MARINE STOCK ENHANCEMENT: A CRITICAL REVIEW OF THE PAST AND A LOOK TO THE FUTURE WITHIN COASTAL COMMUNITY-BASED MARINE RESERVES

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Marine Stock Enhancement: A Critical Review of the Past and a Look to the Future within Coastal Community-based Marine Reserves

by

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Abstract

The diversity of life in the oceans is being radically changed by the rapidly increasing and potentially irreparable consequences of human activity. Past and present methods of fisheries management globally are ineffective in mitigating the problems and pressure being inflicted on the marine environment. With the human population growing and the abundance of protein in the oceans declining, it is apparent that a new form of integrated management be established for the marine ecosystem. This new way of managing could be possible with the integration of Marine Stock Enhancement science and Marine Protected Areas. Though current enhancement projects are on the rise, they are concentrated in artificially rearing and releasing fish into the wild. This can negatively affect the functioning of reproduction of the system in a number of ways. A promising alternate approach would be Enhancement of Reproductive Potential, by way of 'catch, grow-out and release'. The method aims at improving recruitment of a fish population by growing out wild produced juvenile and then releasing them back into the wild after a period of time, inflicting no detriment to the system. This technique enables the fish to grow faster than their wild counterparts and potentially reaching sexual maturity in less time. Under the protection of a regulated Marine Protected Area this method could prove to be effective in restoring fish populations in coastal waters, while at the same time economically benefiting local communities by way of sustainable fisheries and tourism. An integrated approach to the management of the oceans is necessary to reach the common goal of restoring and maintaining a diverse marine environment for the future and conserving an important resource.

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List of Abbreviations and Symbols

MPA – Marine Protected Areas

FRCC – Fisheries Resource Conservation Council

DFO – Department of Fisheries and Oceans

HR – Hatchery Reared

ERP – Enhancement of Reproductive Potential

NAFO – Northwest Atlantic Fisheries Organization

OREHP – Oceans Resources Enhancement and Hatchery Program

ICES – International Council for the Exploration of the Sea

EIFAC – European Inland Fishery Advisory Commission

AOI – Area of Interest

EPLPC – Eastport Peninsula Lobster Protection Committee

Chapter 1: State of the World's Oceans

1.1 ~ Introduction

The diversity of life in the ocean is being radically changed by the rapidly increasing and potentially irreparable consequences of human activities (National Research Council, 1995). The removal of wild organisms from the marine environment through commercial fisheries may be the most significant impact of any influence. The State of the World Fisheries and Aquaculture (FAO, 2001) confirms that 47% of the 441 major fish stocks of the world are fully exploited and are near or at the limit of exploitation. Approximately 18% are over-exploited, 9% depleted, 21% moderately exploited, while less that 5% are under-exploited. This over utilization threatens the permanence of entire ecosystems and as a result it is critical that strategies be found to optimize yields more effectively (Munro and Bell, 1997), as current methods are depleting fish biomass. Fisheries have been closed due to the devastation of stocks (e.g. *Gadus morhua* in the north Atlantic in 1992/93; Hutchings and Myers, 1995) while at the same time many fisheries have increased effort to maintain catch rates for economic reasons. Internationally, the fishery accounts for almost $US 100 billion in first-sale revenues per year (Committee on Ecosystem Management for Sustainable Marine Fisheries, 1999). The over capacity of world fishing fleets putting excessive stress on the productivity of the marine resource is reducing the overall profitability. Approximately $54 billion is lost each year to global fishing enterprises (Moreau et al. 2000). Because of the economic dependence as well as the importance of maintaining a diverse ecosystem it is in the interest of the entire global community that this tragedy of the oceans does not continue.

The economic importance of the fishery, though highly subsidized, is one reason why the exploitation has been constant and relentless; however the demand due to human survival is another. In serious question is the world supply of protein being extracted from a limited ocean supply. The FAO has stated that in order to feed the world population in the year 2010, there is a need to increase the total catch by 50% (Moreau et al. 2000). It was once thought that the ocean was "inexhaustible", now it is realized that it is overexploited and traditional fisheries and sources of protein is in danger of collapse.

A relatively new procedure that has had increased attention in the past decade is Marine Stock Enhancement. It has emerged as a major component of human interaction and research in fisheries management (Coleman et al. 1998). The potential for enhancement to provide a possible solution to the escalating problems of fish stock overexploitation and limited food supply to the global community means that it must be incorporated into future fisheries management systems around the world. It is recognized that fisheries management is in need of critical review and modification, and processes such as Marine Stock Enhancement must be examined.

With the failure of the northwest Atlantic cod stock to recover during the past decade, stock enhancement of northern cod was seriously considered in Newfoundland & Labrador. Cod enhancement was studied in the province in 1994/95 but opposition to the project ended furthering the study. Presently, the 2001/2002 FRCC Report to the Minister of Fisheries and Oceans (page 11), "recommends that DFO in consultation with industry and local and international experts review existing information and investigate the feasibility of using release of hatchery-raised juvenile cod in Newfoundland coastal fjords to rebuild local stock components". Past studies on cod enhancement in Norway published in Howell et al. (1999) and Cowx (1998) have concluded that hatchery-based enhancement efforts have been problematic and unconvincing. It is vital that the scientific community and fishing industry be made aware of alternative methods to hatchery-based enhancement as well as the new criteria for hatchery-release based enhancement.

Such an alternative to the hatchery-based method is called Enhancement of Reproductive Potential (ERP) by "catch, grow-out and release". The technique utilizes wild caught juveniles for the purpose of growing them out on a natural diet and then releasing them back into the wild to contribute to the reproduction of the local stock (Wroblewski and Hiscock, in press). Because this enhancement technique uses local juveniles it provides recruitment into the fishery with no genetic alteration. This is a major concern of researchers and scientists in the field (Munro and Bell, 1997; Howell et el. 1999; Cowx, 1998; Leber, 2002). It is important for such an operation to be carried out in a Marine Protected Area or "no fishing zone", as this would limit the fishing mortality on the population that is to be enhanced.

With this promising option of marine stock enhancement, there is cause for further investigation in Newfoundland inshore waters and with various species of fish that have similar reproduction characteristics. A cod enhancement pilot program in a protected area would be a means to experiment on a bay scale the effectiveness of "catch, grow-out and release" as a stock restoration tool. Through new and innovative management strategies and an objective view that incorporates ecological considerations along with socioeconomic need, effective long-term plans for mankind's use of the marine environment is conceivable.

Through combined Marine Protected Areas and fish stock enhancement efforts this may be possible.

1.2 ~ Purpose and Scope of this Paper

The purpose of this paper is to examine the concept of Marine Stock Enhancement particularly in Marine Protected Areas or Reserves as a means to increase the biomass of marine fish stocks. In this respect the paper will look at past enhancement efforts and critically review the current status of marine stock enhancement throughout the world. I discuss the significance of MPAs to the global marine environment, as well, the significance of the human dependence on the system. In addition, marine reserves and the importance of community involvement to its success will be considered, as will the potential societal benefits of such an establishment.

The method of "catch, grow-out and release" will be presented as a means of successful enhancement of *Gadus morhua* in Newfoundland and Labrador within the context of a potential MPA in Gilbert Bay, Labrador. Other teleost fishes will be considered as well to illustrate effective restoration and conservation of different species within reserves. With this review the economic importance along with the various problem-solving benefits of establishing Marine Protected Area / enhancement programs will be demonstrated.

1.3 ~ Justification for Research

The present status of marine stock enhancement worldwide suggests the need for an in-depth and critical review of current and alternative methods. From the material available on this subject it is evident that the goal of the majority of scientists and researchers of marine enhancement is to evaluate, refine and advance the "hatchery based" method for future enhancement projects. All research conducted globally on marine enhancement has uncovered in various problems and significant uncertainties related to life-cycle development stages in the hatchery environment, genetic changes, as well as behavioral problems of released fish. There has been limited success stories compared to the effort expended over the past decade in many regions of the world.

Contrary to the many rationales for supporting marine enhancement, including recovering endangered species, restoring fisheries, and decreasing the fishing pressure on wild stocks, there is justified resistance to the hatchery-based practice. Dr. Carl Walters, of the University of British Columbia, has presented many ways that this technique can do irreversible damage (Information obtained from conference in Baltimore, Maryland: The Interface between Aquaculture and Stock Enhancement, March 2002). His concerns are on the replacement of wild fish with hatchery-raised fish, unregulated fishing effort responses to the presence of hatchery fish, and genetic impacts on long term viability of the wild stock. In addition, the socioeconomic factor can play an influential role with management decisions.

Currently in Newfoundland and Labrador, there are two private companies building hatcheries to supply cod juveniles for "grow-out" in sea cages and the market. It is possible that hatchery raised cod could be released into the wild for future enhancement activities. It is vital therefore that the scientific community and fishing industry be made aware of the detriment this can cause to our marine environment and in turn bring attention to the alternative method to hatchery-based enhancement, "catch grow-out and release" and habitat restoration, particularly in protected areas.

Chapter 2: Marine Stock Enhancement

2.1 ~ Problems with Fisheries Management

Ludwig et al (1993) advocates that it "is more appropriate to think of resources as managing humans than the converse". It is often overlooked that people are a part of the ecosystem that is being managed. In fact it is the people not the fish that are managed. If it were not for the human dimension there would be no need to manage the natural world around us. The lack of effective management is one of the contributing factors that have led to the current poor state of the world stocks, along with insufficient and limited science and socioeconomic factors. There is often a cross over of all three (Committee on Ecosystem Management for Sustainable Marine Fisheries, 1999).

The history of the fishery can be portrayed as a long series of crisis (Finlayson, 1994; Charles, 1994). This is especially true in Newfoundland & Labrador where the Federal government is considered as being ineffective in managing the resource and the exploitation of it. Though the Government of Canada can take most of the blame for the fishery crisis through mismanagement, there are other factors that have been contributors; those that have made the task of control incredibly difficult. According to the Committee on Ecosystem Management for Sustainable Marine Fisheries (1999), management has failed to deal with uncertainty. There is no definite policy solution to the overexploitation of fisheries. It is a problem that man has created over time. In addition, biological factors of population fluctuation and change are not in accordance with the ability of management or industry to react or respond efficiently. There is also the dynamics of environmental effects on migration patterns and multiple management involvement to consider (Committee on

Ecosystem Management for Sustainable Marine Fisheries, 1999). There is indeed a time and spatial scale difficulty for managers to contend with as surveillance and enforcement on the open ocean is problematic. The difficulty of effectively managing complex multi-species fisheries in addition to single species with multiple harvesting sectors is also an enormous challenge (Day, 1995).

Critics of fisheries management have said that there has been a lack of clear goals and objectives (Blackwood, 1996) and therefore it would be impossible to monitor or achieve them effectively. Political agendas and conflicts at the center of the fishing industry cause confusion making it an environment where there is obvious potential for management decisions not being made in the best interest of the resource. In addition there is pressure on managers to increase effort on under-harvested species when the present by-catch of that species is currently being damaged as it is a less productive fish species (Committee on Ecosystem Management for Sustainable Marine Fisheries, 1999). These are pressures put on fisheries managers on a regular basis but that does not excuse the way in which these demands are handled.

The ineffectiveness of enforcement on a worldwide scale is a major factor in the overall inadequacy of management of world fish stocks. Illegal activity in such a vast and complicated industry is difficult to control in the open ocean. However organizations, including government, have not been strict enough when enforcing regulations of this once massive resource. It is one of the biggest problems facing fish populations today especially in the north Atlantic waters. As Day (1995) testifies "management of these stocks (Canada's eastern straddling stocks) by Canada and NAFO (Northwest Atlantic Fisheries Organization) has failed to prevent stock depletion". The reason is "the lack of enforcement capabilities to make members comply" although it has often been the case where regulations have permitted the "legal" over-fishing of certain fish stocks (Objection Procedure) (Day, 1995). With such problems it is understandable that fish populations globally are in a state of major concern of collapse. Other ways of managing the oceans must be explored. It is also vital that there be a paradigm shift in the way people regard the marine environment, especially those people whose social economic future depends upon its sustainable use.

2.2 ~ What is Enhancement of Marine Stocks?

Stock enhancement is defined by Munro and Bell (1997) as a process whereby the abundance of free-living juveniles is supplemented by the release of juveniles reared in hatcheries or captured elsewhere. The process takes aim at increasing recruitment to a particular fishery when it is at a level that cannot grow or reproduce quickly. With world capture fisheries in such a poor state and the human population increasing, Marine Stock Enhancement is an option that has begun to be seriously discussed as a restoration tool and in all probability as a strategy for future management globally. In the several decades fisheries management has been inefficient in supporting sustainable stocks for commercial benefits (Day, 1995). It is for this reason there has been an increased awareness and interest in enhancement worldwide. The many weaknesses and negative outcomes associated with past techniques require new research and scientific evaluation immediately (Leber, 2002).

Marine enhancement also includes restoration of the marine environment in addition to more carefully controlled fishing activity. Habitats may be rebuilt after such detrimental effect as pollution, environmental interventions, or damage caused by fishing gear, and then carefully managed to restore the former natural environment. There are many scientists and researchers who are advocates of this type of enhancement rather than techniques that are based in artificial reproduction of fish populations (Leber, 2002; Conover, 1998). Though both are utilized, the latter seems to be the method that is gaining the most attention in recent years, as is evident in the available literature.

2.3 ~ Historical Attempts at Marine Stock Enhancement

Worldwide there have been numerous attempts to improve failing fishery stocks. Enhancement of marine populations has a long history around the globe (Wilson et al. 1998). The ongoing poor status of the Atlantic cod in the Newfoundland and Labrador region despite a 10 year closure has evoked calls and challenges for science to improve the natural stocks' condition. Enhancing groundfish stocks along the coast of the world's oceans is not a new idea. Many fishery laboratories in North America and Europe that exist today have their origins rooted in the late 1800's (Wilson et al. 1998). Enhancement programs were thought, and still are, to be a way in which poor stock abundance can possibly be improved. The main objective of stock enhancement is to maintain or strengthen wild populations where production is low for reasons other than natural fluctuations (Working Group on Cod Enhancement, 1994). Wild fish stocks are exhausted today due to a failure to control fishing pressure and the worldwide misuse and abuse of the marine environment. These impacts are often exacerbated by natural fluctuations in the marine environment.

2.4 ~ Production Oriented Stocking

Supplying oceans with hatchery-produced "seeds" of finfish and shellfish was for over a hundred years (since mid 1800's) the tactic used to replenish declining or depleted commercial stocks. However, these programs had limited assessment mechanisms for the success of improving the population in the long term (Leber, 1999). Since that early time efforts have been practiced with little or no scientific research and have shown little evidence of success, as there has been limited advancement in monitoring enhancement releases. According to Cowx (1998) the general consensus is that stocking has been used on many occasions, but many times it has been used inappropriately as a tool for fisheries management. It is for this reason among others, that the concept has fallen out of favor with many fishery biologists (Blankenship and Leber, 1995; Leber, 2002). The most common and fundamental principle behind marine stock enhancement over the past century has been the magnitude of hatchery production (Masuda and Tsukamoto, 1998; Bartley, 1999; Leber, 2002) for the purpose of rapidly restoring exhausted and over-fished stocks. This is termed as "production-oriented stocking", (Leber, 2002).

Newfoundland

An example of "production-oriented stocking" can be illustrated using a local attempt by a Norwegian fisheries inspector named Adolf Nielsen, who was hired by the Newfoundland government in the late 1800's to study the fishery and make recommendations (Baker et al. 1992). It was thought that the resource was in decline compared to previous catches in the area. He established a hatchery in Trinity Bay in 1889, and in its first year of operation released 17 million yolk-sac cod larvae into the bay peaking at 221 million in 1894 (Working Group on Cod Enhancement, 1994). As Leber (2002) contends there was no way to determine the success of a project such as this, even though reports in Trinity Bay a few years later indicated an abundance of young codfish in the Bay. This may have been a natural occurrence and not a result of the project. The funding was discontinued, as there was no indication that the project improved the local stock. It could not be proven that the abundance was the result of enhancement manipulation. Interestingly, Norway began enhancement efforts at about the same time but unlike Newfoundland, the program was continued until the 1970's, though effectiveness was highly debated over the years (Working Group on Cod Enhancement, 1994).

Japan

A form of stock enhancement in Japan dates initially back to the late 1700's. By closing off sections of a river to all fishing efforts, adult salmon were protected during spawning season (Masuda and Tsukamoto, 1998). In the late 1800's modern techniques such as artificial fertilization of salmon were introduced from the United States. These intensive release programs were continued for the next hundred years (Masuda and Tsukamoto, 1998). Scallop enhancement in Japan evolved in the 19th century (1860's) but was only used for a short time. However, since the 1970's, scallops have increased exponentially due to the introduction of seeding beds (Masuda and Tsukamoto, 1998). Only since the 1960's have marine finfish been artificially reared and released in Japan. Flounder (*Seriola quinqueradiata*) has become one of the most important species, accounting for 60% of the country's total cultured fish production (Main and Rosenfeld, 1995). Though these fish are not released back into the wild, they are collected from the wild for grow-out purposes. This method dates back to the early 1970's with production efforts. The species that was first released was red sea bream (*Pagrus auratus*) in 1962, but in the past quarter century extensive research and experimentation has taken place with limited success (Masuda and Tsukamoto, 1998). Mass production and release of hatchery produced fish is the common practice in Japan.

United States

In the United States, the credit for establishing the initial enhancement effort is given to Spencer Baird, the first U.S Commissioner of Fisheries. Woods Hole, Massachusetts along with other hatcheries on the coast served to artificially mass propagate the coastal marine environment (Galtsoff, 1962, in Wilson et al. 1998). The history of culture and release of Atlantic cod in the Gulf of Maine began in 1906 using yolk sac larvae. Booth Bay Harbor continued this method until WWI, when production activities in the laboratory environment were reduced (Wilson et al. 1998). In 1927, lab activities ceased. Instead eggs were stripped, fertilized, and then dumped overboard. Though the history of enhancement efforts is fairly long, no studies began in the area until 1993 (Wilson et al. 1998). Much research and experimentation has been conducted since the early 1990's when the Atlantic cod populations hit low record numbers. In Maine, the Groundfish Hatchery Study Commission was established for the purpose of investigating the feasibility and economic viability of such hatcheries in the area (Wilson et al. 1998). As with the Japanese system, mass production of hatchery animals was, and still is a common practice.

Chapter 3: Impacts on the Natural System

3.1 ~ Consequences of Marine Stock Enhancement

The view of and management use of enhancement as a rapid way to "refill" the fish populations has led to overshadowing of the development of any serious science base (Leber, 2002). While little to no scientific knowledge and research was given to evaluating the success or impacts on wild fishery populations over the past century, millions of dollars were still spent on this practice. Because it has failed to a large degree, there are organizations and fishery scientists that are strong opponents to any enhancement project involving artificial propagation. Such an organization is *National Marine Fisheries Service* in the United States. Scientists from this organization are adamantly against any use of enhancement on wild stocks even if it is considered by others to be an effective technique (Leber, 2002). This view is based on the possibility of permanently damaging and altering natural stocks.

In opposition to this view there are a growing number of scientists and experts who are dedicated to the science based field of marine stock enhancement (Blankenship and Leber, 1995; Cowx, 1998; Munro and Bell, 1997; Masuda and Tsukamoto, 1998; Leber, 1999). Because management of the commercial marine stocks has failed worldwide, many fisheries scientists have taken a great interest and have become aware of the importance and need for change in the managing of the marine environment. Unfortunately not all researchers realize the importance of having a theoretical science base and use an experimental approach in all enhancement projects. This is another reason for enhancement not being supported by other scientists and managers in fisheries.

3.2 ~ Potential Benefits of Stock Enhancement

Stock enhancement has both positive and negative attributes. According to Leber (2002), there is an attraction of stocking that has captured the interest of the science community and the public alike. Proponents of enhancement see it as a management tool that has immense potential. In addition to restoring fisheries and balancing out weak year classes, there are positive means of recovering endangered species, repairing environmental disturbances, and decreasing the pressure on wild stocks in commercial fisheries (Leber, 2002). It is also apparent that enhancement can be used to build knowledge, promote education about wild fish populations and the marine environment, when used as an experimental mechanism (Leber, 2002).

3.3 ~ Inappropriate Use and Problems

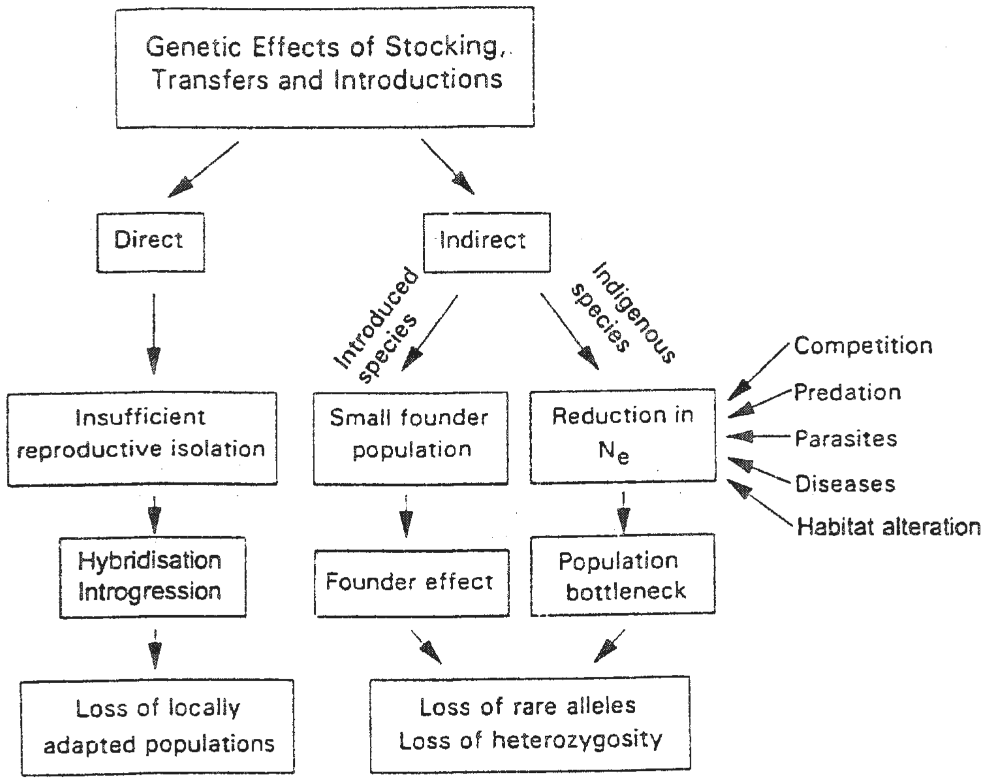
Contrary to the rationales supporting marine enhancement, there are equal justifications for the resistance of this practice. As a new science based procedure enhancement has had little development regarding qualifications for reasonable decision making on stocking. This implies many uncertainties in the field. In addition, as noted by Dr. Carl Walters at the conference on *The Interface between Aquaculture and Stock Enhancement*, March 2002, 'once started, stocking programs are extremely difficult to stop', regardless of detrimental effects. As well, stocking causes over-fishing where there is an abundance of fish, elevating catch rates and negating the benefits. Other problems stem from disease introduction, genetic reduction of diversity and fitness in wild fish populations, in addition to potential competitive displacement by hatchery reared fish (Leber, 1995; Conover, 1998; Leber, 2002). These are the risks of enhancement and the reason for much needed improvement in the scientific research.

3.4 ~ Genetic Alterations to Wild Stocks

According to Tringali and Leber (1999), a responsible approach to stock enhancement includes mitigating negative impacts on gene pools of wild populations. This can be accomplished by implementing genetically safe breeding and release procedures. The technique should be adaptable as the stock enhancement program evolves from the experimental stage to an expanded one (Tringali and Leber, 1999).

There are three levels at which the release of fish into the wild can have genetic impacts. The impact can be on the individuals released, on con-specific, native fish or on indigenous species (Carvalho and Cross, 1999). These effects can be either direct or indirect as Figure 1 illustrates. Direct impacts include such things as hybridization and introgression, which initiates changes in the gene flow within the species. Indirect effects are essentially those that are caused by inadequate numbers of spawner fish. This may be through the release of a small number of individuals or, in the case of indigenous species, through ecological processes such as competition, predation, new diseases or parasites (Carvalho and Cross, 1999). These types of genetic alterations may lead to a loss of the locally adapted populations and genetic diversity (Ryman et al, 1995, in Carvalho and Cross, 1999).

Figure 1. Indirect and direct effects on genetics of a fish population.
(Carvalho and Cross, 1998)



The effects on the genetics of a population are dependent on whether the released fish are from a wild stock or cultured. Domestication, as Carvalho and Cross (1999) indicate, involves changes in the quality, variety or combination of alleles. This produces effects similar to the loss of diversity within populations in nature. The domestication of hatchery fish makes the culture more effective, yet may also decrease the performance of the fish and that of the offspring they produce in the wild (Carvalho and Cross, 1999; Conover, 1998). The problem lies with the reproduction of these hatchery fish with the wild population, which tends to show superior performance comparative to their hatchery counterparts (Munro and Bell, 1997; Leber, 1999). The interbreeding may cause a dilution of the species survival characteristics, making them more susceptible to death. The potential loss to the genetics of wild fish populations is unfortunately difficult to predict because of the intricacy of the ecological interaction within the marine system (Carvalho and Cross, 1999). The complexity suggests that geneticists be involved in the planning, execution and monitoring stages of any enhancement project that involves cultured or wild broodstock from hatcheries.

3.5 ~ Importance of Knowing the Life-cycle of potential species

The life history of an organism can make enhancement ineffective even if factors, such as loss of genetic diversity, displacement of stocks or changes in predation pressure or harvest, have been mitigated (Heppell and Crowder, 1998). As an example, species with delayed maturity can have such low survivorship to age at first reproduction that increasing the number of juveniles as enhancement tends to do, may have little impact on the adult population size years later (Heppell and Crowder, 1999). An example of a marine species that can illustrate this is the Kemp Ridley's sea turtle. It was found that the animal has a delayed maturity and was declining due to the incidental drowning of late juvenile and adults in shrimp trawls. The captive rearing and release of these animals was therefore not effective in greatly enhancing the population growth overall.

The most consequential improvements to the population came with the potential benefits of the turtle excluder devices (Heppell and Crowder, 1999). This was presented as a result of using population modeling and life history analysis. Though the modeling efforts of Heppell and Crowder (1999) have concentrated on sea turtles, it is thought that the basic life history analysis could be applied to fish with relatively constant annual survival rates. This device should be used as a component of the improving science of enhancement. Other components include establishing specific goals and objectives, hypothesis testing, monitoring and evaluation (Heppell and Crowder, 1999).

3.6 ~ Problem's associated with Hatchery Release.

There are many factors attributed to the problems associated with hatchery reared fish. The fitness of hatchery raised juveniles and the releasing strategies are the major ones. Munro and Bell (1997) found that hatchery-reared (HR) juveniles have an inferior survival rate to their wild counterparts. These fish include individuals that have adapted to the conditions in the hatchery environment as well as fish that have only survived because of the safe environment. To add to the detriment, the broodstock fish are often hatchery raised and not wild. This will reduce the characteristics needed for survival in nature after the release of the fish (Munro and Bell, 1997). The fitness potentially is reduced by way of decreased tolerance to stress as well as a greater vulnerability to predation. The poor nutrition of the fish in addition to the unchanging environment is thought to be the reasons why HR fish have a higher mortality than wild fish. To counteract the negative aspects better nutrition may be introduced as well as environmental conditioning of the fish by increasing the amount of stimulus they encounter while in the hatchery. This may be accomplished by temperature and or salinity fluctuations within the hatchery environment (Munro and Bell, 1997).

The second factor that is attributed to the problems of hatchery released fish is the releasing strategies. The main considerations are size at release, the season of release and the habitat in which the fish are released into (Leber, 1995; Leber and Arce 1996; Leber et al 1995). There is also the stocking density to consider. A positive correlation exists between release size and survival that furthers the ability of the young fish to escape predation (Munro and Bell, 1997). There is also the point that environmental factors can cause mortality to smaller, less robust fish. The problem with waiting to release the fish is the cost of growing them longer in the hatchery. There is cost associated with lengthening the time spent in the hatchery.

Mortality due to predation causes problems when releasing the HR fish into the wild. It is thought by Leber et al (1995) that these cultured fish have an increased chance of survival if they are released when they are of a similar size as their wild counterparts. The habitat into which the HR fish are released is also of great importance. It should follow the biological requirements of the wild fish of the same species. These habitats would ultimately be nursery sites or other areas, depending on the life stage that would be natural if they were wild produced. It is therefore necessary to know the biological limitations of the species being cultured (Munro and Bell, 1997).

Another factor to consider when releasing cultured fish into the wild is the carrying capacity of that habitat (Munro and Bell, 1997). The effects of putting too many fish into an area can be detrimental to the entire region. The trophic requirements of the enhanced species must be known, as well as that of the competition species in that habitat area (Munro and Bell, 1997). Much research is needed in order for this to be effective. Overall, it is necessary that marine stock enhancement programs utilize information on population structure of the target species (Shaklee and Bentzen, 1998). This will help optimize the procedure strategies and also enable the proper operations in order to protect the genetic characteristics and biodiversity of all species in the system.

3.7 ~ Monitoring or Assessing Contribution of Stock Enhancement

One of the most critical components of any enhancement program is being able to quantify its success or failure (Blankenship and Leber, 1995). There are two ways in which the number of released individuals that survive can be monitored. One is by means of tagging or marking the fish that makes them conspicuous at the time of capture, the other is by mathematical modeling and sampling strategies (Munro and Bell, 1997).

Regarding tagging individuals, no single tag can satisfy all criteria (Munro and Bell, 1997). Some of these criteria would include the ability to mark small individual fish and be detectable at all life history stages. In addition the tag should be unique to local populations, and suitable for identification of cohorts from multiple releases. Tagging can be expensive. The marker should be harmless to the organism as well as the possible consumer and should be acceptable to the public (Munro and Bell, 1997).

Although no tag can satisfy all the criteria listed above, the coded micro-wire tag (Jefferts et al, 1963, in Munro and Bell, 1997) has been able to meet most for a variety of fishes. Other means of marking include chemical marking of the otolith and manipulating water temperature so patterns occur in scales or otolith (Barlow and Gregg, 1989, in Munro and Bell, 1997). However, there is a type of natural marking that occurs in some species reared in hatcheries. The process of hatchery rearing marks the fish distinctly, as in the Japanese Flounder, which develops darker pigments on the ventral side not found in wild fish (Kitada et al, 1992). Some types of scallops also develop distinct markings on the shell that coincides with time of release (Munro and Bell, 1997).

The object of genetic tagging is to assess the contribution of released fish to future generations (Munro and Bell, 1997). Genetic tagging can be contrived by breeding program that confers distinctive morphology or by having a broodstock that have rare alleles that can be traced (Shaklee and Bentzen, 1998). However, as Munro and Bell (1997) argue, there is a disadvantage of using natural genetic markers. This is the high cost of establishing and monitoring the variants and the potential for reducing genetic diversity in the enhanced stock.

The contribution of cultured juveniles to wild populations has been assessed according to Munro and Bell (1997) in at least four ways. They are (Matlock, 1990; Suda, 1991; Kitada et al.1992),

1) the proportion of released animals in the commercial catch,

2) the survival of released individuals at the same time of first harvest,

3) the ratio of cultured juveniles to the estimated recruitment from the wild stock,

4) increases in the total catch following enhancement.

Marking can be the means by which these can be attained.

Another way of estimating the contribution of stock enhancement in the wild is by sampling strategies and models (Munro and Bell, 1997). It may not be possible in some enhancement programs to tag the species (such as shrimp). Strategies have been developed (Underwood, 1992) to detect changes in the population and environment after the manipulation of an enhancement procedure. It involves sampling of control sites that have not been enhanced as well as the enhanced target sites several times before and after the enhancement. Any increases in abundance can therefore be attributed to the enhancement and not to a bumper year class from within the wild stock (Munro and Bell, 1997).

As mentioned above, stock enhancement systems can also be assessed using the conventional Beverton-Holt (1957) and fishery models (Ludwig and Walters, 1985). The Beverton-Holt yield per recruit model demonstrated that species with low ratios of natural mortality (M) to growth (K), in addition to asymptotic sizes, offer the greatest potential yield-per-stocked-juvenile. These mathematical alternatives to tagging as well as the sampling strategies are designed to evaluate the effect of hatchery releases on the total abundance of a fish population. These can be used when tagging is not appropriate or possible.

Chapter 4: Present Day Efforts

4.1 ~ Present Status of Marine Stock Enhancement

Currently, Japan leads the world in enhancement activities with more than 80 species being researched or being enhanced (Matsuoka 1996; Liao, 1999). Many marine enhancement projects throughout the world are in the experimental stage, approximately 60% according to Bartley (1999). Some are dedicated to sport fishing like barramundi (*Lates calcanifer*) in Australia while others are solely for commercial fishing like sturgeon (*Acipenser ruthenus*) in Caspian Sea (Bartley, 1999). Though salmonids are the most widely stocked group of fish, there are many other important species being enhanced including the red sea bream, flounders and scallops in Japan (Matsuoka, 1996). Yellowtail flounders (*Limanda ferruginea*) are also currently being collected from the wild and grown out to an optimal size for market (Main and Rosenfeld, 1995). This could potentially be modified into an enhancement practice as wild fish are used with no genetic alterations to consider.

Though presently there are some negative views on marine stock enhancement there are many that strongly support it. Though the debate continues among scientists there are those who favor it and fund such programs. One organization in the USA is the Hubbs-Sea World Research Institute, which in 1983 established the "Oceans Resources Enhancement and Hatchery Program" (OREHP), to evaluate the feasibility of using cultured fish for enhancement. At that time, research was directed at developing culture protocols, evaluating tagging techniques, identifying population characteristics of wild stocks (genetics included) and testing patterns of post release survival as well as computer modeling of cost-benefit analysis of the programs. A decade later the organization expanded, building a production-scale marine hatchery and cage-rearing facilities (Information obtained from a conference in Baltimore, Maryland: *The Interface between Aquaculture and Stock Enhancement*, March 2002).

In the past decade restriction of funding, compared to previous years, has been the reason for slow advancement, particularly with tagging techniques (Leber, 1999). In that same time period aquaculture technology has greatly advanced, much farther than the marine enhancement. New techniques created from aquaculture technology research could have positive influences for marine enhancement success, however these may or may not be the best tools for the improved science integrated marine enhancement (Dr. Ken Leber, Mote Marine Lab, Florida, pers. comm). This is where the field presently falters and therefore requires aggressive scientific investigation and pilot studies (Blankenship and Leber, 1995). Impact assessment and theoretical knowledge has to be of the utmost importance for the advancement of enhancement as an effective management tool.

In order for enhancement to be effective, stocking activity has to be well managed and has to take into account the many wider issues that are involved, those which can interfere with the enhancement operation (Cowx, 1998). Most projects do not address the issues that have led to the failed fishery in the first place. There is also little consideration given to environmental long- term issues. Presently, it is not known if there has been any success with stocking programs, whether economically or biologically. They are often altered or terminated due to the political, social and economic issues associated with fisheries management, since many of these issues that are ignored in the beginning of the process (Blankenship and Leber, 1995).

4.2 ~ Management Issues of Enhancement

There are three important management issues pertaining to marine fisheries enhancement (Howell, 1998). These are property rights, cost benefit analysis, and legislation. Private ownership is possible with a single point harvest such as with salmon, however public fisheries may require special licensing or landing tax (Howell, 1998). Cost-benefit analysis is in great need of attention concerning enhancement programs. Objectives are crucial to this analysis. In the USA sport fishermen have motivated three major enhancement programs. Because of the increase in tourism due to these particular enhancement efforts, benefits are not constrained by the market value of the fish itself (Howell, 1998). This example illustrates how varied economic benefits can be and how the profit can come from alternative sources. The third management issue involves legislation. Legislation will be required regarding the utilization of enhancement within fisheries management. Enforcement and control of released fish into natural waters are needed to mitigate diseases and compromising genetic integrity of the marine environment (Howell et al. 1999) in addition to conservation of the population.

4.3 ~ Methods of Enhancement

Within the literature on marine stock enhancement there is a tendency for the terminology related to the practice to be used inaccurately. Stock enhancement and sea ranching are two commonly used terms that are often used interchangeably (Cowx, 1998). This may complicate the nature of stocking exercises to those who are unaware of the differences. According to Cowx (1998) there is a distinction to be made between the two and it is important to do so. Ranching refers to an identifiable stock that is released with the intention of being harvested by the releasing agency (Cowx, 1998). It implies a cost-benefit analysis based on the comparison of the harvested value with the cost of production, release and harvest. Enhancement on the other hand refers to a stock that is released for the public good without the intention of benefiting any one agency or user group. It may include restocking of a depleted natural resource, augmentation of a lost habitat, or creating artificial reefs for the purpose of a new stock in a particular area (Masuda and Tsukamoto, 1998;

Cowx, 1998). It also includes the rebuilding of spawning biomass of a species by kick starting the natural population, as is the premise of "catch, grow-out and release".

Currently the major methods or techniques used in augmenting fish populations globally are 1) the release of hatchery-raised juveniles, which is the dominant practice, and 2) redistributing wild captured and or cultured juveniles. The latter has had limited use. Although the first technique has been used over the past hundred years, today's views are gradually becoming more scientifically supported and based on experimentation and systematic applications of deductive reasoning (Leber, 1999).

The modern capabilities and advancements of hatcheries have allowed for the mass production of juveniles leading to new opportunities in enhancement programs. However, the number of fish that can be reared and released limits these. Mass production release is not based on scientific experimentation conducive to the most effective strategy for improved recruitment in the wild. The progressive alternative approach is termed in scientific literature as 'optimal release' protocol (Leber, 1999) and is emphasized by the experts to promote advancements in the field of marine stock enhancement, along with 'active adaptive management' (Hilborn and Walters, 1992). This 'adaptive management' is essentially strong inference adapted to fishery science (Leber, 1999). Adaptive management usually refers to the use of uncontrolled experiments in place of observational studies. It is thought that inferential is weak in both cases however.

The basis for the second method of enhancement deals with transfer or capture and culture of wild juveniles. This involves collecting larvae or juveniles, nursing them and releasing them back into the wild when they are less susceptible to predation (Wroblewski et al, 1998), or simply transferring them to more adequate habitat (Munro and Bell, 1997). This method has been particularly effective for *pectinid* scallops in Japan and more recently in New Zealand, Australia and Canada (Munro and Bell, 1997). The technique for this is to trap the species at the larval stage just prior to 'settlement' in their lifecycle. The advantage of this less researched and utilized method is the decreased risk relating to genetic alteration of wild stock's as they are 'natural' not hatchery reared. There is however always the chance that diseases acquired during the nursing stage could be transferred to the wild population (Munro and Bell, 1997). This method is gaining more attention especially in the United States (Information obtained from conference in Baltimore, Maryland: *The Interface between Aquaculture and Stock Enhancement*, March 2002). The method of 'catch, grow-out and release', an example of the transfer or capture type of enhancement technique, has been studied since 1994 here in Newfoundland by various researchers at Memorial University (Working Group on Cod Enhancement, 1994).

4.4 ~ Advancement and Appropriate use of Marine Stock Enhancement

Stock enhancement is considered an applied science by some researchers but as stated previously more fundamental studies are required. Notwithstanding, any success will depend on biological and non- biological factors. The following diagrams (Figures 2 and 3) illustrate a summary of elements relevant to the success of marine enhancement.

Figure 2. **Fundamental Biological Studies Required for Marine Stock Enhancement** (Liao, 1999)

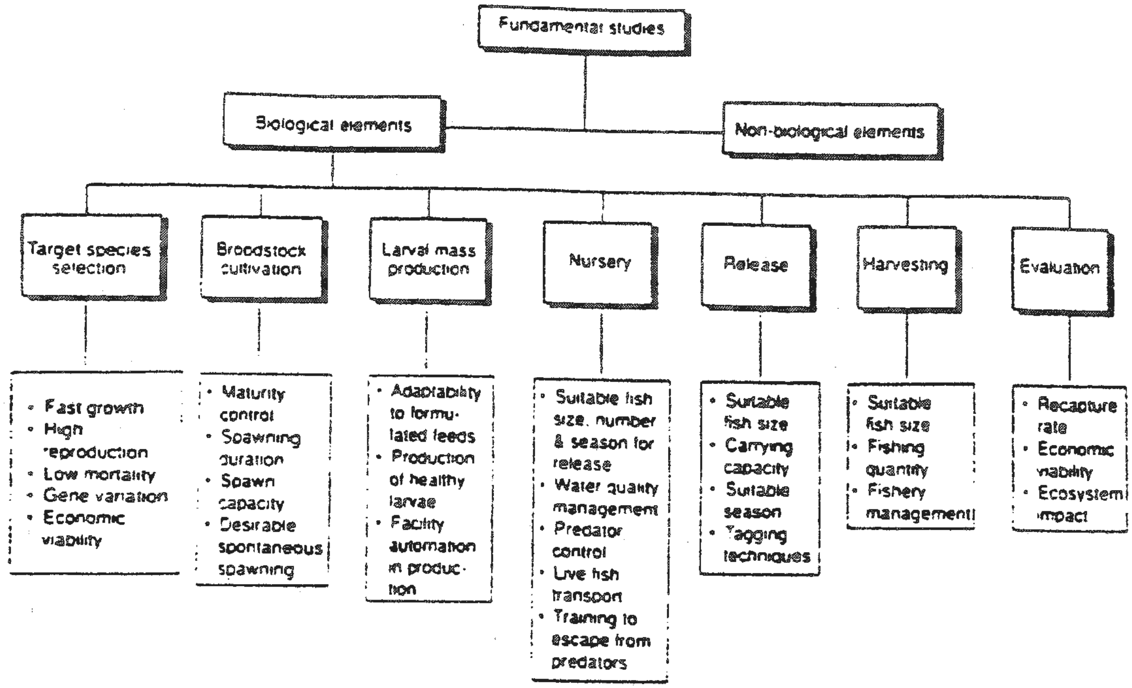
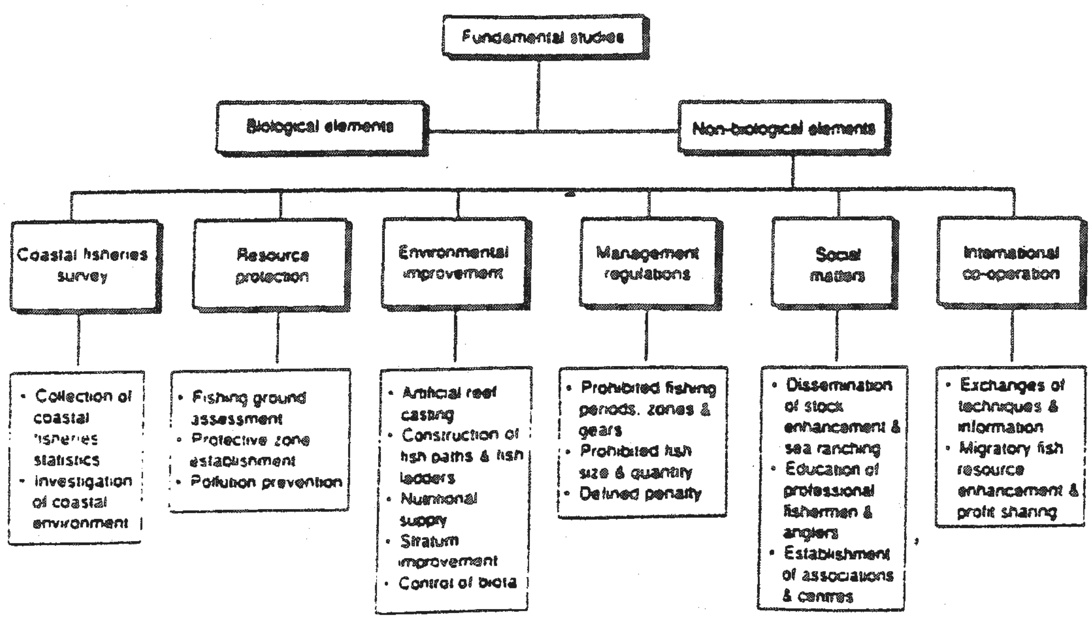


Figure 3. **Non-Biological Studies required for Marine Stock Enhancement** (Liao, 1999)

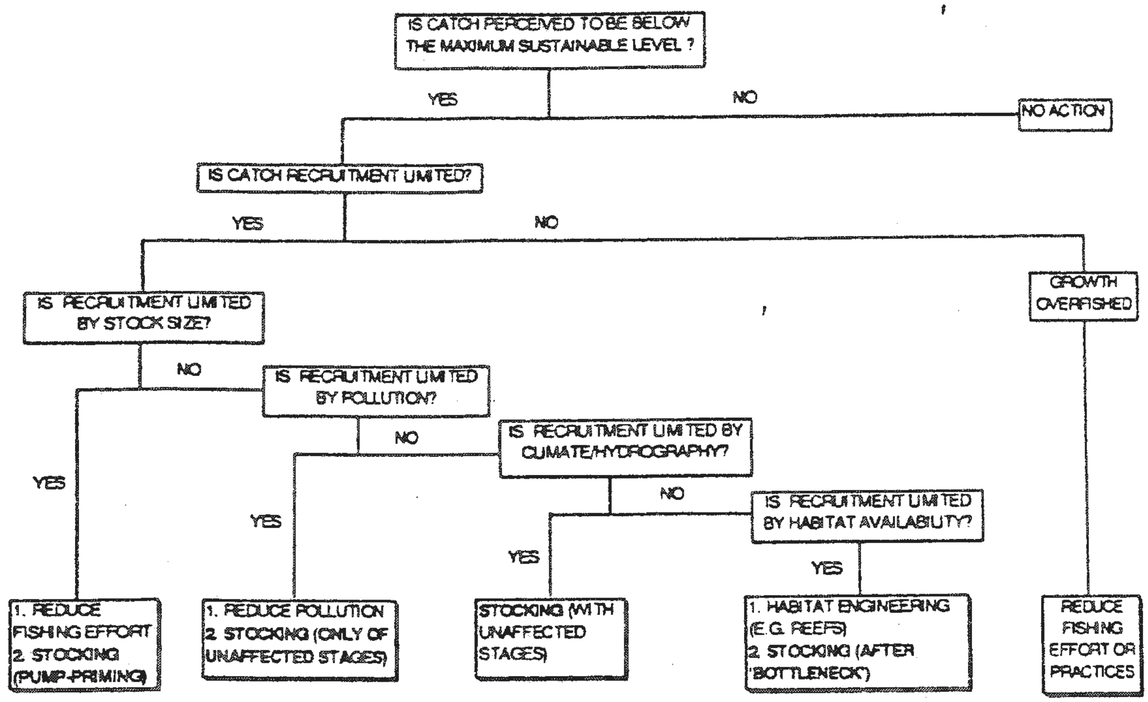


Among the biological elements needed to be investigated and studied for effective enhancement there is the selection of a target species, proper broodstock cultivation, larval production, nursery habitat, time of release, harvesting and evaluation (Liao, 1999). Listed in Figure 3 above are the studies required for the non-biological aspect of marine enhancement. These elements include coastal fishery surveys, resource protection, environmental improvement, management regulations and policy, social matters and international co-operation.

4.5 ~ Fundamentals and Criteria Affecting Success

Success of enhancement is dependent on what the desired objectives are. The importance of clearly defining objective should be recognized, as it will allow for the observation of the defined criteria that success or failure will be evaluated (Cowx, 1998; Leber, 2002). Objectives of stocking may vary with the user. For example, the goal of an enhancement program for fishermen would be to provide more fish for harvest, while the hope of a fisheries manager could be for the operation to relieve political pressure (Hilborn, 1998). It is also important to find out if enhancement is economically efficient since it ultimately uses the funds of the public. In other words does the cost of an enhancement operation surpass the benefits it produces? The following flow diagram from Howell (1998) illustrates a possible interrogative approach to determining the objectives of stocking exercises.

Figure 4. Flow diagram illustrating an approach to determining the objectives of a stocking program (Cowx, 1998).



This approach is to be used by defining fundamental questions relating to the characteristics of the target stock. Some of these questions may be in reference to the catch. If the catch is below its sustainable level, is it due to limited recruitment? Also, questions may attempt to identify the causes of this limitation such as pollution, climate or habitat activity or small spawning stock biomass (Howell, 1998). Another question to be considered is who should pay for stocking efforts of various aquatic environments. Should the user pay or the general public? For example should tax payers be responsible for the costs associated with restocking rivers that are to be utilized by sports fishermen only? When these and more questions are asked, it may be found that stocking is not an appropriate action to take. In addition, it may not be the only way to increase the yield. Other options may prove to more cost efficient and therefore should be pursued.

Though the flow chart above (Figure 4) is a good way to define the objectives of a program, it is recognized that there may not be sufficient information and therefore decision-makers may not be able to make proper judgement. Consequently, an empirical approach may be the only way of getting a better perspective on what is limiting the growth of a stock. In doing this, Howell (1998) suggests a necessary experimental approach. Reared fish must be equivalent to their wild counterparts with respect to survival, growth and movements. Past research comparing wild and HR fish has demonstrated that there are considerable differences (Leber et al. 1995; Conover, 1998; Heppell and Crowder, 1998) thus experiments should continue to possibly reduce discrepancies.

In addition to a program needing definite objectives for effective operation and outcome, a stocking project also has to be justified. There are various stages listed by Hilborn (1998) in determining whether or not a marine enhancement program is merited. One stage is the evaluation of the biological benefits that require the following:

1) Estimating numbers of fish that will survive and contribute to the harvest,
2) verifying whether this survival will be maintained for the future generations,
3) understanding to what extent the harvest can be managed without negatively impacting the wild, and
4) estimating the interactions of reared and wild fish that may decrease net production overall.

The second stage discussed by Hilborn (1998) for determining the success of a program is to estimate the economic benefits of the production. This is accomplished by knowing the value of the net production as well as whether changes in production affect price. The final stage is to estimate the cost of the production, additional costs of management, and then compare them to the benefits accrued (Masuda and Tsukamoto, 1998; Wilson et al. 1998). From material and information obtained at the conference on *The Interface Between Aquaculture and Stock Enhancement*, March 2002, it was understood that the monitoring of the marine environment and compiling adequate statistics on released individual was costly and a limiting factor in many studies.

Up to this point there has been little indication that using these criteria for marine stocking has worked or is economically efficient. It is because of this, and the skepticism of some fisheries scientists, that the new approach of enhancement involves the integration of more extensive theoretical research (Blankenship and Leber, 1995; Leber, 2002). Until this is standard procedure of enhancement programs the scientific community may not recognize enhancement as a management tool.

4.6 ~ Cost Effectiveness and Economic Considerations

The economic viability of stock enhancement is determined by the total cost of producing the desired life-history stage of the fish in question. The expenses include labor costs for hatchery operations, the cost of energy for facility operations, feed, property taxes, insurance costs and capital costs until the fish are recaptured and sold (Langton and Wilson, 1998). These are the factors that can influence the economic viability of any enhancement program (Bartley, 1999). Some biological components include stocking, mortality, growth harvesting, recapture and regulations to protect stocked fish. All factors must be balanced with regards to how they impact the costs on the program overall (Langton and Wilson, 1998).

The economics of stock enhancement is not well documented in the available literature, compared to the biological and social aspects of enhancement, but it is improving. An example of the problem associated with assessing the economic effectiveness of enhancement is evident with Japanese efforts. There is a national policy in Japan of subsidizing research and development in the field of enhancement. This subsidization is at various levels and totals more than 2 billion yen per year (Honma, 1993, in Munro and Bell, 1997). Billions more are spent in creating and restoring habitats for released juveniles. There are studies that do show enhancement in a favorable light. Examples of these positive returns were found with red sea bream (*Pagrus auratus)* and flounder (P*aralichthys olivaceus*), in Japan. In other cases (*Gadus morhua* in Norway and the queen conch, *Strombus gigas*, in the Caribbean), the economic analysis have indicated that enhancement efforts are not profitable due to the high costs of producing juveniles in hatcheries (Munro and Bell, 1997).

4.7 ~ Legal Problems and Issues – ownership of released stocks

In many Western developed countries, as with Japan, the general public considers the ocean as common property and therefore they can fish wherever they want. The operation of systems like this, notably those that have had precedents set in court or definite legislation, are the systems that are not and will not work well. Legal problems of enhancement are a reality in these systems. For instance, agencies stocking animals into common property areas are at risk of having any fishermen harvesting the benefits of their labor (Bartley, 1999). This has occurred in Oregon, USA, where offshore fishermen took advantage of a company's enhancement project by harvesting the company's enhanced salmon. The controversy surrounding this incident ended in many private enhancement programs terminating (Bartley, 1999).

The legal aspects of ownership and access to augmented stocks needs to be acknowledged and integrated into a management plan, policy or strategy before any program is initiated. In Japan it is acceptable for the heavily subsidized enhancement programs to be open to the community as common property. It is thought of as a shared resource (Bartley, 1999). In reality it is the residents closest to the project that benefit the most. Fishers in that vicinity would obviously gain immediate access. Because of this trend, local cooperatives and municipalities contribute financially to enhancement programs as it benefits its people directly (Bartley, 1999). Community based initiatives such as these have great benefits including enforcement compliance and socioeconomic impacts of a positive nature.

Elsewhere in the world, the ownership of released fish and the legalities involved have inhibited stock enhancement programs (Leber, 2002). This is a major issue that requires attention and should be integrated into every plan of enhancement implementation. This will be more difficult and complex an issue for public fisheries and other involved agencies as it includes the general public and a multitude of interest groups. A way in which many of these problems can be mitigated is arranging a partnership between enhancement programs and marine protected area or reserves.

4.8 ~ Code of Practice

There exists a code of practice for stocking and fish introduction (Coates, 1998) which was developed by the International Council for the Exploration of the Sea (ICES) and the European Inland Fishery advisory Commission (EIFAC). It provides a framework for considering enhancement activities (Coates, 1998). Codes of practice can and should be modified and improved over time with advances in relevant knowledge. Currently with regard to enhancement, there are basic concerns and considerations that are addressed in the Code; these are the socioeconomic aspects, ecological interactions, genetic effects, disease control and decision making mechanisms. These are all interrelated indicating a complex analysis when reviewed. As Coates (1998) suggests, any review of these concerns raises more problems than it solves. Review of the code however, is essential to acquiring the optimal code of practice of enhancement programs, minimizing detrimental effects on a number of levels.

Chapter 5: Benefits of Marine Protected Areas

5.1 ~ Importance of Marine Protected Areas

According to Agardy (1997), the ultimate goal of any marine protected area is marine conservation. Roberts et al. (2001) reports there have been more than 100 studies on marine reserves worldwide which illustrate that protection from fishing effort can lead to positive outcomes. These include rapid increases in biomass, abundance, and size of individual fish. Relative to this is the increased species biodiversity of a protected area (Roberts et al. 2001). The protection of critical ecological processes that maintain the ecosystem and allow for the production of goals and services that are beneficial to humankind is the premise of marine reserves. This protection will still allow for uses that are sustainable in the ecological sense. Specific goals and objectives vary greatly from each MPA depending on what the specific requirements for the people are as well as the natural environment. Some advantages pertaining to these reserves and the physical environment include fishery benefits, non-fishery benefits such as biodiversity of biotic communities, and economic gain such as tourism spin-offs. There is also the opportunity to learn and develop programs for an integrated approach to future management of the marine environment on a global scale (Klee, 1999).

Marine Protected Areas are primarily "islands" of controlled and sustainable use (Agardy, 1997). The larger system must be taken into account in order for such a program to work. Though MPAs are essential for the protection and conservation of important ecosystems, they are ineffective if the sea around them are continuing to be degraded, if they are the last refuges for the species, and if the cause of the degradation are not altered (Agardy, 1997). This brings into question the definition of an "ecosystem". Some people see the earth as one big united system including the earth, ocean, sun and sky, all interactive and dependent on the other. Others downsize this into many ecosystems of varying degrees of importance and complexity, each capable of independence from the other. The fact remains that there has to be some protection of specific areas if there is to be species and habitat in the future.

As the number of people in the world grow, many along the coastlines of the world oceans, so are the oceans becoming less diverse and productive. This is due to the excessive use by the growing population in these particular areas. The marginal ocean environments, that is, the coastlines, bays and estuaries, are the most dynamic of the entire marine system (National Research Council, 1995). They account for 30% of the marine productivity, though it is only 10% of its surface and less than 1% of its volume. Estuaries are among the most diverse and rich biomes on the earth, as are the coral reef systems, yet these areas are enduring the most destruction (Agardy, 1997). These areas suffer the most because they are the most productive and therefore have been and continue to be the most exploited. They also have large human populations close by because of the high productivity. It is for this reason that a mitigating process be established in these principal areas.

Without intervention of these negative effects on marine systems, restrictions to and elimination of major resources will occur. These include such things as source of protein, medicines, mangrove nursery, seaweed and marketable products for aquarium hobbyists. In addition, there are the benefits of the buffering services to the land, stabilization of the coasts, nutrient cycling, esthetic value and the many other planetary processes that the protection of this zone will effect (Agardy, 1997). To maintain these productive ecosystems, it is imperative that marine and coastal environments be protected with some form of conservation throughout the world for the benefits of humans, the biosphere and the future (Klee, 1999).

5.2 ~ Establishment of Marine Protected Areas Worldwide

The establishment of Marine Protected Areas and reserves globally in the past two decades has been prolific (Agardy, 1997). What exists ranges from small, specialized parks with a single objective, to vast multiple use areas with complex objectives (Agardy, 1997). As of 1995, the majority of MPA's existed in the region of Australia and New Zealand, and the north Pacific (Table 1). Though an estimated 80 million hectares are included in the world wide MPAs system (approximately 1300 sites) three particular areas, Great Barrier Reef, the Galapagos Marine Park and the Netherlands' North Sea Reserve, account for almost half of this total area (World Wildlife Fund Canada, 2002). It is important to note that the large number of MPAs is misleading, as many have no management plans and are only considered "paper" parks. Only 117 according to Agardy (1997) have management levels that are at a high level, showing significant effort and resources. Approximately 80% of the sites have little or no protection for marine biodiversity (World Wildlife Fund Canada, 2002), allowing various forms of destructive activity to take place. In addition, many MPAs have less than effective enforcement controlling activities within these protected areas.

Table 1 . Existing Marine Protected Areas by region. (Agardy, 1997)

Antarctic	17
Arctic	16
Mediterranean	53
Northwest Atlantic	89
Northeast Atlantic	41
Baltic	43
Wider Caribbean	104
West Africa	42
South Atlantic	19
Central Indian Ocean	15
Arabian Seas	19
East Africa	54
East Asian Seas	92
South Pacific	66
Northeast Pacific	168
Northwest Pacific	190
Southeast Pacific	18
Australia/New Zealand	260
Total	1306

Few coastal nations have systems in place to establish network Marine Protected Areas (Agardy, 1997). However Canada, Australia, the United States and the Philippines are exceptions. In Canada, a *National Framework for Establishing and Managing MPAs* (Fisheries and Oceans Canada, 1999) presents a general approach that the Department of Fisheries and Oceans (DFO) takes to establish and manage MPAs across the country. The program is implemented by DFO at a regional level whereby development of specific guides for implementing the *National Framework* can be suited to local marine conservation and protection needs (Fisheries and Oceans Canada, 1999). Unfortunately, having a national plan for MPAs does not make establishment easier. Those countries without such plans have more success in establishing protected areas (Agardy, 1997).

Though Marine Protected Areas cannot solve all conservation problems they can and have been recognized by scientists, managers and fishermen alike as an effective tool in managing many successful marine areas around the globe (World Wildlife Fund Canada, 2002). By setting aside unique and representative areas of adequate size (Lauck et al. 1998), fisheries and biodiversity of the marine system can be maintained or restored for future use and benefits. By restoring the productivity of the coastal systems it may be possible to correct past human misuse if the proper management plays a part in a new conservation regime for the future.

5.3 ~ Marine Protected Areas as a Fishery Management Tool

In the 1980's, it was realized that the main world fisheries resources were overexploited to the point of near commercial extinction, as evident with northern Atlantic cod *Gadus morhua* (Hutchings and Meyers, 1994). It is thought by many scientist and managers that Marine Protected Areas can be effective as a tool in fisheries management by rebuilding overexploited species (Murray et al. 1998; Roberts et al. 2001; World Wildlife Fund Canada, 2002). It is a part of an ecosystem- based method that is gaining more interest worldwide. In the 1990's scientific studies such as in the Philippines and New Zealand, illustrated that MPAs had a positive effect on fisheries in areas adjacent to the protected area (Roberts et al. 2001; World Wildlife Fund Canada, 2002). Though many skeptics dismiss this occurrence, it was established that the larval dispersal from the MPA would most likely increase the production in nearby waters. A recent publication produced reliable data obtained in St. Lucia showing the positive effects of a series of marine reserves in that area (Roberts et al. 2001). According to this data, the fishery in St. Lucia has increased 46% to 90% within five years. The fishery productivity was enhanced with only 50% of the area being restricted to fishermen. Fish biomass nearly tripled within the reserves and the spillover effect of the area has been greatly beneficial to the local fishery. The skeptics may question the effort that was put on the area outside the reserve, which may be the reason for the increase in catch, not the increase in the biomass. It makes sense however that Marine Protected Areas in combination with other management guidelines can potentially be beneficial to the marine environment.

Though there are various objectives per MPA involving multiple use strategies, it is necessary to include 'no-take' zones for the preservation of certain habitats, limiting fishing mortality in certain areas, and protecting non-target species (Murray et al. 1999). This is illustrated with the Great Barrier Reef in Australia where 'no-take' zones are in the interior of multi use management areas (Guenette et al. 2000). Many MPAs do allow fishing and other activities within the perimeter and this can work well with proper enforcement. However in some cases complete restrictions on fishing may be the most beneficial for the biodiversity of a particular system (Lauck et al. 1998; Murray et al. 1999).

5.4 ~ Importance of Community Involvement with Marine Protected Areas

It is vital for Marine Protected Areas to have the support of the local community. Without this cooperation from the people most affected by its existence, the concept will not work. Resistance can debilitate the process (Kuperan and Abdullah, 1994; Brown and Pomeroy, 1999). MPAs that have the encouragement of the local communities provide the necessary first step toward an attitude shift that is needed to save the oceans from further devastation and ruin (Agardy, 1997). Education and awareness is fundamental in achieving this support as with any conservation project that involves the wilderness as well as people.

With a sense of stewardship and responsibility to the environment, people are in control of their livelihood (Agardy, 1997). This will promote better perspectives and pride toward the ocean environment as is evident in many tropical communities where co-management or marine reserves have been implemented (Kuperan and Abdullah, 1994; Brown and Pomeroy, 1999).

Community residents also can be valuable with regard to potential management problems and resource information (Neis et al. 1996). It makes sense that local residents would have knowledge of the traditional resource use and the historical levels of resource consumption. This can be important in devising a management plan and solving enforcement problems in the area (Crosby et al. 2000). Involving the public in a 'bottom up' approach, and being collaborative in the development of the MPA, should prove more beneficial than the traditional 'top-down' approach used in the past by management officials (Brown and Pomeroy, 1999).

Communities in the Atlantic Provinces of Canada have played a crucial role in many of the Area of Interest (AOI) initiatives (World Wildlife Fund Canada, 2002). For example, since 1995, the lobster fishermen of Eastport, Newfoundland, the Eastport Peninsula Lobster Protection Committee (EPLPC) have had "hands-on" involvement in the management of the lobster fishery in the area. It was initiated by the local fishermen and has thrived. In 1999, the Committee approached DFO and proposed the establishment of two small areas for an MPA in critical lobster habitat. It became an AOI and remains one today. It is hoped that in the near future an official reserve will be established. In spite of this, the lobster catches in the area have increased in part due to the cooperation of the people closest to the resource

(World Wildlife Fund Canada, 2002). Another example similar to this initiative is the Gilbert Bay AOI in Labrador. The local communities, out of concern for the unique local bay cod stock spearheaded the proposed MPA for the area. It is now in the stages of producing potential management plans for the area, and regular meetings with DFO and a steering committee are ongoing (Personal interview with Jason Simms, Oceans Programs, DFO, St. John's, July 2002).

On an international level, Belize in the Caribbean is an example of how important it is having the local community and general public accepting of marine conservation. In this country marine reserves have been established through grassroots activity (Guenette et al. 2000). The initial attempt to establish a form of conservation reserve failed due to the belief that the tourist industry would be the only benefactors. Several years later the entire community perceived that a MPA was essential for the sustainable use of the ocean. In this case all interest groups were consulted on the issues and all had a chance to voice opinions and concerns (Guenette, et al. 2000). However, only when the artisanal fishermen were satisfied with the plan was it designated official. Presently, there are several marine reserves in Belize. Other Caribbean communities that have undergone the same process as the initial in Belize have established a similar community-based system. The reserves have played a major role in protecting the critical coastal ecosystems which include coral reefs and nearby nursery grounds (Guenette et al, 2000), both of which are essential for a productive fishery (Jackson et al. 2001).

5.5 ~ Socioeconomic Importance of Marine Protected Areas

Through direct and indirect human use of marine resources, and the preservation of the marine environment for future generations, the benefits of MPAs can be significant (Crosby et al. 2000). The beneficiaries of MPAs can consist of many individuals, including tourists who want to see intact natural areas and the animals that live in them, divers who seek such habitats as coral reefs, and the fishers who want long-term yields of their catch (National Resource Council, 2001). MPAs can help by potentially increasing the biomass of commercial and recreational fishery resource, increasing tourism, furthering scientific research programs and boosting employment opportunities for the local communities (Murray et al. 1999).

Direct value uses of MPAs come from the contact consumers have with fishery products or tourists have with the marine environment (Crosby et al. 2000; Jamieson and Levings, 2001). MPAs can improve fish yields through the protection of spawning stock, enhancing recruitment and the spillover effect of the adults into nearby waters. This can contribute to the local communities by improving the commercial and recreational fishery and by providing great opportunities for the tourism operators who provide this to the public. In addition, the products that can come from a protected and sustainable area are numerous, including seaweed, cosmetics, food, industrial chemical and dyes, and construction materials (Crosby et al. 2000).

Direct use can also include non-extractive uses such as education, research and ecotourism opportunities (Murray et al. 1999; Crosby et al. 2000). Whale watching, bird and iceberg tours as well as scuba diving can increase revenue of an MPA more so than fishery returns. These activities can give rise to local employment and youth programs that can be important to the communities' social and economic wellbeing.

Indirect uses of MPAs make contributions to all humans. Across the globe indirect use values of marine ecosystems have been estimated at $5.2 trillion for open ocean and $11.7 trillion for coastal ecosystems (Costanza et al. 1997). The maintenance of marine biodiversity at all trophic levels, the protection of food web relationships, and the sustainability of ecosystem processes are paramount to the overall significance to the global community.

Chapter 6: The Future of Marine Enhancement

6.1 ~ The Use of Enhancement within Marine Protected Areas

One important and obvious reason for having a marine reserve of any type is to protect fish stocks from outside negative effects so it can be replenished and grow to a sustainable level for future human use and for a balanced ecosystem. This is a form of enhancement as measures are being taken to allow a population of plants and animals to grow without interference. Therefore all marine reserves can be said to provide or be involved in enhancement programs. However, from the literature reviewed, enhancement within MPAs with definite processes and purposeful techniques are few. One example where enhancement of some kind is being considered is Glacier National Park in Alaska.

Glacier Bay National Park has in recent years closed off sections to fishing for the enhancement purpose of the resident fish and crab populations. The Park has begun to experiment with tagging to find out what the movement or transfer rate of the fish is from one area to another. The purpose is to find out what percentage of the animals' life cycle is spent within the confines of the Park. According to researchers S. Taggart and P. Hooge of the US Geological Survey, if the species does not spend a sufficient amount of time in the protected area as an adult then the Park is not effective in protecting it (Taggart and Hooge, USGS website article <absc.usgc.gov/baywide.htm>). It would be beneficial therefore that another strategy be considered for its protection. However, if by restricting recreational fishing within the Park for a species whose reproduction is being negatively affected by this activity within the Park perimeter then it is effective for the enhancement of that particular population (Taggart and Hooge, USGS website article<absc.usgc.gov/baywide.htm>).

Another example of enhancement within an MPA is illustrated by the transplanting of wild abalone, *Haliotis fulgens*, in a marine refuge (Tegner 1993, in Munro and Bell, 1997). Here, broodstock of this species was put into an area with good larval retention. Researchers recorded dramatic increases in juveniles. This may be most effective with species that are sedentary or naturally stay within a fixed area (Munro and Bell, 1997). This was evident in Japanese waters where the scallop in the area greatly increased in numbers due to the injection of spat as well as the restoration of the marine habitat (Masuda and Tsukamoto, 1998). For marine reserves to be effective in enhancing or augmenting any marine population, the life cycle and its movement patterns must be known. Without this information the effectiveness of MPAs will not be known.

6.2 ~ Enhancement of Reproduction Potential - an alternative method to artificial hatchery enhancement

Enhancement of Reproductive Potential (ERP) by means of 'catch, grow-out and release' (Wroblewski et al. 1999; Wroblewski and Hiscock, in press) is an alternative method to the popular and often utilized technique of replenishing or restoring marine fish stocks through the release of hatchery raised animals. The goal of this method is to significantly increase the spawning biomass of a species and thereby enhance recruitment (Wroblewski et al. 1999). By using wild produced, captive fed animals and releasing them back into their natal habitat, the potential fecundity can increase dramatically for those species whose potential fecundity is an increasing function of body size. By feeding the fish to satiation, the animals grow, reaching maturity earlier than wild fish (Wroblewski et al. 1999; Wroblewski and Hiscock, in press). Recruitment within the stock is therefore assisted in theory. There is a need for further research and development in proving this is the case. For this method to be effective all fishing mortality of that stock has to be restricted for a determined period of time. Fishing mortality will interrupt any recruitment that is taking place, limiting increases in the overall stock biomass. It is necessary that some form of strict protection be implemented as well as a form of monitoring the success or failure of the program.

The following case studies are examples of stock enhancement within the confines of a protected area or reserve. The first is a seahorse project in the Philippines that is a success. The second is an experimental study on a distinct species of cod in Labrador. Both illustrate a technique using wild caught animals and both release the fish back into their natural habitat for future production. Though each species is different the method works in enhancing the population in a way that does not alter the genetics of the stock. Both benefit the local community and both restore the ecosystem to a more healthy state.

The Philippines

The Handumon reserve in the Philippines has been created for the purpose of protecting and conserving the local seahorse population (*Hippocampus sp.*) from over-exploitation (Guenette et al, 2000). Besides there being a global problem with over exploitation of this fish, the depleted resource is a basis of major income for many subsistence fishing communities in the country (Vincent, 1996). The population is under pressure from the great demand on this popular and traditional Asian product that can range in value from US$ 250 per kg to US$ 850 per kg (Vincent, 1996).

The reef in the area of the Handumon reserve was overexploited and as a result the fishermen had trouble catching the seahorse. In fact the catch dropped by 60 to 70% between, 1985-1994 (Guenette et al. 2000). Biologists and the local community worked together to gather information and to learn about this animal's life cycle and habitat requirements (Guenette et al. 2000). To counteract the problem, Dr. Amanda Vincent of McGill University initiated a project concerning the conservation of seahorses, and the employment of the local fishermen in a community in the Philippines.

The project under the organization called the Haribon Foundation for the Conservation of Natural Resources began a program called "grow-out' cages. The cages are corrals in the sea, built by the fishers from confiscated nets from people who have been caught fishing illegally (Vincent, 1997). The fishers continue to catch the tiny animals, as other people will catch and sell them if they do not. They are paid a small loan for their catch but they do not sell them. Instead the animals are put into the corrals in the sea where they are left for about 5 months where they will grow to maturity. At this time, the fishers pay back the money that was given them for their initial catch however, what they will receive for these larger animals is significantly more than the original price paid them. The advantage of this conservation program is that while the seahorses are confined in the sea corrals they are reproducing. For about two and a half months the seahorses will release their young into the sea, escaping through the nets (Vincent, 1997). This replenishing of the wild stock is a successful alternative to any artificial method used today elsewhere in the world, and at the same time the local community is economically benefiting.

Gilbert Bay, Labrador

In October 2000, Gilbert Bay, Labrador was officially identified as an Area of Interest (AOI). The objective of the MPA initiative is to protect and conserve the marine ecosystem, habitat and species, with a specific focus on the genetically-distinct, resident cod population (Oceans Canada Library, 2000). The potential socioeconomic importance of the proposed MPA to the region of southern Labrador is significant. The benefits of an improved commercial fishery, scientific research facilities, tourism, the Trans Labrador Highway, in addition to other natural resource exploitation will greatly boost the local communities in that area.

With regards to the commercial fishery in Gilbert Bay the main species now fished is Icelandic scallop (*Placopecten magellanicus*) with salmon and charr primarily used for recreational and food. Cod was the major commercial species has had a dramatic change over the past several years and limited knowledge is available (Morris et al. 2002). Bay cod has declined dramatically since the mid- 1990's when, as a result of the Atlantic cod moratorium in 1992, fishing effort increased inside the bay. Since that time local people have reported a major decrease in the numbers of cod within Gilbert Bay (Morris et al. 2002).

As an enhancement program, 'catch, grow-out and release', could potentially work as Gilbert Bay is an isolated body of water and has a local inshore cod stock that stays within the bay (Green and Wroblewski, 2000). It also has the community of Port Hope Simpson in favor of its protection. If the MPA is established or the area remains protected this species and region would be ideal for testing effectiveness of the technique. With many protected inlets and coves, grow-out cages could be established in a number of locations with the optimal number of animals over a growth season and then released into the bay after holding. As mentioned, the goal of this method would be to significantly increase the spawning biomass of a species and thereby enhance recruitment of this resident bay cod. The increased benefits to the traditional commercial fishery, the recreational food fishery as well as the natural habitat would be significant. In addition, a key advantage of this method over the more traditional enhancement is that after the stock is rebuilt the program can be terminated.

6.3 ~ Biological Problems solved by 'catch, grow-out and release'

As previously mentioned the method of Enhancement of Reproduction Potential (ERP) by way of "catch, grow-out and release" involves the capture of wild produced juveniles and young adults, growing them out in sea cages, and then releasing them back into their natural habitat (Wroblewski et al, 1999). The fecundities of the female fish raised in such a way should exceed their wild counterparts, as most weight gained will appear in the gonads of the animals (Lee, 1988). Because the broodstock are taken from the same environment as their release, there will be no genetic alterations. Having this major biological problem solved allows the population to rebuild without detrimental effects overtaking the stock.

This procedure within the protection of a "no-take" zone will enhance the local population of fish as well as seed outside population and increase the fish harvest for the economic benefit of the area residents. With the historical population restored or partially restored, the local marine ecosystem can develop into a system that can regain the biodiversity naturally (Roberts et al. 2001) after the enhancement program has been terminated.

6.4 ~ Legal problems solved by Marine Protected Areas

Within individual management plans for Marine Protected Areas, there are varying objectives and goals (Fisheries and Oceans Canada, 1999). Each management plan will be unique. In Canada, the *Oceans Act* allows for areas or zones that have different levels of protection including 'no take' where activity is severely limited or controlled activity where there is human imposition under specified conditions. The strictly controlled areas would not allow fishing activity of any type and would protect critical areas from damaging effects. Under these regulations enforcement by the governing body (DFO) would legally protect everything within the perimeter of these specified zones. If an enhancement project such as 'catch, grow-out and release' were to be in effect under such regulations the problem of fishing mortality of fecundity-enhanced, released fish would be solved. Violators would be fined for non-compliance within the Area under the *Oceans Act.*

Public awareness provided by interpretation and education programs of MPAs provides benefits that will help further protect any enhancement program within an MPA (Fisheries and Oceans Canada, 1999). Compliance with the regulations of a reserve depends on the information provided and the designation of activities with each zone. This falls under the management plan of any MPA. If people are made aware of the importance of a given enhancement site and the benefits are applied to the wellbeing of humans, then a greater respect by the public is likely. It is also important to realize that support for MPAs grow when resource users such as fish harvesters and tourists see the result of a successful MPA. It is vital therefore that all interest groups have a part in the process.

Chapter 7: Summary, Conclusion and Recommendations

7.1 ~ General Summary

Marine systems are inherently complex and the historical failure of fisheries management worldwide is indicative of the unbalanced relationship between humans and nature. The condition of the oceans is illustrated in the current state of the world fisheries. It is evident that a change in attitude and fisheries management techniques is required to alter the course of the declining marine environment all societies depend on throughout the world. Though attempts have been made in the past to restore fish populations and the habitat they rely on for survival, it is only now that there is some prospect of safely doing so.

Marine stock enhancement is not a new way of attempting to augment wild stocks and replenish commercially important species for human use. However, impacts on the natural marine ecosystem are only recently being evaluated and considered on a wider scale regarding experimental techniques, though Norway has been surveying juvenile cod for about 100 years. Consequences of enhancement efforts can be both positive and negative in the biological aspect of the system as well as the socioeconomic elements of the human dimension of resource management. It is hoped that poor experimentation of the past will be replaced by more sound scientific criteria.

It is thought that marine reserves, in combination with other fisheries management strategies and tools, could help solve many problems in fisheries resource management. The importance of Marine Protected Areas is great. The biological restoration of the marine environment and its biodiversity on all trophic levels is the major significance of implementing reserves in addition to the socioeconomic benefits of the local communities and human beings as a whole. The reduction of fishing mortality and the preservation of habitats can restore the physical environment and increase fish abundance and quality of the entire ecosystem. The intrinsic benefits are obvious; however the benefits of tourism and economic gain in and outside these areas are also relevant. Worldwide coastal areas are invaluable; and therefore, safeguarding them from destruction and over utilization is necessary.

Though the most popular technique of marine stock enhancement is based on artificial hatchery rearing and release there is another method that has had only little attention by the scientific community. Enhancement of Reproductive Potential by way of 'catch, grow-out and release' can be a more advantageous way of safely augmenting the spawning biomass of a population of fish, thereby increasing recruitment. By using wild-produced animals in their natural habitat assisting the reproduction of the stock is possible. The connection between this method and MPAs is that this technique requires restriction of fishing mortality for success. The regulations of a reserve would help mitigate this problem, just as the enhancement method would help eliminate the biological problems such as genetic problems and displacement of species, while at the same time boosting the recruitment of a particular species.

7.2 ~ Conclusion

When fisheries decline or collapse because of mismanagement it is an indication of the failure of human institutions (Wigan, 1998). If natural resources as massive as the world fisheries can be exploited to the point of commercial extinction, how can any trust be put into the current management strategies of the governing organization? Until there is a paradigm shift in the way societies perceive the oceans, the management of the fisheries will continue to falter. Until then new ways of rectifying mistakes in marine resource management is being developed. This is evident in the advancement of marine stock enhancement.

Though an ineffective history is associated with stock enhancement, an evolving science-based, experimental approach is being developed and applied. As there can be negative consequences of hatchery-release enhancement on the natural environment (the method most utilized in the field) improved criteria and assessment is greatly needed. It is also important for researchers to conduct studies and share findings with colleagues in order to further the discipline. New and competent techniques can be discovered and shared such as the Enhancement of Reproduction Potential known as 'catch, grow-out and release'. With genetic alterations not being an issue of this procedure, as wild produced fish are used, the health and wellbeing of the marine environment as a whole would not be in question. Restoring the population of local stocks to former sustainable levels would be the objective in the operation, with minimal harm resulting with the fish or the system.

Enhancement of marine stocks could best be implemented by an integrated approach with other marine management strategies. The collaboration of enhancement experts and marine protected areas would be a means for an combined approach to a new way of managing the fisheries and protecting the marine ecosystem from degradation. Though MPAs have varying degrees of restriction of activities, a 'no-take' zone would complement enhancement efforts for the local fish populations. By establishing this type of arrangement both the biological problems and the legal conflicts would be resolved. The stock would be given the chance to recover and increase in biomass on account of it being protected by the regulations associated with MPAs. Enhancement in the absence of effective management is improbable; therefore, sound management strategies should go hand in hand with any efforts made to augment any marine population.

As more responsibility and precaution is taken with fisheries resources and innovative methods are considered for enhancement, coastal communities around the world could begin to experience a more stable resource and not be subject to the boom and bust of the past century. With public involvement and cooperation regarding MPAs, advances can be made in the restoration of depleted fish stocks and the marine environment globally.

7.3 ~ Recommendations

As a result of reviewing the available material on Marine Stock Enhancement and that of Marine Protected Areas, the following recommendations can be made regarding future management strategies of fisheries on a global scale.

- More studies should involve wild produced-fish procedures when promoting stock enhancement.
- Experimentation of non-invasive methods should be conducted in a protected area such as an MPA or marine reserve. These methods should not inflict harm on the marine environment through genetic alterations or displacement of wild stocks.
- Mass artificial production and release of any species should not be considered in Newfoundland and Labrador waters.
- Marine Protected Areas should be larger and more predominant in coastal countries around the world, involving more communities that benefit from their existence.
- Scientists and researchers should be open to new ideas regarding marine enhancement and work with interested parties to promote such an endeavor.
- Much more public education is needed in fisheries in general. If the population of Newfoundland and Labrador, and Canada, had more insight into what has been going on in our waters and just outside the 200 mile exclusive economic zone (EEZ) boundary, public pressure could force government at all levels to act in a responsible manner.

- There should be more concentration on enhancing and conserving the inshore fish stocks. Repeating the mismanagement and over exploitation of the northern Atlantic cod (*Gadus morhua*) is possible with the massive fishing effort on shrimp (*Pandalas borealis*) and crab (*Chionoecetes opilio*) and other species in areas of the north Atlantic. The devastation this would cause could negatively affect coastal communities still reeling from the collapse of cod in the early 1990's.

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