CMFRI

Winter School on
Impact of Climate Change on Indian Marine Fisheries

Lecture Notes

Part 2

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CLIMATE CHANGE AND ITS IMPACT ON AQUACULTURE

35

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Introduction

The aquatic environment will respond to climate changes in ways that are as equally significant as the responses of the terrestrial and atmospheric environments. The changes may be more gradual and less apparent than those taking place in the atmosphere, because of the ability of the oceans and large water bodies to absorb and distribute heat. Therefore, fluctuations about the mean temperature will tend to be smaller than in the atmosphere. By the same token however, the aquatic ecology will be less tolerant to wide temperature ranges than its terrestrial counterparts, and the rate at which natural habitat changes will challenge the adaptive capacity of species.

Little research has been done on the possible impact of temperature rise on aquaculture, possibly because of the inertia of the seas and lakes to temperature change, possibly because of the potential benefits of increased temperature on growth rates, and possibly because the climate change issue has not really emerged on the industry's radar screen. Aquaculture has been assuming greater importance over the last twenty years, and that importance is likely to increase dramatically as the dual effect of reduced catches in the commercial fishery and the improvements in aquaculture technique take effect. Temperature changes will have a direct impact on the species suitable for farming in any specified area and will indirectly influence other factors such as oxygen, pests, and the occurrence of toxic algal blooms.

Climate change will bring social changes, as new business opportunities open up and other industries disappear. Demographic changes, the development of new infrastructures, market development, the creation of new jobs and the disappearance of old ones are all possible consequences.

Global warming may also lead to sea level rise, which will gradually impact some types of aquaculture, although the fluctuations of water level in freshwater lakes due to changes in precipitation may prove to be more troublesome. Increasing extremes of weather patterns and storms will be another hazard to coastal industries. Storm surges, waves, and coastal erosion are likely to have a larger effect than the rise in mean high water levels.

The purpose of this document is not to be definitive in the forecasts and/or solutions of the potential impact of climate change. Such confidence in the future will require more study and research than has yet been undertaken. The document does try to open up the discussion of possible scenarios which the industry and operators themselves can enrich from their own experience and knowledge.

Climate change and its impact

Temperature changes

The temperature of the water in which an aquaculture facility will operate is an important aspect of site suitability. In some cases the expected temperature ranges at a site impact directly the decision to proceed with a facility. For example, the temperature ranges in which a given species of fish can survive is, in general, more restrictive than those of farm animals on land, and an anticipated change of a few degrees may mean the difference between a successful aquaculture venture and an unsuccessful one.

Each species cultured has growth optima for temperature. The health of the fish stock will be more resilient in the range of temperatures preferred by the species, as the stress levels and vulnerability of the individuals to disease will be reduced.

It is not only the fish species themselves that are susceptible to temperature ranges. The range of fish pests and parasites will also be restricted by temperatures and warmer waters will inevitably mean an increase in the incidence of outbreaks of unwelcome infections.

Temperature variations, again of a range of only a few degrees, can also have indirect implications for an aquaculture facility. A temperature rise can lead to plant production in an area that will cause oxygen depletion. Perhaps of even more serious concern would be an increased incidence of harmful algal blooms that release toxins into the water and generate fish kills. Caged fish are more susceptible to these types of occurrences than their free brethren that have a better chance of avoiding contaminated waters.

Temperature rises also have positive aspects. Growth of the stock within the optimum range is also linked to water temperatures, although probably less so than in the wild fishery. In the natural environment food availability is linked to productivity, which may also be partly dependent on temperature. For the case of aquaculture, the food supply is controlled and the effect of temperature on metabolic rate and the scope for growth is the major factor.

For aquaculture in reservoirs and freshwater ponds, the impact of temperature will likely be substantially more serious than in marine locations. The thermal optima for cultured species are pretty well known. It could be assumed that an enclosed water body will be subjected to higher temperature ranges, a greater degree of eutrophication and so possibly be more quickly influenced by the atmospheric climate changes. The availability of natural nutrients and production may also be altered by changes to lake circulation patterns, but the result of such changes will vary from ponds to ponds.

Water levels

The predicted rise in mean sea level due to climate change is one of the more certain outputs of climate change models, but it would take place over a relatively long time scale. It can be expected that this change will be accommodated within the normal operational cycles of an aquaculture facility, for example in the replacement of longer moorings etc. in the normal maintenance cycle.

In a few cases changes to the mean sea level may be critical in terms of tidal currents, but such cases would be rare and in any event the changes would be likely more serious if it were a fall in sea level rather than a rise.

For inland waters, climate change will bring alterations to the evaporation and precipitation cycles that may well be much more serious and take place much more rapidly than for the case of mariculture. Although one may be able to predict temperature rise due to climate change, the evaporation and precipitation will be much more variable and difficult to forecast. The former will depend on cloud cover and windiness in addition to temperature, whilst the precipitation climate is not only expected to change, but may increase or decrease depending on the region concerned. The input to a reservoir system will depend also on intensity, with higher runoff associated with heavier rainfall. The output from climate change models is perhaps adequate to forecast the direction of effect, but computing technology and modeling limitations do not now permit the models to be run at a watershed scale.

Reservoir levels can and will vary at a faster rate than sea level. A rise or fall of tens of feet may occur within a decade, possibly leading to situations where relocation is impossible. Freshwater aquaculture facilities which maintain their water levels artificially, will of course be impervious to the natural variation and the major concern will be one of water supply.

Natural calamities

Although difficult to quantify, the frequency and severity of extreme weather events seems to have increased over the past decade. Indeed, these increases are projected by global climate models. The rise in the numbers of cyclones, for example, is real, as are the catastrophic floods and droughts. Instability in the climate system must be considered as one possible cause of these events and, therefore, the likelihood of even more unsettled and extreme weather in the future is a legitimate concern.

For the aquaculture industry, increased storm conditions would result in more damage and additional losses, both costly to operations. Many coastal processes, such as sediment transport, take place mostly during high energy events (storms). An increase in storm activity may therefore initiate bottom changes, erosion or other events that have an impact on a facility outside the direct exposure to increased wind and wave activity.

Design characteristics for cages, moorings, jetties etc. will need to be extended to include the possibility of higher and more frequent weather activity. The potential for damage to shore-based facilities such as hatcheries, ponds and pens is also serious.

Facilities may also be threatened by high water events due to storm surges associated with severe storms, and high waters are accompanied by greater vulnerability to wave action and currents.

Environmental factors, impacts and mitigation

Associated social changes

Although not directly related to climate change, the public perception of the environment will be heightened by the perceived changes in climate. The realization that anthropogenic effects on the environment are real will be reinforced by the arrival of changes due to the greenhouse warming of the planet. It would be expected that this increased awareness of the interaction between society and the planet will lead to more stringent regulation and a more precautionary approach to management of the environment. At the same time, quota reductions in the capture fisheries are having major impacts on the economic viability of coastal communities outside major centres of employment. Aquaculture provides one on the few alternative sources of employment generally available. The interaction of these two factors in setting public policy has yet to play out.

The impact of changes on the industry will be lessened by some foresight in the planning and selection of sites. Genetic manipulation of stocks may be able to offset the restrictions due to temperature rise. Similarly, advanced warning and precautions taken against new pests and diseases due to warmer waters will enable the industry to prepare for and guard against invasions.

Coastal management and environmental regulation

Given the trend generally for increasing environmentally-based regulation and control, aquaculture, depending as it does on its interaction with the environment, is likely to be more heavily controlled in its licensing and operation than hitherto. The application for site approval will likely require additional environmental data, the criteria for selection may include more parameters, and operational monitoring of the environment may become more onerous. These changes, once absorbed by the industry, will in general lead to better management and a more robust operation.

Aquaculture is not the only marine activity that seems destined for growth. Marine transportation, for example, is projected to increase substantially over the next two decades. In some areas, increased congestion and rising costs in the land transportation system will make coastal marine trade more attractive than in the past. Recreation activities can only increase with the increasing population and the promised warmer waters off the beaches. As one of the coastal activities, aquaculture will be expected to both manage its own activities to lessen its impact on other industries, but also to lobby for its own requirements in the management of others.

Pollution

The population growth and migration to coastal areas will bring an additional burden to coastal waters. Most of the wastes from human activities ends up in the coastal zone, generated locally, brought down by rivers, and deposited from the atmosphere. Not all of the wastes are toxic, but the nutrients and organic matter brought down from lands also have the capacity to cause eutrophication and oxygen depletion.

Environmental susceptibility to these two events is highest in the sheltered coastal inlets that are home to much of Canada's aquaculture.

While not directly related to climate change, industrial effects on water and sediment quality can in some cases be of concern in the marketing for fish or shellfish. Some of the toxic substances in industrial wastes are very persistent and could cause site restrictions for many years. Coastal waters are susceptible to the influence of farming, forestry and mining practices and future coastal management will hopefully extend far enough into the hinterland to merge the interests of both land and fish farmer.

Other marine activities also threaten environmental conditions. Although catastrophic events such as oil spills cannot be entirely eliminated, better management of safety and stricter control of operations has reduced the occurrence of such risks. Nevertheless, the recognition and action taken against all sources of pollution, including from the aquaculture industry itself, should remain a high priority.

Technological advances

The prediction of technological change is always speculative, although the industry operators will be able to identify major trends.

Biotechnology and genetic manipulation may be able to produce species better adapted to temperature rises, and even to cope with new pests and diseases that may arrive with warmer waters.

As aquaculture grows, and as waters warm, the ability of the industry to grow its own food stocks, analogous to the farmer growing corn and hay to feed his cattle, may reduce present rearing costs.

If warmer waters lead to increased problems with quality control, due to blooms, pollution and pests, some products may be able to be raised in onshore facilities under controlled conditions. The markets for such high quality products will be similar to the present trend towards organic and hydroponic terrestrial foods.

Onshore facilities will be safer from weather systems, but engineering advances will reduce the downtime and damage to aquatic systems from storms. Systems capable of submergence offer other advantages, such as easier harvesting when afloat and less interference with other activities when submerged. Larger systems could be moored offshore, away from the coast and its associated water quality problems.

Conclusion

From this cursory examination of the onset of climate change and its impact on the aquaculture industry, one could deduce that the biggest need for mitigation is information and knowledge to allow for advanced planning.

It would be expected that future facilities will be larger, more robust, more independent of the environment and operationally more efficient.

The industry should in general be able to adapt to changing conditions by technological and biological advances and possibly by relocation. Increased opportunities may present themselves to the industry with a warmer climate.