Risk and Risk Management for Feed and Seed for Marine Fish Raised in Off-shore Aquaculture

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For open ocean aquaculture of marine fish, the provision of feed and seed occurs externally to the actual fish culture operation. How such external activities are conducted and applied determines the potential ecological impact for the industry as a whole. Ecological risks associated with marine aquaculture may be addressed using a framework similar to that used for assessment of risks in other areas of our lives. The use of a framework developed for the World Health Organization (WHO) for assessment of risk to human health from various threats has been proposed for assessment of risk to the environment from marine aquaculture (Nash et al. 2005). The identification and characterization of risk are the first steps in determining what risk management strategies might be the most productive in developing supplies of feed and seed for offshore aquaculture that are low risk and will be stable and dependable over the long run. For each risk, the WHO risk assessment framework may be applied to focus research and development on strategies that could be used to reduce or eliminate risk. In most cases, multiple options exist for risk reduction, however I suggest that risk management strategies that improve economic gain and reduce or eliminate multiple ecological risks, are preferred and have a much higher chance of resulting in meaningful improvements. Furthermore, strategies which allow improvement, or change over the long term, provide more flexible and ultimately sustainable solutions. In most cases, research is needed to develop better risk management strategies. Up-front costs associated with research, development and implementation often limit application of risk management strategies to industries large enough to afford such costs even if there are long-term economic benefits associated. This is especially true when governments do not fund such research and development.

Potential up-stream ecological impacts associated with feed and seed from culture of marine fish include over-fishing due to demand for wild juveniles for grow-out, and harvesting industrial fisheries for feeds (Nash et al. 2005). Stated as a simple equation, risk of over-fishing (R) is a function of fisheries management (M) with the effectiveness of management subject to demand [R = f(M)]. On some low scale of harvest (low demand), fisheries management has been shown to be effective, however management can only produce some fraction of what exists naturally, and wild fisheries are not able to increase production beyond naturally set limits. At harvest levels higher than a stock can recover from, over-fishing occurs. When there is a high demand, fisheries management becomes increasingly difficult so alternatives need to be found that reduce or eliminate demand for both wild feed and wild seed. Management to reduce the risk of over-fishing due to feed includes the development of alternative protein and lipid sources (especially long chain n-3 fatty acids) and for seed, the development of hatcheries. In both cases, complete replacement leads to elimination of the risk due to activities associated with offshore aquaculture and partial replacement leads to demand reduction potentially to sustainable levels at least until the industry grows again. In addition, hatcheries and alternative feedstuffs can provide economic benefits (in the way of lower prices and better quality) and thus have a greater potential for adoption by industry once a critical size of an industry is reached.

Potential downstream ecological risks associated with feed include organic loading and benthic

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impacts. In this case risk (R) is a function of the quality and quantity of feed used (F), the organism under culture (O) and management (M) within the context of the specific site chosen for offshore aquaculture [$R = f(F \times O \times M)$]. Activities which improve 1) the efficiency of the diet (for example moving from wet fish to pelleted feeds, defining nutrient requirements, improved pelleting technologies, better feed formulation, feedstuffs processing and so on), 2) the efficiency of the organism (species choice, selective breeding, improved husbandry, and so on) and/or 3) the management systems (optimal feeding regimes, improved fish health management, protection from predators and diseases, better husbandry, improved systems engineering, and so on), will reduce environmental risks. In most cases, these efforts will also improve economic return once a critical level of production is reached by the industry.

Downstream risks associated with seed are associated with the potential ecological and genetic impacts of escapes on conspecific wild stocks if the cultured fish is native or ecological impacts on native species if the escapees are non-native. For the sake of this paper I will only deal with the first risk. Risk (R) associated with the escape of a native species is a function of the number of escapes relative to the number of wild conspecifics (Pe/Pw), the differences in genetic structure between the wild and escaped organisms (ΔG) and the fitness (Fe) of the escapees to reproduce in the wild [$R=f(Pe/Pw)(\Delta G)(Fe)$]. Risk associated with escapes can be managed at the hatchery by several strategies. For example, either raising fish with the same genetic make-up as wild stocks where $\Delta G = 0$, or by domestication of the farmed species which reduces escapees' fitness (Fe) in the wild. In this case, economic gains would favor domestication and not maintaining a wild stock genotype. Risk can also be reduced by raising sterile fish (where $Fe = 0$) which may or may not be economically beneficial, or by maintaining a low number of escapes (for example by better engineering or management practices) relative to the size of the wild population. Note that the converse is also a possible strategy, risk can be reduced by maintaining wild stocks at high levels relative to the number of escapes. This may be addressed by industry by raising a portion of the species they produce under stock enhancement protocols for release (likely to have negative economic implications). An approach that combines several of these strategies may be the most effective.

Risks can be interactive and need to be viewed as a set for a given activity to guide management and research. Often new risks can be created when a different risk is solved, or the choice of a risk management strategy that reduces or eliminates one risk may or may not also reduce or eliminate another risk. For example, the development of a hatchery to reduce the risk of over-fishing to provide seed, potentially creates the genetic risk of escaped fish on their wild conspecifics. If wild fish were used, then $\Delta G = 0$ and the genetic risk from escapees would not exist. This has led some to call for only using local fish as broodstock for hatcheries producing seed for offshore aquaculture and actively maintaining a wild-like genetic make-up in the hatchery. However to do this would forgo the positive ecological risk reduction that selective breeding can produce in terms of seed that uses feed resources more efficiently, that makes better use of alternative feedstuffs, has better disease resistance and so on. Maintaining a wild genotype for fish used in offshore aquaculture would also forgo economic gains and puts environmental and economic goals at odds, reducing the chance for adoption and meaningful environmental risk reduction.

Governments can create win-win situations by fostering research and development where ecological risk management and economic gains are in line and both considered. In the case of feed and seed, this would include development of high quality compound feeds from alternative feedstuffs, and hatcheries with associated selective breeding programs for new and existing marine fish industries. Governments can hasten and improve the potential for the adoption of preferred risk management strategies by first identifying those strategies that provide the best overall options and then by funding the up-front research and development costs to put those practices in place.

References

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