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THE INTRODUCTION OF EXOTIC SPECIES IN AQUACULTURE: A SOLUTION OR PART OF THE PROBLEM?

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SUMMARY

The introduction of alien species in new environments, as a consequence of human activities, contributes to an irreversible and devastating impact to natural ecosystems. As aquaculture is one source of this problem, this paper reviews the role of some governments and international organizations in the development of this activity. We conclude that these organizations should reconsider the use of technical packages that encourage introduction of exotic species. Instead, they should help the development of technologies that propose to cultivate native species with potential for aquaculture. This will require research to determine optimal conditions for culture, and it will improve local research capacities. International technical funding agencies can exert a great influence in encouraging new practices.

Aquaculture makes unique contributions to nutrition throughout the world, thanks to its extremely high productivity in many situations. Aquatic crops are primarily protein sources rather than of starch and in the conversion of primary foods certain aquatic organisms may be more efficient than ruminants, fowl or even pigs. Some aquatic organisms, such as filter-feeding fish and mollusks, feed on microscopic plankton that cannot be used directly for human consumption. In terms of nutritional energy, fish production is more efficient than any type of animal husbandry. On the other hand, local governments must be made aware of the fact that aquaculture is not a panacea for the economic woes or nutritional problems of any country.

In the past thirty years, aquaculture has been actively promoted as a means of providing food to satisfy nutritional needs of populations in developing countries, obtaining extra economic resources from exports and diminishing pressure on fisheries. Promotion of aquaculture in the 70s by the Food and Agriculture Organization (FAO) was accompanied by spectacular projects mainly designed by their aquaculture consultants. But a few years of experience showed that those grandiose development projects had either a small impact or no impact at all on ordinary people's lives. Strong criticism forced the FAO to reappraise its aquaculture activities, and the results of their evaluation seem to have reoriented some policies (Cross, 1991).

If the purpose of aquaculture is to eliminate hunger and rural poverty, fish farming in rural communities ought to be on such a scale that modest farmers may adopt it. Small

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RESUMEN

La introducción de especies exóticas a ambientes nuevos, producto de actividades humanas, produce un impacto devastador e irreversible a los ecosistemas naturales. Como la acuicultura es una de las fuentes del problema, esta publicación revisa el papel de algunos gobiernos y organizaciones internacionales en el desarrollo de esta actividad. Concluimos que estas organizaciones deben reconsiderar el uso de paquetes tecnológicos que promueven la introducción de especies exóticas y en su lugar deben ayudar al desarrollo de tecnologías que promuevan el cultivo de especies nativas con potencial para la acuicultura. Esto requiere de investigación que permita conocer las condiciones optimas para el cultivo, lo cual permitirá además, mejorar las capacidades locales de investigación. Algunas agencias internacionales financiadoras pueden ejercer una gran influencia en promover estas nuevas prácticas.

RESUMO

A introdução de espécies exóticas a ambientes novos, produto de atividades humanas, produz um impacto devastador e irreversível aos ecossistemas naturais. Como a aqüicultura é uma das fontes do problema, esta publicação revisa o papel de alguns governos e organizações internacionais no desenvolvimento desta atividade. Concluímos que estas organizações devem reconsiderar o uso de pacotes tecnológicos que promovem a introdução de espécies exóticas e em seu lugar devem ajudar ao desenvolvimento de tecnologias que promovam o cultivo de espécies nativas com potencial para a aqüicultura. Isto requer de investigação que permita conhecer as condições ótimas para o cultivo, o qual permitirá alem disso, melhorar as capacidades locais de investigação. Algumas agências internacionais financiadoras podem exercer uma grande influência em promover estas novas práticas.

ponds, cheap fertilizers and easy to breed fish are essential for family needs. If the purpose is to farm fish for export, it must be done on a technological scale that requires costly equipment and well-trained staff. Adequate funding must be available, and special consideration must be given to sanitary regulations that are rather demanding and often difficult to comply with, but are compulsory in developed countries. To make their investment worthwhile, farmers must produce high-value products, such as salmon and shrimp. However, it should be noted that wealth derived from these products is frequently concentrated away from the lower economic classes and does not yield any important social benefit. As a third purpose, promoters of aquaculture generally claim that it relieves pressure on fisheries. However, this is not true for carnivorous species. Farmed species such as shrimp and salmon are fed nutrient-rich diets that contain large amounts of fish meal and fish oil extracted from wild-caught organisms. Fish product input is 2 to 4 times the output from these crops (Naylor *et al.*, 1998), depleting rather than increasing fishery resources.

Furthermore, aquaculture can diminish world fisheries indirectly by i) habitat modification, mainly the conversion of coastal ecosystems to aquaculture ponds, destroying breeding areas that support ocean fisheries; ii) collection of wild seedstock; iii) food-web interactions; iv) degradation of coastal waters through the discharge of nutrients and chemicals; and v) disruption of coastal ecosystems by the introduction of alien species (Naylor *et al.*, 2000).

In fact, introduction of alien species is one of the major factors that contribute to the irreversible and devastating impact that human activities cause to natural ecosystems, second only to habitat loss (Pérez *et al.*, 2000). Aquaculture is one of the main causes of the introduction of new species: Out of a total of 3141 new introductions recorded by FAO, 1386 (38.7%) resulted from this activity (FAO, 1998).

Exotic Species in Aquaculture

The impacts caused by newly introduced species fall into two broad categories: 1) Biological, which includes ecological and genetic effects, and 2) Socio-economic. However, these two categories are not independent, and socio-economic changes brought about by alien species can in turn cause more biological changes. A reduction in the number of native species may result from direct interaction with an exotic species, from increased fishing pressure or from changes in land use brought about by the presence of a newly introduced species (Bartley and Casal, 1998).

The main concern when transferring species or populations to a new environment is how they may affect the ecological interactions between species. When dealing with genetic consequences of the introduction of aquatic organisms into new environments, it is necessary to keep in mind the possibility of hybridization between geographically separate but closely related species, joined together by the introduction of one species into the habitat of another, as has been shown in several cases (Gardner, 1997; Pérez and Rylander, 1998).

Unfortunately, most introductions of this kind have been made for purely economic purposes, without proper concern for biological consequences. A good example is the introduction of salmonids in Chile. Several species of salmonids were introduced into Chilean waters in an attempt to establish sea ranching programs, closed-system aquaculture programs, and commercial and sport fisheries. Although there are a few instances where newly introduced salmonids have established small and self-sustaining populations, in general the attempts at sea ranching and the establishment of new fisheries in Chile were unsuccessful. In contrast, the closed-system culture of three species, rainbow trout, (*Oncorhynchus mykiss*), Atlantic salmon, (*Salmo salar*) and coho salmon (*Oncorhynchus kisutch*) has been successful in Chile (Bartley, 1994).

In the Northern Hemisphere, exotic salmon have seriously impacted related species through predation, competition for food and mates, disease transmission and hybridization (Jansson and Ost, 1997; Gross, 1998; Landergreen, 1999; Volpe, 2001; Volpe *et al.*, 2000, 2001). It has been proven to be nearly impossible to completely contain aquaculture stocks in cages, for escapes are inevitable and feral salmon can adapt to a variety of habits, as they consume zooplankton as juveniles, and switch to fishes as they grow (Volpe, 2001). Although little is known about how these salmon have affected Chilean aquatic resources, there is some valuable information (Soto and Jara, 1997) that indicates a negative effect of salmonid escapes from cages, through competition for similar requirements, on several native species of fish such as "robalo" or "bacalao de profundidad" (*Dissostichus eleginoides*), "huayca" (*Macrouronus magellanicus*), "rollizo" (*Pinguipes chilensis*) and "blanquillo" (*Prolatilus jugularis*), or through predation on "pejerrey" (*Odontesthes* sp.), "mote" (*Normanichthys crockeri*) and "huayca" (*Macrouronus magellanicus*)

Although Chile does not have a naturally occurring population of salmon, it does have several species of Galaxids that are related to salmon. Galaxids of the Southern Ocean have been shown to be susceptible to exotic salmon, because the two groups have similar ecological niches, although they did not evolve together (Crook and Andrews, 1998; Woodfield, 2001). One Galaxid is endemic to Chile (*Galaxias platei*) and, therefore, care should be taken that introduced salmon do not cause this unique resource to become extinct (Bartley, 1994). On the other hand, Galaxids (mainly *G. maculatus*) have a great economic potential and efforts are being made in Chile to cultivate them (Anonymous, 1999).

There is considerable concern about the unintentional release of trangenic organisms and special kinds of exotics into the wild (mainly from aquaculture installations), and their possible undesirable ecological impacts, including reduction of biodiversity, although present indicators show that transgenic fish, like other domesticated fish, are likely to be less adaptable than wild fish of the same species. Whether or not transgenic fish will have a significant impact on the environment is debatable and difficult to predict. However, three recent simulation studies (Muir and Howard, 1999, 2001; Hedrick, 2001) have shown that a transgene could be able to spread to a wild population, even if the gene markedly reduces a fitness component.

Although genetic engineering can clearly benefit the aquacultural industry, its development and application are tied to the needs of aquaculture industries in the First World. The benefits of genetic engineering to people in the Third World countries are unclear for several reasons. The development of transgenic organisms is a highly technical and costly enterprise that requires an intensive industry working under rigid controls. An adequate return on investment may be possible in countries where aquaculture is practiced intensively (e.g., salmonid and prawn cultivation), but investments are much less likely to be viable in developing countries, where aquaculture tends to be extensive.

We believe that the use of transgenic organisms with altered temperature or salinity tolerance should be avoided in aquaculture. Such transgenic fish might enter and persist in communities that are not adapted to their presence (Pérez *et al.*, 2001).

The Role of International Organizations and Governments in the Development of Aquaculture

If aquaculture is to provide an important contribution to world nutrition, and if aquaculture is to reduce the pressure on wild fish stocks, substantial changes must be made by international funding agencies, governments, and the private sector. These entities must finance projects to protect coastal ecosystems, to promote research and development of native species, and to encourage farming of low-trophic-level fish, those that are low in the food chain. However, the role of these organizations has, in many cases, been the opposite:

a) The International Development Bank is partially financing a program to cultivate seven exotic species in Panama, the scallop *Argopecten purpuratus*, the "cachamas" *Colossoma macropomus* and *Piaractus brachipomus*, the channel catfish *Ictalurus punctatus*, the peacock bass cichlid *Cichla ocellaris*, the giant prawn *Macrobrachium rosenbergii*, and even the bullfrog *Rana catesbiana* (http://www.iadb.org/EXR/doc98/apr/lepanaq.htm). It is well known that some of these species have caused serious damage to species richness and have reduced biodiversity (Moyle, 1973; Zaret and Paine, 1973; Hayes and Jennings, 1986). Seventy five exotic species of fish introduced into Panama are not enough? (González, 1995).

b) The World Bank (http://www.worldbank.org) finances projects that require the introduction of species of shrimps such as *Litopenaeus vannamei* and *L. stylirostris* into countries where they do not occur naturally, but claims there is no risk in introducing alien species because *L. vannamei* and *L. stylirostris* occur naturally in the Gulf of Fonseca, Honduras. Therefore, the World Bank is well aware of the potential dangers. Why then does it not mention this risk in a Venezuelan project to introduce *L. vannamei*, although this species is not native in the country?

c) FAO has produced several documents to warn about the danger of introducing exotic species, such as the Codes of Practice and Procedures (FAO, 1993; Turner, 1998), and it has even prepared a database on the introduction of exotic species (FAO, 1998), but has not taken its own opinion into consideration in subsequent cases.

In view of the problems encountered in the production of high quality seeds and in obtaining all-male red tilapias, the Autonomous Service for Fishing and Aquatic Resources of Venezuela (SARPA) called upon FAO for help. FAO decided to start a study on the genetic improvement of these fishes, and approved a Technical Cooperation Project with Venezuela that included the selection of breeders from stocks available in the country and the import of adult stocks as required (Pedini and Shehadeh, 1996). The question is then, what about all the recommendations (FAO, 1993) about introductions and transfers of exotic aquatic organisms? How can they spend money on a project like that (which was a complete failure), instead of helping the country to develop the cultivation of local fishes? (Pérez *et al.*, 1999, 2000)

These organizations should reconsider their promotion of technical packages that encourage the introduction of exotic species and, instead, contribute to the development of technologies that propose the cultivation of native species with a potential for aquaculture (Pérez *et al.*, 2000).

Governments bear the largest responsibility when introducing exotic species. Here we examine the case of two countries, Venezuela and Chile.

In Venezuela, even after the negative results of the introduction of *Oreochromis mossambicus* both from the ecological and economic points of view (Pérez *et al.*, 1999), SARPA encouraged the culture of red tilapia (which were introduced illegally, as infertile and innocuous hybrids; MAC-SARPA, 1995), without any studies whatsoever about their environmental impact. Leaflets and posters were made to promote their cultivation, under the name of "pink snapper", a marine fish highly appreciated by Venezuelans. Furthermore, the culture of red tilapia in marine waters close to La Restinga National Park in Margarita Island was allowed (Gómez, 1998) without proper consideration for technical recommendations given by several national and international organizations. Although tilapias are freshwater fish, they are able to live in marine waters, where they can reproduce and have viable progenies (Watanabe *et al.*, 1989a, b; Nirchio and Pérez, 2002).

Shortly after the introduction of red tilapia, it became clear that rearing these fish was not the easy task that government officials claimed it to be. Many small farms went broke, and so did peasants who had started to rear tilapia in small ponds, lured by official claims that it was just a matter of putting fish in a pond and waiting for pay time (Pérez *et al.*, 1999).

Another example of poor policy by the Venezuelan government has been the introduction of two exotic species of marine red algae: *Euchema denticulatum* and *Kappaphycus alvarezzi*, which have proved to be invasive, with asexual reproduction by fragmentation that produces allelopathic substances and are potentially dangerous to coral ecosystems (Barrios, 1999). These introductions were made without studies of any kind, and SARPA approved them after the algae were already in Venezuelan waters.

In Chile, as a consequence of some particular isolation conditions, and despite the fact that they are a reduced group of small-size species with a few inconspicuous individuals for each species, Chilean freshwater fishes are very important from a biological point of view because of the presence of relict groups.

Unfortunately, several species that have been introduced have created an adverse situation for the native species *Cyprinus carpio*, *Carassius auratus*, *Gambusia affinis*, *Cnesterodon decemmaculatus*, *Salmo trutta fario*, *Salvelinis fontinalis*, *Tinca tinca*, *Odontesthes banariensis*, *Cichlasoma facetum*, *Ictalurus nebulosus* (Huaquín-Mora and Manríquez-Leiva, 1986).

Recently, with the purpose of increasing aquaculture production, there have been an astonishing number of introductions, and reintroductions in some cases, of aquatic organisms in Chile (Anonymous, 1996, 2000):

Mollusks. Pacific oyster (*Crassostrea gigas*), red abalone (*Haliotis rufescens*), Japanese abalone (*H. discus hannai*), scallop (*Pecten maximus*).

Crustaceans. Giant prawn (*Macrobrachium rosenbergii*), shrimps (*Litopenaeus vannamei, L. stylirostris*), Australian freshwater lobster (*Cherax teniumanus*).

Fish: Halibut (*Hippoglossus hippoglossus*), hirame (*Paralichthys olivaceus*), turbot (*Scophthalmus maximus*), white sturgeon (*Acipenser transmontanus*), Siberian sturgeon (*A. baeri*), catfish (*Ictalurus punctatus*), trout (*Salmo trutta trutta*), rainbow trout (*O. mykiss*), brown trout (*Salmo trutta fario*), American brook trout (*Salvelinus fontinalis*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), red salmon (*Oncorhynchus nerka*), chum salmon (*O. keta*), Atlantic salmon (*Salmo salar*).

Most of these introductions have been made under the responsibility of Foundation Chile, a technology transfer company established by the government to develop new products, with a clear objective: to increase the economic income of the country.

Conclusions and Recommendations

When FAO, the World Bank and the Interamerican Development Bank promote the introduction and cultivation of exotic organisms, they not only cut short the possibilities of orienting research toward development of cultivation technologies of native species with great potential for aquaculture. They also exclude the knowledgeable expertise that may be found in national universities, which face tremendous economic difficulties. At present, one cannot help but wonder how officials from these institutions can possibly make decisions that may affect all the people from our countries without even the appropriate local consultation. On the other hand, the responsibility for imports of exotics lies with the recipient country. Local politicians often want immediate results and make a case for the introduction of exotics.

Why import exotic species, if species with a great potential for aquaculture can be found in our countries? In Venezuela there are scallops such as *Euvola ziczac* and *Nodipecten nodosus*, fish such as the cachamas *Colossoma macropomus* and *Piaractus brachipomus* and the peackbass *Cichla ocellaris*, crustaceans such as *Litopenaeus smithii*. In Chile there are scallops such as *Argopecten purpuratus* (already a very important item for exportation), the "loco" (*Concholepas concholepas*), superior in texture and flavor to abalone species; and in the case of fishes, how can the fact that it is necessary to import turbot be explained, if Chile owns local species of flat fishes (Paralichthydae: Pleuronectiforms) such as *Hippoglosina macrops*, *Paralichthys patagonicus* and five other large-size species distributed in almost all Chilean waters?

We believe it is necessary to use endemic species in aquaculture wherever possible, even though this will often require research to determine optimal conditions for cultivation, often taking many years, e.g. *Concholepas concholepas.* Unfortunately, many granting organizations are not set up to support long term studies. This is unfortunate since not only do these problems need to be addressed, but long term projects are required to train people. A possible solution would be to establish an international organization whose goal must be to fund long term projects. On the plus side, this will improve local research capacities. It is very important that international organizations and governments understand this situation. International technical funding agencies can exert a great influence in encouraging new practices.

REFERENCES

Anonymous (1996) Nuevos cultivos: la otra cara de la acuicultura en Chile. *Aquanoticias Internacional 33*: 21-53.

Anonymous (1999) Puyes en cultivo. *Aquanoticias Internacional 51*: 68-69.

Anonymous (2000) Diversificación de especies. *Aquanoticias Internacional 58*: 78-85.

Barrios J (1999) La introducción de Eucheuma denticulatum and Kappaphycus alvarezzi (Gigartinales, Rhodophyta) en Venezuela, una revisión crítica. *Fontus 4*: 135-153.

Bartley D (1994) Biodiversity conservation and the establishment of coho salmon broodstock in Chile. *FAO Aquacult. Newslett. 8*: 19-20.

Bartley D, Casal C (1998) Impacts of introductions on the conservation and sustainable use of aquatic biodiversity. *FAO Aquacult. Newslett. 20*: 15-19.

Crook D, Andrews D (1998) Threatened Species Unit Listing Statement. Sawn Galaxias, *Galaxia fontanus*. Park and Wildlife Service, Tasmania http://www.dpirve.tas.gov.au

Cross D (1991) FAO and aquaculture: Ponds and politics in Africa. *The Ecologist 21*: 73-76.

FAO (1993) *Report of the Expert Consultation on Utilization and Conservation of Aquatic Genetic Resources*. FAO Fisheries Report N°491. Rome, Italy. 58 pp.

FAO (1998) *FAO FishStat P.C. Fishery Information, Data and Statistics Unit*. Food and Agriculture Organization of the United Nations. Rome, Italy. 13 pp.

Gardner JPA (1997) Hybridization in the sea. *Adv. Marine Biol. 31*: 1-78.

Gómez A (1998) Sobre el cultivo marino de tilapia en la Isla de Margarita (Venezuela) *Acta Cient. Venez. 49*: 166-172.

González R (1995) Estado de los peces exóticos introducidos en las aguas continentales de Panamá. *Brenesia*: 43-44, 55-59.

Gross MR (1998) One species with two biologies: Atlantic salmon (*Salmo salar*) in the wild and in aquaculture. *Can. J. Fish. Aquatic. Sci. 55*: 131-144.

Hayes MP, Jennings MR (1986) Decline of ranid frog species in western North America: are bullfrogs (*Rana catesbiana*) responsible*? J. Herpetol. 20*: 490-509.

Hedrick PW (2001) Invasion of transgenes from salmon or other genetically modified organisms into natural populations. *Can. J. Fish. Aquacult. Sci. 58*: 841-844.

Huaquín-Mora LG, Manríquez-Leiva A (1986) *Problemática y perspectiva de los peces nativos en aguas continentales chilenas*. Segundo Encuentro Científico sobre el Medio Ambiente. Talca. Chile. Tomo I. pp. 132-138.

Jansson H, Ost T (1997) Hybridization between Atlantic salmon (*Salmo salar*) and brown trout (*S. trutta*) in a restored section of the River Dalalven. *Can. J. Fish. Aquat. Sci. 54*: 2033-2039.

Landergreen P (1999) Spawning of anadromous rainbow trout, *Oncorhynchus mykiss* (Walbaum): a threat to sea trout, *Salmo trutta* L., populations. *Fisheries Res. 40*: 55-63.

MAC-SARPA (1995) La Acuicultura en Venezuela. Ministerio de Agricultura y Cría. Caracas, Venezuela. 230 pp.

Moyle PB (1973) Effects of introduced bullfrogs, *Rana catesbiana*, on the native frogs of the San Joaquin Valley, California. *Copeia*: 18-22.

Muir WM, Howard RD (1999) Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. *Proc. Natl. Acad. Sci. USA 96*: 13853-13856

Muir WM, Howard RD (2001) Fitness components and ecological risk of transgenic release: a model using Japanese medaka *(Oryzias latipes). Amer. Naturalist 158*: 1-16.

Naylor RL, Goldburg RJ, Mooney H, Beveridge M, Clay J, Folke C, Kautsky N, Lubchenco J, Primavera J, Williams M (1998) Nature´s subsidies to shrimp and salmon farming. *Science 282*: 883-884.

Naylor RL, Goldburg RJ, Primavera JH, Kautsky N, Beveridge CM, Clay J, Folke C, Lubchenco J, Mooney H, Troell M (2000) Effect of aquaculture on world fish supplies. *Nature 405*: 1017-1024.

Nirchio M, Pérez JE (2002) Riesgos del cultivo de tilapias en Venezuela. *Interciencia 27*: 39-44.

Pedini M, Shehadeh ZH (1996) Projects and other activities. *FAO Aquaculture Newsletter 14*: 24-30.

Pérez JE, Rylander K (1998) Hybridization and its effects on species richness in natural habits. *Interciencia 23*: 137-139.

Pérez JE, Gómez A, Nirchio M (1999) FAO and Tilapia. *Interciencia 24*: 321-323.

Pérez JE, Nirchio M, Gómez JA (2000). Aquaculture: part of the problem, not a solution. *Nature 408*: 514.

Pérez JE, Mayz J, Rylander K, Nirchio M (2001) The impact of the transgenic revolution on aquaculture and biodiversity. A review. *Revista Científica FCV-LUZ 11*: 101-108.

Soto D, Jara F (1997*) Evaluación de salmonidos de vida libre existentes en las aguas interiores de las regiones X y XI.* Informe Final Proyecto FIP 95-31. Fondo de Investigación Pesquera. Puerto Montt, Chile. 98 pp.

Turner GE (1998) *Codes of Practice and Manual Procedure for Considerations of Introductions and Transfers of Marine and Freshwater Organisms.* EIFAC/CECPI. Paper Nº23 (Mimeo). 44 pp.

Volpe JP (2001) *Super un-Natural: Atlantic salmon in B.C. streams.* http://www.davidsuzuki.org

Volpe JP, Taylor EB, Rimmer DW, Glickman BW (2000) Evidence of natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia river. *Conserv. Biol. 14*: 889-903.

Volpe JP, Anholt BR, Glickman BW (2001) Competition among juvenile Atlantic salmon (*Salmo salar*) and steelhead trout (*Oncorhynchus mykiss*): relevance to invasion potential in British Columbia. *Can. J. Fish. Aquat. Sci., 58*: 197-207.

Watanabe WO, Burnett KM, Olla BJ, Wicklund RI (1989a) The effect of salinity on reproductive performance of Florida red tilapia. *J. World Aquacult. Soc. 20*: 223-229.

Watanabe WO, French KE, Ernst DH, Olla BJ, Wicklund RJ (1989b) Salinity during early development influences growth and survival of Florida red tilapia in brackish and seawaters. *J. World Aquacult. Soc. 20*: 134-142.

Woodfield C (2001) Tasmanian galaxiid: Threatened icons. *The Tasmanian Conservationist 279*. http://www.tct.org.au.

Zaret TM, Paine RT (1973) Species introduction in a tropical lake. *Science 182*: 449-455.