Issues Associated with Non-indigenous Species in Marine Aquaculture

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Abstract

Non-indigenous species have long been employed by aquaculturists. In some instances these species had been introduced and become accepted members of the local ecosystem long before they were reared by aquaculturists. Tilapia in Asia are a good example. In other cases, problems associated with the culture of local species led culturists to find related non-indigenous species as alternatives. Examples are the introduction of Latin American shrimp species into the United States and Atlantic salmon (*Salmo salar*) to the west coast of North America.

The use of non-indigenous species is more widely accepted in association with inland aquaculture than marine aquaculture. A number of diseases, primarily viral in nature, have occurred on shrimp farms around the world. Countries that have used non-indigenous shrimp species have not been immune to the problem, so diseases have been imported along with the shrimp. There is a major concern that these diseases will spread to native populations.

The lack of assurance that animals cultured in the marine environment can be contained is a major factor. Escape as a result of culture system failure, vandalism, accidents and carelessness cannot be completely avoided. Concerns that escapees will become established and possibly displace native species have prompted the marine aquaculture community to reconsider the use of non-indigenous species in general and to concentrate on local species.

Introduction

Non-indigenous (sometimes called non-native) species are herein defined as organisms that have become established in a location that is outside of their native range. The term does not distinguish between species that are introduced from the waters of one nation to those of another (often termed exotic introductions) and those that become established in a location out of their native range but within the same nation (translocation). Narrowing the scope of the discussion further, this chapter deals only with marine, estuarine, diadromous or euryhaline species that are associated in some way with mariculture activities. Non-indigenous species may be the target species of the mariculturist or may be a competitor, predator, parasite or pathogen associated with the target species.

The association of non-indigenous species with aquaculture may be intentional (as in the rearing of Atlantic salmon in netpens in the Pacific Northwest of the United States and Canada as well as in Chile) or accidental (such as appears to have been the case with at least some disease organisms that were introduced in association with the dumping of ballast water).

There are probably less than 200 species of animals currently being reared by aquaculturists around the world for human food. Of these, far fewer than half are reared in brackish or marine waters, and only a fraction of the latter group are non-indigenous. Further, some of the non-indigenous species had become established in the regions where they are being cultured long before mariculture industries had been established. An excellent example are a group of fishes with the common name tilapia, many of which are highly euryhaline. *Oreochromis mossambicus*, for example, have been reported from salinities of 60 and 120 ppt (Potts *et al.*, 1967; Assem and Hanke, 1979). Tilapia are currently being reared in both freshwater and saltwater culture systems in several nations, primarily in the tropics. *O. mossambicus* were spread throughout the Far East after World War II, and may have originated with as few as five escapees from an aquarium (Balarin and Hatton, 1979). Other species were introduced subsequent to the establishment of *O. mossambicus*. Most residents of such nations as Indonesia, Malaysia, the Philippines and Thailand do not realize that tilapia are non-indigenous.

Tilapia are very popular in many regions where they have been introduced. The same cannot always be said of non-indigenous species, though most of the species that have caused problems have been associated with activities other than aquaculture (take, for example, common carp, *Cyprinus carpio*, that were introduced to the United States over a century ago).

Ballast water releases account for large numbers of non-indigenous species introductions. Perhaps the most widely publicized introduction in terms of environmental problems was that of the freshwater zebra mussel, *Dreissena* sp., which has caused significant problems in the Great Lakes region and has spread well beyond that part of North America.

Ballast water is a primary source of non-indigenous species as confirmed by a number of studies. One of those studies was conducted by Subba Rao *et al.* (1994), who analysed ballast water from 86 foreign vessels that visited the upper St Lawrence River and Great Lakes along the St Lawrence in 1990 and 1991. A total of 102 phytoplankton taxa were recognized, several of which had not previously been found in St Lawrence waters. Some 69 diatom and 30 dinoflagellate species were among the 102. Some 21 bloom-forming, red tide and/or toxigenic algal species were present and the authors felt these posed a potential threat to mariculture on the east coast of Canada.

In a later study, the Canadian Department of Fisheries and Oceans (DFO, 1999) reported that in 1995 over 700 ships from 30 countries visited the ports on the St Lawrence River estuary and the Gulf of St Lawrence. More than 66% of the species found in the sediments at those locations and in the ballast water of the ships were non-indigenous.

Ballast water is a global issue. It is also a difficult one to deal with for a number of reasons which are beyond the scope of this chapter. Aquaculture, and particularly marine aquaculture, provides a much more fertile opportunity for the focus of attacks by those opposed to the introduction of non-indigenous species.

Some Examples of Introductions

The intentional movement of aquatic species to locations outside of their native ranges for aquaculture or stocking purposes has a long history, much of which has been documented in the United States (Stickney, 1996). Many of the species that were introduced to new parts of that nation for culture were used as broodstock, with the progeny released in stocking programmes that supported commercial and recreational fisheries. Further, the majority of these introductions were freshwater species.

Atlantic salmon (from both anadromous and landlocked Atlantic coast populations) were introduced to the Pacific Northwest in the latter part of the 19th century, and Pacific salmon were introduced to the east coast. In neither case were reproducing populations established. Pacific salmon were successfully introduced to the Great Lakes in the 1980s, though populations are sustained largely through hatchery programmes in that region, augmented to some extent by natural reproduction.

Atlantic salmon were moved to the west coast in modern times when the National Marine Fisheries Service (NMFS) in Washington State began working with broodstock of this species and several others beginning in 1971 (Mighell, 1981). The Atlantic salmon work was in conjunction with recovery attempts in association with the Endangered Species Act. Commercial production in Washington began with Pacific salmon but by the late 1980s only Atlantic salmon were being reared in Puget Sound netpens. The British Columbia, Canada, netpen industry is also dominated by Atlantic salmon production.

The NMFS studies also involved other non-indigenous species. Included were masu (cherry salmon; *Oncorhynchus masou*) and hybrids of chinook × masu and pink × masu salmon. None of these species and hybrids has been used in aquaculture in the United States.

Escape from netpens has been major news both in the United States and in Canada. Fears that escapees will reproduce successfully and displace native Pacific salmon have been expressed (Gross, 1998), though there seems to be little recognition that attempts to establish breeding populations of Atlantic salmon in regions where they were not native took place over several decades and failed in all instances (Stickney, 1996).

Significant numbers of Atlantic salmon have escaped from netpens in both British Columbia, Canada, and the state of Washington. The first reported catches of Atlantic salmon from British Columbia waters were in 1987 and undoubtedly represented escapes from culture facilities, though the first reported escapes in that province (about 2000 fish) occurred a year later (McKinnell *et al.*, 1997). Washington had an established industry by 1987 and could easily have been the source of the fish captured during that year. Between 1988 and 1997, the number of escapees reported neared 100,000. As of 1997 there had been no reports of successful reproduction of Atlantic salmon in the North Pacific (McKinnell *et al.*, 1997), though alarms expressing fear that Atlantic salmon will successfully reproduce and overwhelm native species of salmon continue to be sounded.

Fears of consequences associated with Atlantic salmon escapees from netpens interacting with native salmon are not restricted to the Pacific Northwest of North America. Interactions between wild and cultured Atlantic salmon on the east coast of North America and in Europe have also been the focus of concern. In Northern Ireland, the annual average percentage of cultured salmon in the capture fishery has ranged from 0.26 to 4.04% (Crozier, 1998). A proportion of the Atlantic salmon farmed in Scotland have also escaped and later been recovered in capture fisheries (Webb and Youngson, 1992). Some of these losses were catastrophic as a result of storms or equipment failure (Black, 1996). Methods of identifying farmed salmon escapees include an abdominal marker related to intra-abdominal vaccination (Lund *et al.*, 1995) and scale morphology (Friedland *et al.*, 1994).

Escapees from culture have been shown to survive, home to their river of origin, and spawn with other escaped returnees as well as wild fish (Crozier, 1993; Webb *et al.*, 1993; Clifford *et al.*, 1997). However, Fleming *et al.* (1996) reported that studies with fifth-generation farmed Atlantic salmon demonstrated that reproductive success was reduced considerably in comparison with wild fish and concluded that domesticated fish were reproductively inferior. Regardless, the use of sterile salmon in culture has been advocated in some circles. Cotter *et al.* (2000) conducted research to evaluate the use of triploids in Ireland.

With the percentage of salmon under culture on the east coast of Canada exceeding 90% of the total population, and with the developmental and environmental biology of the wild and cultured fishes being different, Gross (1998) suggested that cultured Atlantic salmon be treated as an exotic (non-indigenous) species, and that it might be called *Salmo domesticus*.

Striped bass (*Morone saxatilis*), from stocks originating on the east coast of the United States, were established in California in the 19th century. Like tilapia in Asia, striped bass have now been established for so long in California that they are considered to be a native species.

Attempts were made several years ago to evaluate the potential for culture of American lobsters (*Homarus americanus*) in California, though no industry was ever established for that non-indigenous species, nor have wild populations become established. The oyster industry on the west coast of the United States is based primarily on a non-indigenous species, the Pacific oyster (*Crassostrea gigas*). The same is true of British Columbia, Canada (Quayle, 1988). Pacific oysters have also been introduced to the South Pacific, the United Kingdom and France (Mann, 1979).

Because of declines in east coast American oyster (*C. virginica*) stocks due to disease and environmental factors, there is a considerable amount of interest in introducing Pacific oysters to parts of the east coast. Pacific oysters are considered to be adaptable to such regions as Chesapeake Bay and are resistant to some of the diseases that have plagued American oyster populations (Gottlieb and Schweighofer, 1996). Experimental trials have been conducted with primarily triploid Pacific oysters as well as Suminoe oysters, *C. ariakensis* (Calvo and Luckenbach, 1998; Calvo *et al.*, 1998, 1999). Allen and Guo (1997) found that the methods used to produce triploid oysters were not totally effective. It would be necessary to evaluate each oyster produced to certify that all animals stocked were triploids if regulations called for stocking only triploid animals.

During the 1970s, there was considerable interest in the United States in the culture of the freshwater shrimp *Macrobrachium rosenbergii*, which is native to Southeast Asia. Larval development of that species requires saline water, so there is a direct tie to marine aquaculture. Because of marketing and other problems, the small industry that developed collapsed. However, marine shrimp culture has been developed to some extent in the United States. While the industry is very small compared with those in China, Ecuador, Thailand and several other nations, it is a multimillion dollar business. Commercial hatchery and/or growout facilities exist in Arizona, Hawaii, Florida, South Carolina and Texas, plus the territory of Puerto Rico. Virtually all of the shrimp being produced are non-indigenous species from Latin America or Asia. The dominant species is *Litopenaeus vannamei*, though there is also some production of *L. stylirostris* and *Penaeus monodon* (Granvil Treece, personal communication).

A great deal of research was conducted in the 1960s and 1970s on native shrimp species, particularly by investigators at the National Marine Fisheries Service laboratory in Galveston, Texas (Stickney, 1996). Research activity was curtailed when the industry turned to non-indigenous species, though a modest amount of work with native species did continue (e.g. Sandifer *et al.*, 1992).

In many instances, such as in association with tilapia, introductions occurred and species became established long before they were incorporated into aquaculture systems in the areas where the introductions occurred. The original introductions were sometimes accidental but often they were intentional. Many nations now have restrictions on the introduction of non-indigenous aquatic species. Others have no restrictions, and in some the determination has been made that the aquaculture industry should be based largely or in part on non-indigenous species.

Manila clams (*Tapes philippinarum*), which are currently cultured in Washington, were probably introduced to that state incidentally in shipments of Pacific oysters. Those shipments began prior to World War II and continued beyond 1970 (Westley, 1975). Similarly, the varnish clam (*Nuttallia abscurata*) was unintentionally introduced to British Columbia during the 1980s and 1990s and became widely distributed (Heath, 1998). Licensing of the species for culture was under consideration by the Ministry of Fisheries in 1998. The non-indigenous bay scallop (*Argopecten irradians irradians*) was evaluated as an aquaculture candidate in Georgia during the 1980s (Heffernan *et al*., 1988).

In Sri Lanka various species were introduced to augment the availability of fish in rural communities. There, tilapia are grown in fresh and brackish waters, as well as in rice fields (de Zylva, 1999). In Brunei, attempts were made in 1979 and 1980 to introduce the green mussel (*Perna viridis*). Problems associated with a lack of natural spatfall and the presence of toxic algal blooms were encountered (Lindley and Currie, 1982). In other parts of the Middle East, nations such as Egypt, Saudi Arabia and Israel (Colorni, 1989) have been developing shrimp culture based on non-indigenous species. Egypt has had successful rearing trials with three penaeid shrimp species. Freshwater shrimp are usually grown in polyculture with tilapia (Wassef, 2000).

Non-indigenous mullet (*Mugil cephalus*) and oysters (*Crassostrea rhizophorae*) were established as brackish and marine culture species in Colombia some three decades ago (FAO, 1977). More recently, freshwater and marine shrimp culture has been developed in that country (Angarita Zerda, 1989). Chile has become a major producer of Atlantic and Pacific salmon. There have also been attempts to introduce the scallop, *Pecten maximus* (Illanes *et al*., 1999), to Chile.

Marine aquaculture options were studied in the Madeira Archipelago of Portugal and it was concluded that the best option was to culture non-indigenous fishes in offshore cages (Andrade, 1996). Many other nations, without doing such studies, have come to the same conclusion.

It is likely that until recent years, there was little or no regulation in most nations with regard to the introduction of aquatic species. There are exceptions. The federal Lacey Act of 1900 and subsequent amendments serve as the basis for existing regulations on the introduction of species to the United States (Clugston, 1986). In 1977, an executive order was signed that instructed federal agencies to restrict introductions of non-indigenous species into federally owned or controlled lands and waters to the extent legally possible. In 1999, another executive order was issued that established the National Invasive Species Council and directed it to provide national leadership on invasive species, including ensuring that efforts at the federal level are coordinated and effective. With respect to intentional introductions, the Council, according to its draft management plan, will undertake development of a comprehensive screening system for evaluating intentionally introduced non-native species. Screening will be conducted to establish that the risk of intentionally introducing a particular species into the United States is acceptable. Miglarese and DeVoe (1992) reviewed state policies and regulations with regard to the introduction and transfer of non-indigenous species in the United States.

A code of practice was developed in Ireland and governs introductions and transfers by aquaculturists in that nation. The code was touted for its usefulness in reducing the risks associated with introductions (Minchin and Sheehan, 1995), though the major threat appears to come from ballast water discharges. The Global Aquaculture Alliance (Boyd, 1999) has prepared a code of conduct for responsible shrimp aquaculture, which includes the guiding principle which states that those engaged in shrimp farming, 'Shall take all reasonable steps to ascertain that permissible introductions of exotic species are done in a responsible and acceptable manner and in accordance with appropriate regulations'.

The Case Against Introductions

The introduction of non-indigenous species has been objected to on a number of grounds. Most common among the objections involves the introduction of diseases with the non-indigenous species. The concern is that these diseases might be transmitted to native species. Another major issue revolves around the potential establishment of escapees. Interbreeding of non-indigenous animals with indigenous congeners and the resulting population genetic alterations has also been raised as an issue (Naylor *et al.*, 2000). Another concern associated with the conscious introduction of non-indigenous species involves the possibility that, in addition to the possible introduction of diseases, there could be introduction of predators, competitors or pests (Minchin, 1996).

Disease issues

In terms of disease transmission, one of the loudest alarms has been sounded in conjunction with the use of non-indigenous shrimp species in aquaculture. A number of examples concerning where non-indigenous shrimp are being cultured have previously been discussed (above). Viral diseases emerged as a devastating problem for the shrimp industries during the 1990s (Lightner, 1999). Viral diseases in native species in Asia and Latin America have seriously affected production in such nations as China, India, Indonesia, Korea, Taiwan, Thailand, Ecuador and others. Even Asia is not without problems related to the rearing of non-indigenous species. Taura syndrome virus (TSV), for example, was so severe in Taiwan in the non-indigenous Pacific white shrimp (*Litopenaeus vannamei*) during 1998 and 1999 that 90% of the shrimp ponds were abandoned a month or month and a half after being stocked (Tu *et al.*, 1999).

Viruses such as IHHN (infectious hypodermal and haematopoietic necrosis), WSSV (white spot syndrome virus), YHV (yellow head virus) and TSV have occurred in non-indigenous shrimp species reared in the United States. When challenged with WSSV and YHV, native penaeid shrimp species were found to be susceptible (Lightner *et al.*, 1998), though YHV affected primarily juveniles, with postlarvae being less sensitive. Overstreet *et al.* (1997) found that native white shrimp (*Litopenaeus setiferus*) in the Gulf of Mexico and along the southeast coast of the United States are susceptible to mortality from TVS, while brown shrimp (*L. aztecus*) and pink shrimp (*L. duorarum*) are not.

IHHN, HPV (hepatopancreatic parvo-like virus) and MBV (monodon-type baculovirus) were probably introduced to Israel with the introduction of non-indigenous shrimp. These viruses have also occurred in native shrimp in the waters off that nation (Colorni, 1989).

Some of the viruses that have been identified in cultured shrimp can also infect other crustaceans, often without causing signs of disease. Examples include infection of various decapods with WSSV in Taiwan (Wang *et al.*, 1998) and Thailand (Supamattaya *et al.*, 1998).

In situations where non-indigenous culture species are being introduced, the probability of also introducing exotic diseases can be reduced through a quarantine process as suggested for Hawaii by Davidson and Brick (1988). Quarantine has been implemented in some instances; for example in Australia (Garland, 1988) and Indonesia (Arthur and Shariff, 1991), though a general lack of such procedures in Southeast Asia has led to the introduction of various diseases associated with the introduction of non-indigenous species.

For those regions where non-indigenous species continue to be cultured, further introductions of exotic diseases might be curbed by developing broodstock and avoiding further importation. This approach and quarantine have been employed by the Texas shrimp farming industry, but even then, virus outbreaks have occurred. Since Texas shrimp processors handle wild, domestically cultured non-indigenous, and imported shrimp, one theory is that the viruses that made their way into shrimp ponds, possibly from seagull faeces (Garza *et al.*, 1997), came from processing plant wastes.

Transmission of mollusc diseases to native populations from introduced species has been reported. Manila clams were introduced into culture in England and Wales because of their rapid growth, high demand by consumers and high market value. An additional advantage was that the species was judged unable to establish reproducing populations (Spencer *et al.*, 1991). However, a *Vibrio* that was the probable cause of 'brown ring disease' in native clams appears to have been introduced with the non-indigenous Manila clam (Edwards, 1998). The state of Alaska has a permit system for the importation of non-indigenous species, with the Pacific oyster being the only shellfish that can be obtained with a permit. Further, no imports can come from Korea, the Gulf of Mexico or the Atlantic coast of North America (Meyers, 1989).

The potential introduction of non-indigenous diseases in association with the farming of salmon was raised as an issue early in the last decade (Folsom and Sanborn, 1993; Kent, 1994). This potential appears to have been realized a few years later when the bacterium *Piscirickettsia salmonis* was blamed for high mortalities of the non-indigenous coho salmon (*Oncorhynchus kisutch*) in Chile (Getchell, 1998).

The disease issues associated with salmon culture are not restricted to the introduction of exotic diseases. In addition to that concern, Kent (1994) expressed the view that diseases in cultured fish can also impact wild populations by increasing the prevalence of diseases associated with endemic pathogens.

Establishment

In a paper cautioning the introduction of *Crassostrea gigas* to New England, Andrews (1980) reflected the general concern about non-indigenous species introductions. He indicated that such an introduction could have 'consequences to native biota and coastal ecosystems'. Beveridge *et al*. (1997) commented on the direct and indirect impacts of mariculture on biodiversity. Among the impacts they recognized was 'the translocation of exotic plants and animals'. As indicated by Lodge *et al*. (1998), predicting which introduced species might cause ecological change is a problem for natural resource managers. They suggest that managers should focus on preventing introductions in freshwater systems because eradication is often not possible. The same statement is equally or even more valid in marine systems.

There is little doubt that cultured species will escape from aquaculture facilities. Biosecurity is an excellent concept, and it may even be possible to achieve true biosecurity in a closed recirculating water system that is located within a closed building and equipped with the proper control devices to keep everything from gametes to adult animals from being released in the effluent stream, intermittent or minuscule as it may be. Outdoor facilities on land are always susceptible to escape, both in the effluent and through the activities of careless predators or poachers who let the animals they capture escape.

When a facility is established in open water in cages or netpens, the chances of escape increase dramatically. A major storm can destroy an entire facility, potentially releasing thousands, or even millions of culture animals into the wild. Smaller losses can occur through failures of a single netpen or cage, often helped along by predators that rend the netting in their attempts to capture the culture animals. Carelessness and accidents during fish handling can also account for losses, though the numbers of animals involved are typically small.

While there is no known foolproof way to totally eliminate escapes from marine culture facilities, the question of whether escapees will establish self-sustaining populations is a question that cannot be answered in any convincing way as the outcome will vary from one species to another and one environment to another.

Addressing the Issues

Disease

The statement by Elston (1989) that the risk posed from exotic diseases can be reduced by controlling the importation of non-indigenous culture species can be extended to other objections as well. However, as noted above, the policy in some countries is to seek out non-indigenous species for use in mariculture, particularly when appropriate native species either do not occur or there is insufficient information on their culture requirements to support establishment of a commercial industry. In cases where introductions of non-indigenous species are made, there is a clear need to conduct risk assessments and develop risk management strategies (Kern and Rosenfield, 1988).

In the United States, laws associated with non-indigenous species introductions vary considerably, though in general, those laws have become more restrictive in recent years. Many states require permits for importation of non-indigenous species.

Avoidance and prevention of the spread of diseases can be achieved to some extent by employing specific pathogen-free (or high-health) stocks and establishing biosecure culture facilities, as has been discussed in relation to shrimp culture, for example, by Hopkins and Sandifer (1993), Wyban (1993), Wyban *et al*. (1993), Pruder (1994), Lotz (1997) and Clifford (1999). These techniques work particularly well when the entire life cycle of the culture species is conducted in an environment that is totally under the control of the culturist. An example would be an indoor flow-through or recirculating water system supplied with well water.

There are instances where a non-indigenous species became established in nature, apparently without bringing new diseases with them. An example is the presence of non-indigenous blue mussels (*Mytilus edulis* and *M. galloprovincialis*) in British Columbia, Canada, waters. When further introductions were proposed for culture purposes, the proposal was made to determine if non-indigenous mussels already present could be used as broodstock (Yanick and Heath, 1998).

Establishment

As indicated above, there is no doubt that animals can be expected to escape from marine aquaculture facilities, particularly those located outdoors, such as in ponds and netpens. Thus, we are back to the question: Will the escapees become established in the natural environment? Whether established or not, there are concerns that escapees from marine aquaculture systems will have negative impacts on native flora or fauna. That possibility was examined by the Department of Ecology in the state of Washington (Anonymous, 1999). It was concluded that there was no unacceptable risk to native Pacific salmon from the activities of escaped Atlantic salmon in the following areas: colonization, competition, disease transmission, hybridization and predation. However, one cannot extrapolate that conclusion to other situations.

The argument can be made in some inland situations that introduction of certain non-indigenous species can lead to the extirpation of one or more native species through competition or predation. If the extirpated species is one with a highly confined distribution, the threat of extinction is a very real one. In the marine environment, it seems more difficult to argue that an introduced species could lead to extinction of a native species. The argument that an introduced species could eliminate some genetically distinct population is one that can be made, however.

The most responsible approach to marine aquaculture is to limit the species reared to those that occur naturally in the environment where the aquaculture activity is to be conducted. Some nations apply that principle at present, though as shown above, many countries have concluded that their marine aquaculture industry must, of necessity, be based on the rearing of non-indigenous species.

Even when the decision is made to rear only native species, there is opposition to the practice in some circles on the basis that escapees will reproduce with wild congeners and that the genetics of the wild population will be detrimentally altered. The level of concern escalates when there is even a hint of using genetically modified organisms (GMOs). The subject of GMOs is considered in another chapter of this book and is a topic that is likely to become even more controversial in the future.

Ultimately, neither extreme is likely to win the day. Taking the position that there should be no introductions of non-indigenous species into marine aquaculture is unreasonable because, in many instances, introductions have already been made. Opening the door sufficiently wide to allow all introductions without any control is irresponsible. When a new introduction is being considered, a risk assessment should be conducted. Societal need should be balanced against potential environmental impact.

Some will argue that the natural environment should be maintained unaltered at all cost. Again, that horse is not only out of the stable, it has left the ranch. Human activities have altered and will continue to alter our environment, including that of the coasts. That does not mean that human activities should not be conducted without a considerable amount of planning and with the intent of causing as little environmental impact as possible.

Human population continues to grow, and with it the demand for seafood will also grow. That is irrefutable. It is also a fact that humans are exploiting the world ocean up to, and in many cases beyond, the capability of the ocean to sustain the fishing pressure that is placed upon it. Increased seafood supplies can only come from aquaculture. Decrying the practice of marine aquaculture is not going to have much impact on those who demand more seafood, and particularly those who *depend* upon a continuous and growing supply of seafood to meet their routine food needs. In the final analysis, those whose primary goal is environmental protection and maintenance of the status quo with respect to human impacts on the coastal environment and those who are interested in enhancing the food supply through marine aquaculture need to work together. Collaboration and cooperation are the logical approaches, but the fact is that humans do not always do what is logical.

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Robert Stickney studies HistÃ³ria Ambiental-Eco-HistÃ³ria / Environmental History, Latin American Economic History, and Central America.Â ABSTRACT Arsenic, cadmium, copper, mercury, and zinc analyses of 91 individuals representing 35 species of North Atlantic finfish (Chondrichthys and Osteichthys) indicate that these metals occur at similar levels in both inshore and more. Historical records matching Robert Randolph Stickney. Robert R Stickney in 1916 Canada Census of Alberta, Saskatchewan, an Robert R Stickney. Collection: 1916 Canada Census of Alberta, Saskatchewan, and Manitoba.Â Robert Randolph Stickney in FamilySearch Family Tree. Robert Randolph Stickney. Collection: FamilySearch Family Tree. Find Robert Stickney's contact information, age, background check, white pages, divorce records, email, criminal records, photos & relatives.Â Related to: Kimberly Stickney, 49Robert Stickney, 49 Has lived in: Sebastian, FLBillerica, MANorth Billerica, MA Full Profile. Robert A Stickney age: ~82. Known as: Bob A Stickney. Related to: Linda Steen, 75Linda Stein, 77Stickney SteinBob Stein, 80 Has lived in: Henderson, NVFt Lauderdale, FL Full Profile. Robert J Stickney age: ~60.