A regional database management system—the fisheries resource information system and tools (FiRST): Its design, utility and future directions

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Abstract

South and Southeast Asian countries have undertaken demersal trawl surveys to measure the fisheries potential of their waters throughout the 20th century. However, ensuring full use of, and easy access to the resulting data is a challenge in developing countries. The “Fisheries Resource Information System and Tools” (FiRST) was developed through a regional collaborative effort across eight South and Southeast Asian countries to meet these needs. FiRST is a data management system for scientific trawl survey data and includes data summary and visualization tools, an analytical routine to estimate biomass, and data import/export modules. The FiRST software has also facilitated the establishment of a regional database, ‘TrawlBase’, which contains more than 20,000 hauls or stations from scientific trawl surveys in 10 countries conducted between 1926 and 1995. The regional database is an important regional resource for coastal fisheries management complementing national fisheries catch statistics.

This article describes the refined version of FiRST (version 2004) and provides examples on how the database (‘TrawlBase’) has been used to date for analyses aimed at establishing historic resource baselines and examining the status of coastal fishery resources. The results show a severe decline of resource biomass to an average of 22% of pre-exploitation levels, with cases as low as 4%. These results clearly demonstrate the strong impact of fishing on coastal resource biomass and diversity.

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1. Introduction

Information on the status and potential of resources is essential for sustainable management of fisheries. However,
assessing the status of fisheries resources is a challenge, particularly in tropical developing countries where fisheries are usually multispecies in nature and information is limited (Simpson, 1982; Pauly, 1988; Silvestre and Pauly, 1997a). Determining current levels of fishing effort, and assembling time series of catch and species composition with reasonable accuracy and precision is often a monumental task. This lack of robust resource assessments limits the ability of managers to make informed decisions.

Trawl surveys have been used extensively as a fisheries-independent approach to measure the status of resources (Sissenswine et al., 1983; Gunderson, 1993; Smith, 1996). They are suggested to be the most straightforward way of determining the amount and type of species in an area, particularly for demersal species (Pauly, 1996). Many Asian countries have conducted scientific trawl surveys since the 1920s, principally to identify areas with a high fisheries potential (Aoyama, 1973; Simpson, 1982; Pauly, 1988; Silvestre and Pauly, 1997a,b). In South and Southeast Asia, over 300 trawl surveys covering approximately 40,000 trawl stations have been carried out (Table 1, Fig. 1). However, in many cases, the resulting datasets have not been used as fully as they could have to inform fisheries management. This is due to a range of data management issues, including that data are held by individuals who treat them as their private property, or by multiple organizations/institutions in a country or even by another country altogether. Also, such data are usually not in electronic format, poorly maintained, and

Table 1
Scientific trawl surveys that have been conducted in South and Southeast Asia derived from Appendix III in Silvestre and Pauly (1997a), trawl survey data contained in the national and regional (‘TrawlBase’) database within FiRST (version 2004) and current data custodians/users

<table>
<thead>
<tr>
<th>Country</th>
<th>Data custodians/users</th>
<th>Survey area</th>
<th>National database</th>
<th>Regional database (‘TrawlBase’)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period covered</td>
<td>Number of stations</td>
<td>Period covered</td>
<td>Number of stations</td>
</tr>
<tr>
<td>Brunei darussalam</td>
<td>Department of fisheries</td>
<td>Brunei waters (South China Sea)</td>
<td>1949–1990</td>
<td>571</td>
</tr>
<tr>
<td></td>
<td></td>
<td>East coast (South China Sea)</td>
<td>1926–1995</td>
<td>1760</td>
</tr>
<tr>
<td>Myanmar (Burma)</td>
<td>The WorldFish center</td>
<td>Sabah/Sarawak (South China Sea)</td>
<td>1927–1996</td>
<td>1682</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>The WorldFish center</td>
<td>Bay of Bengal (Indian Ocean)</td>
<td>1953–1983</td>
<td>881</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other Areas</td>
<td>1969–1991</td>
<td>210</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Ministry of fisheries and aquaculture</td>
<td>Sri Lanka waters (Indian Ocean)</td>
<td>1920–1980</td>
<td>795</td>
</tr>
<tr>
<td></td>
<td>development</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>Department of fisheries</td>
<td>Gulf of Thailand</td>
<td>1961–1996</td>
<td>10983</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Research institute of marine fisheries</td>
<td>Vietnam waters (South China Sea)</td>
<td>1960–1988</td>
<td>8799</td>
</tr>
<tr>
<td></td>
<td>The WorldFish center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southeast Asia</td>
<td></td>
<td>South China Sea</td>
<td>1969–1973</td>
<td>925</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These are published datasets: Myanmar (Strømme et al., 1981), Pakistan (Yamanaka et al., 1977) and South China Sea (Senta et al., 1977: prov. comm. Tan Sen Min, SEAFDEC, Marine Fisheries Research Department, Singapore).
thus difficult to access and analyze even under the best of circumstances. Retrospective analysis of these data would provide a fisheries-independent measure of resource status.

The data can also be used to generate historic baselines for restoration and management. The availability of such baselines would avoid the potential 'shifting baseline syndrome' (Pauly, 1995) that can occur when only recent observations are available.

The value of these historic time series is not limited to fisheries management, but also extends into general ocean management and conservation. These data could be used to reconstruct past ecosystems (Holm, 2003) and examine the extent of changes over time, and the causes. They can also contribute to our understanding of current structure of marine fisheries assemblages. Generally, ecosystem level approaches require that the data are not only available, but also compatible across countries to enable joint analyses at the ecosystem level.

In July 1996, seven Asian countries participated in the "Sustainable Exploitation of Coastal Fish Stocks in Asia" workshop. There, a consensus was achieved on the value of compiling and analyzing past trawl surveys (Silvestre and Pauly, 1997b). To facilitate the required analyses, a software tool was required to assist countries in addressing the issues regarding storage and access to the data. A prototype database and analytic tool for this purpose was presented and evaluated during the workshop (Gayanilo et al., 1997).

From 1998 to 2001, the database management system was further developed by the WorldFish Center. This was part of a regional collaborative project with eight South and Southeast Asian countries namely, Bangladesh, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Viet Nam (Silvestre et al., 2000; Silvestre et al., 2003a). The result was the FiRST version 2001 (Fisheries Resource Information System and Tools) software which was further refined in 2003. A regional database for scientific trawl survey data, referred to as 'TrawlBase', was also established.

Globally, there is increasing recognition of the need for long-term data management and a trend towards increased data availability via the internet, e.g. OBIS (Ocean Biogeographic Information System) (Zhang and Grassle, 2003). Global public databases such as FishBase (Froese and Pauly, 2000; http://www.fishbase.org), CephBase (http://www.cephbase.org), Hexacoral (Fautin and Buddemeier, 2002), Global Mangrove Database and Information System—GLOMIS (Baha et al., 2004) and ReefBase (Vergara et al., 2000; http://www.reefbase.org) have increased the availability of taxonomic, biological and management information. FiRST and TrawlBase were designed to complement these global databases.

This contribution describes FiRST (version 2004) and 'TrawlBase', with examples of how these have been used to date to facilitate retrospective analysis of trawl survey data in the participating countries. We conclude with suggestions for future directions in the development of FiRST. We recognize that database systems have been designed elsewhere for...
survey data (Strømme, 1992). However, FiRST differs from these not only in that it was developed in partnership with developing countries, and is designed to address their needs, but also in that it is freely available. TrawlBase is also the only regional trawl survey database established to date; as such, it has an important role to play in support of fisheries management at national and regional levels.

2. The fisheries resource information system and tools (FiRST)

2.1. Design and components

The FiRST (version 2001) was developed between 1998 and 2000 as a stand alone application with a user interface using Visual Basic and Microsoft Access as the database software (Garces and Silvestre, 2003). The detailed technical description and documentation of the database system is given by Gayanilo et al. (2001). In 2003, FiRST was reprogrammed into a web-based application. It uses active server page (ASP) and hypertext pre-processor (PHP) programming languages to develop the front-end interface and Microsoft Access or Microsoft SQL server 7.0/2000 as the database software. Key considerations in the development were:

- the use of open source or commonly used software to minimize costs in countries where resources are scarce;
- the ability to function on a range of operating systems (e.g., Windows 98, 2000 and XP, Linux);
- the facilitation of analyses in commonly used statistical software to increase the potential use of the data.

The main differences between FiRST (version 2004) and FiRST (version 2001) are: (1) a more user-friendly interface; (2) an improved system for data entry, summary and reporting modules; (3) a mapping module for displaying the data using Geographic Information System (GIS); and (4) a web-based interface which enables the system to be run from a central server. These improvements were driven by country partner’s inputs through a technical workshop and feedback during the reprogramming.

The web-based version of the FiRST software and related documentation are downloadable at http://www.worldfishcenter.org/trawl/first/download/ with a template of a country database in Microsoft Access format. The software is also distributed on a CD-ROM which can be obtained from the WorldFish Center. FiRST requires the following minimum configuration for the system to work:

- Microsoft® Windows 98/ME/NT/2000/XP/2003;
- Microsoft® PWS or IIS Web Server;
- Microsoft® Internet Explorer 5 or later;
- Microsoft® Access or Microsoft® SQL Server 7.0/2000;
- at least 64MB RAM; and
- a 1024 × 768 high resolution monitor.

Before using FiRST, the data administrator has to install a web server. FiRST can then be installed on individual PCs linked to a local network. This allows the software and database to be held on a central server and accessed via the intranet or internet from other workstations with proper authorization (see section on Data Access). Running the software from a server will help countries to centralize their data in a single database (either in Microsoft Access or Microsoft SQL server formats), which will facilitate database maintenance and integrity. The ‘server’ can also be stand-alone if this is appropriate.

2.2. Database structure and data entry forms

The database system contains 10 interrelated main tables (Fig. 2; Table 2). The relationships of the main tables are illustrated in Fig. 3. The general features of the user interfaces or ‘data entry forms’ to these tables in FIRST are similar to the standard features of other Windows-based programs. The ‘Country form’ contains basic country-level information. The ‘Project form’ contains project level information regarding the implementation and extent of the project, i.e., trawl survey. It also contains the original project objectives, which determined the sampling design. Linked to the ‘Project form’ is a ‘Master Reference form’ offering a list of reports and/or other publications produced by the projects in the country database. Within a project, there may be one or many cruises and the details of these are captured in the ‘Cruise form’. The ‘Vessel Description form’ and the ‘Gear form’ contain the technical specifications of the survey vessel and fishing gear that are relevant to data analysis, respectively. These forms also allow the storage of the scanned or digital image of the gear or trawler (Fig. 4). The ‘Station form’ contains information such as the geographic location of each trawl (fishing) haul/station, geophysical conditions, and the trawling speed and depth (Fig. 5).

The main form in the database system is the ‘Species form’ (Fig. 6), which contains catch data at a given fishing station. The information is at species level where possible, depending on the original survey. The system stores scientific names and
Table 2

Main tables of FIRST (version 2004), and their contents and functions

<table>
<thead>
<tr>
<th>Table Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
</tr>
<tr>
<td>Project</td>
</tr>
<tr>
<td>Cruise</td>
</tr>
<tr>
<td>Gear description</td>
</tr>
<tr>
<td>Vessel description</td>
</tr>
<tr>
<td>Station</td>
</tr>
<tr>
<td>Species</td>
</tr>
<tr>
<td>Grouped length frequency (GLF)</td>
</tr>
<tr>
<td>Ungrouped length frequency (ULF)</td>
</tr>
<tr>
<td>Master references</td>
</tr>
</tbody>
</table>

Fig. 3. Schematic representation of the detailed relationships (all of which are one to many) between the main tables in FIRST (version 2004) including the primary key (in bold) and foreign keys (not bold) in each table.

species codes. FIRST enables scientific names to be checked against FishBase (using FishBase 2003 and its online version at http://www.fishbase.org). Any synonyms detected are stored for information but the valid scientific name is used in summaries and analyses. The species code can be encoded directly, or selected from a list. The list can be based on ISSCAAP, NANSIS or a country-specific list. The storage of the original names and codes used by the countries enables any records to be traced back to original data sources if this is required.

For each taxon, the total catch in number of individuals and/or total weight is stored. If the catch was subsampled, the total catch for a species is calculated before entry. If specimens were sampled for length–frequency information, the number of specimens is recorded. FIRST stores length frequency data for individual species in either a grouped or ungrouped format. When grouped length frequency data are stored, the user defines the size of the length classes, lower limit of the smallest length group and the class interval.

2.3. Data summaries and visualization

FIRST (version 2004) contains analytical routines and reporting formats that allow the user to generate results in terms of catch, catch per unit effort (CPUE, standardized by
duration of the trawl) or estimates of biomass. The biomass is estimated using the swept-area method (Pauly, 1984; Sparre and Venema, 1992) with the formula:

\[ B = \frac{C}{f_{mean}} A \alpha X_1 \]

where \( B \) is the biomass, \( C/f_{mean} \) is the mean catch per unit of effort (CPUE); \( A \) is the total area covered by the survey (and to which the estimated biomass refers); \( \alpha \) is the area swept by the gear during one haul; and \( X_1 \) is the escapement factor, i.e., the proportion of fish in path of the trawl gear that is actually...
Fig. 6. The species form in FiRST (version 2004) to record catch composition for a particular station. Note that the last two columns indicate presence of related data (e.g., length-frequency).

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where \( t \) is the duration of the trawl haul; \( v \) is the trawling speed; \( h \) is the length of trawl’s headrope; and \( X_2 \) is the effective width of the trawl relative to the length of the trawl’s headrope.

This approach requires a value for headline width in the ‘Gear form’. In the absence of headline width, the default value of 0.5, proposed by Pauly (1980a) for Southeast Asian waters is used. Alternatively, the user can enter another value. The procedure is analogous for the escapement factor above \( (X_1) \), whose default value, based on Pauly (1980a,b) is also set at 0.5. The estimates of catch, mean catch per unit effort and biomass can be calculated for the survey area as a whole or stratified by depth.

FiRST (version 2004) also facilitates analyses through other statistical programs. The system enables the user to export data in the required format (see data formats under data access) for fish stock assessment software, notably the FAO-ICLARM Assessment Tools (FiSAT; Gayanilo et al., 1996), or ecosystem modeling tools such as Ecopath with Ecosim (Christensen and Walters, 2004, http://www.ecopath.org). Visualization of the geo-referenced data is possible through the mapping module (see Fig. 1). Currently, the module allows users to map station locations, species distribution and biomass by station. The maps can also display base maps of bathymetry and countries’ Exclusive Economic Zones.

2.4. Data access

Data access protocols in FiRST, established based on consultations with the national research partners, include: (1) restricted—only users with proper authorization (i.e., user level 2 and higher); (2) conditional accessible—data which are older than 5 years, unless otherwise indicated by the national database coordinator; and (3) fully accessible—data with no restrictions as to their distribution and use (Gayanilo et al., 2001). The trawl data contained in FiRST can be obtained from the country and permission must be secured with the particular country for data access of country-specific data (see Table 1 and http://www.worldfishcenter.org/trawl for contact details of the partners). Authorized users can export the data from the FiRST database in Microsoft Access (.mdb) format. The software also enables the user to export reports (or data summaries) in a variety of formats such as Crystal Reports 8 and Crystal Reports 7 (.rpt), Microsoft Excel (.xls), Microsoft Word (.doc), Rich text (.rtf), and Adobe Acrobat (.pdf). The data can be filtered by country, project(s), cruise(s), geographic limit, sampling dates, depth range or station(s).

2.5. Data contents and illustrative examples of the analysis results

Currently eight countries have established national databases (Table 1) mostly Microsoft Access-based and a regional database (in Microsoft SQL format) is maintained by the WorldFish Center. Currently, country custodians have
been designated (see Table 1) and they are responsible in updating their national databases. The updated national databases are then submitted to the WorldFish Center for updating the regional database and in some cases for data validation. The regional database, TrawlBase, contains data from 20,620 hauls, comprising 335,983 records from the partner countries and including published trawl data from Myanmar (Strømme et al., 1981), Pakistan (Yamanaka et al., 1977) and South China Sea (Senta et al., 1977; pers. comm. Tan Sen Min, SEAFDEC, Marine Fisheries Research Department, Singapore) (Table 1, Fig. 1). The data span the years from 1926 to 1995. The major fishing areas covered by ‘TrawlBase’ include: South China Sea (East Coast, Sabah and Sarawak, Malaysia: 1926–1995; Vietnam: 1979–1995); Gulf of Thailand: 1961–1996; Malacca Strait (West coast, Malaysia: 1926–1995); Java Sea (Indonesia: 1974–1979); Bay of Bengal (Bangladesh: 1980–1987; Myanmar: 1979–1980); Indian Ocean (India: 1994–1995; Pakistan: 1976); and several coastal areas within Philippine waters (1947–1995).

Based on analyses of compiled trawl survey data in ‘TrawlBase’ by researchers from national fisheries research institutions, there has been substantive degradation and over-fishing of coastal fish stocks in the areas covered by the studies (Table 3). The analyses indicate that catch rates, and hence resource biomass, have declined to an average of 22% of original (‘baseline’) biomass levels prior to development of trawl fisheries in the areas studied (see Abu Talib et al., 2003; Barut et al., 2003; Kongprom et al., 2003; Khan et al., 2003; Mustafa, 2003; Nurlahidin, 2003). The preliminary ecosystem models are a step towards examining the ecosystem level changes through time (Christensen et al., 2003). This type of information is useful for management, as it allows for designing or revising zonation schemes. We suggest that more analyses of this type should be performed in the future.

The outputs of the analyses facilitated through FiRST have been used for preliminary fish assemblage analyses and ecological modeling. The analyses of current assemblages show boundaries at about 50 and 100 m depth (Silvestre et al., 2003b; Alias, 2003; Campos, 2003; Khongchai et al., 2003; Mustafa, 2003; Nurlahidin, 2003). The preliminary ecosystem models are a step towards examining the ecosystem level changes through time (Christensen et al., 2003). This type of information is useful for management, as it allows for designing or revising zonation schemes. We suggest that more analyses of this type should be performed in the future.

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3. Future directions

Building on the gains from the regional collaborative effort the future development of FiRST is envisioned to:

(i) increase the power and utility of the FiRST for current and future partner countries;

Table 3

Illustrative examples of the declines in demersal fish density from scientific trawl surveys in Asian countries (adapted from Garces et al., 2001; Silvestre et al., 2003b)

<table>
<thead>
<tr>
<th>Country/Area</th>
<th>Year</th>
<th>Stock density (t km$^{-2}$)</th>
<th>Relative density (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippines</td>
<td>Various fishing areas 1947–49</td>
<td>7.88</td>
<td>100.0</td>
<td>Barut et al. (2003)</td>
</tr>
<tr>
<td></td>
<td>1993–95</td>
<td>1.39</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>Malaysia</td>
<td>West Coast</td>
<td>1971/72</td>
<td>2.31</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1997</td>
<td>0.36</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>East Coast</td>
<td>1972</td>
<td>5.09</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>0.20</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sarawak</td>
<td>1972</td>
<td>3.00</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>1.11</td>
<td>28.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sabah</td>
<td>1986</td>
<td>1.52</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>0.87</td>
<td>57.2</td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td>Gulf of Thailand</td>
<td>1961</td>
<td>0.70</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>1991</td>
<td>0.10</td>
<td>14.2</td>
<td></td>
</tr>
</tbody>
</table>

* Units in metric tons × 10$^6$. 

Garces, 2004). These trends in biomass have been incorporated in a report by the Asia-Pacific Fishery Commission to demonstrate the urgent need for action to address fisheries management in the region (see Sugiyama et al., 2004).

The data have also been used for preliminary fish assemblage analyses and ecological modeling. The analyses of current assemblages show boundaries at about 50 and 100 m depth (Silvestre et al., 2003b; Alias, 2003; Campos, 2003; Khongchai et al., 2003; Mustafa, 2003; Nurlahidin, 2003). The preliminary ecosystem models are a step towards examining the ecosystem level changes through time (Christensen et al., 2003). This type of information is useful for management, as it allows for designing or revising zonation schemes. We suggest that more analyses of this type should be performed in the future.

3. Future directions

Building on the gains from the regional collaborative effort the future development of FiRST is envisioned to:

(i) increase the power and utility of the FiRST for current and future partner countries;
(ii) expand the coverage of the database geographically, temporally and the range of anthropogenic impacts; 
(iii) examine key scientific questions at a range of management scales for input into management decision support; and 
(iv) increase awareness of available trawl survey data, and their utility for management, and facilitate greater shar-
ing and collaborative analyses.

3.1. Increasing the power and utility of the FiRST

Based on consultations with partners, it would be of value to increase the power and utility of the FiRST, par-
ticularly in terms of the storage of other resource survey types and linkages to statistical software. The trawl sur-
veys are valuable for documenting the state of demersal resources but for some countries other resources, such as pelagic fishes in India (Vivekanandan et al., 2003), are more important. It would therefore be useful to store research sur-
veys that sample these resources. This would also facilitate ecosystem-level analyses as information would be available on more parts of the ecosystem. Closer links with the key analytical software and decision support software should also be examined to increase access to this software for analyses.

3.2. Expanding geographic coverage of the database

To assist in understanding the response of fisheries resources and ecosystems to human impacts we will con-
tinue to expand the data coverage in terms of geography, time scales and range of human impacts. As shown in Table 1, there are still more than 20,000 stations/hauls that have not been encoded from the trawl survey inventory in the Asian region. Hence, there is a need to continue to input data and increase the number of partner countries. Inclu-
sion of northern Australian and Brunei data in 2003 will expand the range of levels of human impacts covered by the data.

3.3. Key scientific questions for retrospective analyses

Further development of FiRST will continue to assist partner countries in the analysis of the survey data and the ‘translation’ to management implications at a range of geo-
graphic scales. A key question for countries is the state of their resources. The analysis of trawl data has provided broad estimates of biomass declines in the various coun-
tries. However, management of specific fisheries may require sub-national level analyses, and analyses for particular tar-
get species groups. The data can also be used to examine changes in species composition through time, and to model past ecosystems (see for example Christensen, 1998; Juki-
Peladic et al., 2001).

The key research questions that could also be addressed include:

(i) the effects of fishing on stocks, assemblages and ecosystems, at a range of spatial and temporal scal-
es; 
(ii) the effects of previous management strategies on resources; 
(iii) testing of indicators of resource status—FiRST can pro-
vide a historical dataset that can be used to test indicators 
for fisheries and coastal systems.

3.4. Increasing awareness about the database

There is a need to continue to increase awareness regard-
ing the data, to facilitate their sharing, and to encourage collaboration within and between countries. We need to ensure that institutions within countries are aware of what has been collected historically, to maximize its use. This is particularly important for developing countries where resources are scarce. To increase awareness and to pre-
vent ‘shifting baselines’ (Pauly, 1995), summaries of the surveys and geographic locations are available on the web (http://www.worldfishcenter.org/trawl), along with the con-
tact details of the organizations who are responsible for the data.

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References


