

# A sustainable model for infrastructure development of offshore aquaculture bases in Malaysian waters

## Abstract

The aquaculture sector has established itself as a major global source of fish protein. This paper presents a review on the challenges of marine aquaculture and a systematic framework to tackle the issue of robust infrastructure development for open seas. The case is built around the Malaysian context but may be aptly applied to any other regions with similar demographic and oceanographic conditions.

**Keywords:** Aquaculture, Challenges, Fish Protein, Marine, Infrastructure, Malaysia

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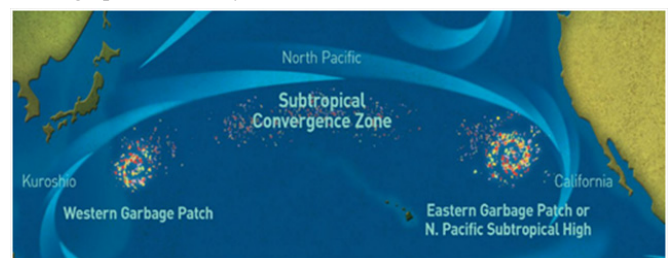
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## Introduction

It is a well-known fact that the world's oceans are being placed under increasing anthropogenic pressures as the maritime and oil-gas industries alongside numerous other coastal cities and island states continue their seaward expansions. A study published in 2015 mapped 66% of the world's oceans to face increased human impact over five year duration with five percent of our oceans coming under increasingly excessive impacts.<sup>1</sup> Known also as the 'Great Pacific Garbage Patch', among the most profound unintended human footprint on earth can be found as litter collected from the West Coast of North America and Japan floating with the North Pacific Subtropical Gyre<sup>2</sup> as depicted in Figure 1. A great majority of plastics that comprise this garbage patch are often made up of micro-plastics which are small enough to be ingested by various marine organisms throughout the entire ecosystem. It is hence, a worrisome statistic that fish stock would play a major role in meeting food security for a great percentile of the world's growing population and already accounts for more than 16 percent of global animal protein consumption.<sup>3</sup> The problem is real, nor is it futuristic or irrelevant as evident by arecent research which studied two fish catch offshore Brazil's coasts, revealing that up to 22% of the marine fish capture to have plastic pellets in their stomachs.<sup>4</sup> Besides the fact that a portion of our edible fishes are now ingesting plastic pellets, the world is also faced with an acute shortage of wild catch fisheries which prompts trending methods to grow our own fish stock, aptly known as aquaculture. In fact, Bloomberg recently released an article stating that the 'world today is eating more fish from farms than from the open sea'.<sup>5</sup> The World Bank in their 2014 press release that aquaculture will provide for up to 62 percent of food fish by 2030 with a projection of Asia as being the major 70 percent consumer of fish.<sup>6</sup> Onshore aquaculture is an immediate option, with containment tanks built on the familiarity of land, but this can harbor credibly high energy consumption and necessitates responsible waste handling protocols. Coastal or near shore aquaculture is naturally the next frontier but is also plagued with pollution concerns as well as space-resource competition with other users of the coasts comprising of industries from eco-tourism to infrastructure developments. Moving further seawards, offshore aquaculture is the recent development of bringing marine farming to deeper waters further out at sea which will avoid competition and

concentrated pollution, typical of coastal aquaculture. It is also an observation of the authors of this work that the offshore aquaculture industry in Malaysia is more than often, highly disjointed and utilizing obsolete technologies, hence not tapping its full potential. Taking note on the gravity of the depleting wild stock shortage alongside the fact that our oceans contain micro-pollutants that may not be visible to the naked eye, there is a need for the presentation of a proper techno-economic model to guide marine farmers in striving for sustainable marine farming developments. We define sustainable herein from the context of both the environment and its end users which eventually consume the food product. It is the intent of this paper that focus be given towards far-coastal and offshore aquaculture due to their massively untapped potential. The case will be presented around a Malaysian context, but may be applied to other regions with similar oceanographic and bathymetric conditions.



**Figure 1** The Great Pacific Garbage Patch, courtesy of NOAA.<sup>2</sup>

## Aquaculture in malaysia

It can be said that the aquaculture industry in Malaysia began in the 1920s with Chinese bighead, grass and silver carps in ex-mining pools which then diversified into commercial farming of other fish and shrimps.<sup>7</sup> It was not till the early 1970's when semi-intensive culture of shrimp alongside marine fish culture began to take place, followed by intensive commercial cultures in the 1990's.<sup>8</sup> In the 2000s, the country saw a source to table approach in improving food safety and fish health management.<sup>7</sup> The Malaysian National Agro-Food Policy for the term 2011-2020 has identified five main aquaculture products namely freshwater fish, freshwater prawn, marine finfish, marine shrimp and mollusks with a cumulative goal to achieve 8.6 percent annual growth.<sup>7</sup> Seaweed farming and culture is mainly performed

in Sabah's Kudat and Semporna waters at the present. More than 49 sites with over 28,000 hectares are designated as Aquaculture Industrial Zones in the country for both land and water bodies.<sup>7</sup> Figure 2 showcases the growth of aquaculture production in Malaysia from 1950 to 2010. As a way forward under the National Agro-Food Policy, the government is looking at zoning of aquaculture areas, development of new areas while increasing existing productions, increased local and export market share, all backed by sound research, development and commercialization.<sup>7</sup>

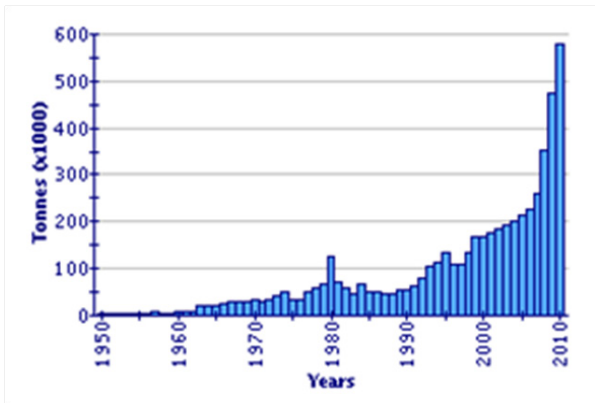


Figure 2 Malaysian aquaculture production.<sup>8</sup>

## Framework for an offshore aquaculture base

Aquaculture in Malaysia is typically developed mainly through either freshwater which form the majority of culturists followed by those developing brackish water systems.<sup>9</sup> In practice, the commercial marine aquaculture species in Malaysia largely revolves around finfish (sea bass, grouper and snapper), crustaceans (black tiger shrimp, white shrimp), bivalve (cockle, mussel, oyster) and seaweed.<sup>7</sup> It is the notion of this paper to push forth the advancement of offshore aquaculture in the country wherein the favorable relatively benign wave conditions permits the use of less structural intensive platforms for open sea farming. Among the main impetus of the sea-ward push for marine aquaculture away from coastal seas is the avoidance of unaccounted pollution and potential upset of sensitive coastal ecosystems. To date, the marine based methods practiced in Malaysia generally work in isolation, not utilizing the entire water column to its full potential. It is not unnoticed nonetheless, that such state of the art developments present various technical, environmental and economic challenges which may be overly daunting for many traditional culturists which are comfortable in their respective domain. The authors herein propose a generic model framework which is anticipated to serve as a guide for those who are keen to pursue innovation in such niche area. Emphasis is given to the various physical methods and infrastructure required to actualize a sustainable offshore farm, rather than politics and genetics or biotechnology advances which is beyond the scope of this paper. The creation of usable space for co-habitation of humans and marine culture on the open ocean can be broadly categorized as a branch effort of the bigger topic on ocean space utilization. To that note, Very Large Floating Structure (VLFS) is a branch of floating systems that possess the required characteristic technologies as highly slender and vast spanning floating structures out at sea, which are common place requirements for aquaculture systems. The body of knowledge of such hydro elastically designed structures is essentially advanced from the foundations of ship and offshore platform design which assumes inherently rigid structures. A vast majority of the marine floating net aquacultures in Malaysian waters are typically

located in sheltered waters and built as floating pontoons reminiscence of that of a local passenger boat jetty. For such installations to survive open sea conditions, a greater degree of engineering design should be incorporated into their built. The key to economic viability of such feats lie in a complex mix of diverse revenue streams from the same facility with associated low operating expenditure. For an offshore aquaculture base located in the South China Sea between 20-80m water depths, this proposed framework herein gathers the key factors required to develop a sustainable base. In the author's experience in dealing with met-ocean hind cast data bases as well as local standards, the generic annual expected average significant wave height for Malaysian waters range from 0.2m to 6m (for the 100 year storm). In a typical year, average wave heights very rarely exceed 3.5m. The proposed key framework components for the floating infrastructure are discussed briefly in the pointers in that follow in sequence

### Local in-situ oceanographic baseline studies

- i. Baseline study on the in-situ physical oceanographic characteristics such as prevalent met-ocean for use as design criteria. As there are currently no standards enforced locally in Malaysia to govern the design of large floating aquaculture farms in open water, this will define the design conditions for the floater in its various limit states, stability and hydro-elastic performance.
- ii. Baseline study on the in-situ chemical oceanographic characteristics to ascertain presence of pollutants, assess water quality and nutrient or gauge potential productivity levels that may be obtained with the natural system.

### Floating infrastructure requirements

- a. There is little point in proposing a fixed structure type for such a slender marine structure in open sea. The infrastructure requirements such as the size and extend of the floating structure or successful turnover of fish stock are largely driven by the project owner. Such requirements may be tendered out to engineering consultancies or even to in house technical teams. Major considerations include that of the type of floater (semi-submersible, pontoon-type), mooring lines, floater materials, design life, risk quantification, damage reserve, local fabrication capability and cost.
- b. From the oceanographic baseline studies, the appointed project team may then advise the project owner on its feasibility, given a budget and time constraint. It is crucial to manage expectations and project goals before proceeding any further. It is useful to design the structure to be scalable with relative ease, in the sense that expansions can be accommodated whilst operating at sea.

### Support or auxiliary systems

- A. Support systems include all outfitting that is required by the floater to serve its purpose as a fully functional aquaculture base. This may include power generation systems, hydraulic power packs, remotely assessable visual devices, automated sensor and feeding stations, automated security protection, structural health monitoring and the like. For regions with good amounts of sunlight, it is a platform to deploy renewable energy systems such as solar power plants on the floater to enable self-sustaining power generation.

### Diversification of revenue & economics of scale

- a) Among the key drivers is the capital costs incurred to the project owner. While optimizing the design of required infrastructure is

certainly one method to reduce costs, the project team should also be looking at diversifying the system's revenue stream and waste management by fully utilizing the entire vertical water column via an ecosystem lifecycle management approach.

The other factors not elaborated here, which are equally or even more important than the preceding considerations are that of pertinent laws and legislation of the seas, available talent or manpower, type of financial facilities for project financing as well as application of genetic and bio-engineering for a faster growing healthier stock. Government backing on such initiatives is often a very positive addition to the project merits.

## Conclusion

It can thus be safely concluded that while aquaculture has clearly established itself today by sheer volume of contribution to the marine products we ingest, much innovation in technologies and methodologies is required to sustainably meet further increases in demand. The design of floating aquaculture systems for the open sea is a feat that borrows its technologies from years of maritime and oil-gas experience. Diversification of revenue streams from utilizing the vertical water column may yield other benefits such as waste minimization. The future of aquaculture is without a doubt, brewing with potential, only if such works are conducted in a responsible and diligent manner.

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## Conflicts of interest

None.

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