Aquaculture and Global Changes

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Aquaculture, a booming sector, now provides almost half of the fish and shellfish on world markets. Climate change will certainly affect aquaculture productions, however the scale is not presently quantifiable given the uncertainty of global models. Impacts will vary by region and type of production. Adaptation of production systems is potentially feasible through actions of all stakeholders involved. Direct impacts will be related to changes in production conditions in freshwater, brackish water and marine environments. The main indirect impact will probably be related to the dependence on an exogenous food supply for the cultivated organisms. However, the negative impacts (eutrophication of inland waters, ocean acidification…) and positive impacts (aquaculture activities in colder areas, better growth of farmed organisms…) could balance out.

At present, aquaculture is booming while global fishing statistics remain stationary. This ancient activity, close to agriculture, consists of animal or plant production in aquatic environments. It has been growing exponentially since the 1980s and now supplies almost more than half of the fish and shellfish for the global market.

It is clear that aquaculture will be severely impacted by climate change. Various publications on this issue state that the forecasted global environmental conditions will affect the aquaculture sector. It is important to note, however, that all the predicted impacts will not necessarily be negative. Indeed, climate change should potentially create development opportunities for countries or regions where current production is low.

In aquaculture, unlike fisheries, human intervention is present throughout the life cycle (with certain exceptions). This therefore allows actors to potentially take actions to adapt to climate change. The success of the adjustments made will depend upon the severity of environmental conditions, the costs and coping capacities of the actors in the field but also upon national and international decision-makers.

DIRECT RISKS OF GLOBAL CHANGE ON AQUACULTURE

In 2012, Global aquaculture production reached a record high of 90.4 million tonnes (fresh weight equivalent; valued at 144.4 billion US dollars), 66.6 million tonnes of which was edible products (137.7 billion US dollars) as well as 23.8 million tonnes coming from aquatic plants (mainly algae; valued at 6.4 billion US dollars). Climate change will threaten certain aquaculture activities but the extent of these impacts cannot yet be quantified in the absence of global models that can take into account all direct and indirect effects of global changes. However, one thing is for certain: there will be consequences on production, which in turn will affect humans. The global demand for fisheries and aquaculture products is the largest of all animal food products (26.85 to 27.45 million tonnes vs. 20.38 to 21.99 million tonnes in 2009). Moreover, aquaculture products are an important source of nutrition for developed and developing countries (viz. a contribution to food security), and represent a source of income for all communities, regardless of the standard of living. Among the impacts of climate change that will affect aquaculture, direct impacts will mainly be related to modification of production conditions. Average production will thus be affected, not only in the marine environment (Table) but also in inland areas (fresh and brackish waters) where the majority of global production is concentrated. These inland areas are more sensitive to changes, in fact, it is expected that global warming and the resulting global surface water temperature rise will impact aquaculture more significantly in these areas than in the marine environment (due to the modification of the optimal temperature range of organisms that are currently cultivated).

Nevertheless, the negative and positive impacts could balance out. Amongst positive impacts of climate change, scientific models predict an expansion of aquaculture activities towards cooler parts of the world, which will have longer thawing periods, better growth rates of cultured organisms,

Table - Synthesis of climate change impacts on oceans and coastal areas of climate change that will affect aquaculture (from Allison *et al.*, 2011):

- Change in temperature
- Change in salinity, density and stratification of the oceans
- Change in ocean circulation and coastal upwellings
- Rising sea levels
- Land-Ocean interactions
- Changes in natural climate variations (ENSO)
- Increasing frequency and severity of extreme weather events
- Ocean acidification and changes in seawater chemistry
- The timing and success of physiological processes, spawning and recruitment
- Primary production
- Changes in the distribution of marine life
- Changes in abundance of marine life
- Phenomenological changes (*i.e.* duration of lifecycles stages)
- Invasion of species and diseases
- Changes in regime and extreme events

and an improved capacity of food conversion for the latter. However, these positive effects will be concurrent with negative impacts (*e.g.* increased eutrophication in inland waters, ocean acidification). In both cases (negative or positive effects), production methods must be adapted.

DIVERSE VULNERABILITIES AND DIFFERENT TYPES OF PRODUCTION

Aquaculture is not practiced uniformly throughout the world. This heterogeneity must be considered in order to obtain for a meaningful assessment of the potential impacts of climate change. Climate change is likely to occur with differing intensities depending on the geographical position, thus resulting in different impacts. It is therefore necessary to keep in mind that aquaculture exists mainly under three climatic regimes (tropical, subtropical and temperate), in three types of environment (seawater, freshwater and brackish water) and covers a wide range of taxa. In terms of different taxa, it is clear that some species are more tolerant than others to changes and that some will be more likely to undergo specific changes (for example, ocean acidification should essentially affect calcifying organisms such as bivalves whose production was 14 million tonnes in 2012).

Asia alone accounts for approximately 90% of global aquaculture production, China being the major producer with a fish production accounting for nearly two-thirds of world production and contributing significantly to the nutrition of the Chinese population. Asian aquaculture production is characterized by a diversity of species and production systems used. However, inland aquaculture (fresh or brackish water) still dominates the production of the continent whereas fish mariculture is underexploited, unlike some other countries or regions that almost exclusively rely on this type of aquaculture (*e.g.* salmon farming in Norway).

In Asia, direct impacts only related to global warming are likely to be beneficial, resulting in better growth rates of cultured stocks. However this should not conceal the impacts of climate change on water availability, worsening weather conditions such as extreme rainfall, increasing eutrophication, sea level rise and stratification of the oceans.

The intensification of aquaculture in certain areas (namely Asia and tropical zones) motivates the development of adaptation strategies to mitigate the impacts of climate change in these areas, especially if the expected difference between demand and supply of aquatic products for consumption needs to be compensated through aquaculture.

Among the different global changes, one is regularly highlighted as its impacts are already being felt on shellfish production on the West Coast of the United States: ocean acidification. Associated adverse effects are, for the moment, well documented for two key product groups in aquaculture: bivalves and crustaceans. The increased presence of dissolved CO_2 in seawater can impact marine life at 3 levels:

1. The limitation of available carbonates, mainly affecting calcifying organisms.
2. The increase in H^+ ions in the water resulting in decreasing pH – *i.e.* acidification of surrounding environment.
3. An increase in the partial pressure of CO_2 in organisms, which would result in a hypercapnia.

Example - What will the impacts of climate change be on the Chinese aquaculture industry?

In terms of risks, the latest IPCC forecasts for East Asia are:

- Average annual temperature: + 3.3°C by 2100
- A possible increase in total annual precipitation
- Increased climate variability

According to several authors the negative impacts on fish production will be: heat stress, increased oxygen demand, aggravation of the toxicity of pollutants, higher incidence of fish diseases. More generally, production systems will be affected by a decrease in the solubility of oxygen in a warmed ocean, eutrophication, stratification, uncertain water supplies and salt water intrusion due to rising sea levels.

The impacts on the production of shellfish and therefore the socio-economic impacts will be significant. In 2012, although farmed shellfish only accounted for a volume of 9.7% (6.4 million tonnes) of the total aquaculture production for human consumption, it represented a value of 22.4% (30.9 billion U.S. dollars). Mollusc production however (15.2 million tonnes), although producing more than twofold that of crustaceans. There have been attempts to adapt to these impacts of climate change on different production systems including the use of cages or closed systems.

INDIRECT RISKS OF GLOBAL CHANGE ON AQUACULTURE

The impacts of climate change are not just limited to the environment of the production site. The conditions will foster, in particular, the remobilization of contaminants that are currently non-bioavailable, the emergence of diseases, increased toxic algal blooms, the disappearance of key species (*e.g.* for phytoplankton for filter feeders) or conversely the occurrence of harmful species in the culture medium.

However, the main indirect impact of climate change on aquaculture will o doubt be linked to the dependence of aquaculture on external food supplies. 70% of the world's aquaculture production depends on the supply and production of raw materials from agriculture and industrial fisheries. These external inputs will be affected by climate change and will therefore have an indirect impact on the aquaculture industry.

The negative impacts are likely to be felt most keenly in the temperate regions where fish farming is entirely based on carnivorous species but they should also affect other areas, as the vast majority of countries involved in aquaculture production uses fishmeal.

Recent changes in the distribution and productivity of a number of fish species can be linked with a degree of certainty to regional climate variability such as the El Nino-Southern Oscillation (ENSO). There is a strong relationship between trends in fishing and climate trends.

Moreover, the increased frequency and intensity of extreme weather events are likely to have a major impact on fisheries production and thus indirectly on aquaculture.

As the indirect impacts on aquaculture activities and/or productivity are subtle, complex and difficult to identify, it is challenging to develop measures to adapt to climate change. A close and interdependent relationship exists between fisheries and aquaculture. This relationship is illustrated by the contribution of certain inputs used in aquaculture by the fisheries industry, including fishmeal, fish oils and to a lesser extent, juvenile organisms. The impacts of climate change on fisheries worldwide will therefore have effects on the aquaculture industry.

CONCLUSION AND RECOMMENDATIONS

There are or will be solutions to help aquaculture adapt to climate change. The resilience of aquaculture *sensus lato* to face unexpected shocks has already been proven. In particular, this can be illustrated by the short time it took for most of Asia to change the species of shrimp when one species had been severely affected by a virus (with a regionally significant dispersion) or by the speed at which some countries affected by devastating weather events very quickly resumed normal production.

Despite these advantages, the aquaculture sector must prepare itself. Advances and development of models and long term predictions are needed to address the multiple and complex impacts of climate change. Moreover, progress in the selection of species that are better adapted to cope with predicted conditions (to multiple stressors) along with a conceptualisation of adaptation solutions for cultivation practices are needed.

Additionally, it is important that the development of aquaculture practices should be as environmentally friendly as possible, involving the efficient use of resources like water, land, energy and nutrients in agricultural systems. Improvements in the formulation of feed are in progress and should ideally include ingredients derived from alternatives marine resources (such as by-products from fish filleting factories). More environmentally friendly aquaculture could also utilize a certification program but even though these programs do exist, the concept of sustainable aquaculture is still under debate. However, the current situation is not as bad as what has been relayed by the media. Even though the current production practices are far from perfect, they are generally more efficient in terms of product produced per unit of food input than other land-based animal production systems. Furthermore, the amount of environmental degradation caused by aquaculture is less than most agricultural counterparts. These conclusions in the media are almost always based on high-value aquaculture products such as shrimps and carnivorous fish like salmon, hence leading to false ideas among the public, planners, developers and investors. In reality, the vast majority of aquaculture is still dependent on fish and shellfish situated at the bottom of the food chain. Moreover, macroalgae are also produced and can potentially act as carbon sinks, thus contributing to carbon sequestration.

Finally, although many uncertainties remain concerning the magnitude of climate change impacts on aquaculture and on the sector's adaptability, aquaculture will undoubtedly be affected. Action must therefore be preventively taken to allow the continuation of this activity upon which the world's population is becoming increasingly dependent.

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