crop Production in Arid Areas: a Materials Flow Analysis	Randall Brummet	
10:00		Biophysical sustainability accounting in aquaculture: Insights from current practice and the need for methodological development	Peter Tyedmers	
10:30	Coffee			
11:00		General discussion		
11:30	Session 6	Working groups		
		Working groups	Organization and goals of working groups	Secretariat

12:30	Lunch			
14:00	Session 6 cont.	Working groups	Break into working groups	
16:30			Report of working groups and plenary discussion	Working group secretary
17:30	Close			
27 APRIL				
Morning	Session 7	Working groups		
Afternoon	Field trip	West Vancouver Laboratory		
17:00	Session 7 cont.	Working groups		
28 APRIL				
09:00	Session 8	Working groups resume to draft report of working group		
11:30		Plenary discussion and adoption of working group report		
13:30	Close			

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Annex 3

Proposed framework for case studies that examine the environmental cost of food production

Valid comparisons between food production sectors or within a sector can only be made when their scope and objective are well defined. There could, for example, be different approaches to the analyses depending on whether the comparison is at the local or macro level of development. Here we examine the elaboration of a framework for analysis and decision-making using a case study that compares tropical marine shrimp farming with rice production. This type of analysis is required when zoning questions are involved, i.e. when it is necessary to choose between activities that compete for the same space (shrimp pond vs rice field). At the local level, case studies like this one could thus help regulators choose between different zoning options – in this case deciding how much area is dedicated to shrimp farming or to rice production.

A three-part framework for analysing local level case studies is proposed. The framework includes: *definition* of system boundaries for comparison; *assessment* of environmental impacts; and *evaluation* of economic and environmental costs.

Definition of system boundaries for comparison

A broad approach should be taken to ensure that upstream and downstream flows, as well as inputs to and outputs from the system are included in the analysis. The production of feed and seed used by the system is particularly relevant to the definition of boundaries, and impacts related to their production or collection should be traced back to the source and the associated environmental costs included in the analysis. For example, wild shrimp larvae collected from remote areas should be considered in the analysis; if larvae were produced in a hatchery from domesticated broodstock, there would be different environmental impacts and costs.

Assessment of environmental impacts and effects

The techniques appropriate for assessing the environmental impacts of the production activity are RA + LCA + EIA. It should be noted that EIA is limited to the assessment of impact but does not quantify the ecological consequences of this impact. For example, EIA will quantify the amount of a pollution discharge (impact), but not the resulting loss in biodiversity (effect or consequence). Since the end result is a modified environment which is not as good as it used to be before the impact, compensation or reduction in pollution effects are likely to be demanded; both measures depend on evaluation (see below).

Evaluation of economic and environmental costs

Once the impacts and effects of a given production system are determined, environmental cost analysis would evaluate the actual costs of those environmental effects for

economies and for individuals. CBA would be applicable here but its results will depend on the system boundaries defined, and on the perspective from which benefits and costs are accounted for (the “accounting stance”). For example, the private and public accounting perspectives differ with regard to the extent to which the pricing of products reflects market factors or social and environmental costs.

Relevant categories of costs to be considered here have been defined by Knowler (2007) and include:

- *external* costs, primarily to the environment, such as abatement costs, costs of adapting to external costs, and residual damages after control measures are in place;
- *user* costs such as local social costs corrected to account for overall losses of welfare incurred from environmental degradation; and
- *rehabilitation* costs based on the life of a shrimp pond or rice paddy and their rehabilitation them to pre-farming conditions.

The framework outlined above can be used to decide between rice or shrimp production in a specific location. It could also be used in similar situations where production systems compete for the same space/land or where specific impacts are to be avoided.

Rice and shrimp are difficult commodities to compare, and the scenario described above looks at comparisons from the perspective of land use. Comparisons could also be made for other commodities using different criteria, such as substitutability of products in the market place. For example wild-caught salmon retailing at CAN\$30/kg could be compared to farmed salmon at CAN\$20/kg to examine how price influences consumers; farmed catfish and poultry would be another comparison of similarly priced items. The environmental impacts may be different depending on the amount of product purchased by consumers.