The Food and Agriculture Organization of the United Nations (FAO) is a willing partner to the Convention on Biological Diversity and is pleased to offer assistance as appropriate in the implementation of the Convention. The FAO Conference, at its Twenty-eighth Session in October 1995, stressed the importance of an integrated approach and full cooperation with the Conference of the Parties to the Convention on Biological Diversity. Toward that end, a Memorandum of Cooperation between FAO and the Secretariat to the CBD was signed on 1st September 1997. Article 2 of this memorandum on “Access to and dissemination of information” calls for, *inter alia*, cooperation “in the dissemination of information and the building of relevant capacity for the effective implementation of the Convention”. The following Case Study, as requested in COP decision V/8, describes an information system on alien aquatic species.

**1. Description of the problem**

In fisheries and aquaculture, alien species and genotypes, also known as introduced species and genetically improved species, are a valid means to increase production. However, exotic species are also recognized as one of the most significant threats to natural aquatic ecosystems and the people that depend on them. While much of the recent attention and Article 8h of the CBD have focused on the adverse impacts, alien species are a valid means to improve production and economic benefit from fisheries and aquaculture; approximately 17% of the world’s production of fin fish is due to alien species (Bartley and Casal 1999). The production of the African cichlid tilapia is much higher in Asia (>700,000 mt in 1996) than in most areas of Africa (39,245 mt); introduced salmonids in Chile support a thriving aquaculture industry that is responsible for approximately 20% of the world’s farmed salmon and directly employs approximately 30,000 people. The practice of using species outside of their natural range to increase production or profitability can be expected to continue. The issue is not to ban alien species, or to abandon regulation of their movement, but rather to assess the risks and benefits associated with their use and then, if appropriate, develop and implement a plan for their responsible use. The problem is how to determine the impact of a proposed introduction into complex and dynamic aquatic ecosystems where often our information base is inadequate.

Significant international instruments have recently been established that address this issue, such as the Convention on Biological Diversity (for example through decision V/8 on alien species) and the FAO Code of Conduct for Responsible Fisheries (FAO 1995). Such international codes and conventions are calling for accurate assessments of the risks of using exotic species and are promoting the creation of information sources and an exchange of information on exotic species, their biological and ecological attributes, and potential impacts (both positive and negative). Toward this end, FAO Fisheries Department has created the Database on Introductions of Aquatic Species (DIAS), to serve as an important initial summary and registry of introduced species. The purpose of this case study is to review the information on introductions of exotic species contained in DIAS in order to raise awareness, and to request feedback on how it may be improved and used to help implement relevant articles in the Convention on Biological Diversity and the Code of Conduct for Responsible Fisheries.
(a) Location and (b) history of DIAS

The Database on Introductions of Aquatic Species (DIAS) was initiated by FAO Fisheries Department in the early 80's and has been used as the standard reference in the field of inland aquatic introductions (Welcomme 1988). In 1991 the database was expanded through distributing questionnaires to national experts throughout the world and by searching the fisheries and aquaculture literature (Bartley and Casal 1999).

In 1997, a Web site on the FAO Fisheries homepage (http://www.fao.org/waicent/faoinfo/fishery/statist/fisoft/dias/index.htm), was created to allow broader access to the database (Garibaldi and Bartley 1999). Through cooperation between FAO and the International Center for Living Aquatic Resources Management (ICLARM), DIAS has been incorporated into FishBase (Froese and Pauly 1998), a relational database containing a variety of information on approximately 25,000 species of finfish. FishBase, including the Introduced Species Module, is available on Compact Disc and on the worldwide web (http://www.cgiar.org/iclarm/fishbase/).

(c) Description of the alien species concerned

DIAS contains 3150 records on aquatic introductions between countries. Most of the records concern fish (Table 1), but other taxa are included as well. The database can be queried to provide information such as the most widely introduced species (common carp, *Cyprinus carpio*) and the overall impact of the introduction. The database contains primarily information on species relevant to fisheries and aquaculture.

<table>
<thead>
<tr>
<th>Table 1. Taxonomic coverage of records in DIAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group of species</td>
</tr>
<tr>
<td>Fishes</td>
</tr>
<tr>
<td>Molluscs</td>
</tr>
<tr>
<td>Crustaceans</td>
</tr>
<tr>
<td>Algae and plants</td>
</tr>
<tr>
<td>Other invertebrates</td>
</tr>
<tr>
<td>Other vertebrates</td>
</tr>
</tbody>
</table>

(d) Vector(s) of invasion(s) (e.g. of deliberate importation, contamination of imported goods, ballast water, hull-fouling and spread from adjacent area. It should be specified, if known, whether entry was deliberate and legal, deliberate and illegal, accidental, or natural.)

DIAS contains information on the reasons for the introduction (Figure 1) and who was responsible (Figure 2). Aquaculture is the main reason cited for introductions in 39% of the database records. The category “Other” in Figure 1 included mechanisms or reasons such as off site preservation, bait and forage, and research. Parasites are not included in the database and introductions from ballast water and ship-fouling organisms are poorly covered and probably only reported in the questionnaires or found in fishery literature when their introduction had a significant effect on fisheries and aquaculture, or when the introduction seriously affected the environment. The extensive use of introduced species in the ornamental fish industry is also not well represented in the database.

Although for most introductions reported in DIAS the responsible party was not identified, national governments were most often reported as being responsible for the introduction (Figure 2).
Figure 1. Reasons for introductions of aquatic species, as a percentage of DIAS records

Aquaculture 39%
Fisheries 17%
Bio-control 6%
Accidental 8%
Ornamental 8%
Other 6%
Unknown 16%

Figure 2. Who is making aquatic introductions?

Unreported 76%
Government 11%
Individual 4%
Int. Organization 1%
Industry 6%
Other 2%
(e) Assessment and monitoring activities conducted and methods applied, including difficulties encountered (e.g. uncertainties due to missing taxonomic knowledge)

In order to conduct an accurate cost/benefit analysis of the use of introduced species, it is necessary to look at both ecological and socio-economic impacts. Analyses of the database by reason for introduction (Table 2) reveals that most of the ecological effects of introduced species reported were negative; however, the socio-economic impacts were reported to be more often beneficial and overall, there were more positive socio-economic benefits reported than negative ecological impacts for a variety of types of introductions.

Table 2. Effects of introduced fishes on ecological and (socioeconomic) environments, by reason for the introduction.

<table>
<thead>
<tr>
<th>IMPACT</th>
<th>FISHING</th>
<th>AQUACULTURE</th>
<th>ORNAMENTAL</th>
<th>BIO-CONTROL</th>
<th>UNKNOWN</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADVERSE</td>
<td>36 (2)</td>
<td>78 (8)</td>
<td>17 (5)</td>
<td>23 (9)</td>
<td>13 (0)</td>
<td>40 (12)</td>
</tr>
<tr>
<td>BENEFICIAL</td>
<td>16 (67)</td>
<td>52 (283)</td>
<td>11 (42)</td>
<td>11 (19)</td>
<td>3 (10)</td>
<td>6 (15)</td>
</tr>
<tr>
<td>UNKNOWN</td>
<td>28 (16)</td>
<td>76 (49)</td>
<td>9 (9)</td>
<td>8 (2)</td>
<td>21 (3)</td>
<td></td>
</tr>
<tr>
<td>BLANK</td>
<td>196 (299)</td>
<td>949 (815)</td>
<td>169 (150)</td>
<td>106 (122)</td>
<td>459</td>
<td>283</td>
</tr>
</tbody>
</table>

The DIAS is not a complete listing of all alien species and has relied heavily on questionnaires and published literature. Much of the ecological impact of introductions is poorly known because of little or no initial assessment or follow-up monitoring of the aquatic environment (Table 2). The data from DIAS should be interpreted with caution because simply counting number of positive vs. negative impacts does not give the complete picture of the situation. For example, many introductions have little adverse ecological impact, but one may have disastrous consequences, such as the introduction of diseased penaeid shrimp into Taiwan, Province of China that lead to the collapse of the marine shrimp industry or the re-introduction of diseased European flat oysters that lead to the decimation of European flat oyster populations.

2. Options considered to address the problem

(a) Description of the decision-making process (stakeholders involved, consultation processes used, etc.)

Evaluating the risk and benefits from alien species will require extensive information from a variety of sources, some of which can be provided by DIAS. The following types of information are included in the data-structure of DIAS:

- Taxonomy of the alien species
- Receiving country
- Source country (i.e. where the alien species was moved from, and it may be a country outside of the species natural range
- Reason(s) for the introduction
- Who made the introduction
- The year of the introduction
- The status of the introduction
- The ecological, social and economic impacts of the introduction

Decision makers and resource managers can consult. DIAS for information to help decide whether an introduction is well-advised. Through the DIAS web-site, users aware of introductions not already included in the database are requested to contribute the new information to the database. In theory, the database is a record where the status of an alien species in a particular country can be checked (see below).
(b) Type of measures (research and monitoring; training of specialists; prevention, early detection, eradication, control/containment measures, habitat and/or natural community restoration; legal provisions; public education and awareness)

Although not complete, the database now contains 3150 records of introductions of aquatic species from one country to another, excluding movements of species within the same country. The web-site allows users to check the status of alien species in a country and to add data on introductions that are missing, incorrect, or for which information is not complete.

(c) Options selected, time frame and reasons for selecting options

The original registry of fish introductions of FAO (Welcomme 1988) was made into a digitized database, i.e. DIAS, in order to query better the variety of information contained on alien species. The DIAS was incorporated into FishBase in order to provide even more information on the alien species. FishBase allows users to find information on, inter alia a species' distribution, uses, biology, genetics, and natural history. Complex queries can be made to examine specific questions, such as the nature of perceived impacts from the use of introduced species for different reasons (Table 2). Such queries will be necessary to provide information on relative costs and risks vs. benefits from using alien species and to examine trends and conceptions regarding alien species (Table 3).

(d) Institutions responsible for decisions and actions

DIAS is maintained by the FAO Fisheries Department for the use of Members and the fishery community in general. The database is a source of reference material for general use by scientists and policy makers. DIAS is available on the worldwide web and on request from the FAO Fisheries Department as a MS Access database. ICLARM distributes FishBase on CD ROM and over the world wide web. Any individual or group may contribute information to DIAS. Although the information in DIAS is not peer reviewed, efforts are made to check the accuracy of contributions and all information is available on-line for comment.

3. Implementation of measures, including assessment of effectiveness

(a) Ways and means set in place for implementation

The web-based version of DIAS provides access to online users and FAO plans to issue a CD version of the database for those users who do not have internet access. ICLARM also distributes FishBase on CD.

(b) Achievements (specify whether the action was fully successful, partially successful, or unsuccessful), including any adverse effects of the actions taken on the conservation and sustainable use of biodiversity

The information in DIAS has been used as the basis for a number of publications by FAO and partners. In addition, the inclusion of DIAS as the “Introductions” module in FishBase further has raised the profile and promoted discussion of introduced fishes in fisheries and aquaculture. The hope is that DIAS will not only raise awareness, but will become a dynamic source of information that is used by a variety of stakeholders to help manage the movement of alien species.

Through the collection and exchange of information, DIAS is one mechanism to help maximize benefits and minimize adverse impacts from introductions. Table 3 presents some popular conceptions regarding impacts of alien species and how the database can provide information to support or refute the generalizations. The purpose of challenging the broad generalizations is not to replace one generalization with another, but to provide some
estimate of their validity so that decision makers have better information on which to manage alien species. The information from the database is not unbiased as it represents a limited number of responses from those responding to a questionnaire and a review of published literature. The information submitted to DIAS has not been peer-reviewed or evaluated except where it came from peer-reviewed scientific publications. The far right column of Table 3 lists some of the potential biases.

**Table 3. Some popular conceptions regarding alien species**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Information from DIAS/FishBase</th>
<th>Possible biases in data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most introductions fail</td>
<td>Where establishment was assessed, 65% of the introductions lead to established populations</td>
<td>Biased reporting to database, data from questionnaires</td>
</tr>
<tr>
<td>Top carnivores are the most dangerous</td>
<td>Herbivores and carnivores were reported to cause negative impacts in &gt;60% of the cases where impact was assessed, whereas the figure for omnivores was 81%</td>
<td>Small sample size of carnivore introductions</td>
</tr>
<tr>
<td>r-selected species most likely to establish</td>
<td>Establishment success negatively correlated with max. size</td>
<td>Larger fish subsequently removed by fishing or other factors after establishment; larger fish take longer to establish noticeable populations</td>
</tr>
<tr>
<td>Diverse environment hinders alien establishment</td>
<td>Data-set cannot address the issue</td>
<td>No fields in database describe receiving environment</td>
</tr>
<tr>
<td>Disturbed environment helps alien establishment</td>
<td>Data-set cannot address the issue</td>
<td>No fields in database describe receiving environment</td>
</tr>
<tr>
<td>Genome size inversely related to invasive ability</td>
<td>DNA content and chromosome number were not related to establishment success</td>
<td></td>
</tr>
</tbody>
</table>

The database is still growing and is incomplete, especially in the areas of marine organisms, ornamental fishes, and those organisms not used for fisheries and aquaculture. The main difficulty in making the database more effective is the lack of resources to update regularly the data, the web-page, and the summary information. Furthermore, an accurate assessment of the impact of an alien species will only be possible if an accurate assessment of the “pre-introduction” ecological and socio-economic environments already exists. Unfortunately, in many areas of the world and especially in many developing countries, this information is lacking. Chinese carp were introduced into barrier lakes in coastal Mozambique to establish aquaculture and a fishery with little or no knowledge of the species existing in this unusual habitat nor of the level of fishing activity the lakes already supported.

Both DIAS and FishBase focus on the species level. This is understandable and effective for many purposes. However, in assessing risk from the movement of species from one area into another, a key factor is the receiving environment. No information on the environment into which the alien species were introduced is listed in DIAS or FishBase. Because DIAS deals with international introductions, it cannot contain the level of detail needed to describe each receiving environment. However, national registries are recommended that could provide such detail (see 4b below).

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1 species with high fecundity, short generation time, early age at maturity and usually small size
(c) Costs of action

The original database and expansion were undertaken as part of the regular programme of the Fisheries Department of FAO. Additional resources are required to perform regular updates and maintenance of the database and to make it more dynamic and useable.

4. Lessons learned from the operation and other conclusions

(a) Further measures needed, including transboundary, regional and multilateral cooperation

Codes of practice exist to assist with the responsible movement of alien species (Turner 1988, ICES 1995) that call for regional cooperation and notification of intent to introduce an alien species. However, often it is unclear how this notification should be made, what legislation exists to address the introduction, and what information should be included in the notification. Cooperation at all levels is needed to improve the contents of information sources such as DIAS. FAO has begun to add a module on national legislation relevant to alien species, but this work has only been started in Asia.

A growing concern in fisheries and aquaculture is the use of genetically improved species and genetically modified organisms (GMOs). Currently, the database focuses on the species level, with subspecies nomenclature, strain designation for genetically improved species, and GMO's not well incorporated nor handled. The major problem in including such information is the lack of standard nomenclature on taxonomic designation below the species level. How databases handle GMOs, hybrids and polyploid organisms similarly has not been standardized.

(b) Replicability for other regions, ecosystems or groups of organisms

In order to make DIAS workable in an international setting such as FAO, only introductions across international borders were considered. However, the movement of aquatic species within a country should also be carefully considered, monitored and assessed. Thus, countries are encouraged to define ecologically and socially meaningful areas, e.g. watersheds, coastal lagoons, aquatic protected areas, etc., and collect data on alien species found in them or planned for introduction to them. The structure of DIAS would move from a global to a local focus with more detail relevant to specific countries or regions.

The Convention on Biological Diversity calls on Members to prepare and maintain a registry of alien species. The format of DIAS may provide one suitable model. The cooperation between FAO and ICLARM that led to the inclusion of DIAS in FishBase serves as a useful model for incorporating this information into other data systems. Revised versions of DIAS will also be incorporated into future releases of FishBase. Although the coverage in DIAS is global, the database can be queried to provide information by country groupings and by continent. Information from DIAS has also been incorporated into the clearing house of the USGS, Biological Resources Division, NBII Clearinghouse http://www.nbii.gov/clearinghouse.html.

(c) Information compilation and dissemination needed

The amount of information necessary to predict accurately the impacts of alien species is extensive. Collaboration and sharing of information through mechanisms such as DIAS and FishBase will be essential in order to take full advantage of the potential of alien species,
while protecting aquatic biodiversity for present and future generations. The information contained in DIAS is readily available to the Clearing House Mechanism of the CBD.

5 Literature cited


