Inventory of fisheries habitats and fisheries productivities

By J.M. Kapetsky with contributions from AWRD authors.

Introduction and objectives

Introduction

African inland fisheries represent an important contribution towards food security, income and employment in many African countries.

A major problem is the lack of information about many fisheries, resulting in fisheries that are not well managed. At the same time many fisheries may be threatened by degradation of the environment, loss of habitat and by overexploitation of fishery resources.

African inland fisheries are diverse in terms of species exploited, kinds of gears used, seasonality of fishing and variety of waterbodies exploited. Ultimately, in order to obtain the maximum benefits from the fishery resources, the fisheries have to be managed waterbody by waterbody, or by natural groups of waterbodies with similar ecological and use characteristics. Because of the threats to fisheries environments, fishery resources and fisheries have to be studied in an ecological context that uses watersheds as its framework. Thus, the first step in management is to inventory and characterize the waterbodies that support the fisheries. The second step is to characterize the watersheds in which the waterbodies reside in terms of natural features and human interventions.

This case study provides a broad inventory of African inland fishery habitats in terms of kinds, quantities and aggregate surface areas on a continental basis. Inland fisheries productivities by country are compared. Although this study is conducted from a continental perspective, the same approach could be used in developing an inland fisheries geographic information system at the country level, or even for sub-national areas.

Objectives

- Make an inventory of the kinds and quantities of fisheries habitats of African inland waters;
- Compare the fisheries productivities of African inland waters among countries.

Materials and methods

Data utilized

Africa-wide waterbody counts and surface areas are from a large number of sources in the Surface Waterbodies Database Component (SWB-DBC), described in detail in Section 2.2. Four primary sources are: World Conservation Monitoring Centre (WCMC); DCW VMap0Ed3; Vector Map Level 0 5th Edition (VMap0); and Geographic Name Server (GNS). Of these, the first three provide area estimates and counts of waterbodies while the last provides counts only.

The fish production data are from FAO FishStat Plus and are the average inland capture production by country for the period 2000–2004 (FAO, 2006).

This case study made use of tools available in the AWRD's Surface Waterbodies Module, Additional Tools and Customization Module, and the Statistical Analysis Module.

Results

a. Inventory of fisheries habitats

The goal is to identify the data sources that account for the most surface waterbody (SWB) area and SWB numbers in the greatest variety of habitats that are important for fisheries.

Another important aspect for inland fisheries is the inventory of waterbodies that can be identified by name and to which important fishery information can be attributed (e.g. limnology, fishery yield); however, this is the subject of the previous case study (i.e. surface waterbodies inventory).

Total fishery habitat area

The term "fishery habitat" is used loosely herein to include the kinds of waterbodies that can support fisheries, or that are otherwise important for growth, reproduction and movements of fishes.

Fisheries area and count compilations in three broad categories from each of the three data sources are summarized in Table 2.21.

TABLE 2.21
Counts and surface areas of surface waterbodies from three sources with non-fisheries habitats removed

Data set	WCMC		DCW		VMap0	
Type	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number
Perennial Waterbodies	24 438 894	369	30 215 995	4 901	29 949 754	5 123
Non-Perennial Waterbodies	19 384 505	61	27 795 242	11 185	28 262 230	11 427
Flood-Plain/ Wetlands	71 672 934	2 166	66 551 760	5 004	37 595 310	3 747
Pans	6 875 563	260	316 466	130	153 278	79
Totals	122 371 896	2 856	124 879 463	21 220	95 960 572	20 376

Note: AWRD authors have interpreted a pan as "a natural basin or depression in land" in which case they could be at least seasonal fish habitats. The great salt pan of N Africa in Egyptian territory has been stocked with mullets, so they can be fish habitats in that sense too.

Looking at total areas, the WCMC and DCW data sets are in fairly close agreement whereas the VMap0 compilation has considerably less. In total numbers of waterbodies, the DCW and VMap0 data sets account for many more than the WCMC set. Looking at areas by habitat type, the WCMC set has considerably more wetlands and less non-perennial waterbodies that the DCW set.

Based on this summary, the DCW data set appears to have the clear advantage. It accounts for the largest total area and it includes the largest number of waterbodies among the three sets.

Area of fishery habitats by habitat type

The SWB data sets have been designed to provide an inventory of each kind of fishery and non-fishery habitat, by surface area and by count, on a country-by-country basis or by sub-national administrative boundaries.

Which data set is most useful from a fisheries viewpoint? The WCMC set includes 15 classes of which six classes of non-fishery habitats and unidentified areas can be removed (Seasonal Salt Pan, Salt Pan, Alkaline/Saline Lake, Islands, MF Unknown, Unknown). In contrast, The DCW data set includes nine classes, but only four of them can be identified as potential fishery habitats. Thus, this data set is less useful from a fisheries habitat perspective (Table 2.22).

TABLE 2.22
Surface areas of WCMC inland fisheries habitats of Africa

Fisheries habitats	Surface area (Ha)
Fresh Water Marsh	71 672 934
Impoundment	3 264 723
Lagoon	659 741
Lake	21 164 588
Mangrove	5 971 310
Pools	9 583
Semi-Permanent Lake	61 081
Swamp Forest	19 323 424
Tidal Wetland/Estuary/Coastal	632 459
Grand Total	122 759 843

The nine remaining WCMC classes of fishery habitats total nearly 123 million ha Africa-wide of which the greatest bulk are fresh water marshes at nearly 72 million ha. In total, inland fisheries habitats account for about 4 percent of the surface of the African continent.

The WCMC data were used to estimate each kind of habitat at the national level as shown in Table 2.23, but disaggregation to the same habitat types at sub-national levels also is possible.

Although the collection of information on inland fisheries has to be based on an ecological-habitat approach, management authority is based on administrative boundaries that often do not correspond to fishery habitats. Thus, it is a handy feature that the AWRD Add-On tools include functions that allow users to identify the administrative units that intersect with datasets such as the WCMC data and the other three data sets. This makes possible an inventory that can characterize any fishery habitat, or group of habitats, according to its ecological setting (watershed) as well as its administrative authority.

Counts of fishery habitats

The GNS data set identifies waterbody types and locations only as points, so there are no corresponding data on surface areas. Nevertheless, it is useful to have counts on waterbodies that are also fishery habitats for all of Africa that can be compared to the surface areas from the WCMC, DCW and VMap data sets.

There are 65 types of hydrological features, with a total of 150 221 separate locations for all of Africa. Many of these hydrological features might serve as fishery habitats (Table 2.23).

TABLE 2.23
Counts of fishery habitats for the African continent from the GNS data set

Fisheries habitat	Count	Fisheries habitat	Count
stream	117 254	crater lake	83
lake	7 891	sea	83
water tank	3 483	anabranch	78
bay	2 744	ponds	74
pond	1 638	bight(s)	68
ravine(s)	1 533	lake channel(s)	54
tidal creek(s)	1 364	roadstead	51
wetland	1 265	section of wadi	46
reservoir(s)	1 122	lakes	41
pool(s)	1 095	navigation canal(s)	39
marsh(es)	1 064	tidal flat(s)	38
canal	1 061	navigation channel	32

reef(s)	959	irrigation canal	30
cove(s)	914	canalized stream	18
swamp	679	docking basin	17
shoal(s)	655	mangrove swamp	14
inlet	546	seaplane landing area	14
waterfall(s)	522	streams	13
distributary(-ies)	417	abandoned watercourse	11
rapids	407	irrigation system	10
drainage canal	405	stream bend	7
lagoon	397	fishing area	6
marine channel	384	salt marsh	6
channel	325	headwaters	5
gulf	200	reach	5
strait	163	section of waterfall(s)	5
section of stream	153	whirlpool	5
lake bed(s)	148	section of lagoon	3
mud flat(s)	131	confluence	2
section of lake	121	lagoons	2
harbor(s)	117	crater lakes	1
estuary	111	watercourse	1
stream mouth(s)	91	Grand Total	150 221

As with the WCMC, DCW and VMap0 data set, the GNS data can be disaggregated in order to provide country level counts by type.

b. Fisheries productivity of African inland waters

Comparative knowledge about fisheries productivities of inland waters is useful for management purposes. The perennial question for managers is "How much fish can be removed without jeopardizing the future productive capacity of the resources?", and often the only indication that is available is based on the observed fishery performances of similar waterbodies elsewhere. From such data, models have been built to predict fishery yields for those waterbodies for which there are no catch data. One example of the use of such a model constitutes another AWRD case study (i.e. Predicting Potential Fish Yield).

The objective here is to compare fisheries productivities across African inland waters on a country basis.

The data are of two kinds: surface area and fish production. The surface area data are the fishery habitat data that have been derived from the WCMC data set as explained above. An assumption going along with the use of these data is that all of the fishery habitats in each country are exploited. In fact, there are five countries (i.e. the People's Democratic Republic of Algeria, the Republic of Djibouti, Eritrea, the Socialist People's Libyan Arab Jamahiriya, and Western Sahara), that have substantial areas of fishery habitats; however, these countries did not report inland capture production in the period 2000–2004.

The fish production data are from FAO FishStat Plus and are the average inland capture production by country for the period 2000–2004. One of the handicaps of using these data is that the production is not actually monitored for all of the countries, but is estimated from various data sources. Oftentimes, even in countries where the catch is monitored, not all of the production is accounted for because of logistical difficulties. It can be assumed that, for most countries, the production reported to FAO underestimates the actual production.

There were 44 countries for which there were production data for the period 2000–20004. The production data were compared with the fishery habitat surface area

data (perennial and non-perennial waterbodies and wetlands). The results, fisheries productivities (kg/ha) by country, ranged from 0.1 kg/ha to 136.9 kg/ha, covering five orders of magnitude (Table 2.24).

TABLE 2.24
Inland fisheries productivities of African countries

Country	Fisheries habitat (ha)	Mean production 2000-2004 (tonnes)	Productivity kg/ha
Egypt	2 098 866	287 387	136.9
Liberia	34 235	4 000	116.8
Benin	295 786	28 919	97.8
Lesotho	584	37	62.7
Ghana	1 367 103	74 700	54.6
Burundi	255 938	13 081	51.1
Uganda	5 007 776	255 116	50.9
Kenya	3 057 628	147 442	48.2
Equatorial Guinea	22 161	1 015	45.8
Burkina Faso	190 082	8 700	45.8
Senegal	1 396 529	50 431	36.1
Togo	140 074	5 000	35.7
Zimbabwe	392 725	13 023	33.2
Sierra Leone	477 147	14 000	29.3
Rwanda	241 584	7 071	29.3
Côte d'Ivoire	492 789	14 366	29.2
Cameroon	1 963 813	56 500	28.8
Tanzania, United Rep. of	10 101 489	287 446	28.5
Madagascar	1 055 501	30 000	28.4
Nigeria	5 848 020	166 193	28.4
Swaziland	3 272	70	21.4
Mali	5 403 449	101 974	18.9
Congo, Dem. Rep. of the	11 372 397	212 000	18.6
Malawi	2 752 591	48 391	17.6
Central African Republic	1 177 094	15 000	12.7
Gabon	852 413	9 493	11.1
Gambia	229 030	2 500	10.9
Zambia	7 306 469	65 334	8.9
Guinea	509 044	4 000	7.9
Niger	4 424 929	33 587	7.6
Sudan	7 123 654	52 200	7.3
Ethiopia	2 204 793	12 518	5.7
Chad	15 225 194	75 640	5.0
Congo, Republic of	5 921 210	25 765	4.4
Angola	2 297 559	8 800	3.8
Morocco	477 682	1 577	3.3
Mozambique	4 676 338	11 792	2.5
Mauritania	2 128 409	5 000	2.3
Namibia	1 635 322	1 500	0.9
Tunisia	1 036 609	894	0.9
South Africa	1 338 576	900	0.7
Guinea-Bissau	375 563	150	0.4
Somalia	1 290 341	200	0.2
Botswana	3 639 024	141	0.0

It is doubtful that Egyptian waters could be so much more productive than others in Africa. Thus, there may be a problem with over-reporting production (e.g. including aquaculture production with capture production), or the fishery habitat surface area may be underestimated. Most of the water surface in the Arab Republic of Egypt is in Lake Nassar (reservoir) and that amounts to about 5 200 km^2 at maximum water levels. The total Egyptian SWB area accounted for in the WCMC is about 7 500 km^2. The highest production tabulated for Lake Nassar by Latif (1984) was about 53 kg/ha. Therefore, over-reporting of production is the most suspect source of the error. In contrast, the fisheries productivities of other countries seem small, but reasonable considering that unfished habitats may be included and that wetlands make up a large part of the fishery habitat surface area.

Fishery productivity and the environment

Two environmental variables that have an obvious relationship to the fishery productivity of inland waters are temperature (setting the rate of biological production) and precipitation (determining fishery habitat availability and nutrients through rainfall runoff). These relationships were tested first by plotting fishery productivity by country with each environmental variable. In the plot of productivity with temperature the Kingdom of Lesotho is an outlier with a much higher productivity than would be expected, 62.7 kg/ha, for its annual average temperature of 11.8 °C that is more than 5 degrees cooler than any other African country. In the plot of productivity with annual precipitation the Arab Republic of Egypt is an outlier. The Arab Republic of Egypt has the least amount of rainfall in the data set, but has a relatively high productivity of 136.9 kg/ha. One of Egypt's most important fisheries is Lake Nassar, which is a desert reservoir. Therefore, the Kingdom of Lesotho and the Arab Republic of Egypt data were removed and the data re-plotted. A correlation matrix was calculated among the variables and the resulting coefficients were 0.44 for annual precipitation on fishery productivity and 0.22 for mean temperature on fishery productivity. Multiple regression of precipitation and temperature on fishery productivity was highly significant ($p=0.007$) and independent variables together accounted for about 22 percent of the variation in fishery productivity.

Given the weakness of the fishery productivity data and the fact that the environmental variables pertain to the entire area of each country and not to SWB areas, the low correlations and low coefficient of multiple regression are understandable. However, this exercise does illustrate how environmental variables can be combined with fishery data to develop useful models.

Conclusions

This case study has used Africa wide data to illustrate how SWB area and count data can be used to inventory fishery habitats across Africa and to relate fishery habitats to fishery productivities and environmental variables. The main point is that fisheries can be managed only when the characteristics of fishery habitats are known. Although relatively coarse data (1: 1 million) were used, remotely sensed data can be employed to acquire data for national and sub-national inventories at finer resolutions and during wet and dry seasons. Such data can be imported and incorporated into AWRD.

The AWRD provides a solid framework for inland fisheries and environmental information in Africa. One of the next steps should be to find ways to assist countries to facilitate the organization of national level fisheries and environmental data collection, storage, and the manipulation and analysis of data within a version of AWRD specifically modified for that purpose for countries in Africa. In effect, AWRD has the potential to become a national level fisheries and aquaculture geographic information system.

Looking over a broader geographic area, a world wide data set of surface waterbodies comparable from country to country and continent to continent would greatly facilitate applied research on comparative inland fisheries. For this purpose the DCW data set could provide a starting framework given its global coverage and despite its few habitat types, but the WCMC could not because its scope is limited to Africa.

References

Latif, A.F.A.1984. Lake Nasser (Egypt). pp 193-246. *In*: Kapetsky, J.M. & Petr, T. (eds.). *Status of African reservoir fisheries*. CIFA Technical Paper. No. 10. FAO, Rome. 326 pp.

FAO. 2006. FISHSTAT PLUS [online]. Universal software for fishery statistical time series [Version 2.3]. Release date: March 2006. (available at http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp).

Predicting potential fish yield

Introduction and objectives

This case study discusses estimation and prediction of potential fish yield from standing surface waterbodies in Africa, demonstrating several potential methods based on the amount of historical catch data available and the morphological and topographic characteristics of those surface waterbodies. This case study also illustrates how estimates of potential fish yield for certain waterbodies can be obtained from reference sources or, when better data are not available, estimated directly using the potential fish yield prediction tools or the statistical analysis tools.

Materials and methods

The examples in this case study use surface waterbody data from the FAO Lakes and Rivers Database, the Water Resources in Africa shapefile "Wria_swb.shp" and the Source Book for the Inland Fishery Resources of Africa (SIFRA). One example utilizes the Water Resources in Africa watershed model "Faoawria.shp" to determine drainage basin boundaries.

This exercise makes use of tools available in the AWRD's Watersheds Module, Surface Waterbodies Module and Statistical Analysis Module, as well as data from the SIFRA Compendium references.

Results

a) Obtaining estimates of potential fish yield from reference sources

Many waterbodies in Africa have already had potential fish yield analyses conducted on them. The AWRD includes two sources of data that provide potential fish yield estimates for many of the major waterbodies in Africa, and it is possible that users of the AWRD may be able to find detailed information on a waterbody of interest directly in these sources.

The FAO Lakes and River Fisheries Database is a comprehensive database of temperate and tropical lakes and rivers around the world, compiled from research efforts conducted by FAO and MRAG Ltd. The database is included with the AWRD in Microsoft Access format (see file ZOCSRC.mdb, available in the "Docs" folder of the AWRD data archive. The history of this database, and definitions of the various datasets included within, are detailed in the Technical Database Specification Document for the FAO Lakes and River Fisheries Database (MRAG Ltd. 1997), available in the AWRD Documents folder.