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## Abstract

*Fish stocks around the world are a growing concern as wild stocks become overly exploited and depleted. Focusing on the Great Barrier Reef (GBR), two options for sustainable management are discussed and examined through real world examples. Previous fish stock management, overfishing, and depletion of fish stocks around the globe are identified are the cause of current supply issues. Greater understanding of genetic flow and the benefits of marine zoning to replenishing fish stocks are discussed with examples of successful zoning methods on the GBR analysed. The benefits of increased reliance of fish farms, their ability to efficiently produce appropriate levels of protein and relieve pressure on natural stocks is discussed, while the negatives of fish farming are examined to identify it as a practical solution. The combination of these two practices is put forth as a solution to the growing pressure on fish stocks with further research into fish farming suggested to make it a viable alternative.*


## Introduction

Fish stocks of the Great Barrier Reef (GBR) are a valuable resource which is necessary to help the world meet its increasing protein requirements (McClanahan & Castilla, 2007). In recent times stocks have been exploited to the point of unsustainability and methods have being put in place to ensure the preservation of natural reserves, and the availability of fish for human consumption (Shaklee & Bentzen, 1998). Methods such as small and large scale fish farming and increased management of wild stocks are essential to achieve this (Lazard et al., 2011). While effective, these procedures are not free of problems. Fish farming still in early stages of development and the animals more prone to disease when compared to terrestrial counterparts, and with management of wild stocks difficult to implement and genetic flow varying from species to species (Doherty, Planes, & Mather, 1995).

## Previous Fish Stock Management

Fish stock management has been a rising concern as the global population grows (Naylor et al. 2000). For the last 80 years the management tended to focus on a single species which has led to the process of fishing down the food web (McClanahan & Castilla, 2007 /figure 1.1). Fishing from one species to another has resulted in 75% of individual fish stocks being either heavily exploited or completely depleted (McClanahan & Castilla, 2007). With these old models assumptions are made which do not reflect the natural abilities of these stocks to replenish.  Growth and mortality rates, the size of stocks and their independence from others, and population dynamics are not accurately accounted (McClanahan & Castilla, 2007).

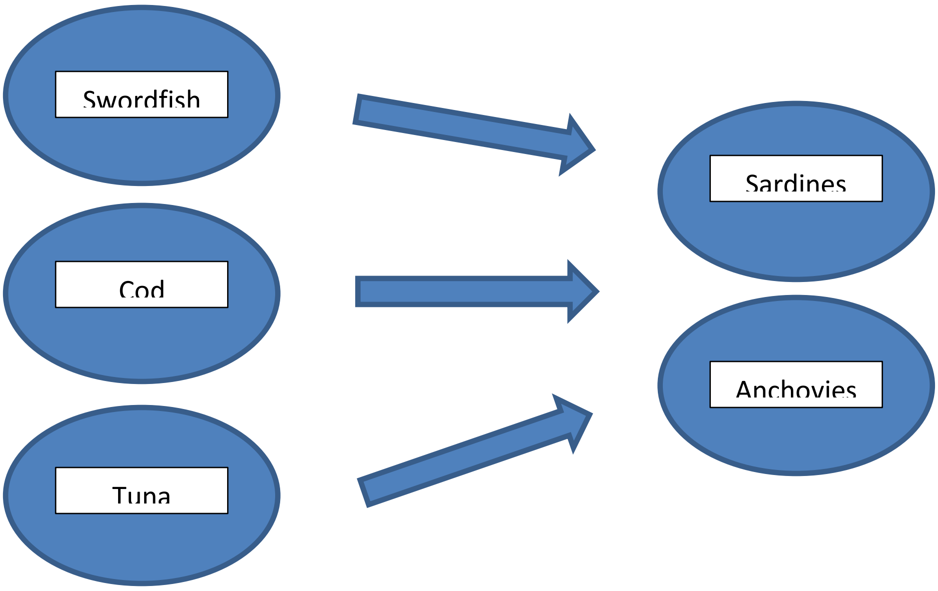


Figure1. Fishing Down the food web. As the stocks from higher trophic fish become depleted, fishing industry moves onto lower trophic species like Sardines and Anchovies. (adapted from Pauly, Chirstensen, Dalsgaards, Froese, & Torres, (1998), Fishing Down Marine Food Webs 1998)

Genetic flow is important in the preservation of fish stocks although it is not very well understood (Doherty, et al., 1995). Larval stages vary from species to species and affects how their genetics are spread throughout the GBR (Doherty, et al., 1995). Species with longer larval stages generally have a more homogeneous stock, while shorter stages result in more heterogeneous stocks (Doherty, et al., 1995). Stock divisions can occur in certain species such as *Acanthochromis*, and while small, the differences are significant (Doherty, et al., 1995). Understanding the distributions of the species and its role in the ecosystem is critical to stock management. Herbivorous fish, such as surgeonfish, parrotfish, and rabbitfish, were generally grouped together under the assumption they performed the same role in reef management (Cheal, Emslie, Miller, & Sweatman, 2012). Closer study of these species has shown that depending on their position on the reef determines how they feed and what their main food source would be (Cheal, et al., 1995). The assumptions of previous stock management systems do not consider these points.

## Management of the Great Barrier Reef

The focus of new methods of wild stock management is the restriction of fishing locations and catch sizes. The Great Barrier Reef Marine Park Authority (GBRMPA) has been a world leader in this field for some time. Since the foundation of the marine park there has been a lot of focus on how to preserve the area for future generations (Fernandes, et al., 2004). In the year 2004, the restricted access areas were extended from 4% of the park to 33% (Fernandes, et al., 2004). When the original 4% was put in place there was a strong bias to areas of greater coral cover, leaving areas of seagrass and open seafloor under represented (Agardy, T. 2010). 70 bioregions, 30 reef and 40 non-reef, were selected during a length consultation process involving scientific data, analytical tools and public consultation. Of each bioregion, a minimum of 20 per cent is represented as a no take zone (Agardy, T. 2010). These areas play an important part in controlling fish stocks, taking into account the natural habits of different fish (Agardy, T. 2010).

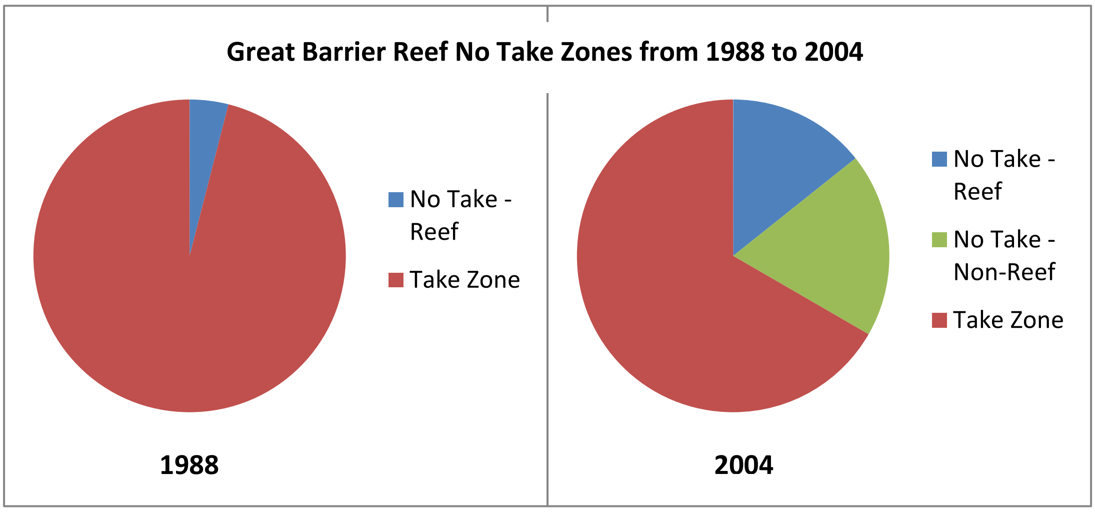


Figure 2 – Great Barrier Reef Marine Park zoning in 1988 and 2004, (adapted from Agardy T., 2010)

The use of zoning it effective as it looks at the whole ecosystem and evaluates the ecological interactions. This method maintains the predator prey-relationships and diversity allowing for greater yields of supply. Coral trout*, Plectropomus* spp., has shown to benefit significantly with the protection zones, and this can be assumed for other target species (Williamson, Russ, & Ayling, 2004). After no fish zones were put in place there was a significant rise in the density and biomass of *Plectropomus* spp. in protected areas. The average fish lengths of the Palm Island sites rose from 30cm in fished zones to 40cm in protected and the density ratio between the pre-protection and protection zone was 1:6.3. Not only was there a benefit in the protected zone, the density of the fish stocks rose slightly in the fished zones at both Palm Island and the Whitsunday Island. There was no significant change in the densities and biomass of non-target fish at these sites (figure 3/Williamson et al., 2012)

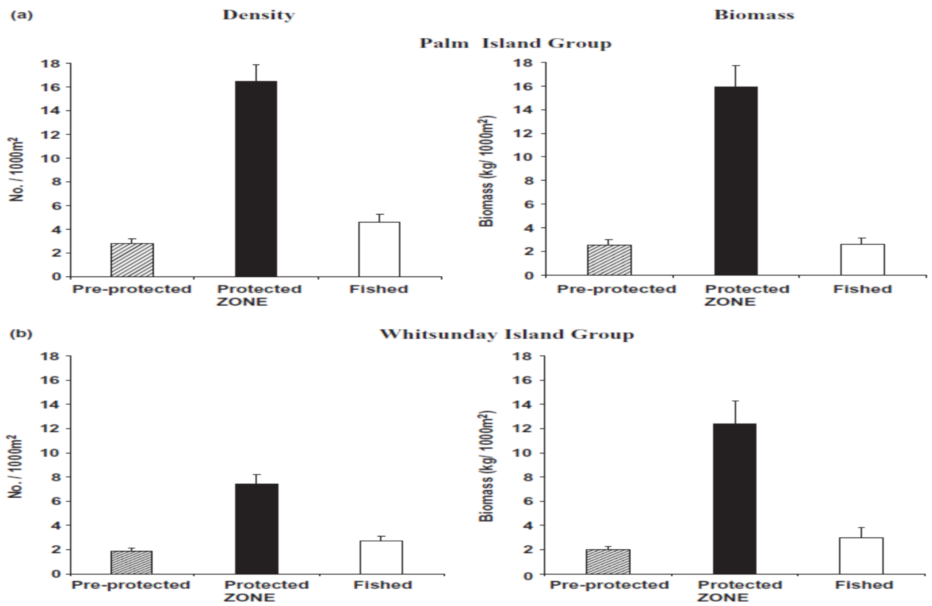


Figure 3. The biomass and density of *Plectropomus* spp in fished and protected areas of the Palm Island group and Whitsunday Island group in the GBR. (Williamson et al., 2012)

## The Benefits of Fish Farming

Fish farming is a low cost way of sourcing high amounts of protein for human consumptions. This process reduces the pressure put on the natural stocks, and is a practical and efficient way to control the levels (Lazard et al., 2011). Growth in aquaculture has grown at a rate of 10% per year between 1980 and 2000 as the cost of other sources of protein continues to increase (Lazard et al., 2011).

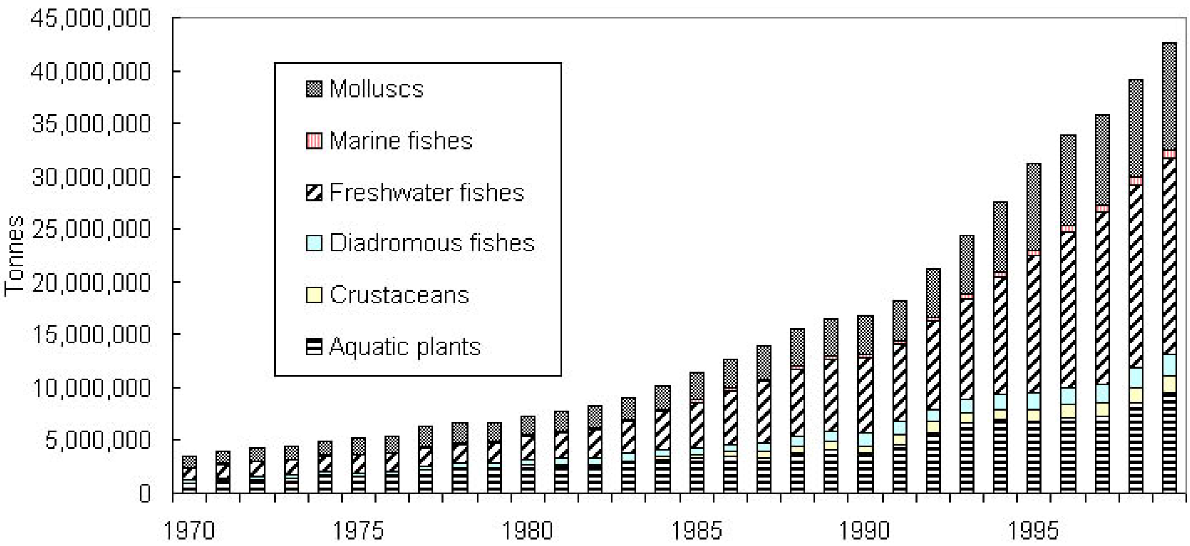


Figure 4. The growth of global aquatic farming since 1970 through 2000 (sourced from FOA n.d.)

Fish farms have a relatively low cost to set up and maintain and it is possible for investors to get fast returns (Ogamba, & Abowei, 2012). Fish farms that have access to the suitable water conditions, location, and an appropriate species are economically feasible (Ogamba, & Abowei, 2012). Comprehensive feasibility studies can assist in the future planning and success of fish farms on small and large scales (Ogamba, & Abowei, 2012)

Large and small scale fish farming have economic value for developing countries while also providing a rich source of protein for the poorest of people (Nguyen, 2009). While the emphasis in developing countries is on small scale farming there has been a shift in recent times (Nguyen, 2009). Vietnam saw the overall area used for fish farming grow from 336,500ha in 1999 to 867,613ha in 2003 (Nguyen, 2009). This increase led to a yield of 1,003,095 tonnes, more than doubling the output of 1999 (Nguyen, 2009). The cost in raising the animals is dependent on their protein requirements with most low income, house hold farms producing low maintenance species such as carp and tilapia (Ogamba, & Abowei, 2012), while fish farms in developed countries generally focus on animal protein dependent species such as trout and salmon (Lazard et al., 2011).

## The Negatives of Fish Farming

Though fish farming has many benefits there are ongoing issues within the process. Due to the high demand of cheap protein, farms are often stocked to a high capacity. The increased number of animals lends itself to poorer hygiene and higher levels of stress which causes disease outbreak. With standard diagnostic testing of fish disease laboratory results are needed to identify the problem. This is a lengthy process allowing for the disease to spread reducing the effectiveness of any treatment and increasing mortality rates (Austin, 1989).

Parasites are another factor to consider when looking at the effectiveness of fish farming. Juvenile Pacific salmon spend their early lives dispersed widely and separate from mature adults, with the transmission of sea lice is limited during this time (Krkosek, Connors, Ford, Peacock, Mages, Ford, Morton, Volpe, Hilborn, Dill, & Lewis, 2011)). In a farmed environment the confinement leads to high rates of infection and higher mortality rates. Juveniles are 50% faster at returning to high risk feeding areas, schooling patterns are significantly affected and infected fish suffer from increased predation.

Fish diseases can be controlled in numerous ways. Management of stocking densities and environmental conditions has a positive effect on the health of fish (Austin, 1989.). Genetically resistant fish and improved dietary supplements high in vitamins and trace elements reduce also reduce mortality rates. Improvements in diagnostic tests help with the successful treatment of cases before the disease can spread (Austin, 1989)

Figure 6: Rainbow trout with kidney disease (Austin, 1989.)

Fish feed is the largest cost involved in the fish farming and has a number of drawbacks (Naylor et al., 2000). The cost of production varies with larger carnivorous species costing up to five times as much fish biomass feed as to what is produced (Table 1, Naylor et al., 2000). This fish feed is generally consists of fish meal and fish oil which are an important source of essential amino acids and fatty acids not found in plant proteins and oils (Naylor et al., 2000). Fish meal is often sourced from mangroves that act as nurseries and has a significant impact on wild fish stocks (Naylor et al., 2000). Another issue arises in the composition of fish feed. Depending on the diet of the farmed species fish feed can often exceed required levels of amino acids leading to a waste of protein (Naylor et al., 2000).

Table 1 – Showing the percentage and ratio of fish meal in food for high trophic (Salmon) to low trophic (Carp and Catfish) fish. Adapted from Naylor et al., 2000.

| Farmed Fish | Total Production | Percentage Produced with Compound Feeds | Production with Compound feeds (kilotonnes) | Percentage Fishmeal in Feed | Percentage Fish Oil in Feed | Average feed conversion Ratio | Wild fish used for fishmeal (Kilotonnes) | Ratio of wild fish: fed farmed fish |
|---|---|---|---|---|---|---|---|---|
| Salmon | 737 | 100 | 737 | 45 | 25 | 1.5 | 2,332 | 3.16 |
| Tilpia | 946 | 35 | 331 | 15 | 1 | 2 | 466 | 1.41 |
| Catfish | 428 | 82 | 351 | 10 | 3 | 1.8 | 296 | 0.84 |
| Carp (fed) | 6985 | 35 | 2,445 | 8 | 1 | 2 | 1,834 | 0.75 |

## Application of Methods to the GBR

Marine zoning and fish farming are two valid options in the preservation of GBR fish stocks while maintaining a constant supply of protein for an increasing population. The introduction of computer databases has become very important in the mapping of wild fish stocks. (Imsiridou, Hardy, Maudling, Amoutzias, & Zaldivar Comenges, 2003) Through varying methods of obtaining concise genetic information the databases allow scientists to access the genetic origins of fish stocks, which will lead to better management of commercial fish stocks (Imsiridou et al. 2003). With this information zoning of genetically important areas within the Great Barrier Reef Marine Park will become more manageable and stocks will be able to replenish at a natural rate (Williamson et al., 2012).

Wild stocks are unlikely to provide a sustainable supply for the whole population but this can be countered with fish produced in farmed conditions (Naylor et al., 2000). Development within the industry has led to a more efficient farming system and investment into medication, feeds and genetic disease resistant stocks has made a more sustainable industry (Austin, 1989). Further investment into lower trophic species can minimalize the cost of production and high protein requirements of carnivorous species and polyculture systems will result in higher production yields (Naylor et al., 2000).

The combination of these two methods is essential for Australia and the GBR in particular. For fish farms to be successful they need a number of physical requirements, such as reliable rainfall, ideal water conditions and certain geomorphic characteristics (Ogamba, & Abowei, 2012). With inconsistent weather patterns fish farms could not be relied upon for complete supply of fish protein.

## Conclusion

The preservation of fish stocks on the GBR will remain an important factor as global populations continue to rise. Through improvements in the understanding of how genetic flow affects wild fish stocks (Bergenius, Mapstone, Begg & Murchie, 2004), more effective zoning can be implicated allowing for the recovery of depleted stocks (Agardy, T.  2010). Fish farming can be effectively used to help cover the short fall in supply from wild stocks and can provide a more sustainable and reliable future (Lazard et al., 2011). Despite a few problems with current systems these methods (Ogamba, & Abowei, 2012), with continued investment, research and development, will result in a balance that is ecologically sound and sustainable.

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