The Ethiopian Fisheries and Aquatic Sciences Association (EFASA)

Proceedings of the 4th Annual Conference on
The role of aquatic resources for food security in Ethiopia

17-18 February 2012 at Heruy Hall
Ethiopian Institute of Agricultural Research (EIAR)
Addis Ababa

Chief Editors: Brook Lemma, Abebe Getahun and Seyoum Mengistou
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Proceedings of the 4th Annual Conference of EFASA on

The role of aquatic resources for food security in Ethiopia

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Heruy Hall, Ethiopian Institute of Agricultural Research (EIAR) Addis Ababa
Fourth annual conference of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA) on: The role of aquatic resources for food security in Ethiopia held at Heruy Hall of the Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, from 17-18 February 2012.

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Email: efasa.ethio@gmail.com

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Articles in these proceedings can be referred to as:

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The day-to-day activities of organizing the workshop was humbly undertaken by Abebe Getahun, Tadesse Fetahi, Elias Dadebo, Yared Tigabu, Ashagrie Gibtan, Akewak Geremew, Tsehaynesh Lemma, Adamneh Dagne, Zenebe Tadesse, Neway Andargie, Seyoum Mengistu, and Brook Lemma.

Brook Lemma (Professor)
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Dear Dr. Solomon Assefa, Director General of Ethiopian Institute of Agricultural Research  
Dear invited guests, EFASA members and conference participants  
Ladies and Gentlemen,  
On behalf of the executive Committee of the Ethiopian Fisheries and Aquatic Sciences Association (EFASA), I welcome you all to the Fourth Annual Conference of the Association.  

Born with hard labor in 2008, our association is now four years old, a child who can think, speak out, and walk on its two feet. I believe that it is quite exciting, and emotionally rewarding to watch the birth and growth of our professional child. It is, therefore, incumbent on all of us to watch, take care of this child and ensure its maturity. The extent and degree of our individual and collective commitment and effort to our profession and the contributions thereof would determine the survival and success of this child.  

One year has elapsed since we had our last meeting at Haramaya University. The last one year has been a successful and productive year, I believe, at least for a couple of reasons: First and foremost,
thanks God, we all have survived the last one year as there is no one member that was reported missing; so a very safe year. Secondly, it has been rewarding in our professional experiences and contributions. As far as I am aware various activities in the form of training, awareness creation, field days and validation workshops have taken place in the last one year, with the involvement of EFASA and/or its members. It is all indicative that members are striving to contribute their share to the development of their profession and tried to make their profession contribute to the welfare of the society. It is also indicative that there are enough spaces and unfilled niches for everyone to operate. Much more is expected from the association and its members in the coming years. The theme of this year’s conference is “the role of aquatic resources for food security in Ethiopia”. It is not intriguing as to why the Association picked this theme for this year’s annual conference. I hope that we all are aware that the region is suffering from food insufficiency for long and that it is being hit by recurrent drought and famine; the recent one being the 2011 disaster. We believe that the aquatic resources of the country and the region haven’t yet been fully explored and exploited and could contribute, if used to capacity and sustainably, to ameliorate this unfortunate situation. For example, Ethiopia has a great untapped potential of aquaculture which I believe is not looked at seriously by all concerned. We hope that there will come a time, quite soon, when this sector will no more be ignored or marginalized and will secure its legitimate place in Ethiopia. This can be achieved neither by dreams nor by good wishes. It requires collective and individual
efforts, hard work, and demonstrations to bring fisheries and aquaculture to the lime-light. The sector need and should attract farmers and investors to be genuinely engaged in productive and sustainable fisheries and aquaculture. The sector, thus, should be able to contribute, significantly, to the larger economy of the country. This, I strongly believe, would bring in the much sought-after and the long overdue recognition of the sector.

As you have noted from the program, the conference is for two days. The first day is dedicated to oral presentations including two plenary lectures. The second day is left for the association’s business and field excursion which the latter has been kindly organized by this year’s host institution, the Sebeta National Fisheries and Other Aquatic Resources Research Center. I believe that each one of us would contribute to make these deliberations and activities successful.

Finally, on behalf of EFASA I would like to acknowledge the contributions of the following institutions:

It is appropriate to start from the host institution, the Sebeta National Fisheries and Other Aquatic Resources Research Center, especially the organizing committee and its mother Institution, the Ethiopian Institute of Agriculture Research for organizing and hosting us and availing all the facilities including this wonderful hall. The Food and Agriculture Organization of the United Nations (FAO) has been supporting this Association through the years and this year’s great contribution is a continuation of that. In connection to this, we should not fail appreciating and applauding the great efforts of our member, Dr. Eshete Dejen, who made all that possible.
The Ministry of Science and Technology has been supportive financially in all our endeavors and we are very much grateful. Haramaya University has been our host in the last annual conference. It has also extended its support to sponsor this year’s event and we are thankful. Addis Ababa University, as usual, has shown its unwavering support to the Association by sponsoring all the conferences we had so far including this one; we are indebted. Executive Committee members of EFASA have devoted so much of their time and intellect to make this conference a reality and to make EFASA going. It would be injustice if I don’t mention the dedication, countless efforts through all these years, of the President of EFASA, Prof. Brook Lemma. Last but not least, I would like to thank all participants and invited guests for honoring our call and coming from near and far to share with us your findings and thoughts; you have made our conference very much colorful and we are grateful. Thank you and God bless Ethiopia and EFASA!!

May I now invite the President of EFASA to give a brief report on our activities in the last one year and then invite the Guest of honor to officially open the conference?

Dr. Abebe Getahun
Vice President of EFASA
17 February 2012
Opening speech

Dear EFASA Executive Committee members
Dear conference participants
Ladies and gentle men,

It is my great pleasure and honor to open the 4th Annual Conference of The Ethiopian Fisheries and Aquatic Sciences Association (EFASA). I am also delighted to welcome you all in this conference and thank you for giving us the chance to host this year’s conference. Association like EFASA brings pertinent problems into a platform to discuss the problem in depth among researchers, scientists, experts and development agents and forward possible solutions to decision makers. They also pick various resources and advertise their importance to the governing bodies.

The theme of this year’s EFASA conference “The role of aquatic resources for food security in Ethiopia’ is appropriate and timely. Intensive agriculture often leads to depletion of soil fertility and decline in yields. In Africa, if soil degradation continues with the present rate, the continent could be able to feed only 25% of its population by 2025. Aquatic resources are therefore, viable alternative means of livelihood for the people.

As you all know, Ethiopia is referred as water tower of Africa, although we fail to recognize and appreciate its potential for food security until recently. A variety of aquatic systems including permanent and seasonal, flowing and standing, natural and man-made water bodies are found in different agro-ecologies of the country. The standing water resources are currently increasing due
to construction of several reservoirs including the Hidase Dam. The government is using water resource as key component of food security program. Indeed, hydroelectric power generation has increased from year to year and the numbers of electrified rural areas have also increased considerably. Agriculture, which employs about 85% of the labor force, is the backbone of Ethiopia’s economy. Moreover, the numbers of farmers using irrigation practices have increased years after years resulting in change in lifestyle of the farmers.

The government is now targeting the water resources for one more additional purpose without affecting the existing hydroelectric power generation and irrigation: that is augmenting fisheries production. Fish food is highly nutritious, with relatively affordable cost and its demand in the country is increasing. The amount of imported fish has increased since the local fishery fails to satisfy the market. This also drains the limited hard currency that would otherwise be used for other development purposes.

The Ethiopian government has issued various enabling environment such as policies, rules and regulations to protect and sustainably use the water bodies. Despite the presence of conducive policies, Ethiopia has experienced a painful total loss of aquatic habitat as witnessed in Lake Alemaya. The death of Lake Alemaya was untimely and resulted from abuse and misuse of the lake water. Lake Alemaya was overused for drinking, washing, irrigation; fishing, recreation etc. It is a fresh memory that the community were suffering from shortage of water in the area. It is unfortunate that the aquatic biodiversity and its beautiful scenery have all gone
forever. The country can not any more afford to lose any other water body. In fact, more effort and commitment is required to increase the production of fishery from the natural as well as man made water bodies. Since the country’s demand cannot only be met from capture fishery, aquaculture or fish farming should contribute a lot in bridging the gap between demand and supply in the fishery sector. It also provides ample employment opportunity in the country. In China, for example, the average annual per capita income of people employed in the fisheries sector (including aquaculture) was about $540 in 1999, which was more than double the earnings obtained from rural agriculture. China, Indonesia and Vietnam have all benefited largely from aquaculture. Now, many developing nations including African countries are turning their attention towards aquaculture, with large government schemes and heavy investment. For example in Kenya, Fish Farming Enterprise and Productivity Program 2009-2012, funded with USD 67 million managed to construct over 47,000 fish ponds countrywide. Ethiopia is now joining the aquaculture sector predominantly through government scheme. Ethiopia has the water resources and favorable environment for fish farming. Moreover, the Ministry of Agriculture recently developed the aquaculture strategy document. Investors are also attracted in this sector such as the Trout Culture in Bale area; Ashraf in Bahir Dar area and Ethio-fishery in Chamo who have already started exporting their product. All stakeholders including researchers, investors and extension agents should work hand-in-hand to bring visible impact in the fishery sector. Ladies and gentlemen,
As many of you already know, research and technology transfer should come in the forefront for food security program. The Ethiopian Institute of Agricultural Research (EIAR) is responsible for the running Federal research centers such as the Sebeta National Fisheries and Other Aquatic Life Research Center (NFALRC), which is dedicated to promote the fishery and aquatic resources. Over the past decade, Sebeta NFALRC has shown considerable improvements in terms of human resource development, infrastructures facilities and dissemination of research out puts to the farmer, fishers and the private sector.

Ladies and gentlemen,

Water has tremendous functions to humankind including fish production, drinking water, recreation (tourism), irrigation, transportation etc. We have to use our aquatic resources in a sustainable and environmentally friendly way so that the resources can also be used by the next generation.

Finally, I wish you every success in your deliberations and a very pleasant stay in these two days’ conference. I declare that the 4th Annual Conference of EFASA is officially opened.

Thank you and God bless Ethiopia

Dr. Solomon Assefa
Director General
Ethiopian Institute of Agricultural Research (EIAR)
17 February 2012
Annual Report of EFASA

His Excellency Dr. Solomon Assefa, Director General of the Ethiopian Institute of Agricultural Research
Dear Ato Mesfin Dejene delegate of Dr. Getnet Assefa, Director of the Animal Science Research Directorate, EIAR
Dear invited guests
Conference participants
Ladies and gentlemen

On behalf of the Ethiopian Fisheries and Aquatic Sciences Association and myself I would like to welcome you all to this fourth annual conference of EFASA of 2012 organized under the theme of “the role of aquatic resources for food security in Ethiopia” held here at the conference hall of EIAR from today 17 – 18 February 2012.

This is one of those momentous days for EFASA and its members where we all witness with the progress of time that EFASA upholds its great achievements and endeavors to cover more new grounds of research and collaborations in the coming many returns of the years ahead.

Since EFASA’s last highly exciting conference at Haramaya University, which we all remember very vividly as if it were today, EFASA has achieved some milestones as I will briefly report to you now. Details of the report will surely come to you at the business session of the Association tomorrow.

1. EFASA has formalized the representation of the Executive Committee members who were elected at the Haramaya
conference last year. This has turned out to be quite a difficult task since collecting and compiling the credentials, signatures and recent identification cards of new members spread out to many places outside of Addis Ababa. As a result, the day-to-day activities of EFASA had to be done with the previous Executive Committee for about three or four months. For this, EFASA highly appreciates the cooperation of the outgoing officers.

2. EFASA has officially recognized the invaluable services provided by the outgoing Executive Committee members by providing them with acknowledgement letters. This Association is where it is today and we are able to gather here today because of the relentless efforts of those members who worked untiringly at those difficult times of getting EFASA stand on its own feet. It gives me a great honor to mention their names here as follows.

2.1. Dr. Tesfaye Woudineh from Fish-For-All
2.2. Dr. Zenebe Tadesse, from EIAR Sebeta Fisheries and Aquatic Life Research Center
2.3. Dr. Misikere Tessema from the Institute of Biodiversity
2.4. Dr. Eshete Dejen from the FAO Subregional Office for Eastern Africa
2.5. Wo. Eskedar Tariku from Oromia Region Zwai Fisheries and other Aquatic Life Research Center
2.6. Ato Aschalew Lakew from EIAR Sebeta Fisheries and Aquatic Life Research Center, and,
2.7. Ato Gashaw Tesfaye from the same EIAR Sebeta Fisheries and Aquatic Life Research Center
3. EFASA has successfully completed its obligatory task of compiling its 2003 Eth. C. financial audit report and submitted the same to the Federal Democratic Republic of Ethiopia Charities and Societies Agency. This has taken lots of precious time of the Executive Committee members, as it had to go through various stages starting from floating the bid on a national newspaper to select a legally authorized external auditor that is at the same time acceptable by the Charities and Societies Agency. This same exercise will continue immediately after the end of this conference to generate the 2004 Eth. C. audit report to be submitted before Sene 30 of 2004 Eth. C.

4. EFASA had applied to be registered as a legal taxpaying association and obtained its certificate with its Tax Identification Number (TIN). As a result, it has paid all its due taxes to the Ethiopian Government, meeting its national obligations and proving its commitments of supporting our government in its development efforts and proving that it is remaining as a legally abiding professional association.

5. EFASA has financially and technically supported two national conferences at Zwai and BahirDar, that that conducted conferences on the achievements gained so far in aquatic science research, community services that emerged out of the same and providing hands-on-training to technical personnel of various national institutes with the ultimate objectives of using aquatic resources sustainably. These efforts are parts of EFASA’s objectives and missions of assisting those efforts that are out there to add value to the expansion of scientific knowledge and technologies in the areas of fisheries and other aquatic sciences.
research. Both platforms have served their intended objectives of getting professionals of the field exchange their findings and design many more collaborative research activities together.

6. The platform at Zwai created the opportunity for EFASA to present its aquatic research outcomes to the most senior officials of Oromia Regional Administration so that knowledge gained over long periods of study at Haramaya and Zwai-Shala Basins could be used for policy development and concerted action for the sustainable management of aquatic resources in the region.

7. The second conference EFASA supported both financially and technically, as mentioned above, is the one conducted at Bahir Dar University to improve extension services in wetlands management, which was organized by both Bahir Dar and Addis Ababa Universities. This conference brought together technical personnel involved in supporting fishermen and aquaculturists from a number of regions and provided them with improved technologies that would help them in their daily field activities. At this conference besides EFASA’s financial assistance its prominent members, namely, Dr. Seyoum Mengistu, Dr. Tadesse Fetahi, PhD candidate Ato Ashagrie Gibtan and Ato Goraw Goshu from Bahir Dar University have actively participated at the conference on behalf of EFASA where they provided hands on trainings to participants. EFASA extends its acknowledgements to these members for their dedication to promote EFASA’s missions and objectives.

8. EFASA has successfully published its third conference proceedings and distributed copies to its members at this conference and made it available to worldwide use. This is
another effort EFASA is always making and is sure to continue in the future. It must be boldly stated that not many such professional associations in Ethiopia do that every year.

9. EFASA has untiringly worked to identify its fifth conference venue. The efforts done so far are those formal and informal discussions picked up with Mekele and Hawassa Universities. This issue will be discussed tomorrow at the business session of the Association so that all members and the Executive Committee of EFASA can continue to work on the preparations of the fifth conference by counting down the days starting tomorrow.

10. EFASA has now its temporary office on the Natural Science Campus of Addis Ababa University at Arat Kilo, which I believe is a very big step forward. This was only possible mainly due to the efforts of Dr. Seyoum Mengistu for whom EFASA extends its greatest appreciation. For those who may want to visit the office, the location is next to the Natural History Museum of AAU on Arat Kilo Campus. This has opened the opportunity for EFASA to employ Ato Asfaw Alemayehu, a long-time member of the Association on contract basis to organize this conference and set the documents of EFASA in order. It is my strong belief that you will find all the support you need in the gentle hands of Ato Asfaw Alemayehu.

All of the above achievements and those that are not mentioned here did come to pass without challenges. The burden of handling the above achievements in addition to their regular duties in teaching, research and community services in a setting where there
is no office and the helping hands of a secretary is a tremendous job. Daily routine activities such as preparing letters, giving them numbers, registering them, filing copies, delivering the originals to their destinations, handling financial matters, searching for sponsors, and many other related activities are not that easy tasks. I seize this opportunity to extend my greatest appreciation to the current Executive Committee members of EFASA, who have helped me a lot.

EFASA has faced some challenges which of course come with its development, increase in the number of its members, finding the appropriate technical and financial sponsors at the right time, and so on are some of the major ones. I do not have to bore our guests of honor, invited guests and fellow conference participants with the nitty-gritty of the routines of running professional associations. The details of these challenges make part of the business session of EFASA tomorrow.

Amidst of all the changes that are taking place in the world and in our country today, EFASA has still supporters and kind sponsors that believe in its activities. As Dr. Abebe Getahun, Vice President of EFASA has mentioned it before me I also acknowledge all the support EFASA obtained from these organizations, namely, the FAO Subregional Office for Eastern Africa, the Ministry of Science and Technology, the Ethiopian Institute of Agricultural Research, Haramaya and Addis Ababa Universities, and, above all, from the EIER and its Sebeta Fisheries research Center.
With these brief remarks, I once again extend my heartfelt appreciations to our guests of honor and conference participants for coming here today to share with us our most wonderful moments of knowledge and technology exchange. I always believe that even those that are not here with us today await the news of the conference and most of all the next issue of the proceedings of this conference.

Thank you for your kind attention!!!

Brook Lemma, Professor
President of EFASA
17 February 2012
Keynote speech

Your Excellency Dr. Solomon Assefa, guest of honour and Director General of the Ethiopian Institute of Agricultural Research
Dear EFASA Executive Committee members
Dear conference participants and
Ladies and gentlemen,
It really gives me great pleasure and honour for inviting me to give keynote speech on the occasion of the 4th annual conference of the Ethiopian Fisheries & Aquatic Science Association (EFASA) which is hosted by the National Fisheries & other Aquatic Life Research center, one of the Federal research centers of the Ethiopian Institute of Agricultural Research (EIAR).
As you all are aware, the fishery sector plays important role in providing quality and cheap animal protein for over a billion people globally. In 2008 FAO estimated that over 142 million tons of fish, with a value of 180 billion USD, have been harvested from both capture fishery and aquaculture. The fish production from natural marine and freshwater bodies appears to be constant over the past decade indicating the stagnation of the production from capture fishery. However, the contribution of the aquaculture to global fish production has grown rapidly over the past four decades with annual growth of about 8.8%. It remains a growing and vibrant production sector for high protein food.
On the other hand, the contribution of fish production varies considerably between nations and continent. Today, Asia mainly China is the leading fish producer followed by Latin America and
Europe. The share of Africa is comparatively low accounting for less than 5% of the aquaculture production. The situation is rather dire when we consider the situation in Sub Saharan African countries.

Ladies and Gentlemen,

Ethiopia is characterized by a diversified geographical and climatic condition. The country is endowed with huge water resources comprising of 6447 Km$^2$ of lakes, some 857 km$^2$ of reservoirs, 275km$^2$ small water bodies and over 7000 km long of rivers. In these water bodies there are over 180 species of fish of which some 40 species are reported to be endemic to Ethiopia. It is also estimated that some 50,000 tons of fish could be harvested annually. However, the current fish production from these water bodies is still below 20000 tons, which is less than 40% of the potential. The paradox is that most productive lakes such as Ziway, Hawassa & Chamo have shown a sign of over exploitation well beyond their potential stock. This is one area that researchers should focus and come up with results that enhance fish production.

On the other hand the fish eating habit of most Ethiopians is quite low. The per capita fish consumption is <300 grams per year. This is way below the average per capita consumption rate of 8 kg for Africans and 16 kg for the world. This shows that there is a huge production gap to be bridged in the future. The demand for fish especially in the cities has grown considerably in the past decade. If we extrapolate with the minimum consumption rate of one and 2 kg/year, the estimated demand for fish will rise to 80000 and 160000 tons/ year respectively. This indicates that we have to look for a means to produce fish other than harvest obtained from the

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natural production. This calls for the role of aquaculture production of fin fish and shell fish using technologies either adopted or generated by researchers and scholars in the sector. The dams constructed in the past few years including the Renaissance dam will create opportunity to boost fish production in Ethiopia. I am confident that EFASA members play important role for the realization of this dream into reality.

Ladies and gentlemen
All success stories and achievements obtained in Asia, South America in the fishery and aquaculture resulted from the integrated efforts of different stakeholders including research, extension and the private sector. In Ethiopia very recently the floriculture and horticulture have shown dramatic progress and entered the export market. Today they are one of the major export commodities and earned hard currencies to the country.

I believe that a similar approach could be followed especially in the aquaculture and bring blue revolution in Ethiopia. The diverse agro-ecology, availability of enormous ground and surface water, if coupled with the state of the art technologies, it is likely to boost fish production both for local market and export.

Ladies and gentlemen
I am optimist that the current environment in Ethiopia appears to be conducive to achieve our target. There are Federal and Regional Research centres as well as higher learning Institutes who are committed to generate technologies. The government have issued decrees that attract the private sector. The theme of the 4th EFASA conference 'The role of Aquatic resources for food security in
Ethiopia’s 4th EFASA was brought at the right time to bring all stakeholders together.
In the EIAR, fishery has been considered as one of the case teams of the Animal science research directorate. As a national coordinator of the fishery research, Sebeta NFALRC hosted this 4th EFASA and brought participants from research, Higher Learning Institutes, the Ministry of Agriculture, and farmers. The establishment of commodity based societies like EFASA is crucial in creating forums for dissemination of results to be used by the customers. Although EFASA is a young toddler, it has produced three volumes of proceedings so far indicating the strength of the society and commitment of the Executive committee and strong leadership.
I hope EFASA will create forums that will facilitate the transfer of full package technologies developed in fisheries and aquaculture to be used by the small scale farmers and the private sector. This will initiate the private sector to join the aquaculture business. I also inform you that the Animal science directorate of the EIAR is committed to provide all the necessary technical support for the success of the fishery sector.
Finally, I would like to express my best wishes for the success of the 4th EFASA conference. I also hope that all deliberations made in the conference will be problem solving and fruitful in tackling the bottlenecks of the fishery sector.
I thank you
Mesfin Dejene
Delegate of Dr. Getnet Assefa
Director of the Animal Science Research Directorate, EIAR
17 February 2012
Overview of Sebeta National Fishery and other Aquatic Life Research Center

Adamneh Dagne
Ethiopian Institute of Agricultural Research, National Fisheries and Other Aquatic Life Research Center, P.O.Box: 64, Sebeta, Ethiopia
E-mail: adamnehdet@gmail.com

1. Background
In the Ethiopian agricultural research system fisheries was recognized as one of the research commodities in 1997 with the establishment of the Ethiopian Agricultural Research Organization, (EARO) through decree (Proc. No. 79/1997). As indicated in article 6 of this code Sebeta Fish culture station was formally transferred to the agricultural research along with soil and forestry research. The fish station was then renamed as National Fisheries and Other Aquatic Life Research Center (NFALRC) and the center was nationally mandated to conduct support & coordinate research on fisheries and other living aquatic resources in the country. Over the past thirteen years, the center has undertaken enormous changes in terms of research coverage and out puts, development on human resources and research capacity, local and international collaboration, deliver and up scale of fishery and aquaculture technologies to the end users.
Sebeta National Fisheries and other Aquatic Life Research Center (the former Sebeta Fish Culture Station) was officially established in January 1977. The cost of construction for the center was supported by the Japanese Overseas cooperation (JICA). Under the Ministry of Agriculture, the center has been administered as a unit of the Department of Livestock and Fisheries for over two decades until it was transferred to the then EARO. The center was engaged in different activities including rearing and stocking of fish into natural and artificial water bodies; provide training to stakeholders and undertake experiments on fish culture. The center has had a long vision “fish for all” aiming at enhancing the fish production in the country.

1.1. Vision
To see the center as one of the best fisheries and aquaculture institute in Eastern Africa.

1.2. Mission
To import and adapt and also generate technologies and scientific information that can sustainably utilize the country's fishery resource and improve production and productivity of fish through aquaculture and increase the contribution of the sector towards achieving food security and improving the economy.

1.3. Objectives
1.3.1. Adapt and generate technologies and scientific information on capture fisheries, limnology and aquaculture.
1.3.2. Coordinate and support research on fish and other aquatic organisms in Ethiopian water bodies.
1.3.3. Establish and strengthen collaborative research with local and international stakeholders.

1.3.4. Provide technical support and training to governmental and non-governmental organizations and private sectors to improve fisheries research and development.

1.3.5. Rearing of fingerlings to stock into natural and man-made water bodies.

2. Center Profile

National Fisheries and other Aquatic Life Research Center (NFALRC) is located in the town of Sebeta, Oromiya Regional State at about 23 kms south west of the capital, Addis Ababa. The center is situated at the edge of the Ethiopian Rift Valley (9° N, 39° E) at an elevation of 2200 m a.s.l and covers a total area of about 16 ha. The center is characterized by a moderately warm climate with annual mean temperature of 21°C and precipitation of 400 mm.

2.1. Infrastructure and research facilities

The center is equipped with basic infrastructures including office blocks, research ponds, borehole water and storage tanks, and communication network.

Very recently three more blocks that included rooms for laboratory, offices, stores and staff lounge were built in the center. Moreover, the construction of 9 earthen ponds each with 250 m² was recently completed through capital budget allocated by the government to upgrade the center.

2.2 Human resource development
The center has shown a dramatic improvement in terms of human resource development over the past thirteen years. When the center was transferred to the then EARO in 1997, there were only 12 staff of which 3 were technical staff. Today there are over 68 full timer research and support staff engaged in research and management (Table 1). Many research staff are trained mainly abroad and secured their MSc and PhD in fishery, limnology and aquaculture from the universities in Austria, Netherlands, Germany and Thailand. Currently there are 4 research staff on study leave abroad for their MsC & PhD. One researcher attends his Msc at Haramaya University. Moreover, one senior staff conducted his post-doctoral research at the University of Washington, Seattle, USA through the Fulbright Senior research program.

**Table 1: Profile of the research and support staff (Note: Numbers in brackets indicate staff on study leave, (4 PhDs & 2 MScs) (NFALRC, 2012)**

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<th>Staff</th>
<th>Ph D</th>
<th>MSc/DV</th>
<th>BS</th>
<th>Diplomas</th>
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<td>Researcher</td>
<td>4</td>
<td>9 (3)</td>
<td>7</td>
<td>2</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Technical Assistant</td>
<td>-</td>
<td>-</td>
<td></td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Support staff</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>10</td>
<td>32</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>9 (3)</td>
<td>11</td>
<td>12</td>
<td>32</td>
<td>68</td>
</tr>
</tbody>
</table>

EFASA's 2012 4th Annual Conference
3. Research highlights
In the past thirteen years, NFALRC has been striving rigorously to implement and achieve the national goal set on fisheries, limnology and aquaculture research. With the view of maximizing its efficiency on delivery of research technologies, the EIAR has undertaken transformations in its research approach from survey, exponent and trial (SET) to research themes and finally to research project. Following the recent civil service reform and Business Process Reengineering (BPR) program, the fishery research has been categorized as one of the case teams of the Animal Science Research Process. The fishery case team has developed eight mega projects, which are then sub-divided into components and research activities.

4. Research out puts
There is a shift from technology generation more to adaptation, from basic research to applied/development, from single SETs to full packaged project, from individual researcher to case team and from a single discipline to multidisciplinary approaches. The center has delivered several research outputs and the major ones are:

4.1. Documented the biodiversity of Ethiopian fish fauna (>180 fish species) in major lakes and river basins of the country in collaboration with JERBE (Golubstov and Mina, 2003).

4.2. Adaptation of aquaculture technologies:
4.2.1. Introduced pond fish farming & cage culture technologies to farmers in north and west Showa.
4.2.2. Proved that manual sexing of male tilapia (monosex) resulted in doubling the production of fish in Sebeta ponds.

4.2.3. Developed different fish feed package from locally available sources (Sebeta 1-4, NFALRC-Sebeta).

4.3. Produced scientific information on fish post-harvest and gear technology in different water bodies.

4.4. Documented & published several scientific articles on fisheries, aquaculture, and aquatic lives on different scientific media.

4.4.1. Published over 15 scientific articles in reputable international Journals.

4.4.2. Published over 20 scientific articles in peer reviewed local journals.

4.4.3. Compiled aquaculture book in Amharic.

4.4.4. Published over 28 scientific papers on different local and international proceedings.

4.4.5. Produced 9 MSc and 4 PhD theses.

5. Community Services and Training

Along with research, the center also provides different services to the community; some of which are listed below.

5.1. Stocking of water bodies

Since its establishment, the center has been involved in rearing fish mainly forstocking water bodies. Fish fingerlings were also stocked to small water bodies (SWB) to enhance fish production and provide fish for local communities. A number of natural and man made small water bodies have been stocked with different fish species. Through this activity,
the stocking of Tilapia fingerlings into Lakes small Abaya, Haiq and Hashenge as well as many micro dams in Tigray could be mentioned as success stories and achievements of the center in enhancing fish production. Currently, the center propagates and maintains some five different exotic and indigenous fish species in ponds mainly for research. However the ornamental gold fish is propagated only for market.

5.2. Training & consultancy service
The center has been actively engaged in providing training and consultancy services to various stakeholders including farmers, extension workers and the private sector. A series of on station and field trainings have been given to Farmers, development agents, High school and University students.

5.3. Teaching and supervision
Graduate programs on fisheries and aquatic sciences are given in several universities including Addis Ababa, Hawassa, Mekele, Bahir Dar and Ambo Universities. Senior researchers of the center have been offering courses for students on block. Graduate students regularly visit our center and obtain field training in the center. In addition, researchers are also involved in supervising and offering courses in different universities.

6. Collaboration with local & international stakeholders
The center has been cooperating with various local and international stakeholders in various activities such as up scaling and dispatching of research; teaching and extension services to the end users.
The national stakeholders include
- Ministry of agriculture & Rural development
- Regional Agricultural Research Institutes
- Regional Bureau of Agriculture
- Higher Learning Institutes
- Non governmental organizations
- Farmers
- Private sector

The international stakeholders include
- Russian Academy of science
- Austrian Academy of science
- Boku University (IPGL), Austria
- UNESCO-IHE- The Netherlands.
- Uppsala University, Sweden.
- Moi University, Kenya.
- University of Washington, Seattle, USA.

7. Challenges of the fishery sector
Although Ethiopia is endowed with resources (land, water & fish species), the contribution of the fishery sector to the country’s GDP is still minimal. Several factors can be mentioned of which the following are important ones.
7.1. Lack of recognition (fishery was and is still under livestock)
7.2. Absence of universities dealing fisheries and aquaculture (till recently) & hence lack of trained personnel.
7.3. Poor coordination among stakeholders
7.4. Poor enforcement of decrees
7.5. High turnover of the fishery staffs into other sectors
7.6. Weak extension services and linkage

Despite the challenges of the sector there are also good opportunities which can be used for the development of the fishery production and utilization in general. Some of these are: government policies and development strategies (irrigation, hydropower development etc...), suitable agro-ecologies, water bodies (surface & ground), diversity of fish species, higher learning institutions dealing on fisheries and aquaculture (e.g. Addis Ababa, Bahir Dar, Ambo and Hawassa universities) and increasing public awareness.

8. Future directions

The fishery sector in general and aquaculture in particular should be considered as a source of livelihood and a sector which can contribute to economic growth and poverty reduction. To exploit such merits of aquaculture more focus should be given on:

8.1. Scaling up of aquaculture technologies to the rural farmer.
8.2. Hatchery seed production of common carp and catfish.
8.3. Enhancement of small water bodies
8.4. Strain selection of Orechromis niloticus suitable for aquaculture.
8.5. Develop fish feed from locally available sources.
References


1. Introduction

1.1. Background

Ethiopia is a land-locked country which has approximately 7400 Km$^2$ surface area of water body and 7185 Km long river network. However, fish production from these water bodies even used to their full potential couldn’t satisfy the increasing fish demand (MoARD, 2003). The government of Ethiopia has proposed aquaculture as an option to boost fish production and as an alternative means to food security and poverty alleviation. Aquaculture is a practice of farming fresh water and salt water organisms including mollusks, crustaceans and aquatic plants in a controlled environment. In Ethiopia it dates back to 1955, when ponds were constructed around Bishoftu and Akaki for growth observation (FAOSFE, 2009). It has generally been conducted at small-scale mainly focusing on Tilapia (Nile Tilapia and Red Belly tilapia).

Nile Tilapia (*Oreochromis niloticus*) is a tropical species which is a predominantly cultured species worldwide. It was introduced to developing countries and cultured on a subsistence level to meet local protein needs. In Ethiopia, the species contributed more than 60% of the annual total fish landing and it is the most preferred variety. Nile Tilapia pond culture or aquaculture in general in Ethiopia is at the very low level of development due to lack of extension support and
training, shortage of expertise at a local level, lack of fingerlings, little research and institutional capacity, etc. Currently, however, the practice is attracting private investors and farmers and there is a demand from government and investors side to be involved in the sector. According to our assessment, so far, there was no organized effort made at national level to differentiate suitable zones for production of Nile Tilapia in artificial ponds. FAO has undertaken a strategic assessment of warm water fish farming potential in Africa for two species (*O. niloticus* and *Clarias gariepinus*) in which Ethiopia is part of the study (Kaptesky, 1994).

Geographic information system aided with experts’ decision making system lends itself well to analyzing and mapping aquaculture potential or suitability based on a variety of factors (Barth *et al.*, 2008). Different factors affect the overall suitability of a given area for pond production of Nile tilapia. They range from biophysical and socioeconomic factors to biology of the species.

In this study major factors that affect pond production of Nile tilapia were identified and analyzed at national level to derive areas which are promising for the practice. The analysis was done based on two scenarios. The first scenario referred to production of the species for subsistence and the second scenario incorporated some economic factors for commercialization purpose.
1.2. Study area

Ethiopia is located in the horn of Africa covering 112 million hectare of land being the 27th largest country in the world. According to population census commission of federal democratic republic of Ethiopia (2008), the total population of the country in 2007 was 73,918,505 with almost 1:1 male to female ratio. Eighty five percent population increases was recorded within the past 23 years from 2007 attributing to fast population growth in the past two decades. The country implements agriculture led industrialization strategy which was initiated in 1994. Agriculture is the back bone of the economy and it contributes about 50% to the total GDP. Fishery contributes very small percent to the GDP as compared to other agriculture sectors. Smallholder farming persisted for centuries and 85% of the population is dependent on rain fed agriculture. Large amount of land is identified as suitable for irrigation; however, currently very small area is reported to be under development.

Different topographies exist in Ethiopia. The highlands (above 1500m.a.s.l.) comprise of mountain belts, valleys, gorges and plateaus. The greatest East African rift valley crosses through the highlands of Ethiopia and extends up to Mozambique. Most of the major lakes of the country are concentrated in the rift valley. The lowlands cover eastern, southern, north eastern and south eastern part of the country. Plain topography dominates in the lowlands. Ras Dashen and
Denakil depression are thepeakand the lowest points with 4,543 m.a.s.l. and 110 m.b.s.l. respectively.

Diverse climatic conditions prevail in Ethiopia. It ranges from humid tropic to dry arid climate. In general rainfall in Ethiopia is correlated with altitude and characterized by varying spatial and temporal distribution. The average annual rainfall for the country is about 448 mm. However, it ranges from 2200 mm in the western highlands to less than 100 mm in the north-eastern and south eastern lowlands. The highlands are characterized by high annual rainfall and low average temperature. Whereas, the lowlands receive low annual rainfall and high average temperature. Unlike most of the tropics where two seasons are common (one wet season and one dry season), three seasons are known in Ethiopia, namely Bega (dry season) which extends from October-January, Belg (short rain season) which extends from (February-May), and Kiremt (long rain season) which extends from June-September (NMA, 2009).

2. Methods
2.1. Data Identification, Collection and preparation
Critical factors and parameters which affect pond production of Nile Tilapia were identified at the first step. Then spatial data which represent each parameter were selected from FAO-SFE geodatabase and other pertinent data sources. Relatively good quality data which provided detailed and up-to-date information were collected. All the data acquired were
extracted to common extent (boundary of Ethiopia) and maintained to the same projection system in order to make them ready for GIS analysis.

2.2. Data Analysis
Ten essential parameters which were categorized under five major factors were analyzed. The level of suitability of each parameter and thresholds were decided based on experts' decision, previous studies and biology of Nile tilapia.

2.2.1. Water Availability
In order to determine sufficient presence of water in ponds throughout production period, readily available sources of water were identified. Rain water harvesting, perennial rivers, nearby water bodies and underground water were selected as potential water sources. However, due to absence of consistent and comprehensive spatial data which shows status of ground water potential at national level and due to lack of estimation on economic cost needed to extract underground water to the surface, annual rainfall, perennial rivers and lakes were considered as main sources of water in the analysis.

The amount of annual rainfall and its periodic pattern is important to determine how long ponds will stay full. Besides, a mechanism should be designed to compensate the amount of water that will be lost
through infiltration and evaporation. As temperature rises up, evaporation from ponds increases. This process significantly reduces the amount of water in ponds which in turn leads to overstocking. Nearby water sources like perennial streams and lakes can be utilized during dry season to compensate the loss. However, available capital to transport water and/or to install pipelines and production return limits use of these sources especially in the case of subsistence production.

Studying the relationship between fish density in farmponds by district with annual rainfall in the same districts of four African countries (Kenya, Zimbabwe, Ghana and Zambia) and by considering the situation in other places (Kapetsky 1994) can be interpreted as the amount of annual rainfall in terms of pond storage potential. The full methodology can be accessed from FAO corporate document repository. According to the study, most farms are found in districts which receive more than 1,000 mm annual rainfall. The effect of annual rainfall on pond fish farming potential was interpreted in the following way as shown in table 1.
Table 1: Interpretation of annual rainfall (Kaptesky, 1994)

<table>
<thead>
<tr>
<th>Annual Rainfall (mm)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1,199</td>
<td>Ample</td>
</tr>
<tr>
<td>1,000-1,999</td>
<td>Sufficient with little or no special engineering</td>
</tr>
<tr>
<td>700-999</td>
<td>Sufficient with cost adding modification such as large watersheds, deeper ponds</td>
</tr>
<tr>
<td>&lt;700</td>
<td>Insufficient unless ground water is ample</td>
</tr>
</tbody>
</table>

The optimum distance of fish farm ponds from water bodies (perennial rivers and lakes) is not investigated. In most parts of Ethiopia where irrigation is practiced farmers use traditional river diversion systems which mostly have more than one kilometer distance. However, characteristics of the terrain and discharge rate determine how far both local and modern schemes can travel. In this study distance of ponds from water bodies were classified based on experts’ opinion. The same distance range was set for subsistence and commercial production. The following four distance ranges shown on table 2 were used to classify the location of ponds in reference to water bodies.

Table 2: Distance range from perennial water body

<table>
<thead>
<tr>
<th>Distance from water bodies (river and lake) in Km</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1</td>
<td>Very near</td>
</tr>
<tr>
<td>1-2.5</td>
<td>Average</td>
</tr>
<tr>
<td>2.5-3.5</td>
<td>far</td>
</tr>
<tr>
<td>&gt;3.5</td>
<td>Too far</td>
</tr>
</tbody>
</table>
Annual rainfall data was obtained from the global climate data. The data layer was generated through interpolation of average monthly climate data collected from weather stations from a large number of global, regional, national and local sources mostly from the 1950-2000 period. It has 30 arc-second (<1Km$^2$) resolution grid which is assumed to capture environmental variability that can be partly lost at lower resolutions. The full method is described in Hijmans et al. (2005). Perennial rivers and lakes were obtained in shape file and distance from them was computed for the whole extent of the study area using ArcGIS 9.3.1 (ESRI ArcMap 9.3.1 ™) spatial analyst tool. Annual rainfall layer and computed distances were classified based on the interpretations given on table 1 and table 2 above respectively. Based on experts’ opinion a weight was given to each parameter to determine the overall availability of water. Accordingly, annual rainfall weighted 80% and distance from lake and distance from perennial rivers equally shared the remaining weight. Table 3 comprehends the level of water availability based on above mentioned interpretations.
Table 3: Interpretation of water availability

<table>
<thead>
<tr>
<th>Scale</th>
<th>Status</th>
<th>Annual Rainfall (mm)</th>
<th>Distance from perennial river (Km)</th>
<th>Distance from lake (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Highly available</td>
<td>&gt;1,199</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>3</td>
<td>Moderately available</td>
<td>1,000-1,999</td>
<td>1-2.5</td>
<td>1-2.5</td>
</tr>
<tr>
<td>2</td>
<td>Marginally available</td>
<td>700-999</td>
<td>2.5-3.5</td>
<td>2.5-3.5</td>
</tr>
<tr>
<td>1</td>
<td>unavailable</td>
<td>&lt;700</td>
<td>&gt;3.5</td>
<td>&gt;3.5</td>
</tr>
<tr>
<td></td>
<td>Weight</td>
<td>80%</td>
<td>10%</td>
<td>10%</td>
</tr>
</tbody>
</table>

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2.2.2. Water Temperature

Water temperature strongly influences the composition of aquatic communities, and is probably the most commonly recorded habitat attribute (Gallagher, 1999). Different fish species survive in a different temperature ranges.

Fig. 1: Water availability based on interpretation given on table 3.
months and areas which maintain water between 12 °C and 24 °C for consecutive six months were classified as moderately suitable. Areas which have temperature that allows pond water to stay between 12 °C and 24 °C for consecutive five months but not more than five months were classified as marginally suitable. The remaining area was classified as unsuitable. The highest converted mean monthly water temperature (39 °C) was obtained in the months of June and July in the Dalol depression and the lowest (-2 °C) was obtained in the Sanete plateau. Figure 3 portrays the overall classification result.

Fig. 3: Water temperature suitability classes.
2.2.3. Engineering Suitability

Construction of medium to large size ponds should put different factors into consideration. Apart from structural requirement which was not focus of this study, topography and soil texture play central role. These two parameters were used to determine relative suitability of the area for pond construction.

The most detailed ever released 30m GDEM (Global Digital Elevation Model) derived from ASTER (Advanced Space-born Thermal Emission and Refraction) satellite stereo bands was obtained from Japan Earth Remote Sensing Data Analysis Center (ERDSAC) (http://www.gdem.aster.ersdac.or.jp/search.jsp) and used to derive slope classes. Soil texture data was obtained from the Harmonized Global Soil Resource Database developed by ISRIC and FAO (Van Engelen et al., 2005). This database provides information on proportion of sand, silt and clay by weight in percent.

Sites with adequate slope which allows easy drainage, reduce construction cost and that are not subjected to high flooding risk are preferable for pond construction. The 30m GDEM data was assumed to capture any elevation difference between two 30m by 30m or 900m² cells and found to be suitable for this study. Slope generated from this data was classified into four classes. Sites which have 0-5% slope irrespective of their size and
length were classified as very suitable for pond construction. Whereas, sites having 5-8% slope were considered as moderately suitable and sites which have 8-15% slope angle as marginally suitable. Greater than 15% slope was taken too steeply for pond construction. Soils used to construct ponds must contain sufficient clay to hold water (Davis, 1990). Only coarse textured soils are not suitable for ponds. The percentage of mass of silt and clay was summed to determine the presence of fine textured soil in each soil unit. It was assumed that soil units which have greater than 75% fine particle by weight are very suitable. Whereas, soil units which contain fine particles between 50-75% by weight were considered as moderately suitable.
2.2.4. Economic Suitability

Before emerging to production it is necessary to assess demand and market facility for Tilapia and availability of production input both at local and regional level especially in case of commercialization. In this study economic suitability is considered only in the commercial sector. Due to unavailability of economic data at local...
level that shows demand, supply, and future consumption rate of Nile Tilapia, existing markets (both specialized and non specialized), presence of access roads and population density were analyzed to evaluate economic reliability. The underlying assumption was where there is high population and fairly distributed road network, costs associated with preservation, transportation and marketing are relatively low.

Road network data obtained from Rural Economy Knowledge Support System (REKSS) CD 1(IFPRI and EDRI, 2007) was processed and all weather roads (both asphalt and gravel) and dry weather roads were extracted. Direct distance from the closest road network was computed for the whole of the study area. This distance didn’t consider any cost associated with terrain, slope and any other natural or artificial barrier which impedes human movement and transportation. Using the distance information the study area was classified in to four suitability classes. Assigning these classes was subjected to experts’ interpretation. Table 4 shows distance interpretation. Data on geographic distribution of available market centers was also obtained from the same source. It was processed in the same way as distance from roads was processed. Suitability classes based on distance from market centers were assigned as indicated on Table 4.
Table 4: Interpretation of economic suitability

<table>
<thead>
<tr>
<th>Scale</th>
<th>Status</th>
<th>Distance from Road (Km)</th>
<th>Distance from market center (Km)</th>
<th>Population Density (per Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Highly suitable</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&gt;25</td>
</tr>
<tr>
<td>3</td>
<td>Moderately suitable</td>
<td>5-10</td>
<td>5-10</td>
<td>5-25</td>
</tr>
<tr>
<td>2</td>
<td>Marginally suitable</td>
<td>10-15</td>
<td>10-15</td>
<td>3-5</td>
</tr>
<tr>
<td>1</td>
<td>unsuitable</td>
<td>&gt;15</td>
<td>&gt;15</td>
<td>&lt;3</td>
</tr>
<tr>
<td></td>
<td>Weight</td>
<td>25%</td>
<td>35%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Population density is used as an indication for availability of man power, presence of alternative market options, and fish demand. Kaptesky, 1994 examined the relation between population density and the occurrence of fish farming in 123 districts found in four Africa countries (Ghana, southwestern Kenya, Zambia and Zimbabwe). It indicated that most fish farms are found in districts that range from 5 to 25 individuals per square kilometer. There is also another mode corresponding to districts with a prevailing population density of from 100 to 250 persons per square kilometer. Based on this information population was interpreted as shown on table 4. Higher weight was given to population due to the assumption
that where there is high population high probability of road and market development is likely.

2.2.5. Land Cover

Land cover simply refers to what actually exists on the ground. Areas which have high relative ecological and economic significance should not be assigned for aquaculture. Thus, classification of the study area into different suitability classes based on land cover was found necessary. The woody biomass inventory and strategic planning project land cover classes (MOA, 2004) derived from landsat satellite images were categorized into four suitability classes based on experts’ input. In the highlands where land is very scarce and expensive farmers may not allocate agricultural land for aquaculture. Thus, dense agricultural lands were assigned as marginally suitable. Whereas, woodlands, shrublands and grasslands were categorized as highly suitable. Areas covered with large natural forest were categorized as unsuitable due to their high ecological significance.
2.3. Model Scenarios
Two production scenarios were considered in order to understand where subsistence and commercial production is possible. In the first scenario it was assumed that no high economic return is expected beyond supplementing household food requirement from production. In this case only biophysical factors were analyzed. In the second scenario some economic parameters were introduced assuming that production involves commercialization and high economic return.

2.4. Factor weighting
Weight was given to each factor based on cost associated with manipulating or altering the factors, comparing their relative importance and putting mode of production in to consideration. Accordingly, water availability and water temperature received highest weights respectively. Although altering the ambient temperature requires high technological intervention, presence of water is most important because water is not readily available anywhere but temperature exists everywhere in a given range. Figure 6 shows the weights given to each factor and how the models were developed for subsistence and commercial mode of production.

Fig. 6: Schematic design of the model
3. Result and Discussion

3.1. Suitability classes
Two maps showing aquaculture suitability for subsistence and commercial production of Nile Tilapia were developed with four suitability ranges. The suitability ranges were interpreted in terms of the level of technological intervention and additional input requirement. Highly suitable areas need relatively low external input and technological intermediation. In moderately suitable zones identification of the main limiting factors is crucial step in order to determine remedial measures. Investment in these zones involves high remedial cost and intensive technological intervention. In marginally suitable zones, where most of the factors are limiting, investment tends to be highly risky in terms of feasibility and production success. Its success depends on introduction of very high technological input. In marginally suitable zones pond production of Nile Tilapia both for subsistence and commercial purpose is not likely due to the highly limiting nature of biophysical and socioeconomic factors prevailing in the area.

3.2. Model outcomes
Figs. 7a and b show the final outcome of factor weighting for subsistence mode of production and commercial mode of production of Nile Tilapia respectively. According to this study about 3.95% (4,427,169 ha), 43.98% (49,203,905ha), 52.02% (58,204,377ha) and 0.036% (40,261ha) of the total terrestrial
part of the country was found to be highly suitable, moderately suitable, marginally suitable and unsuitable respectively for subsistence mode of production of Nile Tilapia. Whereas, about 1.4% (1,573,971ha), 55.49% (62,027,109ha), 43.1% (48,184,263ha), and 0.011% (12,593ha) of the total terrestrial part of the country was found to be highly suitable, moderately suitable, marginally suitable and unsuitable respectively for commercial mode of production of Nile Tilapia. Under both scenarios very small part of the country was categorized as unsuitable and most part of southern, eastern, north eastern and northern part of the country were fell under marginally suitable category mostly due to water scarcity. The western, north western, south western and some central parts of the country were categorized as moderately suitable. The modeling of the first scenario resulted in a few continuous highly suitable zones in Gambela and Benishangul Gumuz region. Distributed patches of highly suitable lands for commercial mode of production were observed in western and north western parts of the country.
Figs. 7(a): Suitability for subsistence production of Nile Tilapia and (b) Suitability for commercial production of Nile Tilapia
Areal coverage of highly suitable zones is decreased by 35.6% for commercial mode of Nile Tilapia production as compared to the subsistence production. This implies that some biophysically suitable areas have less developed infrastructure and/or have low population density which affected their commercial suitability. Commercialization in these areas will face high economic cost associated with access, transportation and marketing. The moderately suitable class was larger in commercial mode of production than subsistence mode. Conversion of large part of highly suitable classes under subsistence mode of production to moderately suitable category under commercial mode increased the areal coverage of moderately suitable class in the commercial mode. Strangely large parts of south eastern and eastern edges of Somali region were categorized as moderately suitable especially for subsistence mode of production. Such unexpected result enforces further scrutinizing and fine-tuning of factors and weights given for each factor. Actually these areas were categorized as highly to moderately suitable zones in terms of water temperature, engineering suitability, and land cover. However, water is rarely available. Thus, practicing aquaculture in these areas is not feasible unless ground water or other sources of water are utilized. Impact of low population density and less developed infrastructure in these areas was reflected in the outcome of commercial mode of production and thus resulted in shrinking of moderately suitable category and expansion of marginally suitable category.
3.3. Identifying Limiting Factors

Identifying factors that make a specific area unsuitable or marginally suitable for production of Nile Tilapia in ponds is crucial step to recommend remedial measures and to estimate cost needed at construction level. One or more factors which can easily or hardly be amended reduce the suitability level of an area or make it less suitable. Amendment depends on the nature of the factor and operability, scale of production and cost associated with technology and intervention to reduce the degree of limitation imposed by each factor.

The modeling enables identification of most limiting factors in a specific area by analyzing the suitability level of underlying factors. Although weights given to each factor were restricted to expert’s level of understanding and knowledge, the principle to identify constraints works well assuming that weights are logical. Figure 8 shows why the area indicated by the red arrow on the upper most layer was fell under marginally suitable category. In terms of engineering and economic suitability the area was interpreted as having moderate to high suitability level. However, in terms of water availability, water temperature and land cover it was found in the last least suitable classes. Consequently this shows that it is difficult to improve the suitability level of the area due to less operability of the factors (temperature) and cost associated with mechanism of obtaining water to fill ponds through production season. Further analysis of factors is also
deemed necessary especially when more than one parameter is used to determine the level of suitability based on a given factor. For example, a given area may have suitable soil for pond construction but may be topographically unsuitable. This reduces the suitability of the area in terms of construction simplicity.

Calculating the percentage of the study area which was categorized as marginally suitable and unsuitable for each factor involved in the model, it was found that 67.1% of the country has scarce or no water, 56.5% was economically marginal, 28.4% was marginally suitable and unsuitable in terms of engineering suitability, 26% had unsuitable and marginal land cover and 5% had marginal to unfavorable temperature.
3.4. Model Drawbacks

The model involved some limitations that restrict its full application. Its use is limited to set directions for further exploration and analysis in areas which are generally identified as promising for pond production of Nile Tilapia at national scale. The main limitations of the model were experts’ subjective judgment on weights and thresholds of factors and parameters, application of surrogate data in place of actual data, dropping off other factors which potentially affect
outcomes of the model, scale of analysis, lack of validation based on field data and adoption of studies and models which haven’t been tested in the context of Ethiopia. GIS models are very sensitive to alterations of weights and incorporation of new factors and parameters. Results will automatically differ for a small change in weights and thresholds. Thus, high attention should be given to interpretations of parameters and weights used in this model.

4. Conclusions and Recommendations
In a presence of appropriate spatial data, spatial data analysis system, experts’ judgment incorporation mechanism, and previous knowledge mapping geographic distribution of suitable and unsuitable zones for pond production of Nile Tilapia and identification of limiting factors at national level was found possible. According to the analysis, significantly large part of Ethiopia was found moderately suitable and marginally suitable for Nile Tilapia production in artificial ponds for subsistence and commercial production system. Very small area was highly suitable and negligible area was unsuitable for subsistence and commercial production. Unavailability of water was the most limiting factor at national level. Introducing addition factors which potentially affect establishment of ponds is deemed necessary. The model will become more informative if it was developed within similar agroecological zones. Finally fine-tuning of weights based on stakeholders input and detailed data analysis was recommended.
The role of aquatic resources for food security in Ethiopia

References


Changes in Lake Tana’s traditional reedboat fishery during the period of 1991-2011: Its contributions to local food security

Martin de Graaf¹, Endale Lemma², and Tesfaye Wudneh³

¹IMARES Wageningen University and Research Centers, P.O. Box 68, 1970 AB IJmuiden, The Netherlands. Email: martin.degraaf@wur.nl
²Amhara Livestock Development Agency, Bahar Dar, Ethiopia
³Fish for All, P.O. Box 27718 code 1000, Addis Ababa, Ethiopia.

Abstract
The current reedboat fisheries started in March 2011 in cooperation with staff from the Bahar Dar Fishery and Aquatic Life Research Center and the Bureau of Agriculture of Amhara Regional State. The aim of the project is to determine possible changes in Lake Tana’s traditional fisheries with regards to CpUE, length-frequency, species composition and fishing gear in comparison with similar studies conducted in 2001 and 1991-1993. A similar methodology was used to monitor the fisheries in comparison with previous studies for two commercially important fish species; Oreochromis niloticus and Labeobarbus spp. Preliminary results appear to indicate a gradual decline of O. niloticus CpUE. Labeobarbus catches in the traditional reed boat fishery decreased dramatically between 1991-1993 and 2001 but remained stable between 2001 and 2011. Despite the claims of the use of small mesh sizes, little change in the length frequency of captured fish was observed over the 20 year period. The reed boat fishery fulfills a dominant role in supplying food for the local community as unlike
the motorized fishery, its catches are predominantly sold around Lake Tana. Unregulated fishery and recent water scheme developments around Lake Tana and its inflowing rivers may form the main threat for especially the Labeobarbus species flock.

Key words: Africa, Ethiopia, Labeobarbus, Oreochromis niloticus, rift valley lakes.

1. Introduction

For hundreds of years Lake Tana fisheries was composed of two predominantly subsistence traditional fisheries. The first is a reed boat fishery, operated by the Woito people (ethnic minority). This type of fishery is limited to the shore areas and targets the native Oreochromis niloticus, using locally made fish traps and small gillnets (length 15-20 m). Secondly, seasonal fishermen (farmers) traditionally target Labeobarbus on the upstream spawning grounds between August and October each year. Motorised boats and modern, more efficient, nylon gillnets were introduced in Lake Tana in the mid-1980s.

To maximise their income, the fishermen of Lake Tana specifically target O. niloticus, the most favoured fish for consumption among Ethiopians. Labeobarbus is less appreciated due to its intramuscular bones and the scale-less Clarias gariepinus is considered “unclean” according to the Ethiopian Orthodox Church. In contrast to other African lakes, Lake Tana’s small sized (<10 cm) fish species, like the pelagic zooplanktivore Barbus tanapelagius, are at present not harvested (Dejen et al., 2009). Only the small,
Cigar shaped *Garra* are occasionally eaten as part of a wedding ceremony in certain area around Lake Tana.

The majority of the catch of the reed boat and seasonal river fishery is sold on local markets and to restaurants around Lake Tana. The traditional fisheries have always played a significant role in the local food security. In contrast, almost all fish landed by the modern commercial motorized gillnet fishery is transported to Addis Ababa. Only in recent years, mid 2000s, the export of dried fish caught by reed boat fishermen to neighboring Sudan has started up.

During a census in the early 1990s 113 reed boat fishermen were counted in the Bahar Dar Gulf (Wudneh, 1998). The overall mean catch per unit of effort (CPUE in kg per day) for the reed boats was 12.3 kg (7.8 kg *O. niloticus*, 4.3 kg *Labeobarbus* spp and 0.2 kg *C. gariepinus*; Wudneh, 1998). Between 1991 and 2001 the total number of reed boat fishermen in the lake has been assumed to remain stable at around 400, landing around 800 t of fish annually. During the 1980s and 1990s the modern motorized gillnet fishery did not develop much, with a small fleet of 5-10 boats landing around 250-400 t annually.

Compared to other water bodies in the Nile Basin (Table 1) fish production and fisher density in Lake Tana were, at least before 2000, low. This is likely partly due to the low productivity of oligomesotrophic high altitude lake (Wondie et al., 2007, Dejen et al.,
but underutilization of Lake Tana’s fish resources has also been suggested (Wudneh, 1998).

Unfortunately since 2001 little reliable data on the development of the fish stocks, traditional fisheries and modern fisheries have been collected. This is regrettable, especially if the reports of a sharp increase during the last 10 years of modern motorised boats from 5 to 50-100 and traditional reed boats from 400 to 1600-3000 is true (de Graaf personal communications with fishermen and staff from the Bureau of Agriculture and Rural Development and FAO).

The last time the fish stocks in Lake Tana were properly monitored and assessed has nearly been a decade ago. Assessing the stock status of commercially important fish species should be done on regular basis for providing base line information, support management and sustainable use of the resources. In July 2010 a study was initiated aiming at assessing the current status of the motorised gillnet fisheries. In this paper we present the preliminary results of the 2011-2012 reed boat fisheries monitoring programme. We compare CPUE and length frequency data of *O. niloticus* and *Labeobarbus* with studies conducted in 1991-1993 by Wudneh (1998) and 2001 by de Graaf *et al.* (unpublished data) and briefly discuss some of the changes of Lake Tana’s fisheries and fish stocks.

2. Material and Methods
Between March 2011 and February 2012, CPUE data of the reed boat fishery was collected monthly during the first six days of each month in the southern part of the Bahir Dar Gulf of Lake Tana. On two locations around Bahir Dar (Bata and Laboratory), the total catch of single individual reed boats was recorded, additional data on number of gillnets used, mesh size (cm stretched mesh), fishing location and unsold fish being discarded or used for own consumption were collected by interviewing the fishermen. Data on length frequency and species composition was collected monthly from the Laboratory site. A maximum of 200 Labeobarbus spp (fork length), O. niloticus (total length) and C. gariepinus (total length) were measured daily to the nearest 1.0 cm. Labeobarbus specimen were identified to species level based on the description and identification key given by Nagelkerke and Sibbing (2000).

3. Results and Discussion

3.1. Changes in Lake Tana’s reed boat fisheries: CPUE and length frequency

Two patterns may be observed in the O. niloticus catches in the reed boat fishery over the past 30 years (Fig. 1). In the first place, CPUE appears to be slowly decreasing from ~8 kg per day in the 1990s, to ~7 kg per day around 2000 to ~5 kg per day in 2011. Secondly a change in catchability over the season seemed to have occurred. In the 1990s seasonality in the catches was pronounced, with high catches in the dry season and start of the wet season (FEB-JUL) and low catches directly
after the wet season (AUG-DEC). In 2011 this seasonal pattern is hardly visible anymore, daily landings are lower compared with the 1990s but the variation between the seasons has reduced.
Fig. 1: Temporal variation in *O. niloticus* CPUE of the reed boat fishery during a) 1991-1993 (Wudneh, unpublished data), b) 2001 (de Graaf, unpublished data) and c) 2011-2012. Dotted lines indicate overall mean.
Figure 2 Temporal variation in *Labeobarbus* CPUE of the reed boat fishery during a) 1991-1993 (Wudneh, unpublished data), b) 2001 (de Graaf, unpublished data) and c) 2011-2012. Dotted lines indicate overall mean.
Figure 4 Length frequency distribution of the *Labeobarbus* landed by the reed boat fishery in a) 1991-1993 (Wudneh 1998), b) 2001 (de Graaf, unpublished data) and c) 2011-2012.
Figure 4 Length frequency distribution of the *Labeobarbus* landed by the reed boat fishery in a) 1991-1993 (Wudneh 1998), b) 2001 (de Graaf, unpublished data) and c) 2011-2012.
In contrast to *O. niloticus* catches, drastic changes have occurred in the daily landings of the *Labeobarbus* spp (Fig. 2). Daily landings dropped by ~75% between 1990 (~4 kg per day) and 2000 (~1 kg day). In 2011 daily landings of *Labeobarbus* spp by reed boat fishermen have remained low at around ~1 kg per day. A similar steep decline in *Labeobarbus* landings between 1990 and 2000 was also observed in the commercial gillnet fishery and a fishery independent trawl survey (de Graaf *et al.* 2006).

Average size of landed *O. niloticus* did not change between 1991 and 2001 (Fig. 3). Between 2001 and 2011 a small decrease in size from ~23 to ~21 cm was observed. However, no change in average size at landing was observed for *Labeobarbus* spp between 1991 and 2011 (Fig. 4). These results are in contrast with the comments made by local researchers that the use of illegal small meshed monofilament gillnets has sharply increased in Lake Tana. The use of these illegal gillnets among reed boat fishermen around Bahir Dar appears to be limited. Maybe future surveys of the reed boat fishery in other part of Lake Tana may corroborate the claim of a decrease in mesh size (and decreased size of landed fish) in the reed boat fishery.

<table>
<thead>
<tr>
<th>Area</th>
<th>Surface (km²)</th>
<th>Fish landings (ty⁻¹)</th>
<th>Year</th>
<th>Main fish taxa</th>
<th>Production (ty⁻¹ km²)</th>
<th>Fisher density (no/km²)</th>
</tr>
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<tr>
<td><strong>Egypt</strong></td>
<td></td>
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<td></td>
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<tr>
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<td>460</td>
<td>50,000</td>
<td>1990-2004</td>
<td>Tilapiine cichlids, <em>Clarias</em></td>
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<tr>
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<td>1989-1993</td>
<td>Tilapiine cichlids</td>
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<td>6.8</td>
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<tr>
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<td>2003</td>
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<td>0.9</td>
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<td>Sennar Res.</td>
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<tr>
<td>Roseires Res.</td>
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<tr>
<td>Sudd</td>
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<td>30,000</td>
<td>2003</td>
<td></td>
<td>0.9</td>
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</tr>
</tbody>
</table>
3.4.3. Water resource developments: The most recent threat to the survival of riverine spawning *Labeobarbus* species are the planned irrigation dams in most of the rivers and the expected negative effects on Lake Tana’s water level of the Tana-Beles hydropower station (McCartney *et al.*, 2010). The location of the irrigation dam that is currently under construction in the Ribb River is in the middle of the *Labeobarbus* spawning grounds. An irrigation dam (Getahun *et al*. 2008) will cause a) the loss of spawning habitat upstream from the dam, b) reduced flow over the dam during the spawning season will prevent sufficient inundation of spawning areas downstream from the dam preventing successful reproduction, and c) reduced flow over the dam will prevent the sufficient inundation of flood plains near the river mouth, negatively affecting fish (also including *O. niloticus* nursery grounds) and farmers.

The Chara Chara Weir in the outflow of Lake Tana has reduced the seasonal variation in water level. This reduction in seasonal variation is also reflected in the reduction of the seasonal variation in tilapia CPUE of the reed boat fishery. Before the construction of the weir, tilapia catches were high when water levels were low, i.e. the tilapia were forced to move from the flood plains to the open water where they are susceptible for gill nets. However, in recent years the Chara Chara weir seems to cause more stable (and higher) water level,
possibly reducing the catchability of tilapia throughout the year.

For the conservation of the Lake Tana ecosystem, continuous monitoring of the catches of traditional and modern fisheries, and conducting regular fishery-independent sampling programs, are of utmost importance to determine the condition of the stocks and to evaluate the consequences of implemented regulations and potentially devastating developments like the construction of irrigation dams in spawning rivers. An integrated (hydrology, environment, livelihoods) management plan and research programme for the Lake Tana basin is urgently required to prevent the collapse of an important fishery and the extinction of the only known cyprinid species flock in the world.

References


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Assessment of motorized commercial gillnet fishery of the three commercially important fishes in Lake Tana, Ethiopia

Brehan Mohammed¹,²*, Martin de Graaf³, Leo Nagelkerke⁴, Minwyelet Mingist¹, and Wassie Anteneh²

¹Department of Fisheries, Wetlands and Wildlife Management, College of Agriculture and Environmental Sciences, Bahir Dar University, Bahir Dar, Ethiopia.
²Bahir Dar Fisheries and Aquatic Life Research Center, PO Box 794 Bahir Dar, Ethiopia. Email: brish399@yahoo.com
³IMARES Wageningen University and Research Centers, P.O. Box 68, 1970 AB IJmuiden, The Netherlands. Email: martin.degraaf@wur.nl
⁴Aquaculture and Fisheries Group, Wageningen Institute of Animal Sciences (WIAS), Wageningen University, Marijkeweg 40, 6709 PG Wageningen, The Netherlands. Email: leo.nagelkerke@wur.nl

*) Corresponding author: Brehan Mohammed, E-mail: brish399@yahoo.com

Abstract
This study was conducted from July 2010 to June 2011 to assess the status of motorized commercial gillnet fishery of the three commercially most important fishes in Lake Tana Labeobarbus spp., Oreochromis niloticus (Nile tilapia) and Clarias gariepinus (African catfish). Catches were monitored daily and additional information on number of gillnets used, mesh size of gill nets and location of fishing grounds were collected. Data on the Labeobarbus species
composition were collected 3 days per month. The total fish yield from the main fishing grounds of the commercial fishery was 238 metric tons/year. The catch of tilapia was 71%, that of catfish 18% and that of *Labeobarbus* 11% of the total catch. Peak production was from March to May, 2011. Most effort (80%) was allocated to the North Eastern Floodplain (NEFP). The total number of gillnets set and boat trips made were 85,943 and 3104, respectively, which is much higher than reported previously. Consequently, the Catch per Unit Effort (CpUE; kg/trip) of the 2010/2011 production year was with $64.7 \pm 3$ (95% CL) kg much lower than reported previously. The CpUE of all three fish taxa was lower than previously reported, but especially the *Labeobarbus* CpUE was much lower than before (6.1 kg). An integrated management plan and research program for the Lake Tana basin is urgently required to prevent the collapse of an important fishery and the extinction of the only known cyprinid species flock in the world:

**Keywords:** *Clarias gariepinus*, CpUE, effort allocation, *Labeobarbus* spp., *Oreochromis niloticus*

### 1. Introduction

Lake Tana is situated in the north-west of Ethiopia at an altitude of 1,800 m above sea level. The Lake is very important to Ethiopia as a permanent source of both water and hydroelectricity. The lake is Ethiopia’s largest lake, which is oligo-mesotrophic with chlorophyll *a*, average 6.4 µgL⁻¹ (Eshete Dejen *et al.*, 2004). The lake in addition is shallow (average depth 8 m, maximum depth 14 m) which covers an area of 3050 km². Seven big perennial rivers flow into Lake Tana: Gilgel Abay, Gelda, Gumara, Rib, Arno-Garno,
Megech and Dirma. The Lake is the source of the only river flowing out of the lake, Blue Nile. High waterfalls (40 m) at Tissisat ('smoking waters'), 30 km downstream from the outflow, effectively isolate the lake’s ichthyofauna from the lower Nile basin.

Nagelkerke and Sibbing (2000) distinguished 15 endemic large hexaploid *Labeobarbus* species forming a unique species flock in Lake Tana, the only cyprinid species flock in the world, after the one in Lake Lanao vanished because of overexploitation (Kornfield and Carpenter, 1984).

In 1986 a motorized, commercial gillnet fishery was introduced in Lake Tana in addition to the artisanal, predominantly subsistence fishery conducted from reed boats. Within Lake Tana’s fish community the *Labeobarbus* species are predicted to be by far the most susceptible to fisheries (de Graaf et al., 2006) as the labeobarbs are: long-lived, form spawning aggregations and are highly specialized.

The three main species groups targeted by commercial gillnet fishery of L. Tana are found to be a species flock of endemic, large *Labeobarbus* spp., African catfish (*C. gariepinus*) and Nile tilapia (*O. niloticus*). The commercial gillnet fishery on *Labeobarbus* spp. is highly seasonal and mainly targets the spawning aggregations, as more than 50% of the annual catch is obtained at the river mouths during August and September (de Graaf et al., 2006).
Fish stocks from the commercial catch in Lake Tana were monitored before nearly two decades by Tesfaye Wudneh (1998) and a decade by de Graaf et al. (2006). Overfishing of *Labeobarbus* near and at river mouths and upstream in the rivers on and near the spawning grounds by fishers for several years reduced their abundance to a very low level (de Graaf et al., 2006). Dereje Tewabe and Goraw Goshu (2010) monitored the catch data more recently, but without considering the effort.

The purpose of this study is to compare the current status of the fishery on labeobarbs, tilapia and catfish by comparing it with the previous studies of Tesfaye Wudneh (1998) and de Graaf et al. (2006). We assessed the catch composition and fishing effort from July 2010 to June 2011 and changes in catch composition and in fishing effort over the period 1990-2010 are discussed.

### 2. Material and Methods

#### 2.1. Fishing grounds

Fishing sites were grouped before analysis within fishing areas following Tesfaye Wudneh (1998) and de Graaf et al. (2006) (Fig. 1). NEFP (North-Eastern Flood Plain; includes, Nabega, Saben, Rib, Dessie Wonz, Sendye and Fikr Mefja); GRM (Gumara River Mouth; includes, Jagrefa, Checkla Menz, Gumara, Gugubie, Rima, Kidara, Genjaba, Abuara); BDWC (Bahir Dar Gulf West Coast; includes, Lijamie Gebriel, Atesta, Gufeza, Ambo Bahir, Gerima, Kibran); BDGE (Bahir Dar Gulf East; includes, Korata, Gelda, Boled, Bet Menz, Zega Wenz). Grouping of fishing grounds was based on geographical
proximity and/or habitat similarity. In contrast to the two previous studies there were in our study no off-shore deep water and Gilgel Abay River mouth sites.

2.2. Catch and effort

Total weight of three taxa (*Labeobarbus* spp., *O. niloticus* and *C. gariepinus*) were monitored from July 2010 to June 2011 for 12 months. These fish were caught by three fisheries organisations. Firstly, by motorized boats from: Tana Haik number 1 Fisher’s Cooperative (THFC) with around 42 boats of which on average 20 boats were active per day. Fish is sold to the Fish Production and Marketing Enterprise (FPME),
secondly, by the Arsema Mariam cooperative (≈17 boats) and thirdly by the FMPE boat cooperatives itself (≈19 boats). The total catch of all motorized boats was recorded daily. When recording the total catch from a motorized boat of single individual, additional data on number of gillnets used, mesh size (cm stretched mesh) and location of fishing ground were collected by interviewing the fishermen.

From the above catch and effort data, the CpUE was computed and analyzed using SPSS version 16 software. In order to reduce bias in the measure of fishing effort, the relationship between total weight per fishing trip (TW) and the number of gillnets (N) carried on the trip was examined. A power curve was fitted for the period.

\[ TW_{i,j} = \alpha_i N^{\beta_i} \varepsilon_{i,j} \quad \text{Eq. 1} \]

Where, \( \alpha_i \) is the coefficient of period \( i \); \( \beta_i \) the exponent of period \( i \); \( \varepsilon_{i,j} \) is the random error.

For these period the results were \( \alpha = 2.42, \beta = 1.01 \) (\( r^2 = 0.756, n = 859260, P < 0.01 \)). The unit of fishing effort, which was used for further analysis, was a fishing trip with the average number of gillnets (22.21) carried per trip.

The Catch-per-Unit Effort (CpUE) is calculated as:

\[ \text{CpUE} = W (22.21/\text{NNETS})^8 \quad \text{Eq. 2} \]
Where, \( W \) is the weight of a particular species category in the catch and \( NNETS \) is number of nets and \( \theta \) is exponent of the period.

2.3. *Labeobarbus* species composition

Data on the *Labeobarbus* species composition of the motorized commercial gillnet fishery were collected every month in the first three consecutive days. Maximum of 200 fishes from each species landed by the commercial gillnet fishery in Bahir Dar were identified to species level and the fork length (FL) was measured to the nearest 0.5 cm.

3. Results

3.1. Total catch and CpUE

3.1.1. Annual Catch

The annual catch from our study (2010/11) was found to be 238 MT. Fish of Lake Tana also varied spatially; 86% of the total fish catch was harvested from the North Eastern Flood Plain (NEFP) and only 14 % from the Bahir Dar Gulf (BDG). The total amount of fish produced in 2010/11 at the NEFP was 205 MT and 33 MT from three sites in BDG by Lake Tana motorized commercial fishery.

The fish harvested in Lake Tana differs by species and months. The catch of tilapia (*O. niloticus*) was higher than that of *Labeobarbus* and catfish (*C. gariepinus*) with a proportion of 71%, 11% and 18%, respectively (Table 1).
3.1.2. Effort allocation

Effort used was motorized boats with gillnets of 100 m length and 9 to 12 (average 10) cm stretched mesh gillnet. The number of motorized boats went daily to fishing from THFC and FMPE to harvest fish ranged from 25 to 57 (average 19±0.6) and each boat sets 16 to 30 (average 22.2±0.06) gillnets. The total number of gillnets set and boat trips made were 85,943 and 3,104, respectively (Table 2, Table 3).

The daily effort used for fishing varied in time and place. The vast majority of the fishing effort (80% of the effort) was allocated to the NEFP (Table 1 and Fig. 2). The rest 5.8, 6.7 and 7.5% efforts were allocated to the BDGW, BDGE and GRM, respectively (Fig. 2). More efforts were allocated in the NEFP in all months except February because there was almost the same effort allocation on this month with BDGW. Therefore, in most of the months of the year majority of the effort is allocated to NEFP. No fish was caught in the offshore deep waters. The motorized commercial fishery is concentrated in NEFP (80% of total effort), the remaining 20% of the effort is distributed over other part of the lake, like Gumara River mouth area, Bahir Dar Gulf, East and West coasts.

The peak production season was between March and May 2011. Catch was below the average of the year during August, September, October, November and
January (four months) (Fig. 3). Fish yield started to decline in June and July, dropped in August and there had not been fishing during September and October 2010. During March – May the catch from the floodplains of Lake Tana was high and it was dominated by tilapia (*O. niloticus*).

### 3.1.3. Catch per Unit Effort (CpUE)

The CpUE (kg/trip) of the 2010/11 production year was 64.7 ± 3 at 95% CI. Catch per Unit Effort proportion varied among species in different periods. The percentage contribution of tilapia (*O. niloticus*), *Labeobarbus* and catfish (*C. gariepinus*) was 75, 11 and 18 %, respectively (Table 1). CpUE also varied seasonally. From July to February CpUE was below the average of the year. The increase in CpUE during March to June was due to the increase in total catch during these seasons, especially due to the high catch of Nile tilapia (Fig. 3).
**Table 1:** Catch proportion of the motorized commercial gillnet fishery by species and fishing grounds in 2010/2011.

<table>
<thead>
<tr>
<th>Species</th>
<th>Total catch in metric tons (MT)</th>
<th>BDGE</th>
<th>BDGW</th>
<th>GRM</th>
<th>NEFP</th>
<th>L. Tana</th>
<th>Proportion</th>
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<tr>
<td>Tilapia</td>
<td></td>
<td>4.1</td>
<td>9.79</td>
<td>9.74</td>
<td>145</td>
<td>168.6</td>
<td>71%</td>
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<td>Labeobarbus</td>
<td></td>
<td>1.52</td>
<td>1.15</td>
<td>2</td>
<td>21</td>
<td>25.6</td>
<td>11%</td>
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<tr>
<td>Catfish</td>
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<td>1.8</td>
<td>1.08</td>
<td>1.51</td>
<td>39.4</td>
<td>43.8</td>
<td>18%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7.38</td>
<td>12.01</td>
<td>13.26</td>
<td>205.38</td>
<td>238</td>
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<tr>
<td>Proportion (%)</td>
<td></td>
<td>3.09</td>
<td>5.04</td>
<td>5.56</td>
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<table>
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<tr>
<th>Year</th>
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<th>Other sites</th>
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<tr>
<td></td>
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<td>Percentage</td>
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<td>1532</td>
<td>41</td>
<td>9411</td>
</tr>
<tr>
<td>2001</td>
<td>1625</td>
<td>41</td>
<td>2338</td>
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<tr>
<td>2010/11</td>
<td>69064</td>
<td>80</td>
<td>16879</td>
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<th>Year</th>
<th>No. of boats (at 95% CL)</th>
<th>No. of gillnets per boat (at 95% CL)</th>
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<tr>
<td>1993</td>
<td>7±0.4</td>
<td>19.6±0.4</td>
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<tr>
<td>2001</td>
<td>5±0.5</td>
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<tr>
<td>2010/11</td>
<td>19±0.6</td>
<td>22.2±0.06</td>
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</table>
Fig. 5: *Clarias gariepinus* CpuE (kg/trip) in 2010/2011. (a) Total catch, the horizontal line indicates the overall mean, (b) catch in the major fishing grounds.
Fig. 6: *Oreochromis niloticus* CPUE (kg/trip) in 2011/11. (a) Total catch, the horizontal line indicates the overall mean, (b) catch in major fishing grounds.
3.1.6. *Labeobarbus* species composition

From the riverine spawner species *L. tsanensis*, *L. truttiformis*, *L. megastoma* and *L. acutirostrosis* only form a significant part of the commercial catch in July and August, when they form spawning aggregations near river mouths. Lacustrine spawning *Labeobarbus* species, *L. intermedius*, *L. crassibarbus*, *L. gorgorensis*, *L. nedgia* occur in July and August. Although it is expected that in July and August the most dominating species should be the riverine spawners, the dominating species was the lacustrine spawners *L. intermedius* (Fig. 7).

4. Discussion

4.1. Annual Catch

The annual catch from our study (2010/11) was found to be 238 MT. Lake Tana fish production for the last 20 years did show a decreasing tendency from time to time. The total fish catch from main fishing grounds was 360 MT in 1997 (Tesfaye Wudneh, 1998), 255 MT in 2001 (de Graaf et al., 2006) and 238 MT in 2010/2011 (current study). Dereje Tewabe and Goraw Goshu (2010) reported that *O. niloticus* catches increased from 2003 to 2007, but after 2007, it declined sharply for consecutive two years. *C. gariepinus* did not show significant change, but *Labeobarbus* species showed significant decline during 2007 (P < 0.05).

Fish of Lake Tana also varied spatially; more fish was harvested from the Bahir Dar Gulf (BDG) during 1997 and the
North Eastern Flood Plain (NEFP) in 2010/11. The proportion of catch in the BDG was 71% in 1993 and in the NEFP was 86% in 2011. The total amount of fish produced in 2010/11 at the NEFP was 205 MT and the rest 33 MT (14%) only produced from other three sites of Lake Tana motorized commercial fishery.

The fish harvested in Lake Tana differs by species and months. In the present study, the catch of Nile tilapia in Lake Tana was higher than that of Labeobarbus and catfish (C. gariepinus) with a proportion of 71%, 11% and 18%, respectively (Table 1). This proportion was 32%, 34% and 32%, respectively in 1997; more or less all the species had equal contribution in the Lake Tana Fisheries in 2001 (De Graaf et al., 2006). The commercial gillnet fishery of Labeobarbus was highly seasonal and mainly targets the spawning aggregations during 1991-1993 (De Graaf et al., 2006). At the same time, catfish catch was taking place during July to September when rivers flooded the plain areas of Eastern Lake Tana and as a result the contribution of these species dropped sharply through time.

In Lake Tana fishery, the daily effort used for fishing varied in time and place. The number of boats and gillnets used increased alarmingly since the last 10 years. In 2011 more than 20 times more gillnets were set than in 2001 (Table 2).
4.2. Effort allocation

In our study the vast majority of the fishing effort (80%) was allocated to the NEFP. The remaining efforts were more or less equally allocated to the BDGW, BDGE and GRM, respectively. The percentage of effort allocated in the NEFP has been grown from 14% in 1993 to 41% in 2001. After 10 years, the current effort increased to 80%, exceeding by almost two fold from 2001. The possible cause for the trend shift of fishermen to deploy their boats and gillnets to the NEFP is expected to be the concentration of the fish species to the floodplains where the availability of breeding grounds, shelter and food are good.

The total effort applied during 2001 was lower than 1993 due to lack of spare parts and skill in maintaining the imported boats (Table 3). Since the last 5 years, production of fishing boats has been started and maintenance was given locally enabling the fishermen to have more and more boats from time to time (personal communication).

In the present study, the peak production season lied between March and May 2011. Catch was below the average of the year during August, September, October, November and January (four months) and fishing stopped completely during September and October 2010. These observations are in contrast with those reported for 1993 and 2001 where peak fish production was highest between August and October (Tesfaye Wudneh, 1998; de Graaf et al., 2006). The probable
cause for the increment of catch during this period is that Orthodox fasting season (Hudade) and tilapia breeding season falls during this time of the year and the consumers prefer fish instead of meat.

4.3. Catch per Unit Effort (CpUE)

The CpUE (kg/trip) of the 2010/11 production year was 64.7 ± 3 at 95% CL, by far lower than 140.5±5.2 in 2001 (de Graaf et al., 2006) and 177.3±6.5 in 1993 (Tesfaye Wudneh, 1998), the CpUE of the last 10 and 20 years. The CpUE trend is decreasing from 1993 to 2011. This decrease from 1993 to 2001 was caused by a lowered daily effort (number of boats per day: 7±0.4 in 1991–1993 and 5±0.5 in 2001 (de Graaf et al., 2006). But in 2011, the daily effort (average number of boats) grew to 19±0.6. The decrease in CpUE in 2011 was mainly due to the excessive increase in effort from 10, 943 gillnets in 1993 and 3963 in 2001 to 85, 943 in 2011 (Table 2).

Catch per Unit Effort proportion varied among species in different periods. The percentage contribution of Nile tilapia (O. niloticus), Labeobarbus and catfish (C. gariepinus) CpUE was 27%, 35% and 38% in 1993 and 54%, 20% and 26% in 2001, respectively, but in the present study the contribution is dominated by tilapia and the proportion became 75, 11 and 18, respectively.

Catch per Unit Effort of 2010/2011 varied seasonally. It was high during March to June and low in the rest of the months.
most of the rivers and the expected negative effects on Lake Tana’s water level of the Tana-Beles hydropower station (McCartney et al., 2010). The location of the irrigation dam that is currently under construction in the Ribb River is in the middle of the *Labeobarbus* spawning grounds. An irrigation dam causes the loss of spawning habitat upstream from the dam and causes reduced flow over the dam during the spawning season preventing successful reproduction downstream (Abebe Getahun et al., 2008).

The drastic and rapid consequences of an unregulated gillnet fishery on spawning aggregations of large African cyprinid fishes has become clear problem with the collapses of *Labeo mesops* fisheries in Lake Malawi (Skelton et al., 1991), *Labeo victorianus* and *Barbus altianalis* fisheries in Lake Victoria (Ogutu-Ohwayo, 1990; Ochumba and Manyala, 1992) as well as the virtual disappearance of *Labeo altivelis* from the Mweru-Luapula system within a period of 20 years (Gordon, 2003).

4.3.2. *Clarias gariepinus* (African catfish)

In the present study, the mean *C. garipinus* CpUE in the commercial gillnet fishery is 7.8 kg/trip. This shows a decrease from the previous studies, 67 kg/trip in 1993-1997 and 37 kg/trip in 2001. The decline in catfish may be due to the new dry fish marketing to Sudan (Gelabat
town) which targets on catfish (Berihun Tefera et al., 2009). In 2001, *C. garipienus* CpUE decreased more or less equally in all months and fishing areas. In our study, CpUE was higher from November-January and it is higher in NEFP compared to other areas. In 1991–1993, larger spatial variation occurred in CpUE, peaking in Gilgel Abay River mouth and NEFP. In 2001, NEFP had the highest CpUE but the difference with GRM and the Bahir Dar Gulf was relatively small.

### 4.3.3. *Oreochromis niloticus* (Nile tilapia)

This species is very much targeted by the fishermen as it is highly preferred by the Ethiopian Society for consumption and it yields a better price than *Labeobarbus* and Catfish. Due to the low catches of Nile tilapia, most fishermen ceased fishing completely during the months of September and October while only limited fishing occurred in August and November. The low catches were probably caused by a rise in water level (personal communication) and the subsequent migration of Nile tilapia to the inshore littoral areas and the adjacent wetlands where the fishermen cannot fish efficiently.

In our study the mean *O. niloticus* CpUE was 42.2 kg/trip, as compared to 75 kg/trip in 2001 and 47 kg/trip in 1991–1993. In 2010/2011 the CpUE was relatively high from February to June peaking from March to May but in
2001 CpUE was relatively high in December–June, peaking in March–May.

In 1991–1993 CpUE in the northeastern floodplains (NEFP) was two to three times higher than in both Bahir Dar Gulf East and West (BDGE and BDGW) and in Gumara River Mouth (GRM). In 2001, CpUE was the same in NEFP compared to the earlier period but CpUE in BDGE and BDGW had both doubled, reaching the same level as in NEFP. However, in our study, NEFP and BDGW had almost the same CpUE and GRM had CpUE relatively better than BDGE. The increase in *O. niloticus* can largely be explained by a shift in fishing grounds, from the Bahir Dar Gulf to the inshore areas adjacent to the extensive floodplains along the northeastern shores of Lake Tana. Such shallow, protected areas are the preferred habitat of *O. niloticus* (Kolding, 1993).

5. Conclusions

In Lake Tana, the effort applied increased more than 20 folds over the period 1993 – 2010/11. As a result the CpUE decreased for all species, but most dramatically for the riverine spawning *Labeobarbus* spp., these species need urgent protection. It is, therefore, of utmost importance that the existing fisheries regulations is implemented as soon as possible. Furthermore, an integrated management and monitoring plan for Lake Tana and its catchment is urgently required.
Acknowledgements

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Preliminary survey of fishes in Chefa Wetland around Kemisse, Oromia Zone

Assefa Tessema\(^1\), Minwyelet Mingist\(^2\) and Eshete Dejen\(^3\)
\(^1\)Wollo University, Department of Applied Biology. E-mail: asefao9@yahoo.com
\(^2\)Bahir Dar University, College of Agriculture and Environmental Sciences, Department of Fisheries, Wetlands and Wildlife Management. E-mail: minwyeleltm@bdu.edu.et
\(^3\)Food and Agricultural Organization, Sub-regional Office for Eastern Africa, Addis Ababa, Ethiopia. E-mail: dejeneshete@yahoo.com

Abstract
Preliminary survey of fishes was conducted in Chefa wetland in April and October, 2009 using gillnets of stretched mesh size from 6-12 cm, monofilaments of different mesh size, hook and line, and beach seines. A total of 1171 fish specimens were collected in both dry and wet season from the three sampling sites: Gulo, Hotspring and Nursery site. Fish species identification was made using literature and specimen deposited in the laboratory. Index of Relative Importance (IRI) and Shannon index ($H^\prime$) were used to evaluate abundance and diversity of fishes in Chefa wetland. Two families, three genera and four species were recorded from the three sites. Family Cyprinidae was best represented in all sites. *Clarias gariepinus*, *Garra dembecha*, *Labeobarbus intermedius* and *Labeobarbus nedgia* were recorded in Chefa wetland. *Clarias gariepinus* and *Garra dembecha* were the
dominant fish species in Chefa wetland with percentage IRI of 40 and 31.4 in dry season but in wet season *Clarias gariepinus* and *Labeobarbus intermedius* were the dominant fish species in the wetland with percentage IRI of 68 and 26 respectively. The Shannon diversity index value of Gulo site was the higher than either of Hotspring or Nursery in dry season (0.94, 0.69 and 0.9) respectively. Chefa wetland has high fishery potential however the vegetation (*Typha latifolia*) used as nursery ground for fish is destructing at alarming rate to use it as raw material for mattress and other different house holding materials. Therefore, proper wetland management should be implemented to use the fish of the wetland sustainably.

**Key words:** Chefa, Gillnet, Index of relative abundance and Wetland

1. Introduction

Ethiopia is uniquely rich in water resources. It has numerous water bodies including ponds, lakes, rivers, reservoirs and wetlands. Based on the estimation of FAO (2001) the surface area of major lakes and reservoirs is 7,334 Km² and the length of rivers is 7,185 km.

Even though the diversity of the Ethiopian fish fauna is not fully researched, these water bodies give a refuge for more than 150 species in 29 families: of which around 40 of them are endemic to Ethiopia Abebe Getahun (2007). Even though no systematic survey and assessment of the potential of all water bodies have been made, the rough potential harvest estimate from 7 main
2.2. Sampling

In this study, three sampling sites were selected. Site selection was done by considering human activities, interference by farm animals and vegetation coverage (Table 1). Each sampling site was sampled twice at dry and twice in wet seasons. Gillnet of stretched mesh size of 6 - 14 cm and hook and lines were used to sample fish by setting the net and the hook for 14 hours overnight at deeper part of the river. Monofilament with mesh size of 5 - 55 mm was set on rivers for one hour to sample small-sized fish species. In addition to this, beach seines were used in suitable areas of the wetland. Total length, fork length, standard length and weight of all specimens of fish were measured.

Fig. 1: Map of Chefa wetland with sampling sites (Gulo, Hot spring and Nursery)
Table 1: Sampling sites in Chefa wetland

<table>
<thead>
<tr>
<th>Fishing site</th>
<th>Location</th>
<th>Distance from nearby town</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulo</td>
<td>10°42'09&quot; N 39°49'08&quot; E</td>
<td>4km from Kemisse</td>
</tr>
<tr>
<td>Hot spring</td>
<td>10°37'55.4&quot; N 39°55'42.2&quot; E</td>
<td>10 km from Cherete</td>
</tr>
<tr>
<td>Nursery</td>
<td>10°38'09&quot; N 39°55'58.2&quot; E</td>
<td>15km from Kemisse</td>
</tr>
</tbody>
</table>

Pictures were taken for each species. After taking the necessary information individual specimen was preserved with 4% formalin in plastic jar and transported to the laboratory for further identification and measurement.

Gulo site is found in Gulo village where the bank of Borkena River is exposed to agricultural activity. Hot spring site is located near the hot springs in Chefa. Nursery site is found near Artumafursie nursery where the bank of the river is highly vegetated.

2.3. Laboratory studies
Specimen of fish were soaked in tap water for one day to wash the formalin and were identified to species level using specimen deposited at Bahir Dar Fish and Other Aquatic Life Research Center and by using identification key Golubtsov et al. (1995).
2.4. Species diversity and relative abundance

Estimation of relative abundance of fish was made by the contribution of the catch in each sampling effort. An Index of Relative Importance (IRI) and Shannon diversity index ($H'$) was used to evaluate relative abundance and diversity of fish, respectively. An index of relative importance is a measure of relative abundance or commonness of the species based on number and weight of individuals in catches as well as their frequency of occurrence (Kolding 1989). The IRI gives a better replacement of the ecologically important species rather than the weight, number or frequency alone.

**Index of relative importance (IRIi):**

\[
IRI_i = \frac{\left( \% W_i + \% N_i \right) \% F_i}{\sum_{j=1}^{n} \left( \% W_j + \% N_j \right) \% F_j} \times 100
\]

Where, \% $W_i$ and \% $N_i$ are percentage weight and number of each species of total catch, respectively. \% $F_j$ is a percentage frequency occurrence of each species in total number of settings. \% $W_j$ and \% $N_j$ are the percentages weight and number of total species in total catch, respectively.
Shannon index of diversity ($H'$) is a measure of species weighed by the relative abundance (Begon et al. 1990). This was calculated using:

$$H' = -\sum P_i \ln P_i$$

Where, $P_i$ - the proportion of individuals in the $i^{th}$ species. Shannon index was used to indicate diversity of fishes at different sampling sites or rivers.

3. Results and discussions

3.1. Abiotic parameters

Physical and chemical parameters (temperature, transparency, conductivity, oxygen and pH) that were taken from all sites in Chefa wetland were analyzed and the result of the analysis showed difference in all parameters. The pH and DO value was the lowest in Hot spring site due to debris of sphagnum plants and highest temperature. The transparency value was the highest in Nursery sites, probably due to purification/buffering potential of Chefa wetland (Table 2).

<table>
<thead>
<tr>
<th>Sites</th>
<th>pH</th>
<th>Dissolved</th>
<th>Oxygen</th>
<th>Temp.</th>
<th>Transparency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulo</td>
<td>7.5</td>
<td>5</td>
<td></td>
<td>29.8°C</td>
<td>20</td>
</tr>
<tr>
<td>Hot spring</td>
<td>5</td>
<td>4</td>
<td></td>
<td>37.1°C</td>
<td>40</td>
</tr>
<tr>
<td>Nursery</td>
<td>8</td>
<td>6.4</td>
<td></td>
<td>28.2°C</td>
<td>75</td>
</tr>
</tbody>
</table>
### Table 3: Fish species composition and abundance in Chefa wetland by sites

<table>
<thead>
<tr>
<th>Sites</th>
<th>Fish species</th>
<th>Season</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gulo</td>
<td><em>Gara dembecha</em></td>
<td>130</td>
<td>155</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Labeobarbus intermedius</em></td>
<td>35</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>C. gariepinus</em></td>
<td>49</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>220</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td>Hot spring</td>
<td><em>L. intermedius</em></td>
<td>0</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>C. gariepinus</em></td>
<td>56</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>G. dembecha</em></td>
<td>61</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>L. negia</em></td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>117</td>
<td>217</td>
<td></td>
</tr>
<tr>
<td>Nursery</td>
<td><em>C. gariepinus</em></td>
<td>0</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>G. dembecha</em></td>
<td>126</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>L. intermedius</em></td>
<td>82</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>L. nedgia</em></td>
<td>23</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td>321</td>
<td>208</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: Per cent (%) IRIii of dominant fish species in Chefa Wetland

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Sites with respect to seasons</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Gulo</td>
<td>Hot spring</td>
<td>Nursery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td><em>G. dembecha</em></td>
<td></td>
<td>30.80</td>
<td>2.48</td>
<td>27.5</td>
<td>1.9</td>
</tr>
<tr>
<td><em>L. intermedius</em></td>
<td></td>
<td>16.50</td>
<td>0.48</td>
<td>0</td>
<td>70.6</td>
</tr>
</tbody>
</table>
Table 5: Shannon index and number of fish species in Borkena and Mille Rivers

<table>
<thead>
<tr>
<th>H'/N</th>
<th>Gulo</th>
<th>Hot spring</th>
<th>Nursery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
</tr>
<tr>
<td>H'</td>
<td>0.94</td>
<td>2.48</td>
<td>27.5</td>
</tr>
<tr>
<td>N</td>
<td>3</td>
<td>0.48</td>
<td>0</td>
</tr>
</tbody>
</table>

3.2. Fish species composition and Abundance
Chefa wetland has four species (*Clarias gariepinus*, *Gara dembecha*, *Labeobarbus intermedius* and, *Labeobarbus nedgia*) grouped under family Claridae and Cyprinidae. Family Cyprinidae was highly represented in the wetland. Among the three sites in dry season, Nursery site was the highest fish specimens (321) and Hot spring was the lowest (117). In wet season, Hot spring was the highest (217) whereas Gulo was the lowest (178) fish specimens (Table 3).

3.3. Species Diversity and Abundance
Chefa wetland was dominated by family Cyprinidae mainly by genera *Barbus* and *Garra*. The result of the present study agrees with Robert (1975) and Abebe Getahun and Stiassny (1998) in that fish species in Awash basin are dominated by family Cyprinidae (genera *Barbus*) and *Garra*. Percentage IRI of *G. dembecha* was higher at Nursery (35.2%) and lower at Hot spring (27.5) in dry season and it was higher at Gulo (2.4%) and lower (0.80) at Nursery site in wet season. Percentage IRI of *L. intermedius* was higher at Nursery (46.9%) and lower at Hot
spring (0) in dry season whereas it was higher at Nursery (71.2%) and lower at Gulo (0.48%) in wet season (Table 4).

**Shannon diversity index:** Shannon diversity index was used to evaluate species diversity of sampling sites in Chefa wetland. Shannon diversity index explains both variety and the relative abundance of fish species (Naesje *et al.* 2004). The number of fish species was higher in dry season than wet season in all sites as a result the Shannon diversity index (H') was higher in dry season in all sites except Gulo. In dry season Shannon diversity index was the highest at Gulo (0.94) and the lowest at Hot Spring (0.69). In wet season, Shannon diversity index was highest at Nursery (1.07) and lowest at Gulo (0.43) (Table 5).

4. Conclusions and recommendations
Fish diversity of Chefa wetland is less as compared to other studied wetlands in Ethiopia, but the abundance is higher. *Clarias gariepinus* is consumed by the people around Kemisse unlike most people living in Amhara Region. The watershed of Chefa wetland is highly degraded. Therefore, afforestation program should be practiced around the wetland. Socio-economic aspect of fishing in Chefa wetland should be studied in detail. Training on post-harvest loss prevention and preservation should be given for fishermen.

**Acknowledgements**
We would like to thank the Amhara Regional Agricultural Research Institute (ARARI), Bahir Dar Fish and Other Aquatic Life Research Institute (BAFARI), and Bahir Dar University for their assistance and support.
Center and Bahir Dar University for budget and logistic support which is required for field and laboratory work.

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Effect of water temperature on the growth performance and feed utilization efficiency of juvenile Nile tilapia, *Oreochromis niloticus* L., (1758) in aquaria

Kassaye Balkew¹, Shiferaw Ayele² and Zinabu GebreMariam³

¹,²&³ Department of Biology, Hawassa University, P.O. Box 05, Hawassa, Ethiopia

¹ E-mail: kassbat1@yahoo.com

Abstract

This study aims at investigating the effect of different water temperature on the growth performance and feed utilization efficiency of juvenile *Oreochromis niloticus* cultured in aquaria. The experiment was conducted in biology laboratory, Hawassa University, Ethiopia, Juvenile fish having average body weight of 4.18g and total length of 6.48 cm were collected from Lake Chamo and reared at 24, 26, 28, 30, 32 and 34 °C water temperature for 90 days. They were stocked in aquaria at a rate of 10 fish per 50 L of water. The fish were fed 10% of their body weight per day manually with locally available feed having 27% crude protein. At the end of the experiment, the mean total body weight, body weight gain, specific growth rate, feed conversion ratio and survival rate were computed and were found to be significantly (p<0.05) affected by water temperature. The growth performance and feed utilization efficiency of the juvenile *Oreochromis niloticus* was low at 24, 26 and 34 °C water temperature as compared with 28, 30 and 32 °C . The maximum growth performance and feed utilization efficiency of juvenile *Oreochromis niloticus* was observed at 32°C followed by
30°C, while the lowest growth performance was observed at 24°C water temperature. The growth performance of juvenile *Oreochromis niloticus* at 28 and 34 °C were similar. However, the colour of the fish reared at 34°C water temperature was reddish. This might be due to some physiological disturbance caused by high water temperature. In addition, there was an early sexual maturation of fish reared at higher water temperature (28-34°C). In conclusion, the best growth performance of juvenile *Oreochromis niloticus* was observed between 28 and 32 °C water temperature, whereas lower and higher temperature resulted slow growth performance and lower feed conversion efficiency. This study also demonstrated the possibility of *Oreochromis niloticus* and other warm fresh water fish culturing could be considered for supplementary food production and means of livelihood.

**Key words:** Water temperature, aquarium culture; growth performance; feed conversion efficiency, *Oreochromis niloticus*

1. **Introduction**

Nowadays, the demand of fish food is increasing throughout the world due to the recognition of their nutritional value (Tingman et al, 2010). In addition, the rise of food price and rapid world population growth increase the demand of fish consumption (FAO, 2010). For this reason, there are varieties of farming fish species such as tilapia which are expected to increase the world fish production. Tilapia are the second largest farmed fish group in the world next to carp (El-Sayed, 2006). The most commercially cultured species in the global tilapia farming was dominated by three species namely: *Oreochromis niloticus, Oreochromis*
mossambicus and Oreochromis aureus (Suresh, 2003). Of these, Oreochromis niloticus is by far the most widely cultured fish in the world tilapia production and accounted for over 81% of the total cultured tilapias; Bentsen et al., 1998, Suresh, 2003, Pillay and Kutty, 2005, El-Sayed, 2006).

The worldwide expansion of Oreochromis niloticus faming is because of its tolerance to a wide range of environmental conditions factors such as pH, temperature nitrogen wastes, dissolved oxygen concentration and its easiness for handling practices (Fitzsimmons, 2004, Noor and Mona, 2010). However, most tilapias do not feed and grow at lower water temperature. Water temperature is known to be critical factor that influence the growth performance of tilapia (Britz et al., 1997, Azevedo et al., 1998). Although, there are lots researches done on tilapia worldwide, there is little or no study conducted in Ethiopia, to determine the optimum growth and feed utilization efficiency of Oreochromis niloticus at different water temperature. Therefore, the present study was conducted to investigate the effect of different water temperature on the growth performance, feed utilization efficiency and survival rate of juvenile Oreochromis niloticus. in aquaria under controlled system.

2. Materials and Methodology
2.1. Aquaria set up and experimental design
The study was conducted in biology laboratory, Hawassa University, Ethiopia using glass aquaria having 80cm x 30cm x 35cm size with the capacity of 50 L water. The water in
Aquaria was aerated by a constant supply of compressed air pump and was changed in two days interval with 100% of the water volume with fresh aerated tap water. Juvenile *Oreochromis niloticus* of mixed-sex were collected from Lake Chamo using a 50m length and 2.5m width beach seine (indicate the mesh size mesh) whose stretched length was 20mm. Immediately after capture, juvenile *Oreochromis niloticus* of the required sizes were sorted manually and kept in plastic bags to be transported to Hawassa. Polyethylene bags containing about 50 liters of water were used to transport 100 individuals of juveniles *Oreochromis niloticus*. Pure oxygen was provided for the fish using oxygen cylinder containing 11 litters. Juvenile *Oreochromis niloticus* which were transported in oxygenated bags were transferred into aquaria for acclimatization. The acclimatization period lasted for three weeks until the fish become more active and the mass mortality due to transportation stress stopped. During the acclimatization period, dead and weak fish were removed daily from the aquaria before the start of the actual experiment.

After acclimatization, juveniles *Oreochromis niloticus* having an average body of weight 4.18g and length of 6.48cm were stocked in 50 L glass aquaria at the rate of 10 fish per aquarium. Fish were reared at a fixed water temperature of 24, 26, 28, 30, 32 and 34 °C for 90 days. A 2.0 KW immersion thermostatic heater with a temperature regulator was
installed in each aquarium to maintain the required water temperatures.

The experimental fish were manually fed five times a day with locally available fish feed which is prepared in biology laboratory. The fish were fed 10% of their body weight per day (Abdel-Tawwab, 2004). The nutritional composition of the diet used for the experiment contains 27% crude protein. The amount of daily ration is adjusted once in two weeks based on change in body weight of the fish. Thus, the amount of daily feed ration (DFR) was calculated and adjusted using the average body weight (ABW) and the total number of the fish (N) and the feeding rate per day (FR d⁻¹) using the following formula: DFR=ABW×N×FRd⁻¹ (Nandlal and Pickering, 2004).

2.2. Data collection and analysis
During the experiment, water quality parameters such as temperature, dissolved oxygen concentration, pH and water conductivity was measured daily using Hydrolab, Model “Multi 340I/SET. To determine the growth performance of juvenile Oreochromis niloticus, all fish were sampled every two weeks for measuring their body weight and body length to the nearest 0.1 gram and 0.1 cm respectively. Mortality of fish from each aquarium was regularly recorded throughout the experiment.

Based on the data collected during the experiment, growth performance such as final body weight (FBW), body weight
gain (Wg), specific growth rate (SGR); feed conversion ratio (FCR), gross fish yield (GFY) and rate of survival were calculated as described by Hardy (2002) and Ridha (2006):

\[
Wg (g) = Wf - Wi
\]

\[
SGR (% day^{-1}) = \frac{((lnWf - lnWi)/dt)) \times 100}{dW/dt}
\]

\[
FCR = \frac{FI (g)}{Wg (g)}
\]

\[
GFY = \frac{Wf}{Wv}
\]

\[
\text{Survival rate} \% = \frac{(NSF - NDF/NSF) \times 100}{NSF}
\]

Where: \(Wf\) and \(Wi\) are the final and initial body weight of the fish, respectively, \(dt\) is the time interval in days during the study period, \(FI\) is amount of feed intake (g) in dry weight basis, \(Wg\) is weight gain in gram (g), \(Wv\) is the total water volume used for culturing fish in \(m^3\), \(NSF\) and \(NDF\) are number of stocked and dead fish during the experiment, respectively.

2.3. Statistical Analysis
Mean growth performance parameters, feed conversion ratio and survival were analysed using analysis of variance (General Linear Model). T-test and Turkey test were used to identify the mean value differences for the analysis of variance. Statistical significance was determined at \(p<0.05\). All calculations were performed using SPSS 14 version statistical software.

3. Results
The mean value of some water quality and growth parameters were calculated and summarized in Table 1 and 2. According to Table 1, all the aquaria have similar water quality parameters and were not significantly different.
The different growth parameters of juvenile *Oreochromis niloticus* reared at different water temperatures were summarized in Table 2. All values were calculated based on results obtained in the 90 days experimental period. The highest and the lowest mean body weight and weight gain were observed at temperature 32°C (57.24g) and 24°C (29.32g), respectively. The highest specific growth rate was also achieved at 32 °C (2.93% day⁻¹) followed by 30 °C (2.79 % day⁻¹), while the lowest specific growth rate was observed at 24 °C (2.10 % day⁻¹). Similarly, the highest daily growth rate was observed at 32 °C water temperature (0.59g fish⁻¹ day⁻¹) followed by fish reared at 30 °C. The best mean food conversion ratio was achieved at 32 °C water temperature (2.43) followed by 28°C (2.47), while the poorest food conversion ratio was achieved at 24°C water temperature (2.83). In general, optimum growth performance of juvenile *Oreochromis niloticus* was achieved between 28 and 32 °C water temperature. However, the growth performance of juvenile *Oreochromis niloticus* at 28 and 34 °C water temperature was almost similar except that the fish reared at 34 °C developed red colour around fins and operculum. The general order of growth performance of *Oreochromis niloticus* wass 32>30>28>34>26>24°C (Fig 1).
Table 1: Some water quality parameters measured (mean ± sd) in experimental aquaria set at different water temperatures

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>pH</th>
<th>DO (mg l⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>8.27 ± sd a</td>
<td>6.7 ± sd b</td>
</tr>
<tr>
<td>26</td>
<td>8.24 ± sd a</td>
<td>6.7 ± sd b</td>
</tr>
<tr>
<td>28</td>
<td>8.18a</td>
<td>6.2b</td>
</tr>
<tr>
<td>30</td>
<td>8.21a</td>
<td>6.3b</td>
</tr>
<tr>
<td>32</td>
<td>8.32a</td>
<td>6.7b</td>
</tr>
<tr>
<td>34</td>
<td>8.30a</td>
<td>6.5b</td>
</tr>
</tbody>
</table>

*Mean values in the same column having the same letters are not significantly different (P>0.05)*
Table 2: Growth parameters of juvenile Nile tilapia (*Oreochromis niloticus*) reared in aquaria under different water temperatures.

<table>
<thead>
<tr>
<th>Growth Parameters</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Initial mean body weight (g fish⁻¹)</td>
<td>4.20a</td>
</tr>
<tr>
<td>Final mean body weight (g fish⁻¹)</td>
<td>29.32a</td>
</tr>
<tr>
<td>Mean body weight gain (g fish⁻¹)</td>
<td>25.12a</td>
</tr>
<tr>
<td>Specific growth rate (% day⁻¹)</td>
<td>2.16a</td>
</tr>
<tr>
<td>Daily growth rate (g fish⁻¹ day⁻¹)</td>
<td>0.28a</td>
</tr>
<tr>
<td>Feed conversion ratio</td>
<td>2.83a</td>
</tr>
<tr>
<td>GFY</td>
<td>3.67a</td>
</tr>
<tr>
<td>Survival rate</td>
<td>100%</td>
</tr>
</tbody>
</table>

* Mean values in the same row having the same letters are not significantly different (P>0.05)
Fig. 1: The overall trend in the growth performance of juvenile *Oreochromis niloticus* reared in aquaria at different water temperatures.


Socio-economic assessment of the fishery in Rivers Borkena and Mille Awash Basin, Ethiopia

Assefa Tessema¹, Minwyelet Mingist² and Eshete Dejen³

¹Wollo University, Department of Applied Biology. E-mail: asefao9@yahoo.com
²Bahir Dar University, College of Agriculture and Environmental Sciences, Department of Fisheries, Wetlands and Wildlife Management. E-mail: minwyeletm@bdu.edu.et
³Food and Agricultural Organization, Sub-regional Office for Eastern Africa, Addis Ababa, Ethiopia. E-mail: dejeneshete@yahoo.com

Abstract
Socio-economic data of fishes from Dawachefa and Artumafursie districts around Borkena River and Tehulederie and Ambasel districts around Mille River were collected in May and April 2009. The objectives of the study were to assess the current fish production and post harvest handling of fishes in these rivers and recommend possible fishery management option to fishermen around these rivers. Structured questionnaires and Checklist were used to collect the necessary socio-economic data. Annual yield of fishes in these rivers were analyzed using the formula developed by Welcome, 1985. Univariate and Descriptive analysis were used to analyse the collected data. The annual fish yield of Mille River was 278.544 t/y higher than Borkena River, 154.176 t/y. There were 50 fishermen in Dawachefa and Artumafursie districts that engaged in Borkena River fishery, among these 30 were permanent and they were fully depend on fishery as their source of income and 20 were seasonal. The number of fishermen in Tehulederie and Ambasel districts that engaged in Mille River was 30, but all were...
seasonal fishermen. Most of the fishermen in Oromia zone (Dawachefa and Artumafursi) are dependent on river fishery fully as source of income, because they have no land for crop or animal farming. But the fishermen in Tehulederie and Ambasel are partially dependant on seasonal fishing. There was significant variation in income from fishing between fishermen around Borkena and Mille Rivers (P<0.05). The mean monthly income of fishermen around Borkena and Mille Rivers was 760 and 300 Birr respectively. Price of G. dembecha, Labeobarbus species and C. gariepinus was significantly different in Borkena and Mille Rivers (P<0.05). People around Mille Rivers prefer G. dembecha than other species to use it in Wedding ceremony. People around Borkena River prefer only C. gariepinus. The fishermen in Borkena River do not have the knowledge of fish processing. Therefore there should be training in fishery management and fish processing in these rivers.

Key words: Awash Basin, rivers, Socio-economic, Wedding

1. Introduction
The fishery resource has significant socio-economic contribution through generating income, employment and used as a cheap protein sources for local people in developing countries including Ethiopia (Sewmehon Demsie, 2003).

Ethiopia is endowed with sizable amount of lotic (running) and lentic (stagnant water) environments whose fishery potential has not yet been fully realized (Brook Lemma, 1987). The inland water body of the county is estimated at about 7,400 km² of lake area and about 7,000 km total length of rivers (Shibru Tedla, 1973). These water bodies harbor more than a hundred edible fish
species, and the annual potential fish yield of the main lakes is roughly between 30,000 and 40,000 metric tons (FAO, 1995).

Even though no systematic survey and assessment of the potential of all water bodies have been made, the rough potential harvest estimated from seven main lakes, two small lakes and one reservoir covering a total area of 7,005 km² was about 51,500 tons of fish per year (Eshete Dejen, 2008).

The fishery industry in our country has many limitations as indicated in different sources of materials done by scholars, especially in post harvest technologies. These studies showed that post harvesting of fish require careful handling, processing and preservation in order to provide quality and quantity products to the market (cite the studies).

In the process of handling these products more than 50% of the total catch has been estimated as post harvest losses in some developing countries (FAO, 1981). According to Sewmehon Demssie (2003) some 50% of the total landing was discarded and lost due to poor handling and distributing and this accounts for high economical loss. Hence, the objectives of the study were to assess the current fish production and post harvest handling of fishes in Rivers Borkena and Mile and recommend possible fishery management options to fishermen around these rivers to improve food security and reduce malnutrition.
2. Materials and Methods

2.1. Study Area

Awash basin has three main catchments, upper, middle and lower Awash. Rivers Borkena and Mille are found in lower Awash with catchment area of 3212 km² and 5803 km², respectively. Borkena and Jara are the main tributaries of Borkena River. Genale, Wekele and Tekre are major tributaries of River Mille (Wehner, 2001). Borkena River is located at latitude of 11.65° N and longitude of 39.65° E whereas Mille River lies at latitude of 11.63° N and longitude of 39.8° E. Borkena River has three sub-basins: Dessie, Kombolcha and Chefa (Tadesse Ketema, 1980). River Mille has two sub-basins: upper and lower Mille. Both Borkena and Mille originate from South Wollo, Borkena from Kutaber and Mille from Ambasel and Tehulederie Woredas (SWA, 2006)
2.2. Method of data collection

Structured questionnaires, personal observation and checklists were administered in Kebeles near Borkena (Gulo, Chefa and Chereti) and Mille Rivers (Jara, Basomille and Chefie). Fishermen in these Kebeles were randomly selected for data generation. Moreover, two focus groups were considered for additional information about the fishery status in both rivers by consulting key informants using participatory rural appraisal (PRA). The information collected
include number of fishermen and their family dependants, family size, type of fishing gears used, type of fish caught, number of fish caught per week, fish consumption habits and preference etc. Empirical model of Welcome (1985) was used to estimate the annual fish production of the two rivers. The model gives rough estimate which is based on area. According to Welcome (1985) fish yield in rivers can be calculated using yield models for rivers as stated below:

\[
\text{Catch} = 0.048 \times \text{drainage Area}, (r = 0.95)
\]

2.3. Statistical analysis
Descriptive statistics and univariate analysis were used to analyze the collected data using SPSS software.

3. Results and Discussion
3.1. Fish composition
Clarias gariepinus, Labeobarbus intermedius, Labeobarbus nedgia and Gara dembecha are found in River Borkena and in addition to the above fish species Labeo horie and Varicorhinus beso are also common in River Mille. However, it is only the catfish, C. gariepinus which is caught by the local people in Borkena River. Whereas in Mille River all the six species found in the River are used by the local people. The diversity of fish species found in the two rivers was low as compared with the 27 fish species reported from Rivers Ayma, Guang, Shinfa and Gendewuha (Dereje Tewabe, 2008). Similarly the number of economically important fish species in these two rivers was much less (6) than the number (19) of...
species reported from rivers in Gambella region by Gashaw Tesfaye et al. (2011)

3.2. Fishermen categories and practices
According to Berihun Tefera et al. (2009) there are four categories of fishermen involved in Lake Tana and rivers around lake Tana, these are: full time fishermen, seasonal fishermen, contractual fishermen and part-time fishermen. In Borkena and Mille Rivers unlike the case mentioned above, there are only two types of fishermen, seasonal and full time fishermen participating in river fishery. There were about 50 fishermen in Oromia zone who are engaged on Borkena River, among these 30 were full time fishers and fully depend on fishery as their source of income. The remaining 20 were seasonal. The number of fishermen engaged in Mille River was around 30, and all were seasonal fishermen (OARD, 2010). Most of the fishermen in Oromia zone (Dawachefa and Artumafursie) were fully dependent on river fishery as source of income because they have no farm land to grow crop or raise animals. But the fishermen in South Wollo are partially dependant or seasonal fishers.

Fishing gears used by the fishermen are based on the preferred fish type demanded both by consumer and fishers. In Oromia zone, the people preferred to eat catfish and the fish gears used beach seines, spear and hook which are good in catching catfish. But in South Wollo the people consume all fish species in Mille and hence the fishing gears used include cast nets, gillnets, mosquito net and local hives.
3.3. Fish consumption and production potential

The presence of Chefa wetland in Oromia Zone along Borkena River in Chefa sub basin contributes to the high production of *C. gariepinus* around Borkena River than Mille River. Therefore Gulo, Chefa and Chereti Kebeles were the highest *C. gariepinus* producer in kg per week, 41.8, 35 and 28 respectively (Table 1). Price of *G. dembecha*, *Labeobarbus* and *C. gariepinus* was significantly different between South Wollo and Oromia Zone (P<0.05). Even though, there was high potential of *G. dembecha* and *Labeobarbus* species in Borkena River, the people and the fishermen lack the skill of fish processing (Fletting, gutting and avoiding tiny bones) these fish. The people in Oromia zone have good feeding habit of *C. gariepinus* as the result the price of this fish is higher than in South Wollo.

Fishermen and the people in South Wollo have better knowledge of fish processing and hence all type of fish species (*C. gariepinus, G. dembecha, Labeobarbus V. beso and L. horie*) have better price (Table 2). The people around River Mille prefer *G. dembecha* than other fish species, because they use the fish as spice for making fish sauce (wot), especially during wedding ceremony.
Table 1: Weekly fish production in kg from Borkena and Mille Rivers

<table>
<thead>
<tr>
<th>Zone</th>
<th>Woredas</th>
<th>Kebele</th>
<th>Mean fish in kg per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oromia</td>
<td>Dawachefa</td>
<td>Gulo</td>
<td>41.8</td>
</tr>
<tr>
<td></td>
<td>Artumafursie</td>
<td>Chefa</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Artumafursie</td>
<td>Chereti</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Tehuledere</td>
<td>Jari</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>Ambasel</td>
<td>Chefie</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Tehuledere</td>
<td>Worteye</td>
<td>11.3</td>
</tr>
<tr>
<td>South Wollo</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The riverine fish potential of Borkena river was better associated with high biodiversity supported by the Chefa wetland. However, there is higher catchment degradation associated with overgrazing by pastoralists that come every year especially during the dry season from different localities such as Afar and the surrounding Oromia districts. In addition to this, there is high completion to use the water of Borkena River for irrigation to harvest horticultural crops. This intensive withdrawal of water from the river is becoming a problem for fishery production.

The area of Mille and Borkena Rivers are 5803 km² and 3212 km² respectively and their annual fish yield was calculated to be 278,544 t/y for River Mille and 154,176 t/y for River Borkena. The yield obtained following Welcome (1985) for Mille River was higher than Borkena River, but currently the result obtained during sampling was much lower for Mille than
Borkena River. This might be due to the catchments degradation and pollution released from Dessie Tannery.

River Borkena in its lower basin at Chefa is found in Chefa flood plain and hence was better than Mille River in its fish production similar to mentioned above. The total area of ponds available to fish as refuges and the intensity of fishing in these ponds are two parameters likely to influence the decolonization rate and therefore the catch the following season. The fish production in Oromia zone is decreasing from time to time due to high intensity of fishing and reduction of pooling areas due to irrigation activities.

However the people in South Wollo G. dembecha (Fishers and Consumers) have the knowledge of processing all fish species to make ready for meal. As the result all fish type caught from Mille River is equally consumed.

### 3.4. Fishing income

Univariate analysis showed that income generated from fishing showed significant variations among Kebeles with fishing activities (P<0.05). There was significant variation in fishing income between River Borkena, Oromia Zone and River Mille, South Wollo (P<0.05). In Oromia Zone fishermen generate more money from River Borkena than South Wollo from River Mille (Table 3). This is because of the higher C.gariepinus production from River Borkena and higher price of the fish around Kemisse. The mean income generated from fishing has direct relation with fishing experience. Because fishermen
knowledge in fishing and fishing site selection will be improved though experience.

Table 3: Monthly income from fishing from two rivers

<table>
<thead>
<tr>
<th>Zone</th>
<th>Woredas</th>
<th>Kebele</th>
<th>Income in Birr (Mean and SD)</th>
<th>Fishing experience in years (Mean and SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oromia</td>
<td>Dawachefa</td>
<td>Gulo</td>
<td>700±135.4</td>
<td>5.6±4.6</td>
</tr>
<tr>
<td></td>
<td>Artumafursie</td>
<td>Chefa</td>
<td>533.33±208.2</td>
<td>9±8.2</td>
</tr>
<tr>
<td>South Wollo</td>
<td>Artumafursie</td>
<td>Chereti</td>
<td>760±371.5</td>
<td>13.8±9.4</td>
</tr>
<tr>
<td></td>
<td>Tehulederie</td>
<td>Jari</td>
<td>300±81.7</td>
<td>8±6.9</td>
</tr>
<tr>
<td></td>
<td>Ambasel</td>
<td>Chefie</td>
<td>240±114</td>
<td>7.8±4</td>
</tr>
<tr>
<td></td>
<td>Tehulederie</td>
<td>Worteye</td>
<td>100±0.0</td>
<td>8.3±9.3</td>
</tr>
</tbody>
</table>

3.5. Post harvest handling

There is no surplus fish production in both areas. Market areas are close to the production and even the price that they sold kg of fish is better than Lake Tana and Tributary Rivers. The fishermen in Oromia zone, Borkena River have no experience in processing *Labeobarbus* and other small fish species which are economically important fish in South Wollo, Mille Rivers. Preservation is not commonly practiced in both areas due to market accessibility and good price for fresh fish in the surrounding markets.
3.6. Problems in fishing activities
Main problems mentioned by fishermen in both Rivers Borkena and Mille areas were lack of effective fishing gears for river fishery, lack of knowledge of fishing, fish processing especially in Borkena area, lack of post harvest technology in case of fish excess production, reduction in water volume in both rivers during dry season. In addition to the above problems, pollution from industries is also a new problem in both rivers. But the problem is more severe in Mille River, because there is high pollution load from Dessie Tannery factory which is very close to the upper Mille near Jari. According to the fishermen contacted in Mille during field study, they have observed fish killed by this pollution and their cattle were also poisoned.

4. Conclusions and recommendations
*C. gariepinus* is economically the most important fish species in River Borkena. *G. dembecha* was the most preferred fish species in River Mille especially for preparing wot during Wedding ceremony. The people around Borkena River should get training on how to process *Labeobarbus* efficiently and economically. Socioeconomic aspect of fishing in Both Borkena and Mille Rivers should be studied in detailed. Training on reducing post harvest loss and preservation methods should be given for fishermen in both Borkena and Mille Rivers.
Acknowledgements
I would like to thank the Amhara Regional Agricultural Research Institute (ARARI), Bahir Dar Fish and Other Aquatic Life Research Center and Bahir Dar University for financial and logistic support which is required for field and laboratory work.

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Spatial and temporal distributions and some biological aspects of commercially important fish species of Lake Tana, Ethiopia

Dereje Tewabe
Amhara Regional Agricultural Research Institute (ARARI), P.O.Box 794, Bahir-Dar, Ethiopia, E-mail: drjetewabe@yahoo.com

Abstract
The distribution of fish species in Lake Tana was studied from November 2009 to July 2011 based on samples collected every other month using gill-nets of 60, 80, 100, 120 and 140 mm stretched mesh size. *Labeobarbus* species, *Claris gariepinus*, *Oreochromis niloticus*, and *Varicorhinus beso* are commercially important fish species and form 68 %, 18 %, 14 % and 0.5 % of the pooled experimental fish catch. There was significant variability among years and sampling sites of both temporal and spatial aspects, Mann–Whitney U tests were used for pair wise comparisons of sites and years. Population densities of *Labeobarbus* spp. and *V. beso* were significantly declining, in contrast, the composition of *O. niloticus* did not change, but *C. gariepinus* increased by 100 % in catch composition. The most likely explanations for the total decline in abundance of fish species are the increase of the illegal commercial gill-net fishery targeting their spawning aggregations in the wetlands and river mouths, and the increasing trend of the degradation of spawning and nursery habitats both in the lake and major tributary rivers of the catchment area. Therefore, there
should be a need for urgent development of a management plan focusing on ensuring sustainable utilization of a resource by fishing effort, gear mesh size and gear type restrictions, and control the spawning grounds from different type of human encroachment and design closing seasons and spawning grounds during the breeding seasons of different fish species of Lake Tana.

**Key words:** *Clarias gariepinus*, breeding season, size at first maturity, spawning migration and species composition

1. Introduction

Since Ethiopia is a land locked country, it depends only on inland water resources for the supply of fish as a low-cost protein source. Ethiopia could be described as the water tower of Eastern Africa in a continent, which is, for the most part, arid. The inland water body of Ethiopia is estimated at about 7400 km² of lakes and reservoirs and a total river length of about 7000 km (Wood and Talling, 1988). The total annual discharge of rivers was 63 billion cubic meters of which the Blue Nile accounts for 80 % (Aubrey, 1975).

There are over 180 species of fish and numerous other aquatic resources in Ethiopian drainage systems, of which the Lake Tana sub basin with diverse ecosystem (the lake, the wetlands and the rivers) supports unique endemic *Barbus* spp. flock (Nagelkerke, 1997). There is one cichlid, *Oreochromis niloticus* (Nile tilapia), which is the most widely spread tilapia species in Africa. The
catfish family (Clariidae) is also presented by one species, *Clarias gariepinus* (African catfish), which is the most common member of the genus (Teugels, 1986). This species is a facultative piscivore, feeding occasionally on fish as well as on zooplankton, benthic invertebrates and algae (source). The largest fish family in the lake is the Cyprinidae which are represented by five genera: *Varicorhinus*, *Garra*, *Labeobarbus* and *Barbus*. *Varicorhinus* is represented by a single species *V. beso* which scrapes algae from substrates, and which is a common species in the rivers and lakes of the Ethiopian Highlands. The genus *Garra* is represented by four species in Lake Tana, *G. dembecha* Boulenger which is common and generally distributed in the Ethiopian Highlands, *G. dembeiansis* found on the northern part of Lake Tana and two endemic species, *G. microstoma* and *G. tana*, recently described by Abebe Getahun (2002). The fish community contains furthermore three diploid species of small (< 10 cm) barbs: *Barbus humilis*, *B. pleurogramma* and the recently described *B. tanapelagious* (De Graaf, 2003). The last two species are endemic to L. Tana, *B. pleurogramma* is mainly present in the wetlands around the lake, *B. humilis* is a littoral species, whereas *B. tanapelagious* is common in the large pelagic zone of the lake.

However, the four main genera/species targeted by Lake Tana fishery are a species flock of the endemic large *Labeobarbus* spp., African catfish (*Clarias gariepinus*), Nile tilapia (*Oreochromis niloticus*), and *Varicorhinus beso*. Despite this unique fish biodiversity and and its high economic value, fish resources are under pressure from several threats. The major threat include illegal fishing followed by habitat destruction (wetland, rivers and
the lake itself) due to unwise human intervention. The purpose of this study was therefore, to assess the current spatial, temporal distributions and some biology of commercially important fish species of Lake Tana. (I think a lot has been studied on the distribution and biology already. What is the justification for this study?

2. Material and methods

2.1. Study area description

The study was conducted in the southern and northern part of Lake Tana (source of the Blue Nile). The lake is the largest (3150 km$^2$) in Ethiopia, comprising 50 % of the total freshwater resources of the country. It is a shallow lake with a mean depth of 8 m and maximum depth of 14 m. It is situated at 1800 m above sea level and seven large, permanent rivers and about 40 small seasonal rivers feed the lake.

Lake Tana is oligotrophic to mesotrophic lake (Nagelkerke, 1997; Tesfaye Wudneh, 1998). Its bottom is volcanic basalt mostly covered with a thin layer of organic matter (Howel and Allan, 1994) and the Bahir Dar Gulf and Mehal Zegie area is also covered by plant debris. The Lake Tana area has a warm climate with mean annual rainfall of about 1564 mm, of which 59 percent falls in the months of July and August.

2.2. Sampling sites and data collection

A total of six sampling sites located in the southern and northern parts of Lake Tana were sampled every other month from November 2009 to July 2011. The mesh sizes of the gill-
nets used were 60, 80, 100, 120, and 140 mm stretched mesh and the size of each mesh panel was 3 m x 50 m. The various mesh sizes were chosen because the gill-nets must be able to efficiently catch the whole range of species and size classes.

Fig. 1: Study area description, indicating the study sites. Key: 1- Dirma River mouth 2- Sekela open water 3- Gedamat Littoral habitat 1*- Abay River mouth 2*- Zegie open water and 3*- Gerima littoral habitat.

Five panels were combined to form one multi-mesh gill-net. Fish sampling methodology was standardized throughout the project to ensure comparability within and among years. The nets were set at 6:00 pm and collected at 6:00 am and the catch data were adjusted to units of catch per trip as a standard estimate of relative abundance.
Representative sampling sites/habitats were selected. These were Abbay, Zegie, and Gerima in the southern part, and Dirma, Sekela, and Gedamat in the northern part of the lake (Fig. 1). The sites selected reflect the different habitat types present in the lake such as river mouths, deep water, muddy or rocky bottoms, and dense stands of aquatic macrophytes. The Dirma and Abbay sites are representatives of river mouth habitats. Sekela and Zegie represent a habitat of open water (> 9 m) and Gerima and Gedamat represent a habitat of shallow water with dense stands of aquatic macrophytes. Littoral habitat in the southern part is similar to the northern part except that the human influence is significantly larger in the southern part.

Immediately after capture all specimens of total length, fork length, standard length and body weight were measured to the nearest 0.1 cm and 0.1 gm precision of length and weight respectively. Gonads of fishes was analyzed based on five maturity stage categories immature (i), developing virgin or recovering spent (ii), ripening (iii), ripe (iV) and spent (V). Of these maturity stages iii, iV and V were considered as matured gonads (Holden and Raitt, 1974).

2.3. Data analysis
Data were analyzed using statistical soft wares and simple descriptive statistics. PASGEAR, SAS for windows version 2.4 and Mintab for windows version 14 were used for analysis. An Index of Relative Importance (IRI) and Shannon diversity index
(H') were used to evaluate relative abundance and species diversity of fishes, respectively.

3. Results and discussion

3.1. Composition and abundance of fish

A total of 1111 specimens representing 16 species in three families were collected from six sampling sites which represent river mouth, open water and littoral habitats. Catch compositions of Varicorhinus beso, Nile tilapia (Oreochromis niloticus), African catfish (Clarias gariepinus), and species flock of endemic, large Labeobarbus spp. were the four main species groups targeted by exploratory fishery program of Lake Tana and form 0.5%, 14%, 18%, and 68% of the pooled annual catch compositions by number of fish species during the study period respectively (Fig. 2). Clarias gariepinus catch composition increased significantly from 9% to 18% this is probably due to less demanded by the consumers as a result not targeted by fishers. Oreochromis niloticus catch composition has not show significant change. Goraw Goshu et al. (2010) reported a total of 14 878 specimens representing 18 species in three families were captured from the river mouth, open water and littoral habitats of the same sampling sites and duration of study periods as the present study and catch compositions by number was Labeobarbus spp. and O. niloticus formed 77% and 13%, and C. gariepinus and V. beso formed 9%, and 1% respectively. Of the Labeobarbus species; Labeobarbus macrophthalmus and Labeobarbus dainellii are missed from the total catches of the study periods. The composition in terms of fish weight also
followed the same trend as a result *Labeobarbus* spp. and *C. gariepinus* formed 54.5 % and 31.4 %, and *O. niloticus* and *V. beso* formed 14.1 % and 0.2 % (Table 1). The *Labeobarbus* spp was composed of 15 large Labeobarb species. Among the *Labeobarbus* spp., *L. intermedius* dominated the catch by weight 24.3 %, 8.6 % and 4.5 % followed by *Labeobarbus crassibarbis* and *Labeobarbus megastoma* respectively (Table 1).

Table 1: Species catch composition and IRI

<table>
<thead>
<tr>
<th>Species</th>
<th>No</th>
<th>% No</th>
<th>Weight (kg)</th>
<th>% Weight</th>
<th>FRQ</th>
<th>% FRQ</th>
<th>IRI</th>
<th>% IRI</th>
<th>H'</th>
<th>J'</th>
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<td>3.4</td>
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<tr>
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<tr>
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### Table 2: Average number and weight of fishes caught per set of experimental gillnets

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<tr>
<th>Species</th>
<th>No.</th>
<th>% No.</th>
<th>Weight(kg)</th>
<th>% Weight</th>
<th>No/set</th>
<th>SD No/set</th>
<th>Weight(kg)/set</th>
<th>SD Weight(kg)/set</th>
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</thead>
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<tr>
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<td>199</td>
<td>17.9</td>
<td>126.668</td>
<td>31.4</td>
<td>0.7</td>
<td>1.2</td>
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<td>41.5</td>
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<td>1.7</td>
<td>2.6</td>
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<td><strong>403.933</strong></td>
<td><strong>100</strong></td>
<td><strong>4.1</strong></td>
<td><strong>3.9</strong></td>
<td><strong>1.5</strong></td>
<td><strong>1.6</strong></td>
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Table 3: Gillnet selectivity of 6 cm, 8 cm, 10 cm, 12 cm and 14 cm stretched mesh sizes

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<th>Gil,10</th>
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<th>Gil,14</th>
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<td>117</td>
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<td>10.5</td>
<td>6.4</td>
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<tr>
<td>SD No/set Length (cm)/NO</td>
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<td>3.8</td>
<td>2.7</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Length (cm)/NO</td>
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<td>35.5</td>
<td>37.4</td>
<td>40.5</td>
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<tr>
<td>SD Length (cm)/NO</td>
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<td>11.7</td>
<td>11.5</td>
<td>16</td>
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<td>Weight (g)/NO</td>
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Table 4: Maturity stages by sex

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</tr>
<tr>
<td>Total</td>
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<td>734</td>
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</table>

3.2. Spatial distribution
The total percentage distribution of fish caught by number and weight respectively during the research period in the river mouths of Abbay and Dirma were 33.6 %, 41.7 % and 13.8 %, 11.6; open water of Zegie and Sekela were 10.1 %, 12.9 % and
8.1 %, 6.8 % and shore habitats of Gedamat and Gerima were 20.7 %, 18 % and 13.5 %, 8.8 % respectively. There were significant spatial differences in the numbers and weight of fish among the habitats of the experimental gill net catch (p < 0.05, n = 3*48, Kruskal wallis H test). The river mouth habitat had significantly higher numbers of fish and fish weight followed by shore vegetative habitat and the open water station had the lowest than others (Fig. 3). Despite its importance of catch abundance, river mouth Dirma and shore habitat Gerima are sampling sites where human encroachment pressure is very high including heavy fishing, as a result it registered the lowest catch composition.

The *Labeobarbus* spp. was the most dominant species in Lake Tana, this species comprised 58.2 % IRI of the catches, of which *L. intermedius* was the most abundant species according to IRI (50.7 %), while *L. tsanansis* was second (1.8 %) and *L. crassibarbis* third (1.6 %) in the total catch (Table 1). The second most dominant commercially important fish species in the total catch was *Clarias gariepinus*; that comprised 31 % IRI (Table 1). *Oreochromis niloticus* was the third dominant species in the total catch, which comprised 10.8 % IRI. The average weight (kg) per set was registered 1.5 kg/set, which is very small catch harvested with 250 m gillnet length with 3m width set on over night. *Clarias gariepinus* was the first dominant fish species by weight, which was 0.5 kg/set followed by *L. intermedius* of 0.4 kg/set (Table 2).
Fig 2: Species catch composition of L.Tana through exploratory fishery program me

Fig. 3: Percentage of catch number and weight in sampling sites
Fig. 4: Length-Weight relationship of the dominant fish species: (upper) L. intermedius, (middle) C. gariepinus, and (lower). O. niloticus.
The role of aquatic resources for food security in Ethiopia

Fig. 5: Percentage of matured fishes of commercially important fish species of Lake Tana

Fig. 6: Percentage of matured fishes of *O. niloticus*, *C. gariepinus* and *Labeobarbus* spp. on monthly bases
Fig. 7: Size at first maturity of *L. intermedius* obtained by determining the average size at which 50% of the fish of both sexes reach maturity.

Fig. 8: Size at first maturity of *O. niloticus* obtained by determining the average size at which 50% of the fish of both sexes reach maturity.
Gillnet selectivity has made with in 6cm, 8cm, 10cm, 12cm and 14cm. Of those 6cm mesh size has caught 43.6% of the total catch by number followed by 8cm mesh size of 28.6%. The total catch distribution along experimental stretched mesh size gillnets 6cm and 8cm has shown significant difference among the others during the study periods (Table 3). This implies that, Lake Tana fisheries pressure has put a negative impact, that small sized fishes became more abundant than table sized ones. Mean length of fishes caught by different stretched mesh size gillnets showed an overlapped length differences when the fish caught by wider mesh sizes than the smaller mesh sized gillnets (Table 3).
3.3. Some biological aspects of dominant fish species

Length-Weight relationship: The relationship between total length and total weight for most dominant species of *L. intermedius*, *C. gariepinus*, and *O. niloticus* was curvilinear, and as a result the line fitted to the data was described by the regression equation shown in (Fig. 4). In fishes, the regression coefficient $b = 3$ describes isometric growth, when the value becomes exactly 3, if the fishes retain the same shape and their specific gravity remains unchanged during their life time (Ricker, 1975). If the weight increased according to the fish length it is said to be isometric growth (Mansor Mat Isa S.A.S.A., 2002). However, fishes may have “$b$” value greater or less than 3, a condition of allometric growth (Bagenal and Tesch, 1978). Therefore, according to the present study *O. niloticus* exhibits isometric growth, on the other hand *L. intermedius* and *C. gariepinus* exhibit negative allometric growth (Fig. 3). Opposite results from the present study (isometric growth) were obtained for *L. cf intermedius* by Demeke Admassu and Elias Dadebo (1997) in Lake Awassa and by Nagelkerke *et al.* (1997) in Lake Tana.

Sex ratio: During the sampling period, from the total population of catches those specimens which were considered matured by taking maturity stages of iii, iv and v as matured were 34 % of the population. Of the matured population, percentage of maturity for males was 53 % and for females 24 %. Of the 1111 fish samples 373 (33.57 %) were males while
the remaining 738 (66.43%) were females. The overall sex ratio of males to females was 1:1.9, this ratio was significantly different from the hypothetical ratio of 1:1 ($x^2$, p<0.05) (Table 4). Elias Dadebo et al. (2003) reported the same phenomena of predominantly higher proportion of females in larger size classes in another cyprinid fish _Labeo horie_ (Heckel) in Lake Chamo. This could be because of the difference in growth rate of both sexes where females attain larger size than males. Other biological mechanisms such as differential mortality rates, or differential migratory patterns between the male and female sexes may also cause unequal sex ratios (Matsuyama et al., 1988).

**Breeding season:** Matured fishes during the different time of a year was evaluated, as a result three months considered pick spawning seasons for commercially important fishes of Lake Tana, these are May, June and August (Fig. 5). The proportion of fish with ripe gonads was relatively low during the other months. The above mentioned months might be very important for management options of lake Tana to be closed seasons, so that spawners could have a chance not to be targeted by fishers.

The breeding season of _O. niloticus, C. gariepinus_ and _Labeobarbus_ fish species was determined from percentages of fish with ripe gonads taken monthly during the study periods. Therefore, May was found to be peack breading season for _C. gariepinus_, April for _O. niloticus_ and August belongs to the
peacock breeding season of *Labeobarbus* spp (Fig. 6). *O. niloticus* exhibited a long pick breeding season where intensive breeding activity occurred during the months of April, May and June in decreasing order. During the other months, even though considerable proportions of fish were found in breeding condition, their proportion was much lower than the main breeding season. Several environmental factors could be responsible for the high breeding activity of particular fish species such as change in temperature, water level, beginning of rainy season, change in conductivity (Elias Dadebo *et. al.*, 2003).

**Size at first maturity:** The percentage of male and female *L. intermedius*, *O. niloticus* and *C. gariepinus* species having gonad stages iii, iv and v (Holden and Raitt, 1974) in different lengths were plotted against length for each species and sex using the data from the study period. The average length at which 50 % of the *L. intermedius* males reached maturity was 25.9 cm FL while the length at which 50 % of the females attained sexual maturity was 35.7 cm FL (Fig. 7). The average length at which 50 % of the *O. niloticus* males reached maturity was 23.4 cm TL while the length at which 50 % of the females attained sexual maturity was 21.2 cm TL (Fig. 8). The average length at which 50 % of the *C. gariepinus* males reached maturity was 43.2 cm TL while the length at which 50 % of the females attained sexual maturity was 57.7 cm TL (Fig. 9). The sizes at 50 % maturity of the above different fish species of females were much higher than those reported by
other investigators of Lake Tana (Tesfaye Wudneh, 1998; De Graaf, 2003). Size at maturity is negatively correlated to the degree of fishing mortality. As the fishing mortality increases, fish population responds to the new environmental circumstances by changing their life history pattern in order to compensate the losses imposed by fishing activity (Wootton, 1998).

4. Conclusions and recommendations

The spatial and temporal differences of fish in terms of distribution and composition observed over the years. As a result there is ten fold declines in number of specimens caught and *L. macrophtalmus* and *L. dainalli* were totally missed from the composition of the present study compared with a study in eight years time interval. There has been also observed a significant species composition difference, which is more pronounced in *Labeobarbus* spp. that shifts from 77 % to 68 % of the total experimental catch and *V. beso* has dropped from 1 % catch composition of the former study period to 0.5 % of the present study, on the other hand *C. gariepinus* increased from 9 % to 18 % by composition. It is most likely that the commercial gill-net fishery targeting the spawning aggregations, illegal fishing with small mesh sized monofilament gillnets, beach seins, ecosystem degradation particularly spawning grounds through human encroachment, river disconnectivity and channelization had a harmful effect on the population densities and composition of the stock.
On top of this lack of enforcement actions on fisheries resource legislation had severe negative impact on the stocks of the shoreline spawning *O. niloticus* and *C. gariepinus*; and *Labeobarbus* spp aggregations at river mouths during spawning seasons.

In order to protect the breeding population of fishes fishing should be restricted in the shallow littoral areas and river mouths as well as up streams during the peak spawning months of the specified fish species. Since females start reproduction at larger size than males in the case of *L. intermedius* and *C. gariepinus* and at smaller size than males for *O. niloticus*, capture size of the stock should be determined taking into consideration the size at first maturity of females.

**Acknowledgements**

I am greatly obliged to the Ethiopian Institute of Agricultural Research (EIAR) and Amhara Regional Agricultural Research Institute (ARARI) for financing this research project.

**References**


Integrated tilapia-horticulture farming system at Sheled, Arsi, Oromia, Ethiopia

Daba Tugie and Tokuma Nagisho,
Zeway Fisheries Resources Research Center, P.O.Box 229, Zeway, Ethiopia
dtuge@yahoo.com

Abstract
The experiment was conducted to investigate integrated fish-horticulture farming system so as to maximize productivity and economic efficiency of small holders' farmers at Sheled. *Oreochromis niloticus* fingerlings with an average weight of 26.23 g were stocked at 2 fish m\(^{-2}\) density in earthen pond of 1,640 m\(^{2}\) area. The fish were supplemented with 70% Wheat bran and 30% Noug cake at 5% body weight twice a day for 216 days. Final weight of the fish was ranged from 85.4 to 273.5 g, with an average of 148.8±2.04 g. The mean daily growth rate and specific growth rate were 0.57±0.01 g day\(^{-1}\) and 2.23% respectively. The horticultures treatments were conducted simultaneously with fish raising under two groups (plots irrigated with direct river water and fish pond water). Each group has with two treatments and replications for Gurage Cabbage (*Brassica oleracea*) and Bombey Red Onion (*Allium cepa*) on 15 m\(^{2}\) for 76 growing days and 6.48 m\(^{2}\) for 81 days respectively. The estimated yield of *Brassica oleracea* under Group I of T\(_1\) (river water +0 fertilizer) was 85.80q/ha while yield of T\(_2\) (river water + fertilizers) of similar group was 106.20 q/ha. The extrapolated yield under Group II of T\(_1\) (fish pond water +0 fertilizer) was 140.60q/ha.

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whereas the yield of T2 (fish pond water + fertilizers) was 153.70q/ha. The yield obtained from T1 and T2 under Group II were significantly higher (P<0.05) than the T1 of Group I, but no significant difference (P>0.05) among T2 of Group I and T1 and T2 of Group II. Regarding to Allium cepa, the marketable estimated yield of T1 and T2 under Group I was 568.05q/ha and 593.64q/ha, respectively. The extrapolated yield under Group II from T1 was 657.56 q/ha while of the same group T2 was 604.50q/ha. Statistically there was no significant different (P > 0.05) of yield between both groups and among all treatments.

Keywords: Allium cepa, Brassica oleracea, fingerling, fish-horticulture, integrated, Oreochromis niloticus, Sheled

1. Introduction
Integrated fish-horticulture production system is designed to maximize productivity and economic efficiency of small holders' farmers. It enhanced the productivity per acreage of land and increased smallholders fish farmers' income. In many of the integration processes, fish production remained as the most important activity (Mukherjee T.K., 1995) and the other agricultural sector integrated with fish farm is to diversify farmers' income, create job opportunity for family, meet future protein, carbohydrate and vitamins demand. Most integrated agriculture-aquaculture systems use low levels of inputs and fall within the type of aquaculture (FAO, 2001).
Tilapia species are hardy and tolerant than most commonly farmed freshwater fish to high salinity and high ammonia concentrations, high yield potential and able to survive at low oxygen tension and wide range of water temperature for optimal growth and reproduction (Wohlfarth and Hulata, 1981; CTA, 1996; Berg, 2005 and SRAC, 2005). Tilapia harvest has surpassed 800,000 metric tons worldwide and it is only second to carps as the most widely farmed freshwater fish in the world (SRAC, 2005). The waste products of one biological system serve as nutrients for a second biological system in agriculture (Aquaponics 2010). The amount of nitrogen produced in fish pond from algae fixation, dead and decomposed algae, and aquatic animals, and unconsumed fish feed give additional nitrogen to the field. Algae may be employed for increasing soil fertility, as manure and blue green algae release fixed nitrogen, oxygen and increase soil phosphates (Bhatia K.N. 1993).

Onion (*Allium cepa*) is one of the most popular vegetable in the world with various species/type. Onion grows bi-annually for bulb and annually for seed production and grows between 500-2400 m altitude and the best growing elevation is between 700-1800 m with the optimal temperature from 18- 24 °C. Bombay Red Onion is more preferred by consumers and well adapted in Ethiopia. It matures depending on climatic conditions for bulb production up to 120 days and the production is ranged from 250- 300 q/ha under research situation (Lemma Desalegne and Shimeles Aklilu, 1993). Cabbage (*Brassica oleracea*) is native in western Europe, Mediterranean and temperate regional Asia while cultivated...
species are grown world wide and is remarkable for containing more important agricultural or horticultural crops (Brassica, 2010). Gurage Cabbage (*Brassica oleracea*) *Acephala* group is one of the preferred vegetable in mid rift Valley area, Ethiopia with high demand and widely cultivated in the southern part of the country. The aim of the study was to evaluate the integrated fish-horticulture farm production system in rift Valley (mid agro-ecology).

2. Materials and Methods

2.1. Description of the study area

Sheled community pond is found in Sheled Goto Peasant Association and located in semi-arid agro ecology at an altitude of 1700m in Zeway Dugida district, Arsi, Oromia regional state, Ethiopia. It is far away from capital city Addis Ababa about 175km to South direction. Sheled is known for its large irrigation site in the region and contributes a lot in horticulture and fruit productions. The pond was constructed in 1994/1995 for the purpose of irrigation by Federal Government and NGO's. Generally the area of the pond is (50m x 50m) 2500m² where the surface area covered by water is fluctuated even within a day by controlling the inlet and outlet using the water all the day for irrigation until decreased to less than (40m x 41m) 1,640m² area and 1m depth.
2.2. Fish production

Preparation of the pond and fish production process: The earthen pond of surface area 1640 m² with water depth from 1.0 to 2.0 m was partially drained to 1.0 m at the center and unwanted materials including wood branches, leaves and grass were removed. In addition to these trees’ branches, grasses and herbs were cleared. The pond was filled with water to an average of 1.30m gradually and after two weeks 3,295 Oreochromis niloticus fingerlings and post fingerlings (juveniles) with wide ranged of body weight 18 to 62.1 g and with an average weight of 26.23 g were collected from wild, Lakes Hora, Babogaya and Kuruftu and stocked at the socking rate of 2 fish/m² in October 2009.

Fish were fed a compound feed of 70% Wheat bran and 30% Noug cake in powdered form at 5% of their body weight twice a day (from 9.00 to 10.00 AM. and from 4.00 to 5.30 PM) for 216 rearing days. Feeding was done by hand casting/spread over the water. The feed rate adjusted frequently every month based on fish weight sample analysis. For sample collection small mesh size beach seine was used to catch the fish. After the fish caught transfer to buckets of 2/3 volume filled with water. The fish individual total length (TL) and total weight (TW) measured using measuring board and sensitive balance to minimum mm and 0.01 g respectively every month to harvesting period of 216 days.
Horticulture land preparation and production process: The selected plot/land ploughed and prepared for vegetable types on suitable site for irrigation and different plots allocated for individual vegetable types were organized under two groups where each group consisted of two treatments and three replications.

**Treatment I:** Plot area for Gurage Cabbage (*Brassica oleracea* *asephalla*) group; one treatment plot = 1.50m x 5.50m = 8.25m² for two groups under each group two treatments with three replications of each = 99m²

**Treatment II:** For Bombay Red onion (*Allium cepa*); one treatment plot = 2.50m x 1.50m = 3.75m² for two groups under each group two treatments with three replications of each = 45m².

**Table 1:** Treatments for each horticulture type:

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment I</th>
<th>Treatment II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>Irrigated horticulture farm with direct river water without chemical fertilizer</td>
<td>Irrigated horticulture farm with direct river water + inorganic fertilizer</td>
</tr>
<tr>
<td>Group II</td>
<td>Irrigated horticulture farm with water from the fish pond without chemical fertilizer</td>
<td>Irrigated horticulture farm with water from the fish pond + chemical fertilizer</td>
</tr>
</tbody>
</table>

Bombay Red Onion (*Allium cepa*) and Gurage Cabbage (*Brassica oleracea*) seedlings were transplanted on prepared plots (each plot 3.75m² of Onion and 8.25m² of Cabbage)
according to their designed plan under two groups where within each group, two treatments with their three replications without fertilizers and with fertilizers at the rate of (150Kg Urea and 200kg DAP per hectare for *Allium cepa* while 100Kg Urea and 200Kg DAP per hectare for *Brassica oleracea*). Onion transplantation was done respecting space between plants 3-4 cm. Vegetables growing were conducted simultaneously with fish raising period. Irrigating, weeding, hoeing and spraying of pesticides were carried out. Inorganic fertilizer application for both vegetables was based on recommendations of AdamiTulu Agricultural Research Center.

Both onion and cabbage were harvested at their matured stage on 81 and 76 experimental days, respectively.

2.3. Data collection and production

Horticulture data was collected once before harvested when the vegetables were matured to consume. During data collection sub-samples have taken respecting boarder effects or by excluding plants on the boarder of the plot.

Bombay Red Onion (*Allium cepa*) samples have taken when its bulb matured to harvest on the 81 days from two groups that each was with two treatments and three replications. Each sampled plot area was (2.16 m x 1m) 2.16m². During sampling operations were carried on, the stand count/number of plants on each line and plot, bulb length (cm), bulb diameter(cm) and bulb weight(g) were measured and
recorded. Marketable bulb size determined based on AdamiTulu Agricultural Research Center recommendation of bulb diameter ≥2.5cm and ≤6.5cm.

Gurage cabbage (*Brassica oleracea*) samples were collected when the leaf was matured. There were two groups where each has two treatments with three replications. After 76 growing days samples of each plot was collected from an area of (5m X 1m) 5m² considering border effects. During samples collection stem length (cm), number of matured leaves on each plant, individual leaf/blade length (cm), leaf/blade width (cm) and individual leaf weight (g) were measured and recorded at the end of 76 growing days.

2.4. Fish data Analysis

Fish data were analyzed using analysis of variance (ANOVA) single factor. The following data such as stocked fish initial weight (g), final weight (g) and amount of supplementary feed in % body weight and the following parameters were analyzed using the appropriate designed formulas.

The specific growth rate (SGR) in weight is which defined as the percentage increases in body weight per day.

\[
\text{Specific Growth Rate (SGR \% /day)} = \frac{\ln(\text{final weight (g)} - \text{initial weight (g)})}{\text{Culturing days}} \times 100
\]
Daily Growth Rate (DGR, g/day) = $\frac{\text{Final weight}(g) - \text{Initial weight}(g)}{\text{Experimental days}}$

Relative Growth Rate (RGR %) = $\frac{\text{Final weight}(g) - \text{Initial weight}(g)}{\text{Initial weight}(g)} \times 100$

2.5. Horticultural data analysis

Bombay Red Onion (*Allium cepa*) data and Gurage Cabbage (*Brassica oleracea*) data were also analyzed using ANOVA-single factor.

3. Results and Discussion

The experiment was conducted in October 2009, to study fish-horticulture integrated farm production system at Sheled irrigation site with stocking of 3,295 *Oreochromis niloticus* (tilapia nilotica) fingerlings and post fingerlings at the stocking density of 2 fish/m² in earthen pond of surface area 1,640 m² and 1.0-1.20m water depth. At 216 growing days, the fish were attained final weight ranged from 85.4 to 273.5 g with a mean of 148.8±2.04 g. The fish mean daily growth rate (DGR), Specific growth rate (SGR) and Relative growth rate (RGR) were 0.57±0.01 g/ day 2.23% day⁻¹ fish⁻¹ and 473.4% respectively. To evaluate the given feed for fish, the analyzed mean food conversion ratio was estimated to 1.503±0.003.

The wide variations of final fish size may be due to the stocked fingerlings/juveniles with wide size range 18 to 62.1 g with an average of 26.23 g collected from wild environment and because

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of the mixed sexes. As earlier working reports described, tilapia males grow faster than females and they are mostly bigger at the same age (CTA, 1996). Another investigation was supports the present study result specially, the daily growth rate of *O. niloticus* of mixed sexes was \((0.42 \pm 0.0; 0.52 \pm 0.04\) and \(0.68 \pm 0.04\) g) from fish culture conducted in fertilized earthen pond to evaluate three feed brans in Kenya (Liti, *et al.*, 2006). Comparing to the previous study, the daily growth rate of the tilapia of present study \(0.57 \pm 0.01\) g/day was relatively optimal. As reported from Rwanda fish farms the results that of mixed sexes Nile tilapia harvested on an average 100 to 200 g in earthen ponds depending on the intensity of management and varies from 10 to 12 months (Lieven Verheust & *et al.*, 1995). Fish weighs >145 g is desirable as the table size (Ashagrie & *et al.*, 2008).

In general, the results of present study of fish growth performance was very good when compared with different papers which mentioned above were reared in earthen ponds supplemented with different bran. The experiment of vegetables was conducted on commercially important type in the country such as Gurage Cabbage (*Brassica oleracea*) Acephala group and Bombay Red Onion (*Allium cepa*) integrated with fish that simultaneously with fish raising period.

The Cabbage yield obtained from all experimental and replications plots were separately analyzed and extrapolated to the yield per hectare (Table.1). The yield of T₁ (irrigated with fish pond water without fertilizer) and T₂ (irrigated with fish pond water +
fertilizer) under Group-II were significantly different (P< 0.05) than T₁ (direct river water without fertilizer) of under Group-I (Table.1). The T₁ yield under Group-II was higher than T₂ under Group I but not statistically significant different (P>0.05) (Table.1). There were no statistically significant differences (P>0.05) between T₁ and T₂ under Group-I, and T₁ under Group-II and T₂ under Group-I. Also when compared the yield under Group-II of T₁ and T₂ no significant difference (P>0.05) (Table.1). The yield obtained from T₁ under Group-II irrigated with water from fish pond extrapolated to 140.6q/ha was greater by 32.39% of T2 yield under Group-I extrapolated to 106.2q/ha irrigated with river water with chemical fertilizer.
Individual plant parameters such as stand count, plant length, leaf number, blade/leaf length, blade/leaf width and leaf weight were contributors for the variation of yield of each treatment of the experiment (Table 2). There is no difference between mean leaf weight under Group II, T₁ and T₂ while different was observed with Group I treatments. The marketable bulb Bombay Red Onion yield of all treatments under two groups (Group-I, T₁ and T₂ and Group-II, T₁ and T₂) with their replications were extrapolated to yield per hectare (Table 3). Statistically there is no significant differences (P>0.05) among all treatments. However, the yield of T₁ (irrigated with fish pond water without fertilizer) under Group-II was higher by 15.73% q/ha of Group-I T₁ (direct river water without fertilizer). The yield extrapolated from Group-II of T₁ (14.20 ±0.904Kg /2.16m²) to 657.75q/ha was highest of all. Also statistically, there is no significant difference (P>0.05) between bulb diameter and bulb weight among treatments. The maximum marketable bulb weight 112.2g and minimum bulb weight 10.8 g were observed under Group II from T₁.

According to Lamma Desalegne and Shimeles Aklilu (2003), Bombay Red Onion with bulb size 85-90 g produced in Nazreth, Bako and Holeta 173.2; 162.1; and 23-171q/ha respectively from cultivars while at Melkasa Research Center on station similar researchers have reported that larger onion bulb yield obtained ranging from 250-300q/ha. Comparing the present study result with previous ones, a better result was obtained at mid rift Valley (Sheled site) at an altitude of 1700m. The best yield obtained from plots irrigated with fish pond water without chemical fertilizer. In general higher
yield obtained in this experiment by minimizing the space between plants to 3-4 cm using zigzag way of planting (from recommended space of 10 - 20 cm) with almost all the bulbs at marketable size.

In addition to this, in general we observed that above ground leaf production biomass of *Brassica oleracea* was larger than underground bulb production biomass of *Allium cepa* in this study. According to Lamma and Shimeles (2003), at Malkassa and NuraEra sites on three N(Urea fertilizer) applications, 92Kg/ha gave high dry bulb onion yield than the highest doses (138Kg/ha). Hence they recommended the applications of 92Kg/ha N for *Allium cepa* was found adequate for dry bulb production in Upper Awash region. We assume that the better result obtained from fish pond water without inorganic fertilizer may be the contributions stated by (Bhatia K.N. 1993) as that the amount of nitrogen produced in fish pond from algae fixation, died and decomposed algae, band small sized aquatic animals, and fish feed give additional nitrogen and algae employed for increasing soil fertility, as manure and blue green algae release fixed nitrogen, oxygen and increase soil phosphates.

The parameters such as stand count, bulb length, bulb diameter and bulb weight of the plant had a great contribution to yield quantity variations between treatments (Table.4).
Table 4: Comparing the effects of fish pond water and direct river water (without and with chemical fertilizer) on Bombay Red Onion (*Allium cepa*) stand count, plant length, leaf number, blade length, and blade width and leaf weight.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Treatments</th>
<th>Average stand count</th>
<th>Average bulb length (cm)</th>
<th>Average bulb diameter (cm)</th>
<th>Average bulb weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group- I</td>
<td>T₁+no F rw</td>
<td>240.67</td>
<td>3.97</td>
<td>4.37</td>
<td>51.0</td>
</tr>
<tr>
<td>Group- I</td>
<td>T₂+F rw</td>
<td>213</td>
<td>4.13</td>
<td>4.73</td>
<td>60.2</td>
</tr>
<tr>
<td>Group- II</td>
<td>T₁+no F pw</td>
<td>246.33</td>
<td>4.13</td>
<td>4.53</td>
<td>57.67</td>
</tr>
<tr>
<td>Group- II</td>
<td>T₂+F pw</td>
<td>266.33</td>
<td>3.97</td>
<td>4.17</td>
<td>49.03</td>
</tr>
</tbody>
</table>

4. Conclusion and recommendations

Integrated fish-horticulture farming practice in Ethiopia is at infant stage. The potential advantages and economic benefits of this integrated system are enormous because of the low levels of inputs, thereby maximizing yield by using biological waste of one farm as input/serve as nutrients for the other farm. Resource wise, the use of integrated fish-horticulture farming is good approach in efficient utilization of land and water in the region.

In this study at Sheled, the mixed sexes tilapia growth performance result was in optimal range in this present condition (feed type and feeding system and water inflow and outflow frequency might limited natural feed availability). Though the fish were not uniform in size, they reached an average size of 148.8±2.04 g in 7 months. The highest yield of onion (*Allium cepa*) was obtained from irrigated plots with fish pond water without inorganic fertilizer. In *Brassica oleracea* the yield obtained from
plots irrigated by fish pond water without chemical fertilizer was better than those irrigated by direct river water with and without fertilizers. Generally the achieved results in both the fish production and vegetables irrigated with water from fish pond are encouraging, revealing the possibility for farmers to attain their protein, carbohydrate, vitamins and minerals requirements through integration of fish farm with other agriculture on small area of lands.

4.1. To solve the problem of fingerling shortage, availability in quantity, quality and time, variable growth rate in tilapia within a pond, establishment of hatchery is a crucial issue. It is also possible to produce mono sex male tilapia.

4.2. The technology is new and needs awareness creation among users to transfer this technology to other places

4.3. Conducting research on integrated fish farming system with other agricultural crops, such as vegetables and fruits and livestock is also necessary.

Acknowledgements
We are grateful to technical staff of Zeway Fisheries Resource Research Center for their assistance. Also we wish to thank Sheled Goto Peasant Association, specially, Mr. Amano. Also we thank Oromia Agricultural Research Institute for financial support.

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Survey on fish diversity, resource potential and current production level of major rivers in the Benishangul Gumuz Region, Ethiopia

Alayu Yalew Hussein Abegaz and Ermias Mengistu
Aquaculture & fisheries Researcher, Bahir Dar Fish & Aquatic Life Research Center
Fish Technologist, Agricultural Extension Directorate, Ministry of Agriculture
Agricultural Economist, Plan & Program Directorate, Ministry of Agriculture

Abstract
With an estimated total population of 667,049 people, the region is situated at the lower fresh water reaches of the Abay basin. The rivers mainly grouped as Flood Rivers, where there are extremes of annual fluctuation in water level from severe flood to sometimes complete desiccation in dry season. There exists also considerable difference in numbers of species inhabiting various river systems attributed to the size of the river as represented by its basin area or correlated with the length of main channel or stream order. Five major rivers of the basin were chosen purposely. Sampling was made during 2011 and gillnets of different mesh sizes were used. For the estimation of the potential fish yield of each river, the simplest model relating catch and river length was used. Compared to the other rivers, the diversity of fish in Dabus River was lower. Totally 29 commercially important fish species, grouped in to 11 families, has been known to present. The dominant family in these river systems is Cyprinidae with a diversity of 9 species. Current fish production in the region is estimated only as 183 tons/yr. The estimated total fish production potentials of sampled rivers is found to be 2,400 tons/yr indicating that there is the possibility to
increase the current level of production more than 13 times. In addition, the exploitation is limited to subsistence level. The most potential river in the region is Abay with an estimated potential of 1680 tons/year and Anger contributes the least potential.

Keywords: Bertha, fish biodiversity, flood rivers, Gumuz, fish production potential

1. Introduction

1.1. Area description

The Benishangul Gumuz is among the National Regional State of the FDRE; with an estimated total population of 667,049 on which 86% of the population lives in rural and 14% in urban areas (CSA, 2008). The study was carried out focusing on the fresh water reaches of the lower Abbay Basin in the Benishangul Gumuz region, Ethiopia. The Abay Basin is one of the 5 river basins of Ethiopia having many tributaries. Five major rivers of the basin were chosen purposely; Abay, Anger, Beles, Dabus, and Dedessa. Study sites of Anger, Dedessa and Abay Rivers are located in Kamashi zone, Dabus River in Assosa zone and Abay and Beles Rivers and Diga Reservoir are situated in Metekel zone. Sampling was made during the third and fourth week of February for Abay, Anger, Dabus and Dedessa Rivers.

Findings revealed that there are about 153 to 183 valid indigenous freshwater fish species included in 25 families in Ethiopian freshwaters; 37 to 57 of them are endemic to Ethiopia (Glubtsov and Mina, 2003). The Benishangul Gumuz...
Regional State is under the Abay basin with ample natural resources; water bodies constitute perennial and seasonal rivers, small reservoirs and flood plain areas with diversified fish species and potential for production. The region mainly flounders under the Abay River, with many tributary rivers derived from the highlands of Amhara and Oromiya regions. The fish fauna that inhabited the Nile Basin appeared throughout big and small tributary rivers and streams. However, there is a natural and artificial ecological change and conditions limit some type of fish species to inhabit definite areas.

According to Welcomme’s (1985) river classification, the Benishangul-Gumuz region rivers are mainly grouped in flood rivers, where there are extremes of annual fluctuation in water level from severe flood to sometimes complete desiccation in dry season. In addition to this, the considerable difference in numbers of species inhabiting various river systems are largely attributable to the size of the river as represented by its basin area or correlated with the length of the main channel or stream order.

1.2. Objectives
The objectives of this survey in the fisheries resources of the region were to assess the diversity of commercially important fish species, assess the current exploitation level of the region, and estimate the yield potential of major rivers in the region.
2. Materials and methods

2.1. Materials used

The following materials have been employed for the survey;

- Set of fishing gillnets with 2 m height and 25 m length
- Inflatable boat and outboard engine (15 HP)
- Weighing balance (Capacity of 30 kg)
- Measuring board (1 m long)
- Digital camera (Sony DCS-W170 Super Steady Shot)
- GPS (Garmin Venture - M350)
- Secchi disc

2.2. Location and sampling

Specific location of the water bodies (altitude, latitude and longitude readings) where fishes were sampled has been measured using GPS. Water transparency and depth reading has been taken with secchi disc and tape meter respectively. Fish samples were collected in each river using 25 meter long gillnets each having mesh sizes of 6, 8, 10 and 12 cm. Weight and length of fish caught during sampling was measured using field balance and measuring board.

Sampling was done from January to May in 2011. Basic information regarding current exploitation type and level was obtained by direct observation and questioning the fishers and fisher groups as the fishers and consumers of the region used to eat all kinds of fish as opposed to other regions of the country. Secondary data on fisheries and related activities being undertaken and/or planned in the region were collected...
renaissance dam. The water here was warmer than Chesega and difficult to swim for long time during April.

The specific study/sampling area at Anger River was located at a distance of 18 km North West of Sogie, Belojiganfoy Woreda capital. The water was clear enough for the penetration of sunlight and the maximum temperature was 29°C during sampling at 9:00 am in February. It is the river where crocodile population is very high and road access is not found.

Beles River was sampled at Pawie Woreda on two locations. One sampling site was 3 km far from Gilgel Beles town (Metekel zone capital) under the bridge towards Guba main road. The second sampling was at the upper most part of the river diversion dam (Diga) located in Mender 7 at a distance of 18 km from Gilgel Beles town. The river is full because of the water coming from the Tana Beles hydro electric project.

Sampling at Dabus River was taken at the bridge of the river towards Lekemt at a distance of 6 km from Bambasi town and the water is deeper (more than 3 m) and turbid throughout the year. This river is a shelter of hippos (*Hippopotamus amphibious*) and their number reached up to 10 in one location.

Dedessa River is found at a distance of 33 km from Kamashi town on the way to Yaso woreda. Sampling was taken around the main bridge of the river Dedessa, at Kobi Kebele. This water has a depth of 50 cm on the shallower and more than
2.5 m at its deeper most part. The water is very clear and warm all the day, its temperature reached 27°C at mid day reading.

3.2. Diversity of commercial fish species of the region
According to Glubtsov et al. (2003), the number of species appears to be negatively correlated with altitude. The decrease in number of fish species from lower to upper reaches is typical of most river system of the world (Nikolsky, 1963; Sydenham, 1977). In Ethiopia this decrease is especially pronounced because of steep altitudinal gradients and occurrence of rich lowland faunas in most basins (Glubtsov and Mina, 2003).

This survey revealed that apart from the altitude of the area, which mainly matters the diversity, long term turbidity of the river water also seen determining the number of species to be found in the water body. Compared to the other rivers, the diversity of fish in Dabus River is by far lower than the other rivers because of its lower transparency and higher altitude (Table 1). As the river is located at the lower altitude area and its altitudinal gradient is very low, Abay with warm and clear water had many fish species (Table 2, Fig 1) compared to other rivers.

Within the same Abay, the diversity of fish species differs from site to site; more fish species has been recorded at Yarenja than Chesega. During this survey, 15 fish species have been identified at Chesega kebele and other 10 extra species have
Fig. 1: Species diversity in studied rivers

Fig. 1: Frequency of occurrence

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### Table 5: Fish production potential of the rivers

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of River</th>
<th>Location (Zone)</th>
<th>River Length (km)</th>
<th>Estimated catch (t/yr)</th>
<th>% contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abay</td>
<td>Kamashi, Metekel,</td>
<td>710</td>
<td>1680</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Anger</td>
<td>Kamashi</td>
<td>89</td>
<td>26</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Beles</td>
<td>Metekel</td>
<td>210</td>
<td>147</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Dabus</td>
<td>Asossa</td>
<td>261</td>
<td>227</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Dedesa</td>
<td>Kamashi, Asossa</td>
<td>310</td>
<td>320</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>2400</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Spatial distribution of fish species

<table>
<thead>
<tr>
<th>Family</th>
<th>Abay</th>
<th>Anger</th>
<th>Beles</th>
<th>Dabus</th>
<th>Dedessa</th>
<th>Occurrence</th>
<th>No. species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagridae</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Centropomidae</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Channidae</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Characidae</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Cichlidae</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Clariidae</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Cyprinidae</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Distichodontida</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Malapteruridae</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Mochokidae</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Mormyridae</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Tetraodontida</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23</strong></td>
<td><strong>13</strong></td>
<td><strong>12</strong></td>
<td><strong>3</strong></td>
<td><strong>6</strong></td>
<td><strong>29</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 4: List of Fishes found in each river (Ab stands for Abay, An for Anger, Be for Beles, Da for Dabus and De for Dedesa rivers)

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Common name (Gumuz/Bertha)</th>
<th>Distribution of species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagridae</td>
<td><em>Auchenoglanis occidentalis</em></td>
<td>Jajumua/Jaja</td>
<td>+  +  +  +</td>
</tr>
<tr>
<td>Centropomidae</td>
<td><em>Latus niloticus</em></td>
<td>Tsembelela/ Eimattia</td>
<td>+  +</td>
</tr>
<tr>
<td>Channidae</td>
<td><em>Parachanna obscura</em></td>
<td>Beluwa</td>
<td>+  +</td>
</tr>
<tr>
<td>Characidae</td>
<td><em>Brycinus nurse</em></td>
<td>Lekewar</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Brycinus m. macrolepidotus</em></td>
<td>Zaza/ Yechacheya</td>
<td>+  +  +  +  +</td>
</tr>
<tr>
<td></td>
<td><em>Hydrocynus forskahlii</em></td>
<td>Siliya</td>
<td>+  +</td>
</tr>
<tr>
<td>Clariidae</td>
<td><em>Clarias gariepinus</em></td>
<td>Bedena</td>
<td>+  +  +  +  +</td>
</tr>
<tr>
<td></td>
<td><em>Hetrobranchus longifilis</em></td>
<td>Piza/Bareda</td>
<td>+</td>
</tr>
<tr>
<td>Cichlidae</td>
<td><em>Oreochromis niloticus</em></td>
<td>Begbah/Bultti</td>
<td>+  +  +  +  +</td>
</tr>
<tr>
<td>Cyprinidae</td>
<td><em>Labeobarbus nedgia</em></td>
<td>Eibra/ Abgedum</td>
<td>+  +  +</td>
</tr>
<tr>
<td></td>
<td><em>Labeo forskalii</em></td>
<td>Tsehiya</td>
<td>+  +  +</td>
</tr>
<tr>
<td></td>
<td><em>Labeo bynni</em></td>
<td>Goshe</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Labeo horie</em></td>
<td>Wuzig'na/Buli'ga</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Labeo coubie</em></td>
<td>Bactracia</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>Labeobarbus intermedius</em></td>
<td>Tsie'a</td>
<td>+  +  +</td>
</tr>
</tbody>
</table>
To estimate the total production of fish in a year, an interview of fishers in each river has been made and secondary data was taken from Bureau of Agriculture. For the estimation of the potential fish yield of each river, the simplest model of Welcomme (1976) relating catch and river length, by the formula:

\[ C = 0.0033L^{1.9539} \], or more approximately

\[ C = \frac{L^2}{300} \]

where \( C = \text{Catch (t/yr)} \) and \( L = \text{River Length (km)} \) was used.

Data analysis was done using Microsoft excel spread sheet 2007, to make proportions and graphs.
Table 2: Physical parameters of sampling sites

<table>
<thead>
<tr>
<th>Rivers</th>
<th>Specific sampling site</th>
<th>Location</th>
<th>Altitude (m)</th>
<th>River width (m)</th>
<th>Transparency of water (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abay</td>
<td>Chesega kebele (Sirba Abay Woreda)</td>
<td>10°07'36.9&quot;N 592 35° 21'40.6&quot; E</td>
<td>ca.300</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yarenja Kebele (Guba Woreda)</td>
<td>11°59'35.2&quot;N 553 36° 11'33.6&quot; E</td>
<td>ca.200</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NW of Sogie town (Belojiganfoy Woreda)</td>
<td>09° 29'00.1&quot;N 1000 36°10'11.1&quot; E</td>
<td>45</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mender 7 (Pawe Woreda)</td>
<td>11° 21'03.4&quot;N, 1023 36° 24'00.2&quot; E</td>
<td>ca.120</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bridge to Guba (Pawe Woreda)</td>
<td>11° 11'57.8&quot;N 987 36° 19'34.1&quot; E</td>
<td>50</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Beles</td>
<td>Bridge near Bambasi (Bambasi Woreda)</td>
<td>09°45'44&quot;N 1337 34°48'31.7&quot;E</td>
<td>75</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dedessa Bridge to Yaso (Kamashi Woreda)</td>
<td>09°41'10.4&quot;N 835 36°01'29.2&quot; E</td>
<td>65</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>
been known to occur at Yarenja kebele of Guba Woreda. Totally 23 fish species (Table 2) have been identified in Abay. Apart from its richness in diversity, the biggest fish weighing 4.5 kg has been recorded in this river caught by a gill net of 12cm stretched mesh.

The second richest river in diversity was Anger with 13 fish species caught in one sampling. More fish production would have been recorded in this river if the crocodiles did not disturb the sampling activity. The biggest fish species caught during sampling of this river weighed 3 kg. The river with lowest fish diversity was Dabus only with 3 species followed by Dedessa (Fig 1). In the Dabus River, the dominant fish species caught during sampling was catfish (*C. gariepinus*) with a proportion of 83%.

In this survey, a total of 29 fish species important for food has been known to be present in all the studied rivers (Abay, Anger, Beles, Dabus and Dedessa). These species are grouped into 11 Families (Table 3). The dominant family in these river systems is Cyprinidae with a diversity of 9 species of fish followed by Mormyridae with 5 fish species. Characidae and Distichodontidae each had three species and Clariidae has two species. But the families Bagridae, Centropomidae, Channidae, Cichlidae, Malapteruridae, Mochokidae and Tetraodontidae are each represented only by a single species in this survey.

As opposed to other Families, the Cichlidae and Cyprinidae were found in all sampled river systems in the region (Fig 2).
The family Characidae, Clariidae and Mormyridae are the second most popular families found in four river systems. But the Family Tetraodontidae appeared only in Abay River (Fig 2, Table 3).

3.3. Fish resource potential of major rivers in the region

Knowing the fish resource potential means information needed for a rational decision-making in fisheries management and development. Data with regard to fisheries activity, biological and bio-economic information are very important for fisheries development. Therefore, accurate fisheries statistics in the rivers and their adjoining flood plains is vital to make an inventory of the fisheries resources of major and tributary rivers. Rapid assessment methods frequently require information on the state of the fishery, and to formulate a sound development and management plan of the resources on which the fishery is based and to answer logistic questions about how and where to deploy limited resources.

The ecosystems of larger Benishangul Gumuz Rivers are generally very poorly understood and there is a great lack of data on most aspects of the fishery and the fish community. Sampling large river systems is known to be extremely difficult. Direct assessment and/or survey in fishery is practically impossible due to the nature of the resource itself being found in a unique environment, and requires long time, high financial input and skilled man power. In the absence of
direct assessment data, indirect ways and methods for the estimation of the fishery potential of water bodies is crucial.

For this survey, methods adapted to other African river environments for the rapid assessment of the potential of the Benishangul Gumuz Rivers were used. The simplest of parameters, sought to directly relate fish catch with simple morphological features of the rivers are mostly used for the estimate. According to the model of Welcomme (1976), the total fish production potential of major rivers of the region (Abay, Anger, Beles, Dabus and Dedessa) is estimated to be 2,400 tons/yr (Table 3).

The most potential river in the BGRS is Abay with an estimated potential of 1680 tons/year which covers 70% of the region’s total production potential. Anger contributes the lowest potential among the rivers sampled in the region. The estimated fish production potential of Abay River in particular and the Benishangul Gumuz region in general will increase after the construction of the Grand Renaissance Dam. This dam having a reservoir with an area of 1680 km$^2$ will have an estimated production potential of 7628 tons/yr.

3.4. Annual fish production
Fishing is mostly artisanal in the region and its purpose is limited to meet subsistence needs of the households, mainly for food (MoA, 2003). Local people living in the near-by towns and some settlers in some areas also used fish as a means to support their financial needs. Though rivers are rich in fish
resource, fishing is carried out mostly for limited months of the year, mainly from November to May. But Gumuz and Bertha people used to fish all seasons of the year though their catch declines during summer (rainy season) when the water level become higher that makes it difficult to set fishing gears.

Most fishing is subsistence and being practiced using traditional gears like hook and line, trap, cast net and spears. Modern fishing is being practiced using motor boat with gillnets by some group of fishers like Chesega Fishers Association. There are also some destructive fishing methods using poisonous plant materials and poisonous agrochemicals like Malathione, Endosulfan, DDT and 2,4D.

Fishing is practiced in the region from main river systems like Abay, Anger, Didessa, Dabus, Beles, and their tributaries (small rivers and streams). According to the report of the regional government (2011), the level of fish production increased from 3.6 tons in 2006 to 5 tons in 2010 (Fig 3). As of this field survey, the group experienced that the catch has never been recorded systematically and the reports of Bureau of Agriculture towards the annual fish production fails to include fish consumed by the households in marginal areas.

This survey identifies that November to April are the main fishing seasons of the year in the Benishangul Gumuz region. The number of fishing House Holds (HHs) in the region varied from Kebele to Kebele and a total of 1527 HHs are known to involve in fishing. Each household comprises of 5.5 family
members, most of them are also involved in fishing, who consume fish. It is normal for a household to fish at least once in a week and gets a minimum of 5 kg fish. Based on this data, it is estimated that a minimum of 183 tons of fish is being produced annually by the people of the region found around the surveyed rivers.

4. Conclusions and Recommendations
The survey showed that fish is one of the main food components in the region and very important business for the native ethnic groups; Betha and Gumuz. Almost 29 different fish species found in 5 major rivers are identified as edible by the people. However, the current exploitation is limited to subsistence level, only 183 tons/yr. The estimated fish production potentials of sampled rivers alone is found to be 2,400 tons/yr. This indicates that there is a possibility of increasing the current level of production more than 13 times.

According to this study, the level of exploitation of fish from the sampled rivers is approximately only 8%. If access to reach these and other rivers is possible, trainings are going to be provided and the necessary fishing gears and other facilities are fulfilled, the level of exploitation will increase and more fish will come to the market.
References


Preliminary survey of Geray Reservoir, Amhara National Regional State, West Gojjam, Jabitehnан Woreda, Ethiopia: Focus on wetland management

Miheret Endalew Tegegnie
Amhara Region Agricultural Research Institute, Bahir Dar Fish and other Aquatic Life Research Center, P. O. BOX, 794. Bahir Dar, Ethiopia, miheretendalew@yahoo.com

Abstract
Wetlands are the most fragile, productive and important centers of biodiversity serving as regional terrestrial water regulatory system and play vital role in the atmospheric carbon cycle. However, despite their importance in maintaining the ecology and economy, wetlands are endangered by negligence and lack of appreciation for their role. Increased anthropogenic activities such as intense agriculture practices, indiscriminate disposal of effluents and wastes have changed the physical, chemical as well as biological integrity of the ecosystem resulted in the ecological degradation, which is evident from the current ecosystem valuation of wetlands in different parts of Ethiopia. The local communities benefit grazing and watering for livestock, irrigated agriculture, water supply and sanitation, cultural values and fishery from the Geray reservoir. Traditionally reservoirs are engineered from hydrological point of view without considering environment, socio-economics and ecology as part of the ecosystem. The role of hydrology regulating the biota and the role of biota on hydrology is not given due consideration. The open access and inadequate management has
increased anthropogenic factors resulting amplified decline of ecosystem goods and services. Sustainable management strategies to protect and recover the lost wetland benefits are not well emphasized. Thus, sustainable management of ecohydrological, socio-economical, and biodiversity based on knowledge and experience, calls different stakeholders to alleviate negatively impacting factors on the wetland.

**Key words:** biodiversity, conservation, hydrology, management, reservoir, wetland functions

1. Introduction

Ethiopia has wetlands that vary in size, type and location. Even though wetland resources of Ethiopia are not fully documented, it is known that they represent a significant micro-environment in many parts of the country. Studies showed that the wetlands in the various parts of the country is estimated to be 1% - 1.5% of the country's area (FAO 1984, Afework Hailu 1998, Leykun Abunie 2003, EEPA, 2006). The area coverage appears small but the ecological and socioeconomic benefits are significant.

Amhara National Regional state (ANRS) is one of the regions which is endowed with various types of wetlands. Lake Tana the largest fresh water lake in Ethiopia, Fogera and Dembia Flood Plains, the Cheffa valley (Borkena), are some of the many wetlands that dominate the region’s land surface. These wetlands make a significant contribution to the livelihood of many local communities in the region. According to Abay Kindie (2001) the wetlands in ANRS covers about 288,744 ha of swamps and
marshes. These wetlands are distributed all over the region. However, the largest portion of the wetlands is found in Abay River basin in Awi, West Gojjam, and South Gondar administrative zones. The Awash basin also has a significant area of wetlands, (e.g. Cheffa Borkena River valley wetland) especially in South Wollo and Oromia administrative zones.

On a larger scale, anthropogenic activities impact physical, chemical and biological processes, which impair the ecosystem functioning causing decline and degradation of ecosystem services and value of wetlands. Wetlands predominantly endure change in wetland hydrology and habitat loss of catchment areas adjacent to urban growth, increasing runoff of nutrients and pollution, introduced species replacing indigenous species, land clearance and over-use of resources by losing its subsistence economies of that region mainly due to conversion. Traditionally wetlands are considered as wastelands in their natural state without considering their valuable services for environmental quality and the local community. They are often converted completely to other uses that change the services they provide ecologically, economically and socio-culturally.

The expansion of land demand for agriculture, poor land use practice in the wetland watershed, population growth and economic development are the main factors impacting wetland conversion for agriculture, urban development and other uses. Degraded wetland watershed suffers from excessive runoff which reduces infiltration of water into the watershed and water storage for slow release into the wetland to maintain dry season water
supply. Current rates of soil erosion documented in Ethiopia range 16-300 tons ha\(^{-1}\)yr\(^{-1}\) (Hurni, 1988). The Ethiopian Highlands Reclamation Study (EHRS, 1984) estimated the average annual soil erosion rate of 100 tons ha\(^{-1}\)yr\(^{-1}\) for the Ethiopian highlands. The steep and rugged topography and intense rainfalls have caused severe soil erosion. The indiscriminate forest clearing, complete removal of crop residue, overgrazing, and poor soil management and land use practices further aggravate the situation.

The consequences are depletion of water resources, declining soil fertility, shortage of cultivable land, non-or under employment of the rural population and food insecurity. An increasing number of the population is becoming vulnerable to the effects of drought due to land degradation. Due to population pressure and the subsequent demand for more land resources to sustain rural livelihoods, wetlands are now under threat and in some parts of the region many wetlands have been drained for agricultural production. The benefits which may be lost are not effectively quantified in viable markets and also in terms comparable with economic services, are often specified with too little weight in policy decisions. Hence, quantifying economic values of ecosystem are essential to respite human activities apart from accounting their services in the regional planning.

The environment and the socioeconomic values of the wetlands of the region in general and the Geray wetland in particular are not well studied. There is no complete data and information about the extent and nature of wetlands in the region. Based on the gaps stated the research tries to generate baseline data of
Geray wetland that can be used by policy makers in the region. The objectives of the research were (1) to collect baseline information, (2) to raise public awareness on the reservoir wetland situation, (3) to establish an intervention mechanism to sustain its ecosystem services.

2. Materials and methods

2.1. Study Area

Geray reservoir is located in Amhara National Regional State, West Gojjam Administrative Zone, Jabitehnan and Finoteselam Woredas, bordering, Shembekuma-Yedafas and Arebayitu-Inesa kebeles (Fig.1). The wetland covers 10 ha with weir crest length of 105 meters, height 4 meters, $10^6$ m$^3$ of water with a potential of irrigating 618 ha, of arable land. The vegetation coverage differs between eastern and the northern part of the watershed. The western area is devoid of natural cover due to intensified agricultural activities whereas the eastern area is covered with natural shrubs. Preliminary survey on Geray reservoir was carried out in 2010 -2011.
Fig 1: Map of Amhara National Regional State and West Gojam Zone in rectangle (a) Map of Jabitenan and Finoteselam Woredas with Kebeles boundary (b) and Geray reservoir bordering kebeles in rectangle (c)

2.2. Data collection and analysis
Questionnaire survey to collect data in Geray reservoir watershed kebeles was deployed and the data includes land use and land cover, livestock and human population, crop patterns, topography and soil type in these kebeles. Focus group discussion with local community to obtain indigenous knowledge was considered. Other supportive secondary data

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were collected from Jabitehenan Woreda Agriculture and Rural Development Office. Field observation on major human impacted activities and major ecological changes for the last two and three decades was considered. Jabitehenan Woreda Office of Agriculture and Rural development experts were contacted and consulted. GIS was used for mapping to ease communication among the stakeholders. Libraries of the Amhara Regional Agricultural Research Institute and Bahir Dar Fish and Other Aquatic Life Research Center were searched for relevant literature. The collected data were analysed with Descriptive statistics.

3. Results

The total annual rainfall recorded in the watershed was about 1350mm and most rain from June-October and the average annual temperature is about 25 degree-Celsius (Table 3). The topography of Geray wetland watershed (Table 2.) consists of 97% plain, 3% mountainous and valley. The topography varies greatly on the peripherals of south and north sides of the watershed. It is generally flat on the east and west side of the wetland. Undulating slopes exist on the outer northern and southern. In areas with flat topography, stream flow is relatively slow, and floodwaters tend to spread out into adjacent lands such the floodplain around the wetland.

The land use pattern consists of 90% farmland, 6.72% forest and bushes, 2.94% grazing and 0.34% construction (Table 1). The undulating slopes and soils types facilitate the natural erosion and landslide problems that exist in the western and northern high
lands (Table 2.). The soils of the watershed consist 63% red, 11% brown and 26% black. The undulating slopes increase rain water runoff rates, which can increase erosion and sediment in the wetland, and deposit sediments in downstream. The Agro-Ecological Zone of the wetland watershed consists of the traditional category 100% Woina Degä (Table 3).

The major crops grown in the wetland watershed are cereals (68.25%), pulses (6.34%), oilseeds (1.2%), spices (8.94%) and vegetables, root crops and fruits 15.27% (Table 4). The livestock population in Geray watershed has was estimated to be 10413 in number (37.83% cattle, 6.2% equine, 12.49% sheep and goat, 5.52% apery and 37.96% poultry) (Table 6). The human population of Geray watershed is around 8014 (Table 5). Critical problems observed on the wetland and the surrounding watershed include vegetation removal, land degradation, wetland hardening, pressurized grazing, expansion of floating macrophytes on the reservoir, water seepage at the dam, water use management and water use conflicts, drainage structures maintenance and lack of institutional accountability.
Table 1: Land Use Pattern

<table>
<thead>
<tr>
<th>Kebeles</th>
<th>watershed</th>
<th>Area (ha)</th>
<th>cultivated</th>
<th>forest</th>
<th>grazing</th>
<th>construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shemibekoma</td>
<td>upper</td>
<td>1606</td>
<td>1451</td>
<td>101</td>
<td>51</td>
<td>3</td>
</tr>
<tr>
<td>Arbaituinsesa</td>
<td>lower</td>
<td>2517</td>
<td>2261</td>
<td>176</td>
<td>69</td>
<td>11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>4123</strong></td>
<td><strong>3712</strong></td>
<td><strong>277</strong></td>
<td><strong>120</strong></td>
<td><strong>14</strong></td>
</tr>
<tr>
<td><strong>%</strong></td>
<td></td>
<td><strong>100</strong></td>
<td><strong>90</strong></td>
<td><strong>6.72</strong></td>
<td><strong>2.94</strong></td>
<td><strong>0.34</strong></td>
</tr>
</tbody>
</table>

Table 2: Topography and soil types

<table>
<thead>
<tr>
<th>Kebeles</th>
<th>plain %</th>
<th>mountain%</th>
<th>rugged %</th>
<th>Valley %</th>
<th>Red soil %</th>
<th>Brown soil %</th>
<th>Black soil %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shemibekoma</td>
<td>95</td>
<td>5</td>
<td></td>
<td></td>
<td>75</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Arbaituinsesa</td>
<td>99</td>
<td></td>
<td>1</td>
<td>50</td>
<td></td>
<td>17</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 3: Elevation, temperature, and rainfall patterns in a completely Woina Dega area

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Kebeles</th>
<th>Elevation in m</th>
<th>Temperature °C</th>
<th>Rain fall in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>1880</td>
<td>1840</td>
<td>1860</td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>1840</td>
<td>1880</td>
<td>1860</td>
<td></td>
</tr>
<tr>
<td>Av.</td>
<td>1860</td>
<td>1860</td>
<td>1860</td>
<td></td>
</tr>
</tbody>
</table>
and poor watershed management (Mebrat Alem, 1993; Miheret Endalew, 1997; Zinabu Gebre Mariam, 2002; Miheret Endalew and Tollner, 2009). There are cases of natural lakes in Ethiopia which either disappeared or nearing to disappear as a result of mismanagement (Brook Lemma, 2003; Tamiru Alemayehu et al, 2007, Miheret Endalew et al, 2010). Lake Alamaya, Lake Kilole and Lake Gudera as well as man-made dams that are completely or nearly silted up as a result of over abstraction, poor land use and sedimentation can be mentioned in Ethiopia. Excessive exploitation and withdrawal water can lead to a total collapse of the resources as evidenced at Lake Alemaya in Eastern Ethiopia (Brook Lemma, 2004).

The wellbeing of wetlands is of vital importance for people and the environment in Ethiopia. Their contribution to poverty reduction and ensuring food security is massive especially in rural areas. They also play significant role in nation wide development endeavors. In addition to this local contribution, the wetlands of Ethiopia play great role in providing a stopover ground for transcontinental migratory birds and ameliorate climatic changes/global warming through carbon sequestration. However, these resources are exposed to anthropogenic impacts due to various problems. Some of which are lack of a national wetland policy/strategy and a lead institution that coordinates the efforts of wetland affiliated stakeholders. Capacity limitations, absence of adequate information sharing system and weak integration among the stakeholders are also fueling wetland degradation. Policy makers at various levels are short of information on the
multidimensional values of wetlands in poverty reduction and sustainable development.

Participatory management approach and use of indigenous knowledge of the local community and experience of the stakeholders in extension services, research and management is the priority measure for Geray resources management to sustain its ecosystem services for the present and the next generations. However, these resources are exposed to anthropogenic impacts due to various problems. Some of which are lack of a national wetland policy/strategy and a lead institution that coordinates the efforts of wetland affiliated stakeholders. Capacity limitations, absence of adequate information sharing system and weak integration among the stakeholders are also fueling wetland degradation. Policy makers at various levels are short of information on the multidimensional values of wetlands in poverty reduction and sustainable development.

The wetland issues of Ethiopia stated at national and regional level in natural resource management policies and strategies such as, in water resources development, forestry development, agricultural and rural development, land use and environmental protection are diffused and overpowered by these broader objectives of the sectors. This further hinders to protect, conserve and sustain the existing ecosystem functions and values of wetlands. There is a need of advocacy for a stand-alone, unique wetland policy drawing which gives considerable attention to wetland issues particularly by legislators.
The bad experiences learnt from Ethiopia and Africa lakes should alarm us to take preventive and mitigative measures before things went to irreversible situation in the other wetlands of Ethiopia in general and the wetland of Geray in particular. Thus, Geray and its basin are a fragile and a complex ecosystem under growing stress and nearing to disappearance unless and otherwise timely measures are not taken to mitigate the prevailing encroachment towards the wetland. Sustainable management of Geray wetland basin for its ecological, social, biodiversity and economic values require attention from its stakeholders in maintaining maximum benefit for the present and future generations.

5. Conclusions and recommendations
The loss of wetlands and their resource will affect those who are directly and indirectly dependent on the resources for their livelihoods. A core area and a buffer zone demarcation are highly demanded confirmed with stand alone wetland policy, legal and institutional framework for wise use and safety of wetlands. Sustainable management of hydrological, ecological, social, biodiversity and economical values based on knowledge and experience on environment, land use, extension services and research to restore and sustain the various values and functions, calls involving different stakeholders to alleviate negatively impacting factors on the wetland. Further information generation on the wetland situation on Ethiopia in general and the Geray wetland in particular specifically on wetland valuation are highly demandable.
Acknowledgements
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References


