

Production Systems – EP (Extensive production) and IP (Intensive production)

Aquaculture systems are very diverse in their design and function. The three most basic categories of culture systems are *open*, *semiclosed* and *closed* systems. *Open system* culture generally refers to fish farming in natural water bodies such as oceans, bays, estuaries, coastal lagoons, lakes, or rivers. *Semiclosed* systems are those in which the culture water makes one pass through the system and is discharged. Systems of this nature are referred to as *flow-through* or *once-through* systems. The raceway falls into this category. *Closed* systems are those where the water is reconditioned and recirculated to the culture unit(s). A more recent term for this type system is the *closed recirculating* system. We will discuss them in the lecture and expand more about EP (Extensive production) and IP (Intensive production) methods and conclude with water supply and discuss briefly about dams and Water Storage.

Open Aquaculture Systems: Sea-cage (active feeding)

Open sea-cage aquaculture refers to the rearing of aquatic species, within enclosures in natural waterways. Open systems are being implemented in a wide range of environments including freshwater rivers, brackish estuaries and coastal marine regions. Floating mesh cages are anchored to the seafloor and vary in size depending on the scale of operation and the species cultured.

Juvenile stock is sourced either from hatcheries or wild populations, and grown out in pens until a marketable size has been reached. Finfish grown in open systems are primarily carnivorous species which are fed on a diet of fishmeal (pellets comprising small schooling fish species). Some rapidly developing open systems include yellowtail kingfish, southern bluefin tuna, Atlantic salmon, trout and barramundi.

There are numerous concerns associated with the expansion of open sea-cage aquaculture. One of the primary objections relates to the requirement of fishmeal to feed carnivorous species. In some cases, the conversion ratio may be in the order of more than 5kg of fishmeal to produce just 1kg of marketable fish. Other significant issues include increased disease and parasite transmission due to high fish densities, the risk of escape and interbreeding with wild populations, and reduced water quality resulting from the accumulation of faecal waste.

Open ocean aquaculture is basically defined as the rearing of marine organisms in exposed areas beyond significant coastal influence. Open ocean aquaculture operations would be located at a considerable distance from shore and subject to relatively harsh environmental conditions resulting from wind and wave action. Open ocean aquaculture employs less control over organisms and the surrounding environment than do inshore and land-based aquaculture, which are often undertaken in enclosures such as ponds.

Development of offshore aquaculture has become a controversial topic for aqua-culturalists, environmentalists, recreational fishermen, and commercial fishermen. Many environmentalists and fishermen have asserted that poorly regulated aquaculture development could degrade the environment and have negative effects on wild fish populations.

Proponents of open ocean aquaculture believe it is the beginning of the "blue revolution"—a period of broad advances in culture methods and associated increases in production. Potential outcomes are difficult to characterize because of the diverse nature of potential operations and the lack of aquaculture experience in open ocean areas. However, most agree that industry regulation is needed for orderly development of aquaculture while minimizing its effects on the environment. Several terms for open ocean aquaculture are used interchangeably, including *offshore aquaculture* and *offshore fish farming*. Open ocean aquaculture facilities generally consist of systems (e.g., cages, net-pens, longline arrays) that can be free-floating, secured to a structure, moored to the ocean bottom, or towed by a vessel. Currently operating commercial aquaculture farms in nearshore waters and estuaries use a variety of methods including ponds with earthen dikes, cages and net-pens moored to the ocean bottom, enhancement and seeding of the bottom, and suspended lines.

Challenges of Open Ocean Aquaculture

A broad array of questions is associated with the viability and impacts of open ocean aquaculture initiation and expansion. These concerns are further complicated by factors such as evolving production technology, uncertain economic costs and benefits, and environmental and social impacts. Generalizations are also difficult to make because of the variety of candidate species, associated technologies, and potential scales of operation.

Major categories of concerns related to open ocean aquaculture development include

(1) biological, operational, and business concerns related to development of a new industry;

- (2) potential social and economic impacts;
- (3) potential environmental impacts; and
- (4) the legal and regulatory environment.

Semi-closed Aquaculture Systems

Semi-closed aquaculture refers to the land-based production of aquatic animals, in which water is exchanged between the farm and a natural waterway. Waste water is released from the ponds into the local waterway, whilst the farm is replenished with fresh water pumped back into the system. Prawn farming is the predominant form of semi-closed aquaculture, also representing the most extensive use of pond systems. Semi-closed aquaculture operations can have large-scale effects on coastal ecosystems. As ponds require continual water exchange, they are often located adjacent to waterways, where coastal wetlands and mangroves are reclaimed for development. The result can be a vast loss of habitat which is critical for the juvenile stage of many species. Constant outflow of water may also reduce surrounding water quality if not treated adequately. Prawns are supplemented with fishmeal (pellets comprising small schooling fish species) at conversion ratios generally between 1-3kg of feed to 1kg of prawns, placing continued demand on wild fish stocks.

Closed Aquaculture Systems

Closed system aquaculture refers to the land-based rearing of aquatic species in raceways, tanks and ponds. Recirculation technology is implemented which cycles water through filtration processes and returns it back into the aquaculture system. This process aids in maintaining water quality whilst ensuring minimal exchange with natural waterways. Closed aquaculture systems are primarily used for freshwater species with silver perch, barramundi, yabbies and marron amongst the most common marketable species. Blacklip and greenlip abalone are the main marine species produced in closed systems, and are experiencing rapid growth due to demand from other world markets. Closed system aquaculture is considered one of the more environmentally benign methods of rearing aquatic species. Fishmeal (pellets comprising small schooling fish species) may be added to feed carnivorous aquaculture species, and is a concern as it places continued demand on wild fish stocks. However, there

is negligible interference with waterways as a result of tight control over waste water and the prevention of fish escape.

EP (Extensive production) and IP (Intensive production)

Extensive production of fish usually refers to fish farming conducted in medium- to large-sized ponds or water bodies; the fish production relies merely on the natural productivity of the water which is only slightly or moderately enhanced. Externally supplied inputs are limited; costs are kept low; capital investment is restricted; the quantity of fish produced per unit area is low. In brief, the control over the production factors is kept low. The return on labour is high.

Intensive production of fish, on the other hand implies that the quantity of fish produced per unit of rearing area is great. To intensify the culture, production factors, such as feed, quality of water and quality of stocked fingerlings, are controlled to improve the production conditions. There is steady monitoring during the production cycle. It goes without saying that all these controls entail high-tech practices and capital-intensive investments, which add to the production costs. The returns must justify increased production costs. The contribution of natural productivity into fish production is low or negligible. Besides this, intensive fish farming carries with it high costs or threats to the environment.

Apart from these two forms of fish farming, some speak about **semi-intensive fish production**, referring to intermediate practices, taking elements of both forms. This is, however, ill-defined. Before suggesting which of these forms is to be recommended, one should look at the context under which fish farming is practised. What are the farmer's objectives? The first objective is to ensure food security/livelihood for his household. This can be secured, firstly, by growing food crops, and then by diversifying the farmer's activities over a range of agriculture and non-agriculture ventures in pursuit of his income generating strategies.

Water Source and Supply.

Regardless of the system or species cultured, good water quality and adequate supply are essential for success and must be a primary consideration from the earliest planning stage.

Groundwater can be obtained from aquifers. Useful information on groundwater is usually available from well drillers in the area or from the government (both local and national) geological survey. The necessary governing bodies put up by the government have aquifer maps as well as other important information on water quantity and quality. Test wells maybe necessary to ensure that a sufficient flow is available, especially for large operations where rapid filling or flushing will be required. Because well water is usually deficient in oxygen and is saturated with nitrogen it must often be aerated before being introduced into the system. Chemical analysis of all water for ammonia, pH, hardness and alkalinity, contaminants, dissolved oxygen, etc., is essential before it is used for aquaculture. Surface water represents an alternative water supply. Though frequently less expensive to develop and pump than groundwater, there are often restrictions that present problems for the farmer. Surface water may be more variable with regard to flow, temperature, and quality; chemical and biological contaminants may also be present. In addition, water must be filtered or screened to eliminate unwanted fish and insect larvae. Other treatments such as aeration or filtration to remove particulates may also be necessary. Water from municipal systems may be used, but it is expensive and usually limited to recirculating systems because they require less water to produce high value products. Still, this water must often be treated to remove chemical agents such as chlorine, which is added in order to sanitize municipal supplies for human consumption. In marine operation, proper salinity is critically important. Inflows of fresh water may stress or kill cultured animals. Both point and non-point runoff must be surveyed and the presence, or extent, of disease, fouling organisms, and predators determined. Potential problems must be addressed during site selection.

Dams

A dam is a barrier that stops or restricts the flow of water or underground streams. Reservoirs created by dams not only suppress floods but also provide water for activities such as irrigation, human consumption, industrial use, aquaculture, and navigability. Hydropower is often used in conjunction with dams to generate electricity. A dam can also be used to collect water or for storage of water which can be evenly distributed between locations. Dams generally serve the primary purpose of retaining water, while other structures such as floodgates or levees (also known as dikes) are used to manage or prevent water flow into specific land regions.

Types of dams

Arch dams

In the arch dam, stability is obtained by a combination of arch and gravity action. If the upstream face is vertical the entire weight of the dam must be carried to the foundation by gravity, while the distribution of the normal hydrostatic pressure between vertical cantilever and arch action will depend upon the stiffness of the dam in a vertical and horizontal direction. When the upstream face is sloped the distribution is more complicated. The normal component of the weight of the arch ring may be taken by the arch action, while the normal hydrostatic pressure will be distributed as described above. For this type of dam, firm reliable supports at the abutments are more important. The safety of an arch dam is dependent on the strength of the side wall abutments, hence not only should the arch be well seated on the side walls but also the character of the rock should be carefully inspected.

Gravity dams

In a gravity dam, the force that holds the dam in place against the push from the water is Earth's gravity pulling down on the mass of the dam. The water presses laterally (downstream) on the dam, tending to overturn the dam by rotating about its toe (a point at the bottom downstream side of the dam). The dam's weight counteracts that force, tending to rotate the dam the other way about its toe. The designer ensures that the dam is heavy enough that the dam's weight wins that contest. The designer tries to shape the dam so if one were to consider the part of the dam above any particular height to be a whole dam itself, that dam also would be held in place by gravity, i.e., there is no tension in the upstream face of the dam holding the top of the dam down. The shape that prevents tension in the upstream face also eliminates a balancing compression stress in the downstream face, providing additional economy.

Gravity dams are classified as "solid" or "hollow" and are generally made of either concrete or masonry. The solid form is the more widely used of the two, though the hollow dam is frequently more economical to construct.

Arch-gravity dams

A gravity dam can be combined with an arch dam into an arch-gravity dam for areas with massive amounts of water flow but less material available for a pure gravity dam. The inward compression of the dam by the water reduces the lateral (horizontal) force acting on the dam.

Thus, the gravitational force required by the dam is lessened, i.e., the dam does not need to be so massive. This enables thinner dams and saves resources.

Barrages

A barrage dam is a special kind of dam that consists of a line of large gates that can be opened or closed to control the amount of water passing the dam. The gates are set between flanking piers which are responsible for supporting the water load, and are often used to control and stabilize water flow for irrigation systems. Barrages that are built at the mouths of rivers or lagoons to prevent tidal incursions.

Embankment dams

Embankment dams are made of compacted earth, and are of two main types: "rock-fill" and "earth-fill". Like concrete gravity dams, embankment dams rely on their weight to hold back the force of water.

Concrete-face rock-fill dams

A concrete-face rock-fill dam (CFRD) is a rock-fill dam with concrete slabs on its upstream face. This design provides the concrete slab as an impervious wall to prevent leakage and also a structure without concern for uplift pressure. In addition, the CFRD design is flexible for topography, faster to construct and less costly than earth-fill dams.

Earth-fill dams

Earth-fill dams, also called earthen dams, rolled-earth dams or simply earth dams, are constructed as a simple embankment of well-compacted earth. A homogeneous rolled-earth dam is entirely constructed of one type of material but may contain a drain layer to collect seep water. A zoned-earth dam has distinct parts or zones of dissimilar material, typically a shell of locally plentiful material with a watertight clay core. Modern zoned-earth embankments employ filter and drain zones to collect and remove seep water and preserve the integrity of the downstream shell zone.

Because earthen dams can be constructed from local materials, they can be cost-effective in regions where the cost of producing or bringing in concrete would be prohibitive.

Fixed-crest dams

A fixed-crest dam is a concrete barrier across a river. Fixed-crest dams are designed to maintain depth in the channel for navigation. They pose risks to boaters who may travel over them, as they are hard to spot from the water and create induced currents that are difficult to escape.

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