

editorial

The roots of the WorldFish Center lie in Asia and the Pacific, where we started as ICLARM in 1977. But as the Center has developed and our global reach has expanded, so our focus on poverty alleviation and food security has drawn us to invest steadily in Africa. From starting our first work in Malawi in 1986, through projects in Sierra Leone and Ghana between 1990 and 1995, the opening of our regional center at Abbassa in Egypt in 1997, to the establishment of our new program in Cameroon in 2000, we have built a substantive program and presence on the African continent.

Looking forward to the challenges facing fisheries and aquaculture in the coming decades, the Center has long recognized that our investment in Africa needs to be increased even further. To guide this investment we have now developed a Strategy for Africa and West Asia for 2002-2006 and are currently moving ahead to implement this. The present issue of *NAGA* introduces the Strategy, while also reporting on a number of key issues that the Center is working on to address.

Africa's capture fisheries contribute to the livelihoods of some 15 million people and provide the principal source of animal protein for many millions more. Well managed, these resources can continue to play an important role in nutrition and livelihoods across large parts of the continent, notably in the coastal regions, along the shores of lakes and reservoirs, and throughout the continent's extensive river systems. Yet many of these resources are undervalued and rarely feature in planning and management processes. The articles by Rudy van de Elst, Robin Welcomme, and Christophe Bene and Arthur Neiland explore several of the critical issues facing these systems and point towards approaches that may help address these.

Despite their importance, however, Africa's capture fisheries alone cannot meet the growing demand for fish. The per capita consumption of fish has declined in several countries in Africa in recent years. WorldFish believes that aquaculture has great potential to meet this demand and become an effective component of agriculture and rural development strategies across large parts of the continent. However, the Center's experience in Malawi, Ghana and Cameroon underlines that this will only happen where the right technical solutions are applied in social, economic and institutional contexts that are conducive to aquaculture adoption. The article by D.M. Jamu and O.A. Ayinla examines this potential.

By developing our new regional strategy, the WorldFish Center recognizes the need for long-term investment in Africa. We also recognize the importance of building and working through effective partnerships in order to achieve the breadth and depth of impact that we believe is required. Over the course of the coming years we will be strengthening our partnerships in Africa and we invite the readers of *NAGA* who are working in the region to contact the Center.

Meryl J. Williams
WorldFish Center



Our commitment:

WorldFish Center is committed to contributing to food security and poverty eradication in developing countries.

We aim for:

- poverty eradication;
- a healthier, better nourished human family;
- reduced pressure on fragile natural resources; and
- people-centered policies for sustainable development.

A way to achieve this:

Through research, partnership, capacity building and policy support, we promote sustainable development and use of living aquatic resources based on environmentally sound management. The research thrusts are:

- improving productivity;
- protecting the environment;
- saving biodiversity;
- improving policies; and
- strengthening national programs.

We believe this work will be most successful when undertaken in partnership with national governments and nongovernmental institutions, and with the participation of users of the research results.

Our corporate makeup:

WorldFish Center is an autonomous, nongovernment, nonprofit organization, established as an international center in 1977. The Center is an operational entity with programs funded by grants from private foundations and governments.

WorldFish Center is governed by an International Board of Trustees and its policies are implemented by the Director General.



WorldFish Center is one of the 16 international research centers of the Consultative Group on International Agricultural Research (CGIAR) that has initiated the public awareness campaign, Future Harvest.

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Investing in Africa: the WorldFish Center's African Strategy in summary

P. Dugan

Abstract

Across much of Africa, freshwater and coastal fisheries provide an important source of food and livelihood for many millions of people. In addition, the aquaculture potential of the continent has only recently begun to be developed. To help sustain these capture fisheries, support the emergence of aquaculture and foster the contribution of both to sustainable livelihoods and improved food security, the WorldFish Center is increasing its investment in Africa. The framework for this investment is provided by a new Strategy for Africa and West Asia 2002-2006 that identifies priorities for the Center's work in rivers and floodplains, lakes and reservoirs, coastal fisheries, aquaculture, policy research and capacity building. The present article summarizes the issues being addressed by the Center and describes initial research priorities.

Introduction

Africa's challenges are very much in the news and are the focus of attention for many in the international development community. From the ongoing conflicts in West and Central Africa to food shortages and famine in Ethiopia and southern Africa, the HIV/AIDS pandemic, persistent environmental degradation and the underlying slow pace of economic development, the scale of the problems is daunting. The launching of the New Partnership for Africa's Development (NEPAD) as a defining framework for the continent's economic and social development and a mechanism for stronger regional cooperation, has opened up new opportunities for the continent and a growing sense of urgency that these need to be seized. For the international agriculture research community, and notably for the CGIAR, this combination of challenge and opportunity has provided an important incentive to reassess where our efforts have the greatest impact. At the WorldFish Center, we have given careful thought to what the challenges in Africa mean for fisheries and aquaculture and the role of research and extension in responding to them.

Across Africa fisheries and aquaculture supply high quality food at low cost to millions of people, generate income for farming and fishing households, and play a central role in many local and national economies. Capture fisheries dominate this picture, providing well over 90 per

cent of fish harvested in the region (FAO 1999). However, aquaculture has grown steadily in recent years. For example, production increased from 60 000 t in 1990 to 340 000 t in 2000 in Egypt and from 7 000 t in 1990 to over 20 000 t in 1998 in Nigeria (FAO 1999).

Despite the productivity and importance of the region's capture fisheries and the promising though slow emergence of aquaculture, the current supply of fish falls short of demand. In Africa as a whole, per capita availability of fish is declining and in some countries the average diet contained less fish protein in the 1990s than in the 1970s. Africa is the only geographic region of the world where this has occurred. Current projections of supply and demand to the year 2020 indicate that the gap between supply and demand will continue to grow, even if current harvests of wild caught fish can be maintained and aquaculture continues to progress at the current rate (Ye 1999).

However, even these are fragile assumptions. There is currently widespread concern about over-fishing of both marine and freshwater resources across the region and many of the coastal and river habitats that sustain the fisheries are being degraded, their water supply diminished, and pollution increased in both coastal and freshwater systems. Unless action is taken to address these problems, the region's capture fisheries risk a sustained decline. If aquaculture is to realize its great promise and the successes

of Egypt and Nigeria are to be repeated in other countries and different farming systems, carefully targeted research and investment will need to be sustained over many years.

To help meet these challenges the WorldFish Center has developed a new Strategy for Africa and West Asia. We believe that sustained harvest of the region's capture fisheries together with continued development of aquaculture can provide the region with an enhanced and sustainable supply of fish protein and employment for millions of people. The Center's Strategy focuses upon four aquatic production systems: rivers and floodplains, lakes and reservoirs, coastal fisheries, and aquaculture; and a number of overarching policy studies and capacity-building activities. The Center seeks to generate research results that will help strengthen national and regional policies and capacity to sustain and enhance the development benefits from capture fisheries, while identifying and designing ways to overcome technical, economic and social bottlenecks to the development of aquaculture.

Challenges facing African fisheries and aquaculture

Capture fisheries

Africa's extensive rivers sustain important fisheries (Table 1), ranging from the large floodplains of the inner Niger delta in Mali to the forest rivers of Cameroon,

where surveys have shown fish to be the most important of all non-timber forest products. These river fisheries are severely stressed across much of the region, with inadequate management systems, intense fishing pressures and changes in water quality and flow regimes leading to declining productivity and yields. To address these challenges, a major investment is needed to understand and establish governance systems for river fisheries that foster sustainable levels of use, while also maintaining the water flow required to sustain them. In support of these efforts, the value of river fisheries needs to be better understood and communicated, and ways to assess water requirements should be developed and used to improve the information upon which water and fishery management decisions are based.

The continent's lake fisheries play an equally important role in many local economies. The annual harvest from most of these is in excess of 20 000 t/year (Table 2) (Lévêque 1999) and the fisheries of the largest lakes are of national and regional importance. Yet many of these lake fisheries face over-fishing compounded by eutrophication caused by urbanization, agriculture, and catchment degradation. Long-term sustainable use of lake fisheries will require better governance and significant improvements in the management of land and water use in the catchment areas.

Artificial reservoirs play a significant role in fisheries production in the region. Published annual harvest data show production ranging from 1 500 t from Manantali (Mali), 31 000 t from Lake Nasser (Egypt) and 40 000 t from Lake Volta (Ghana), with yields commonly around 50 kg/ha or above (Table 2) (Lévêque 1999). While some of this variation is due to the natural productivity of these artificial lakes, much of it is because of differences in the management regime, including timing and extent of draw-down and whether or not there has been any stocking. To fully exploit their potential, the management requirements of the individual systems need to be assessed and appropriate regimes agreed upon with key stakeholders.

Many thousands of small dams and small water bodies (SWBs) are also fished. In

Table 1. Fisheries production from some African floodplains

Floodplain	Area (km ²)	Catch (t)	Number of fishers	Yield (kg/ha)
Niger (Benin)	242	1 200		49.6
Niger (inner delta)	20 000	90 000	54 112	45
Niger (Nigeria)	4 600	14 340	4 600	31.2
Benoue	3 100	9 570	5 140	30.9
Pongolo	104	400		38.5
Shire (1970)	665	9 545	2 445	143.5
Shire (1975)	665	7 890	3 324	118.7
Yaérés (Cameroon)	7 000	17 500		25
Logomatia	600	300	70	5
Kafue (1970)	4 340	6 747	670	15.6
Kafue (1982)	4 754	7 400		15.6
Ouémé (1957)	1 000	10 400	25 000	104
Ouémé (1968)	1 000	6 500	29 800	65
Sénégal	5 490	30 000	10 400	54.7
Barotse	5 120	3 500	912	6.9
Cross	8 000	8 000	4 000	10
Nile (South)	31 800	28 000		8.8

Source: Lévêque 1999; Welcomme 1989

Table 2. Fisheries production from some African lakes and reservoirs

Systems	Surface (km ²)	Catch (t)	Yield (kg/ha)	Period
Reservoirs				
Kossou	900	4 700 - 9 300	67 - 147	1972-78
Lagdo	700	7 700 - 13 400	175 - 340	1985-91
Maga	360	700 - 3 600		1984-92
Manantali	500	1 500	30	1995
Sélingué	400	4 000	100	1995
Jebel Aulia	1 500	7 000 - 8 000	50	1975
Mtera	600	3 250 - 5 000	80	1986-91
Mwadingusha	1 000	674 - 8 000	50	1953-83
Kafue Flats	4 300	2 450 - 10 850	6 - 25	1957-82
Kainji	1 270	4 500 - 6 000	35 - 47	1974-78
Kariba	5 300	30 700	30 - 41	1990
Nasser	6 200	15 600 - 31 200	6 - 25	1981-91
Volta	7 400	40 000	55	1970-79
Lakes				
Turkana	7 560	350 - 22 000	9 - 16	1962-88
Baringo	130	152 - 600	10 - 50	1964-86
Naivasha	115-150	44 - 950	5 - 60	1964-86
Albert/Mobutu	5 270	23 900	47 - 65	1989
Chilwa	750	13 700	77	1989
Chiuta	200	1 100	75	1989
Edward	2 300	14 400	61 - 70	1989
Kivu	2 370	4 600	27 - 42	1991
Malawi	30 800	69 400	35 - 45	1991
Mweru	4 650	20 200	60	1990
Tanganyika	32 900	133 900	90	1990
Victoria	68 000	562 900	29 - 59	1991

Source: Lévêque 1999

eastern and southern Africa alone, there are an estimated 50 000 to 100 000 such SWBs (Haight 1994). Even though most of these have been built for purposes other than fisheries, are usually located in rural areas with difficult access, have low fish yield and revenue and are low in the government's list of priorities, there is potential for improving their yield. As efforts to improve water productivity at the basin level increase in the coming years, the potential of these water bodies to provide fish and income for rural people is likely to be developed (Dugan et al. 2002). Management of SWBs also provides an important transition to aquaculture in some areas.

Africa's extensive marine waters provide the bulk of the region's fish harvest (FAO 1999), with industrial fleets dominating the catch. However, artisanal harvest is significant throughout the region. For instance, the artisanal catch along the Atlantic coast of West Africa is in excess of 1 million t (Horemans 1998) and in Mozambique it is 80 000 t valued at US\$ 50 million. The economic and social importance of these fisheries is high. For example, in the coastal region from Mauritania to Angola there are estimated to be over 570 000 full-time artisanal fishers and many more farmers who fish part-time. In addition, some 1.8 million people in this area are estimated to be engaged in fish processing and marketing (Horemans 1998).

The importance of these resources is highlighted by the pressures upon them. Moreover, the collapse of other economic sectors combined with population increases and migration to coastal areas have led to an increase in the number of coastal fishers in many parts of the region. In the face of this increased fishing pressure, traditional management systems are rarely adequate to ensure sustainable use of these resources, and

the situation is further exacerbated by the impact of the market economy and environmental degradation (Horemans 1998). Urbanization, increased tourism and industrial expansion have all damaged important coastal ecosystems in many parts of the region. Pollution from land-based sources, increased sedimentation and changes in river flows as a result of building dams have contributed to the degradation of many others. These changes can have major impacts upon coastal fisheries and the people dependent upon them. Therefore, they need to be understood better, documented convincingly, and communicated effectively to key stakeholders if action to prevent and/or mitigate them is to be taken.

Aquaculture

Aquaculture will need to be developed progressively if the projected increase in the demand for fish protein in the region is to be met. There is also a growing recognition of the considerable potential of small-scale aquaculture to diversify livelihood options for poor farmers and increase their income while reducing their vulnerability, and also to improve land and water management.

The potential for aquaculture across the region is enormous. For sub-Saharan Africa (SSA) alone, Kapetsky (1994) has estimated that 9.2 million km² (or 31 per cent) of the land area is suitable for smallholder fish farming. If yields from recent smallholder development projects can be replicated elsewhere, only 0.5 per cent of this area would be required to produce 35 per cent of the region's increased fish requirements up to the year 2010 (Kapetsky 1995).

This potential for aquaculture remains largely untapped over much of the region at the present time. In 1999,

total aquaculture production in SSA was only 117 000 t, which is 0.4 per cent of the world production. Yields in most countries remain low, commercial operations have yet to develop in most areas, and fish farmers are relatively few in number (Moehl 2001). The precise reasons for the poor adoption of aquaculture by small-scale farmers have varied from case to case, but the fundamental cause is now widely recognized to be the failure of effectively integrating aquaculture into the farm economy (Harrison et al. 1994; Stomal and Weigel 1998; Brummett and Williams 2000). This in turn is due to several factors.

- Too much emphasis on the role of central government structures, both in terms of technical support and provision of inputs, and not enough on the farmers.
- Poor understanding of the household economies and rural livelihood strategies into which aquaculture has to be integrated and the constraints and opportunities they present.
- Poor understanding of the roles of people comprising the household and in particular the role of women.
- Poor understanding of social constraints.
- Poor assessment of markets.
- Too much emphasis on bio-technical methods rather than simpler, more readily adopted and more adaptable approaches.
- Inadequate extension services.

As a result, attempts to promote the development of aquaculture on small farms have failed to recognize the real needs of the farmers, assist them in adjusting aquaculture practices to their specific context, and so resolve the constraints of time and resources that limit the adoption of aquaculture.

Over the course of the 1990s, a number of initiatives have tried to remedy past shortcomings, in particular by placing greater emphasis on the development context (Stomal and Weigel 1998). Several of these new initiatives have pursued an integrated and adaptive action-research-development approach, rather than the compartmentalized approach of pursuing research followed separately by extension that characterized the failed efforts of the 1970s and 1980s. For example, in

Table 3. Countries where WorldFish Center's Regional Strategy 2002-2006 has been initiated

Fish Production System	Countries with initial WorldFish activities
Rivers and floodplains	Cameroon, Ethiopia, Ghana, Malawi, Nigeria, Zambia
Lakes and Reservoirs	Egypt, Ethiopia, Malawi, Mozambique
Coastal Fisheries	Egypt, Mozambique
Aquaculture	Cameroon, Egypt, Ethiopia, Ghana, Malawi, Mozambique, Nigeria, Zambia

Malawi, this integrated "action-research" approach developed by the WorldFish Center and our partners has resulted in the successful adoption of small-scale pond aquaculture by a growing number of smallholder farmers as an integral part of their farming practice (Brummett and Noble 1995).

Much greater investment will be required over the course of the coming decades to build upon these successes and realize the region's potential for developing aquaculture. As experience improves the understanding of the opportunities and constraints facing the adoption of aquaculture, new approaches can be developed to address the constraints and failings of the past. In particular the social, economic and institutional constraints to aquaculture need to be understood, and the approaches used adjusted to address them. A thorough understanding of the socio-cultural context and of the market forces that determine the return to the farmer is a prerequisite for designing successful aquaculture. The role of the government, the private sector, and NGOs should be clearly defined and supported. In particular, the training and extension system needs to be adapted to the dynamic environment within which aquaculture is being pursued and adopted.

As for most other crops, prices, demands on the farmer's time, environmental conditions, and a range of other factors will vary seasonally and annually, from province to province, and in many cases from farm to farm. This means that emphasis needs to be placed upon developing the capacity of the farmer as an entrepreneur by providing a wider suite of understanding and tools from which they can draw in order to adapt to the dynamic environment in which they are operating. The success of this approach has been demonstrated by the WorldFish Center through the use of Research and Extension Teams (RETs) in Malawi and more recently in Cameroon. However, this approach has to be adapted to a much wider range of locations for it to bring about the magnitude of change that is required to meet the growing need for enhanced livelihood and increased fish production from aquaculture in SSA.

In support of these approaches increased investment is required to address

technical and environmental constraints. These include the availability of high quality fingerlings at an affordable price, good quality low-cost feeds, control of disease, and efficient use of water resources. The impact of urban development and associated pollution on aquaculture is also of serious concern, as is the impact of aquaculture on natural capture fisheries. The possible loss of biodiversity as a result of escapes from aquaculture is likewise a major issue. To help understand such potential impacts the region's fish biodiversity needs to be better understood.

The Center's strategy 2002-2006

These challenges have to be addressed at many levels. Therefore, the Center's strategy (Box 1) seeks to build upon past work by the Center and its partners; complement other programs already underway, notably those of FAO, national and regional organizations, bilateral development assistance programs, and the NGO community; and identify a limited number of issues that the Center has particular expertise and opportunity to handle. This is an ambitious agenda that will take time to achieve and success will depend upon forging a wide range of partnerships within and outside the region. In the immediate future, priority will be given to the following areas of research and capacity building.

- Analysis of governance arrangements and valuation of capture fisheries in rivers, lakes, and coastal areas.
- Assessment of environmental requirements of river fisheries.
- Assessment of factors affecting production and benefits to poor fishers.
- Assessment of threats to capture fisheries in rivers, lakes, and coastal systems and ways to mitigate these.
- Assessment of means to enhance production from capture fisheries, notably in lakes and reservoirs, including the rehabilitation of depleted stocks.
- Improved understanding of the aquaculture adoption process and development of ways to foster adoption.
- Enhanced aquaculture productivity.
- Development and use of methods to maintain environmental integrity in

the face of aquaculture development.

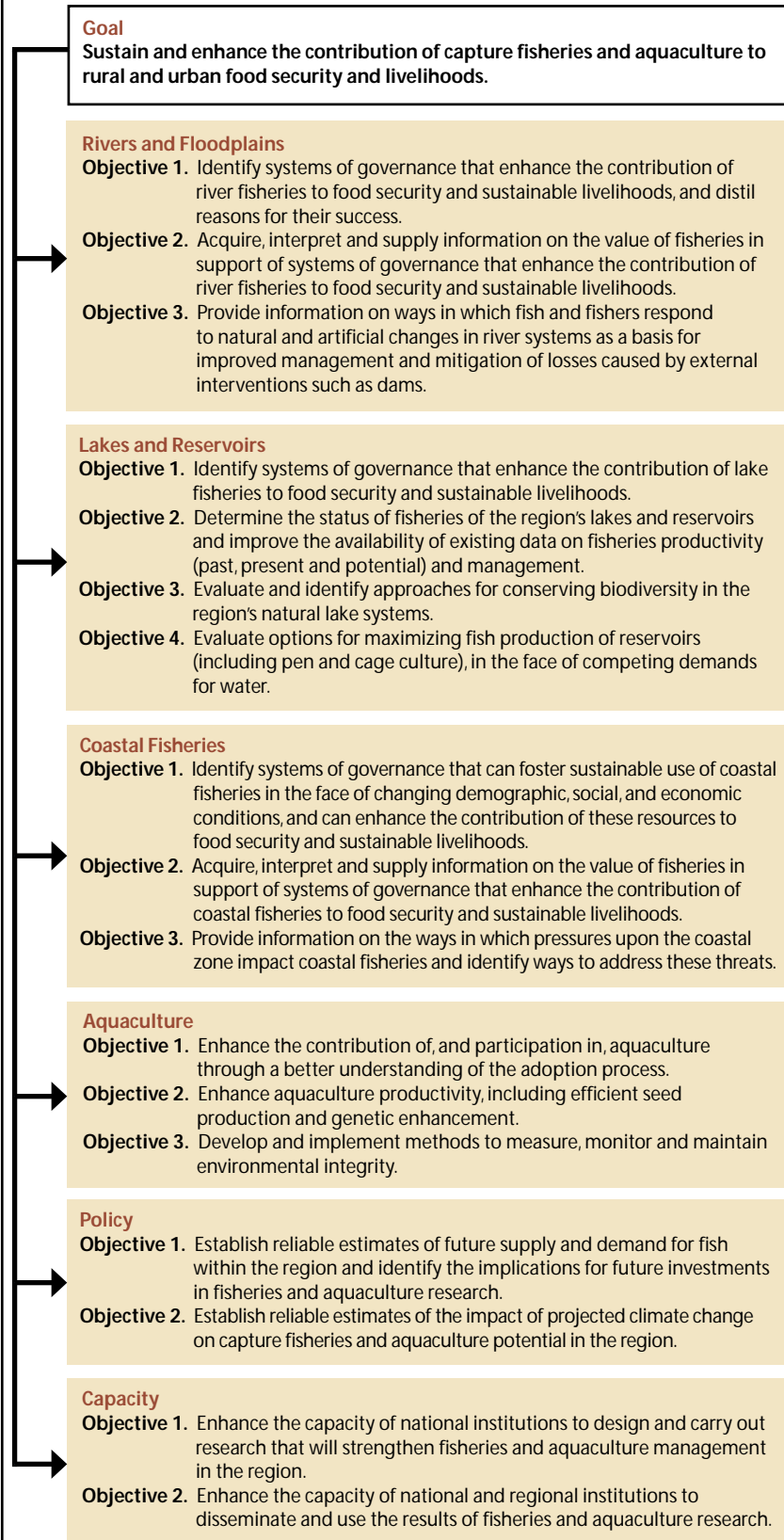
- Assessment of demand and supply of fish and its implications for fisheries development.

In pursuing these priorities, special attention is being given to working with national agriculture and fisheries research and extension institutions (Table 3), advanced research institutes, NGOs, and international institutions. Wherever possible, the Center will help to build capacity at the national level and special attention will be given to develop training programs.

References

- Brummett, R.E. and R.P. Noble. 1995. Aquaculture for African smallholders. ICLARM Tech. Rep. 46. 69 p.
- Brummett, R.E. and M.J. Williams. 2000. The evolution of aquaculture in African rural and economic development. *Ecological Economics* 33:193-203.
- Dugan, P.J., E. Baran, R. Tharme, M. Prein, R. Ahmed, P. Amerasinghe, P. Bueno, C. Brown, M. Dey, G. Jayasinghe, M. Niasse, A. Nieland, V. Smakhtin, N. Tinh, K. Viswanathan and R. Welcomme. 2002. The Contribution of aquatic ecosystems and fisheries to food security and livelihoods: a research agenda. Background Paper Theme No. 3. Challenge Program on Water and Food. IWMI. 20 p.
- FAO. 1999. State of the world's fisheries 1998. FAO, Rome.
- Haight, B.A. 1994. Report of the technical consultation on the enhancement of small water body fisheries in southern Africa, Harare, Zimbabwe, 25-29 January 1993. FAO, Harare. 35 p.
- Harrison, E., J.A. Stewart, R.L. Stirrat and J. Muir. 1994. Fish farming in Africa, what's the catch? Overseas Development Administration. 51 p.
- Horemans, B. 1998. The state of artisanal fisheries in West Africa in 1997. IDAF Technical Report No. 122. FAO, Cotonou. 46 p.
- Kapetsky, J.M. 1994. A strategic assessment of warm-water fish farming potential in Africa. CIFA technical paper No. 27. FAO, Rome.
- Kapetsky, J.M. 1995. A first look at the potential contribution of warm water fish farming to food security in Africa. *In* J.J. Symoens and J.C.

The goal and objectives of the WorldFish Center's Strategy for Africa 2002-2006 are set out below.



Box 1. WorldFish Center Strategy for Africa

Micha (eds.) The management of integrated freshwater agro-piscicultural ecosystems in tropical areas. Technical Centre for Agricultural and Rural Cooperation, Wageningen.

Lévêque, C. 1999. Les poissons des eaux continentales africaines: diversité, écologie, utilisation par l'homme. IRD, Paris, 521 p.

Moehl, J. 2001. Aquaculture research priorities in Sub-Saharan Africa. Background paper for a regional program planning workshop held during 23-25 April, 2002 at the WorldFish Center Abbassa, Egypt. 16 p.

Stomal, B. and J.Y Weige. 1998. Mythes et réalités des aquacultures africaines. Afrique contemporaine 187:60-76.

Welcomme, R. 1989. Review of the present state of knowledge of fish stocks and fisheries of African rivers. In D.P. Dodge (ed.) Proceedings of the International Large Rivers Symposium, Canadian Special Publication of Fisheries and Aquatic Science 106: 515-532.

Ye, Y. 1999. Historical consumption and future demand for fish and fishery products: exploratory calculations for the years 2015/2030. FAO Fisheries Circular No. 946. FIPP/C946. FAO, Rome. 31 p.

P. Dugan is from the WorldFish Center's Regional Research Center for Africa and West Asia, PO Box 1261, Maadi, Cairo, Egypt.
E-mail: worldfish-egypt@cgiar.org

Potential for the development of aquaculture in Africa

D.M. Jamu and O.A. Ayinla

Abstract

Aquaculture production in Africa has remained low despite the huge potential that exists on the continent. In order for this potential to be realized, it is necessary to refocus the direction of aquaculture development. This paper concludes that for further growth to occur it is necessary to: (i) widen the range of production systems; (ii) increase production intensities and efficiencies; (iii) develop management technologies for indigenous species that target local niche markets; (iv) put more emphasis on marketing and processing of high value products; (v) promote policy research on how aquaculture production can respond to changing macroeconomic policies; and (vi) accelerate the disengagement of government from activities that can best be done by the private sector.

Introduction

Aquaculture in Africa has come a long way since it was first introduced. However, in comparison to the rest of the world, aquaculture production in Africa is still insignificant at the global level and accounts for about 0.9 per cent (404 571 t) of the total global aquaculture production in 2000 (FAO 2003). Nonetheless, aquaculture in Africa is going through an exciting phase of evolution and growth after numerous false starts that did not result in any meaningful aquaculture development. This lack of development exists against a backdrop of conditions that would benefit greatly from the rapid development of aquaculture on the continent, namely, high incidence of poverty, malnutrition and unemployment (Hecht 2000). The reasons for the lack of growth have been reviewed elsewhere (Brummett and Williams 2000; Huisman 1990; Harrison 1995) and include overzealous and unplanned promotion of aquaculture that placed emphasis on technical research and technology transfer without regard to the natural resource base and the socio-cultural and economic context within which the technologies were being promoted. It became apparent that technical research and technology transfer had to fit within the local conditions (natural resources, socio-cultural and economic) of the specific area where aquaculture development was being planned.

Since the early 1980s, some international development agencies and advanced

research institutes have been promoting aquaculture within the context of integrated agriculture and have begun addressing socio-cultural and economic factors that have been impeding aquaculture development. This approach resulted in sustained aquaculture growth in some African countries, such as Côte d'Ivoire, Egypt, Ghana, Malawi, Nigeria and Zambia. The development of domestic and export markets for fish, changing macro-economic environments and the stagnation of inland capture fisheries in sub-Saharan Africa has made investment in aquaculture attractive. Private investment in commercial aquaculture production and growth of this sector have been reported in Egypt, Kenya, Namibia, Nigeria, Malawi, South Africa, and Zimbabwe. In order for aquaculture to register further growth and meet its potential of bridging the gap between fish supply from capture fisheries and the demand for fish, the direction of aquaculture development in Africa will have to be refocused. This paper explores the potentials of aquaculture in Africa and proposes future directions for the implementation of aquaculture research and development in the continent. The paper concentrates on four issues, namely, production systems, culture species, marketing and policy.

Production systems

A wide variety of production systems, such as cages, ponds, tanks and raceways, are being used for aquaculture in agriculture, freshwater and marine environments in Africa. These systems are

being used in small, medium and large-scale operations and at various levels of intensity (Machena and Moehl 2001). Currently, earthen ponds are the dominant production system in Africa. A major proportion of public sector research and development effort has been directed towards increasing the productivity of pond systems. In contrast, very little public sector research and development has been geared towards improving and understanding other production systems such as brushparks, cages, and culture-based enhancement fisheries in floodplains, rivers and lakes. In order to increase the production potential of aquaculture in Africa, research and development should focus on a wider range of production systems for fish farming and on increasing the intensity of production in fishponds to help farmers achieve higher yields.

Production intensity and efficiency

The future of aquaculture in Africa lies in increasing production efficiencies and intensities so as to produce more fish using less land, water and financial resources. In order to achieve this, research on genetic enhancement of aquaculture species to allow for faster growth and more efficient use of feed is needed.

The species used in African aquaculture are in the early stages of domestication and, therefore, their response to improved management is limited. For meaningful production gains to occur,



M. Prein

The utilization of perennial streams to establish ponds is an option for small-scale farmers to diversify activities and have a year-round supply of fish for home consumption and income, east of Zomba, Malawi

emphasis should be placed on developing better performing strains through genetic enhancement. Genetic enhancement methods such as those used to produce the GIFT strain Nile tilapia (Eknath et al. 1993) should be widely disseminated in Africa to accelerate national genetic enhancement programs. In addition, development and application of improved broodstock and hatchery management techniques are required to avoid inbreeding, interspecific hybridization, and contamination of improved strains through introgression from feral species and vice versa.

One way of achieving high production intensities is through the use of recirculating aquaculture tank systems (concrete or fiberglass). These systems require aeration and complete feeds to support the high stocking densities. Moreover, they rely on organized urban markets to move the products (directly or through brokers and middlemen). Use of these systems is increasing in the urban and peri-urban areas of West Africa where land availability is a major constraint to investment in aquaculture. For example, in Nigeria intensive recirculating systems are being used to culture African catfish (*Clarias gariepinus*). Intensive recirculating systems are likely to be important in the production of fish for the peri-urban and

urban areas to meet the demand from the growing urban populations.

Fish Nutrition

As aquaculture production becomes more and more intensive, fish feeds will be a significant factor in increasing the productivity and profitability of aquaculture. Feed management determines the viability of aquaculture as it accounts for at least 60 per cent of the cost of fish production. At present, the high cost and low quality of fish feeds are major factors limiting the development of aquaculture in Africa and are likely to remain so in the near future. Therefore, nutrition research that helps to reduce the cost of fish feeds without reducing their efficacy will be crucial to the successful development and commercialization of aquaculture in Africa.

So far, nutrition research has concentrated on the replacement of animal protein by plant proteins with a view to reducing the cost of supplemental feeds (de Silva 2001). Hecht (2000) contends that research on inexpensive feed ingredients has not contributed greatly to aquaculture development in Africa and suggests that more effort should be put into research on how plant proteins can best be used in the

feeding of fish. Recognizing that ponds will remain the major aquaculture production system in Africa for the foreseeable future, developing nutrition strategies that maximize the contribution of natural and supplemental feeds in fishponds would help to expand aquaculture production. This requires the development of revolutionary feed and fertilization regimes that increase the nutritive value of fish diets (both supplementary and natural), and increase profitability and productivity without degrading the environment. Recent work on staged pond inputs in Thailand (Brown et al. 2001; Yi and Lin 2000) where feed costs are reduced by delaying the timing of supplemental feeding without reducing fish yields provides a framework for application and adaptation to aquaculture in Africa.

Species for aquaculture

Aquaculture research and development in Africa have concentrated on several tilapia species and on the African catfish. The tilapias have been more widely promoted for fish farming and now dominate aquaculture production. Other indigenous fish species that have a high local demand in the different countries also have a tremendous potential to contribute to higher aquaculture production. For example, clariids such as the African catfish (*C. gariepinus*) have overtaken tilapia as major culture species in Nigeria (FAO 1999), and common carp (*Cyprinus carpio*) production in Egypt is in decline in preference to the indigenous Nile tilapia (*Oreochromis niloticus*) (Brummett 2000). This trend of market demand dictating the choice of indigenous fish species for culture is likely to continue in the future and will direct aquaculture expansion towards the production of fish for niche markets. Therefore, efforts should be made to develop production and management technologies for indigenous species that have a high local demand. The development of production techniques for local species and their successful culture may also help to protect natural fish populations, which are threatened in many cases due to unsustainable fishing practices.

Culture of marine species is underdeveloped in Africa. Except for the culture of a

few species such as oysters, seaweed, and sea bass in Egypt, Namibia, South Africa, and Tanzania, very little effort has been spent on promoting this sector. Focused attention on the development of this sector has a potential to generate employment and take advantage of the opportunities that exist for export-oriented production.

Floodplain aquaculture and culture-based fisheries

Although earthen ponds will continue to be the dominant aquaculture production system in Africa, the potential of other production systems such as culture-based fisheries in floodplains, lagoons, and small water bodies needs to be fully explored. Simple management interventions in floodplains can increase fish yields. For example, fish yields ranging from 300 to 1 700 kg ha⁻¹ have been reported from floodplain fish culture systems in Bangladesh, Malawi, and Vietnam (Dey and Prein 2002; Chikafumbwa et al. 1998). Culture-based fisheries in the form of brushparks also have a long tradition in West Africa and recent studies conducted in Malawi (Jamu et al. 2003) suggest that brushparks could be a viable technology for fish production in other parts of Africa.

The high production potential of floodplain aquaculture and culture-based fisheries, their accessibility to the rural poor and landless people, and the fact that little initial capital investment is required to implement aquaculture in floodplains compared to proprietary land-based aquaculture (Lorenzen et al. 2001), provide a good option for supplying high quality protein and additional income to the rural poor. To realize this potential, the traditional aquaculture technologies that are practiced in African floodplains need to be aggressively reviewed and refined to allow for better control of production and management. Development of aquaculture in floodplains should concentrate on introducing simple management interventions, e.g., stocking, and supplemental feeding of fish in enclosures, temporary pools, channels, etc., as well as on testing different co-management arrangements that maximize the social and economic benefits to the communities using these resources.

Cage culture

Existing cage culture operations in Africa indicate that cage culture is viable and has tremendous potential to produce high quality fish products for domestic and export markets (Windmar et al. 2000). However, the dependence of these production systems on formulated feeds, intensive land-based hatcheries, and initial high capital outlay all suggest that commercial cage culture operations can only be undertaken by industrial investors. Since most of the information and technology on the operation of cage culture systems are in industrialized countries, the potential of this sector to contribute to fish production will depend on the formation of partnerships between developing country operators and developed country investors.

Research on small-scale cage culture operations in irrigation canals, rivers, and lakes is still in its infancy in Africa, but these systems have the potential to contribute to rural incomes and fish production (Mikolasek et al. 1997). For example, experience in Asia indicates that small cages can provide rapid returns to the rural poor who do not have access to land for pond aquaculture (Hambrey et al. 2001). To develop small-scale cage culture operations, the focus should be on consolidating research on small-scale cage

operations in rivers and small water bodies, establishing management and institutional guidelines for the use of cages in water bodies, and generating information on the costs and profitability of small-scale cage culture.

Marketing

Markets and marketing are essential for the development of aquaculture (Huisman 1990). Small-scale aquaculture development efforts in the past have emphasized the importance of aquaculture for food security without focusing on the commercial dimensions of fish farming (Hecht 2000). However, the FAO Strategic Assessment of Aquaculture and a review of the literature suggest that there is a high market demand for fish that will support commercial fish farming in Africa (Aguillar-Manjarrez and Nath 1998). In order for small-scale aquaculture to take off in Africa, future research and development should emphasize both the development of aquaculture for income generation and the production of more affordable fish for the rural and urban poor. The demographic shifts that will result in 61 per cent of the African population residing in urban areas by 2025 (de Nigris 2000) suggest that there is also a need to focus on urban markets. While small-scale aquaculture will still continue to produce for the rural markets,



A low-risk option for farmers to start growing fish on their farms and gain experience and skills through rice-fish farming

R. Brummett



Fisheries Dept., Zambia

Harvesting of small-scale tilapia ponds in Northern Zambia

these demographic shifts indicate that there will be a market for small-scale and large-scale commercial farmers to produce high quality fish and processed fish products for the urban markets. Research is required to study market demand and supply, with projections for the future, and how farmers should target consumer groups for the future success of the industry in Africa.

Small-scale farmers have fragmented production units that require collective production and marketing to ensure that fish are delivered to markets at a cheaper price. This requires the formation of producer groups or associations. Although there is very little information on group formation by commercially-oriented small-scale aquaculture producers, experience of other market-oriented agricultural products such as cocoa, coffee, horticulture products, milk, and tobacco suggest that producer associations are beneficial for the collective procurement of inputs and marketing of products. Producer groups and associations would benefit small-scale aquaculture through high volume purchases of inputs, including feed, fertilizers, and fingerlings, and ensuring lower marketing costs. Currently, extension services to individual farmers are focused on improving production, while neglecting marketing, processing (cold chains, live marketing, smoking and valued added products), socio-economic factors, and the adoption of aquaculture. However, future development will depend on how African fish farmers are prepared to meet the challenges of market orientation and, hence, the identification of effective aquaculture adoption and dissemination strategies.

Policy

Aquaculture development in many African countries is hampered by the lack of sector-specific development policies and plans. The policy environment under which aquaculture development has been promoted has actually received very little attention compared to the development of production technologies. To ensure an increased contribution by aquaculture to food security and incomes, issues such as credit availability (to farmers, producers and local marketing chains), facilitation and promotion of aquaculture enterprises, aquaculture technology adoption and dissemination processes, the protection of the environment, and biosafety need to be addressed.

African governments are promoting democracy, trade liberalization, and decentralization. These changes are affecting the way that aquaculture development is facilitated. For example, the Nigerian government is disengaging itself from direct production of fish by promoting the development of aquaculture through the participation of all stakeholders, with the government guaranteeing loans to groups of fish farmers. Uganda is privatizing agricultural extension services and giving farmers the choice of extension advice by providing them with government money to buy the advisory services they want (NARO/MAAIF 2002). Research on the impact of national policies on aquaculture development needs to be undertaken in order for aquaculture development plans to respond better to macro-economic policies.

One of the major policy issues that should be addressed in Africa is the role of government and government stations in the promotion and development of aquaculture. Until recently, the model for aquaculture development in Africa involved the construction of government stations to produce fingerlings and table fish for sale to farmers and the general public. This model has proved to be unsustainable (Moehl 1999) and has resulted in the privatization of fingerling production in Madagascar (van den Berg 1996). The stations now have a new role as sites for participatory technology development and maintenance of improved strains of fish, as is the case for

Malawi and Nigeria. The experience of Malawi on the efficacy of participatory aquaculture research and extension is currently being documented. However, the lack of documentation of successful privatization and redefined roles of government stations make it difficult to use them to influence policy change in the African continent. Documenting the processes and impacts of successful aquaculture policies will provide information that can be used in the formulation of similar policies in other African countries. Accelerating the disengagement of governments from functions that can be done efficiently and profitably by private farmers will allow governments to concentrate on delivering quality services that cannot be undertaken by the private sector, e.g., the genetic improvement of fish and maintenance of improved fish strains.

Conclusion

Aquaculture is now a known food production enterprise in Africa and has become established in a number of countries. However, in order to realize the full potential of aquaculture in Africa there is an urgent need to develop and promote aquaculture technologies that increase intensification of production; make it accessible to the poor and the majority of the African population through the use of culture in resource systems such as floodplains, rivers, and small water bodies; and develop production and marketing strategies that allow farmers to respond better to changing consumer demands. The public sector should devote more resources to policy research on the facilitation and promotion of aquaculture, as well as the response of aquaculture enterprises to changing macro-economic policies.

References

- Aguillar-Manjarrez, J. and S. Nath. 1998. A strategic reassessment of fish farming potential in Africa. CIFA Tech. Pap. No. 32. FAO, Rome. 170 p.
- Brown, C.L., R.B. Bolivar, E.T. Jimenez and J. Szyper. 2000. Timing of the onset of supplemental feeding of Nile Tilapia, p. 237-240. *In* K. Fitzsimmons and J.C. Carvalho Filho (eds.) *Tilapia Aquaculture. Proceedings of the Fifth International Symposium on Tilapia in*

- Aquaculture, Panorama da Aquicultura-Magazine, Rio de Janeiro, Brazil.
- Brummett, R.E. 2000. Indigenous species for African aquaculture development. *In* J. Nielsen and T.M. Bert (eds.) Ecological and genetic effects of aquaculture on the environment, and their solutions, Kluwer Scientific, Dordrecht, The Netherlands.
- Brummett, R.E. and M.J. Williams. 2000. The evolution of aquaculture in African rural and economic development. *Ecological Economics* 33:193-203.
- Chikafumbwa, F.J., K.L. Katambalika and R.E. Brummett. 1998. Community managed "thamandas" for aquaculture in Malawi. *World Aquaculture* 29(3): 54-65.
- de Nigris, M. 2000. Urbanization and food demand in Africa. *FAO Food into Cities Collection*. www.fao.org/ag/ags/agism/sada/docs/doc/dt0497.doc
- de Silva, S.S. 2001. A global perspective of aquaculture in the new millennium. p. 431-459. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery and J.R. Arthur (eds.). *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. NACA, Bangkok, and FAO, Rome.
- Dey, M. and M. Prein. 2002. Alternating rice and community-based fish culture in seasonally deep-flooded ecosystems. *Agricultural Technologies for Rural Poverty Alleviation*. IFAD Advisory Notes Number 2.
- Eknath, A.E., M.M. Tayamen, M.S. Palada-De Vera, J.C. Danting, R.A. Reyes, E.E. Dionisio, J.B. Capili, H.B. Bentsen, B. Gjerde, T. Gjedrem and R.S.V. Pullin 1993. Genetic improvement of farmed tilapias: the growth performance of eight strains of *Oreochromis niloticus* tested in different farm environments. *Aquaculture* 111:171-188.
- FAO. 1999. *Fishery Statistics: Aquaculture production*. FAO Fisheries Series No. 58. FAO, Rome, 178 p.
- FAO. 2003. *Fisheries statistics*. <http://www.fao.org>.
- Hambrey, J., L.A. Tuan and T. K. Thuong. 2001. Aquaculture and poverty alleviation II. Cage culture in coastal waters of Vietnam. *World Aquaculture* 32(2):34-40.
- Harrison, S. 1995. Aquaculture in Africa: socio-economic dimensions. *In* J. Muir and R. Roberts (eds.). *Recent Advances in Aquaculture*. Volume 5. Institute of Aquaculture, Stirling, UK.
- Hecht, T. 2000. Considerations on African aquaculture. *World Aquaculture* 31(1): 12-19.
- Huisman, E. A. 1990. Aquacultural research as a tool in international assistance. *Ambio* 19(8): 400-403.
- Jamu, D.M., K. Chaula and H. Hunga. 2003. A preliminary study on the use of fenced brushparks for fish production in Lake Chilwa, Malawi. *NAGA WorldFish Center Quarterly* 26(1):4-8.
- Lorenzen, K., U.S. Amarasinghe, D.M. Bartley, J.D. Bell, M. Bilio, S.S. de Silva, C.J. Garaway, W.D. Hartmann, J.M. Kapetsky, P. Laleye, J. Moreau, V.V. Sugunan, and D.B. Swar. 2001. Strategic review of enhancements and culture-based fisheries, p. 221-237. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery and J.R. Arthur (eds.). *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand. NACA, Bangkok, and FAO, Rome.
- Moehl, J. 1999. Aquaculture in Africa: perspectives from the FAO Regional Office for Africa. *FAO Aquaculture Newsletter* 21:22-23.
- Machena, C. and J. Moehl. 2000. Sub-Saharan African aquaculture: regional summary, p. 365-381. *In* R.P. Subasinghe, P. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery and J.R. Arthur (eds.). *Aquaculture in the Third Millennium*. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok. NACA, Bangkok, and FAO, Rome.
- Mikolasek, O., O. Patout, J. Lazard and M. Massou. 1997. Aquaculture development facing the reality: example of cage tilapia in the Niger river (Niger), p. 348-356. *In* K. Fitzsimmons (ed.) *Tilapia Aquaculture*. Proceedings from the Fourth International Symposium on Tilapia in Aquaculture, Northeast Regional Agricultural Engineering Service Cooperative Extension, Ithaca, New York.
- NARO/MAAIF. 2002. NAADS Special: Private Sector Agricultural Advisory Services. *Uganda Fish Farming News* 2(1): 3-5.
- van den Berg, F. 1996. The private sector: a potential key element in the development of small-scale aquaculture in Africa – lessons from Madagascar. *FAO Aquaculture Newsletter* 12:14-16.
- Windmar, L., S. Jarding and R. Paterson. 2000. Current status of tilapia aquaculture and processing in Zimbabwe, p. 595-597. *In* K. Fitzsimmons and J.C. Carvalho Filho (eds.) *Tilapia Aquaculture*. Proceedings of the Fifth International Symposium on Tilapia in Aquaculture, Panorama da Aquicultura-Magazine, Rio de Janeiro, Brazil.
- Yi, Y. and K. Lin. 2000. Analysis of various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): profitability and potential environmental impacts. *In* K. Fitzsimmons and J.C. Carvalho Filho (eds.) *Tilapia Aquaculture*. Proceedings of the Fifth International Symposium on Tilapia in Aquaculture, Panorama da Aquicultura-Magazine, Rio de Janeiro, Brazil.

D.M. Jamu is from the WorldFish Center, Zomba, Malawi, and **O.A. Ayinla** is from the Nigerian Institute of Oceanography and Marine Research, Lagos, Nigeria. E-mail: worldfish-malawi@cgiar.org

Local solutions to challenges of West Indian Ocean fisheries development

R. van der Elst

Abstract

The West Indian Ocean is rich in biodiversity and marine resources. This paper gives an overview of fisheries development and resource management in the region. There are many shared issues that must be addressed within countries and at the regional level. These are illustrated by examples from three countries. In Mozambique the issues of lack of information about artisanal fisheries, excessive harvesting of juveniles and conflicts between artisanal and commercial sectors are highlighted. Elements in addressing this include targeted research and decision-making support tools. The challenges faced in Somalia stem primarily from the political instability that contributed to an absence of sound fisheries policy. An example of a highly participatory process to develop the policy provides a model for other countries. In Tanzania, the issue of dynamite fishing was addressed by local communities initiating a program to promote wise use of the resources. There is a clear opportunity for better collaboration and greater integration of fisheries research and management on a regional basis. There is also much to be learnt by the sharing of experiences between countries. This has been initiated by some recently launched regional cooperation projects, but there are still many challenges facing this region.

Introduction

The West Indian Ocean (WIO) is geologically fascinating. Created through the break-up of Gondwanaland millions of years ago, it is a sea with deep canyons, mid-ocean ridges, large fluvial banks, granitic islands, and coral atolls. There are regions of strong seasonal upwellings, narrow continental shelves, and some of the largest boundary currents on the planet. Its role in the early distribution of seafaring peoples, and subsequent trade and shipping routes, dates back many centuries. Equally fascinating is the rich biodiversity of this ocean, with its high levels of endemism and unique species – such as the nearly extinct coelacanth (*Latimeria chalumnae*). But its importance is not confined to its natural features alone. This body of water provides sustenance and job opportunities to an ever-increasing human population. The Indian Ocean is the only sea surrounded by developing countries with close to half the world's population. The challenges faced in meeting expectations and demands are enormous – especially so in times of drought and unsettled socio-economic development.

The Food and Agriculture Organization of the United Nations (FAO) has divided the world's marine environment into 19 major fishing areas. One of the largest of these is

the WIO, an area of 30 million km² and accounting for some 8 per cent of the total marine waters. While global trends in fish landings for most of the 19 areas are negative, the WIO has maintained a steady rate of increase in its total landings (FAO 2000). This has largely been the result of the increased harvest of tuna and mackerel-like species, with recent additions of toothfish and orange roughy. While the total catch is relatively modest at about 4 million t, being only 4.6 per cent of the world's total marine fish landings (FAO 2000), it is seen by distant fleets as an opportunity to offset their decreased landings from other regions.

Fisheries development and management issues

Unfortunately, the WIO has not enjoyed the same level of research interest and coordinated resource management as many other regions. There was a spate of academic interest many years ago, mostly from countries outside the region (Table 1).

Many of these initiatives were of an exploratory nature and, while they did generate interesting scientific data, they did little to assist the sustainable development of resources for the surrounding countries.



Map of the West Indian Ocean

More recently, local institutions have implemented research programs of their own, many with a focus on sustainable fishery development. The results from some of these programs are available and several vexing issues have been resolved.

Table 1. List of past initiatives on resource management in the West Indian Ocean

Expedition	Activities and Outputs	Country	Year	References
International Indian Ocean expedition	Mapping of physico-chemical parameters	Numerous (36 ships)	1966-70	Wyrтки 1971
The Tyro expedition	Bio-physical research	Netherlands	1993	Wiese et al. 1994
Several Fridtjof Nansen surveys	Stock estimates	Norway	1960s –95	na
South West Indian Ocean Programme (SWIOP)	Fishery resources assessment	WIO countries, Norway and FAO	1986 – 87	na
Indian Ocean Commission (IOC)	Regional collaboration	WIO island states	1982-present	na

A few examples from different countries are detailed below.

Mozambique

Mozambique has one of the longest coastlines in Africa, a total of about 2 750 km. The coastal areas have rich offshore banks, muddy estuarine bays, fringing reefs and islands, all of which contribute to potentially rich and diverse fisheries. Indeed, for many years these resources have been the primary contributors (about 40 per cent) to the GDP of Mozambique. More than 50 per cent of that nation's protein food intake is stated to comprise fish, while some 400 species are harvested for food in one way or another. Many Mozambicans also rely on fishing as a source of income. Historically, only the industrial fisheries received attention and a full recognition of the role and importance of the artisanal sector is comparatively recent. A census conducted by the Mozambican small-scale fisheries development unit at the Instituto para o Desenvolvimento da Pesca de Pequena Escala (IDPPE) in 1996 documented the magnitude of the informal and artisanal sector. It found that at least 80 000 artisanal fishers, located in 787 fishing centers, were woven into the fabric of life and culture of the Mozambique nation. This prompted the need for a closer understanding of the relationship between the artisanal fishers and the socio-economic development of coastal regions in several parts of Mozambique. With support from the International Fund for Agricultural Development (IFAD), the Norwegian Agency for Development Cooperation (NORAD) and FAO, an ambitious program was launched by the Instituto Nacional de Investigacao Pesqueira (IIP), with the aim of establishing clear development linkages between artisanal fisheries and regional development. The districts of Angoche and Moma were selected as pilot study areas,

as the intensity of the artisanal fishery there is exceptionally high, with an estimated 7 602 seine nets operational.

A comprehensive stratified sampling program was designed and, with the engagement of a dozen or more trained monitors, the artisanal fishery was surveyed on a daily basis for a period of four years. Backed by an in-house developed database, the results of some 50 per cent of all fisher outings produced some startling facts.

The estimated total catch made by the artisanal fishers in these two districts alone exceeded 30 000 t in some years, almost equal to the total catch reported by Mozambique to FAO. By far the largest proportion of the catch comprised small pelagic species, mostly anchovies and sardines. The availability of these short-lived species varied enormously from year to year, which has implications for the economies of the coastal communities.

Of particular note was the high incidence of juvenile and especially larval fish and shrimp in the catch. Overall these accounted for 11 per cent of the catch by weight. The high larval by-catch was attributed to the mosquito net liners that had been inserted into the nets. An entire "cottage industry" had developed where women would deep-fry the larvae as a quick snack along the roadside.

Not only did the larval catch potentially compromise future recruitment to the artisanal fishery, the larval shrimp catch was also seen as a threat to optimizing the valuable offshore industrial shrimp catches and, hence, creating a serious conflict of interest between the users. On the other hand, the industrial trawlers ventured extremely close to shore, thereby impacting the artisanal beach seine fishery. Clearly, this situation offered opportunities for compromise. Using the information

generated by the project, a management agreement was implemented whereby mosquito net liners were removed in exchange for trawlers remaining further offshore. The monitoring program soon recorded lower harvests of larval fish, down to 4 per cent of the total landings in the first season.

Despite the fact that the artisanal catch of shrimp was only 1.5 per cent of the industrial catch, with a further 0.2 per cent as juveniles, the industrial versus artisanal conflict remained. The IIP program provided decision-making support. Using a bio-economic model based on yield per recruit, and taking the market value of shrimps each month of their first year of life (by size), valuable information was derived concerning the size limits of the prawns. Although several assumptions had to be made, the model indicated that by closing the fishery completely for the first month of juvenile growth (either by banning fishing or changing selectivity) the potential total yield in terms of market value to the artisanal fishers increased by 18 per cent. The profitability increased for the first four months of juvenile life being closed to fishing, when it reached a potential 55 per cent increase in value in the fifth month of fishing. Thereafter, the profitability decreased substantially (Fig. 1).

Thus, while the artisanal fishers could potentially benefit from a 55 per cent increase in the value of their catch, the industrial fleet would also stand to benefit, although only marginally. While it was shown that a four-month closed season would increase the survival of the larval shrimps six-fold, the actual contribution to the industrial catch would be no more than one metric tonne – about 0.1 per cent of their total annual catch. Part of the reason for this lies in the fact that the natural mortality for shrimps is exceedingly high and that the artisanal catch of juveniles is relatively small.

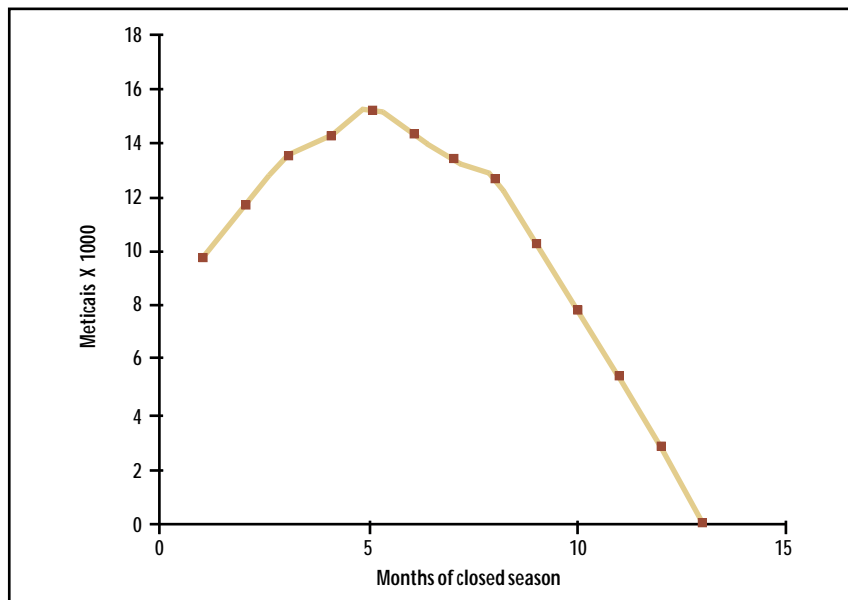


Fig. 1. Relative income to artisanal fishers from shrimp recruits (1 000 meticals per kg: 25 000 meticals = 1 US\$)

Tanga artisanal fisheries program that not only sought to monitor catches, but promoted the wise use of resources. Some fishing zones were declared voluntary sanctuaries. The use of dynamite was seen as a negative factor, not only for the environment but also for the community. The scourge of dynamite fishing has now been significantly reduced and co-management of fishery resources is generating perceptibly increased returns. Several other fishery-related initiatives in Tanzania have been successful. For example, the development of marine parks and, especially, the implementation of the Mafia Island Marine Park Management Plan, has led the way in participatory management and multiple-use of resources.

Challenges and opportunities for fisheries management

The WIO is exceptionally rich in biodiversity and marine resources. The region supports a great many fisheries, ranging from subsistence gathering to the most sophisticated industrial fleets. Most countries in the region depend on these resources, either as primary contributors to their GDP or as vital elements of socio-economic stability in their coastal regions. In addition, fisheries in all these countries share similar problems and challenges. Examples include conflict between artisanal and industrial fishers, how to deal with the by-catch, management of straddling stocks, setting of regional harvesting targets for migratory species, etc. However, a number of competent marine research institutions are located in the region, many of which have excellent scientific know-how.

Yet, these countries have so far failed to implement a regional plan for fisheries. The potential benefits of a collective approach to living marine resources development in

Somalia

Somalia presented a different challenge. With the longest coastline in Africa and its rich upwelling system off the Horn, theoretically Somalia has great potential for fishery development. Yet political instability has impeded the wise use of marine resources and little benefit has been generated for its citizens. The absence of a sound overall fisheries policy was seen as a key shortcoming and in response the World Conservation Union (IUCN) and the Oceanographic Research Institute in Durban (ORI), with donor support from the European Union (EU) and the Italian Aid Agency (COOPI), stimulated policy development in two of the more stable regions of Somalia, namely, Somaliland and Puntland. In a process that was executed by local NGOs, a comprehensive marine resource-use policy was formulated. Trained volunteers traveled thousands of kilometers under extremely difficult conditions to reach coastal communities in order to canvass their opinion on fisheries matters. In the end, a near-consensus draft policy was formulated and subsequently presented to the respective regional parliaments. An added bonus was the consensus reached between otherwise antagonistic factions that clearly shared similar problems and interests vis-à-vis fisheries.

Some of the key elements included in the policy are:

- Who owns the resources?
- How are fishing rights allocated and who has access to the resources?
- Approaches to resource management.
- Institutional structures for management of fisheries and resources.
- Funding and finance.
- Research, monitoring, awareness and training.
- Environmental protection.
- Coastal zone management.
- Surveillance and compliance.
- Fishery facilities.

One interesting element of the Somali policy initiative was that it could benefit from the South African experience of developing a new fisheries policy. Both countries were emerging from a troubled past and were thus presented with a unique opportunity to develop new policies.

Tanzania

The five million people living along the 800 km coastline of Tanzania are heavily dependent on marine resources. Most fish are taken in freshwater lakes in Tanzania. The marine catch comprises 15 per cent of the total catch and is generally poorly managed and in some cases under threat. One cause has been the extensive use of dynamite in coastal waters, which has not only damaged fish stocks but has also destroyed large tracts of coral reefs. In response, local communities initiated the



Quinea netting for small shrimps and fish is a widespread activity amongst coastal women of East Africa

R. van der Elst

Table 2. List of fisheries research and management projects/activities in the West Indian Ocean

Name of project	Purpose/Activity	Funding support
Regional Fisheries Information System	Standardized and verifiable fisheries data collection	DFID ^{*1}
Monitoring, control and surveillance	Improving compliance	EU
Harmonizing fisheries policy	Towards compatibility in management of resources	FAO
Indian Ocean Tuna Commission	Sustainable management of tuna and related species in the IO	FAO
South West Indian Ocean Fisheries Commission	Sustainable management of non-tuna species in the WIO	FAO
East African Marine Eco-region (EAME)	Threats and root causes of biodiversity loss	WWF ^{*2}
Global International Waters Assessment (GIWA)	Assessment of status of defined regions, including fisheries of Agulhas large marine ecosystem (LME).	GEF: UNEP/NOAA/Sida/Finland ^{*3}
Somali and Agulhas large marine ecosystems (LME)	Understanding the two largest LMEs in the WIO	GEF – UNDP ^{*4}
South West Indian Ocean Fisheries Project (SWIOFP)	Assessment and management of the offshore fisheries resources	GEF-World Bank
Jakarta Mandate: small-scale fisheries of the WIO	Identification, understanding and improved management of the small-scale fisheries of the region in the context of biodiversity protection	IUCN, NORAD

*1 Department for International Development

*2 World Wildlife Fund

*3 Global Environment Facility: United Nations Environment Programme/National Oceanic and Atmospheric Administration/Swedish International Development Cooperation Agency/Finland

*4 Global Environment Facility - United Nations Development Programme

the region have thus not been realized. Nor have the experiences in one country necessarily been beneficially shared with others. In addition, many coastal fisheries are poorly understood and often not well managed, while offshore stocks are mostly taken by nations from other parts of the world, hence, generating little real benefit to countries of the WIO region.

This situation offers opportunities for better collaboration and greater integration of fisheries research and management among countries in the region. Therefore, a number of regional cooperation projects have been launched recently (Table 2).

The Jakarta Mandate project, a marine component of the Convention on Biological Diversity (CBD), is now generating valuable insights. This work, managed by the IUCN office in Nairobi, has brought together a number of national institutions to document the great diversity of fishery types in the region. Based on existing knowledge, at least 100 different types of fisheries from Kenya, Mozambique, Tanzania, Seychelles and South Africa have been described. Preliminary assessment of these fisheries has revealed some disturbing findings.

- Very few small-scale fisheries in the study region are subject to any significant form of management.
- Most of the fisheries are open access,

- with little or no control over effort.
- The level of compliance is very low in most cases.
- Very few of the fisheries are subject to specific management plans or have published harvesting target levels.
- In many cases there is good scientific information available that could be applied to the management of a particular fishery.
- In less than 10 per cent of all the documented fisheries is there a reasonable linkage (or application) between scientific information and a structured management plan.
- There are a great many existing or potential conflicts between different fishery types and other forms of coastal and marine development.
- The level of wasted bycatch is quite low, as are its impacts on vulnerable species. However, impact on juveniles of target and other species is generally seen to be high.

Clearly, many problems remain to be solved. However, fascination with the wonders of the WIO may well hold a key to its future wise development. Interest in the study of this rich marine environment should be promoted. In particular, there should be a concerted effort to create, and be seen to create, career opportunities for the region's own citizens in this field. Part of a future vision should be that young people consider

a career in marine and fisheries science as a rewarding challenge in life. This will contribute to finding local solutions to the challenges facing the WIO fisheries.

References

- FAO. 2000. Fishery statistics. Capture production. Rome. Vol. 90/1. 619 p.
- IDPPE. 1998. Projecco de Pesca Artesanal em Nampula. Mid-term review. Documento de Apoio. Componente: Desenvolvimento da Pesca.
- Wiese, K., J. Stel, and F. Hoogvorst. 1994. The third ocean. Foto. Leusden Netherlands. 105 p.
- Wyrтки, K. 1971. Oceanographic atlas of the Indian Ocean expedition. University of Hawaii. Honolulu. 531 p.

R. van der Elst is the Head of Oceanographic Research Institute (ORI), Durban, South Africa. www.ori.org.za. E-mail: rudyp@xsinet.co.za. The Oceanographic Research Institute (ORI) was founded 50 years ago as a marine research NGO dedicated to generating knowledge, and providing decision-making support, on the sustainable use of living marine resources in KwaZulu-Natal and other parts of the West Indian Ocean (WIO). ORI has links with the University of Natal and collaborates closely with many other institutions and colleagues in the WIO region.

Valuing Africa's inland fisheries: overview of current methodologies with an emphasis on livelihood analysis

C. Béné and A.E. Neiland

Abstract

While Africa's inland fisheries are widely recognized to be of great importance to local people, accurate and up-to-date information on their value is sparse and its absence is a serious constraint to the formulation of effective fisheries policies and management practices. As a contribution to current efforts to address this constraint, this paper reviews the different methods that are potentially applicable to the valuation of inland fisheries and discusses their respective rationales and limitations within a multi-sectoral, multi-user context. The livelihood analysis approach is given special emphasis. The complementarity of this recently developed approach with the other, more conventional, environmental economics methods is illustrated.

Introduction

It is widely perceived that Africa's inland fisheries play an important role in many rural economies. However, as efforts have increased to build upon this awareness and improve the management of these resources, it has become very clear that in most parts of the continent (as in Latin America and Asia) accurate and up-to-date assessments of the economic value of small-scale fisheries are lacking (LARS2 2003; Neiland 2003). Similarly, recent assessments of the potential role of small-scale fishing activities in economic development (both at the local and national levels) also systematically highlight how poorly the true socio-economic value of this sector is reflected in official statistics and discussions on food security and livelihoods (European Commission 2000; Kaczynski and Looney 2000; Anon. 2001). Faced with this lack of information, national policy-makers and planners, as well as international development agencies, are severely constrained in their ability to propose appropriate rural development policies.

Methods do exist, however, that can help evaluate more precisely the economic and social value of inland fisheries and aquatic resources. The purpose of this article is to review the different valuation methods and to discuss their respective rationales and limitations. The Livelihood

Analysis (LA) method will be given particular attention in this review because of its promising usefulness in the specific multi-use/multi-user context characterizing inland aquatic resources. In particular, the article will underline the rationale for using LA and also highlight how it complements more classic, economic and socio-economic valuation methods.

Valuation of fishing activities

Economic valuation in fisheries can be approached in a number of different but complementary ways. Three broad approaches to estimating economic value have been developed and are now widely used: (i) conventional economic valuation; (ii) economic impact analysis; and (iii) socio-economic analysis.

Conventional economic valuation

Economic efficiency analysis. The arithmetic of conventional economic valuation is underpinned by economic efficiency analysis (EEA) that has as its goal the maximization of social welfare (defined in terms of the optimal allocation of resources). There are two ways in which EEA is commonly applied: cost-effectiveness analysis and cost-benefit analysis. With cost-effectiveness analysis there is a presumption that the least-cost option will achieve a given

objective; whereas with cost-benefit analysis the presumption is in favor of the option that produces the highest ratio of monetary benefits to costs. In short, there is an implicit value judgment underlying EEA, i.e., that improvements in economic efficiency are desirable. In a policy-planning context, this assumption of efficiency is the basis of a number of decision criteria that can be used to select and prioritize project options (or other interventions) in terms of their economic value to society.

Total economic value. It is now recognized that a natural resource may provide a range of benefits according to the particular use or function it fulfils, and this forms the basis of the concept of total economic value (TEV). The components of TEV in respect of an aquatic resource, such as a river system and its adjacent floodplains, are shown in Fig.1. The obvious and tangible benefits would be those derived from *direct use* of the resource, and these may materialize in the form of commodities (e.g., fish, aquatic plants, fuel-wood) or services (e.g., recreation and amenity). The aquatic resource may have an additional *indirect use*, such as coastal protection and providing a habitat for juvenile fish. Individuals may derive a benefit from being able to postpone their personal use of the resource to a later date; they attach an optional value to using the resource. Finally, there is

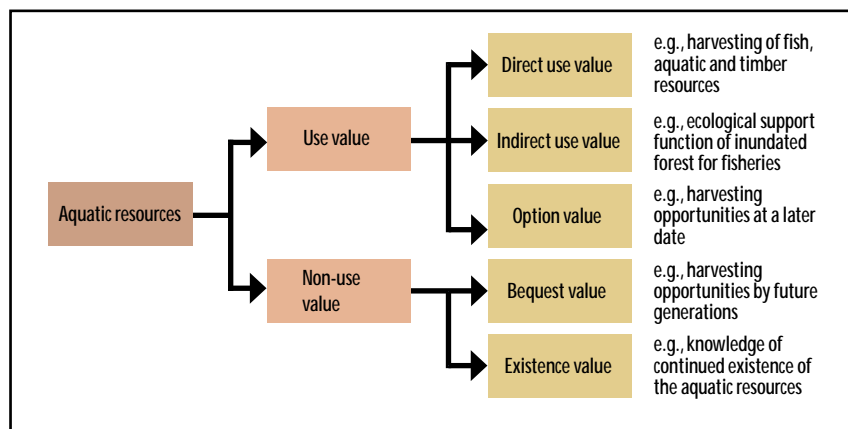


Fig. 1. Components of the total economic value (TEV) of an aquatic resource, such as a river system and its adjacent wetlands

also another set of benefits that are quite distinct, termed *non-use* (or “passive” use value). This might include the value associated with the desire to maintain a river fishery intact for future generations (bequest value) or simply the satisfaction of knowing that a particular aquatic habitat has been preserved in perpetuity (existence value).

Economic impact analysis

In contrast to the EEA described above, economic impact analysis (EclA) does not set out to determine whether a particular policy intervention or project is either beneficial or detrimental in terms of its economic value to society. While EclA will consider the level of benefits generated by an intervention, it does not consider costs of implementation (i.e., there is no benefit-cost framework). Instead, EclA aims to establish what effects a particular policy intervention or project has on specific variables. This might involve using *revenue analysis* to see whether a new fisheries management system is likely to raise fishers’ gross earnings or revenue. More ambitiously, EclA might also involve the application of *multiplier analysis* to measure the total economic activity generated by a new fisheries management system (e.g., output, income or employment) as a consequence of the interdependence between fishing and the other sectors comprising the regional economy. The total economic impact will be made up of direct and secondary (i.e., indirect and induced) effects.

Socio-economic analysis

Conventional economic valuation is concerned with the analysis of whether particular interventions or projects improve the net wealth of a society. In some cases this outcome might also involve the creation of “winners” and “losers”. For example, the building of a dam across a river for hydro-electric power involves a wide diversity of effects, including major changes in environmental quality and aquatic resource use. Conventional cost-benefit analysis sidesteps the issue by invoking the principle of “potential compensation” (i.e., the intervention represents a net gain to society if the winners could compensate the losers and still be better off). However, since this principle does not insist that compensation actually be paid, it is often of limited relevance when the losers are amongst the poorest of the poor.

In such situations (especially where there is poor governance within the weak state context), something more than economic valuation is warranted, specifically a *distributional analysis* to examine how the net costs and benefits are apportioned across different groups affected by the change. Socio-economic analyses can often provide an important starting point in identifying and characterizing the socio-economic strata in a community or region. Once the social strata are known, further in-depth economic studies (e.g., income-expenditure surveys) can provide a better understanding of benefit flows

(or the lack of them) in relation to specific policy interventions.

Livelihood analysis

In recent years, socio-economic analysis has been further extended with the development of techniques for livelihood analysis (LA) (Carney et al. 1999). When underpinned by conceptual frameworks such as the sustainable livelihoods approach (SLA) (Scoones 1998), these techniques can help to provide a better understanding of the relationship between human society and natural resources.

Rational for adopting livelihood analysis

Intrinsically, economic valuation techniques do not permit identification of the factors that influence or affect people’s access to resources. However, very often the key issue is not the availability of the resource (or symmetrically its scarcity, to which its economic or even social value is related), but the access to this resource. Extending Sen’s (1981) main conclusion, which was initially framed in the specific context of famine, to the wider domain of natural resources, an increasing number of empirical studies have clearly demonstrated that poor people in rural areas are usually those who lack access to natural resources, e.g., forests, fishing grounds, grasslands, etc. (Kremer 1994 ; Devereux 1996 ; Leach et al. 1999). In the specific context of fisheries, Béné (2003) shows how socio-institutional mechanisms governing people’s access to fisheries resources, rather than the resources themselves, play a critical role in vulnerability to poverty.

The main lesson pointed out by these different empirical studies is that determining the economic value of a natural resource becomes irrelevant if people whose livelihoods depend on these natural resources cannot access them. Therefore, a key question is: what are the factors (including policies) that influence people’s access to, and control over, natural resources?

The conceptual framework provided by LA appears to be particularly useful to address this question. Indeed, the real

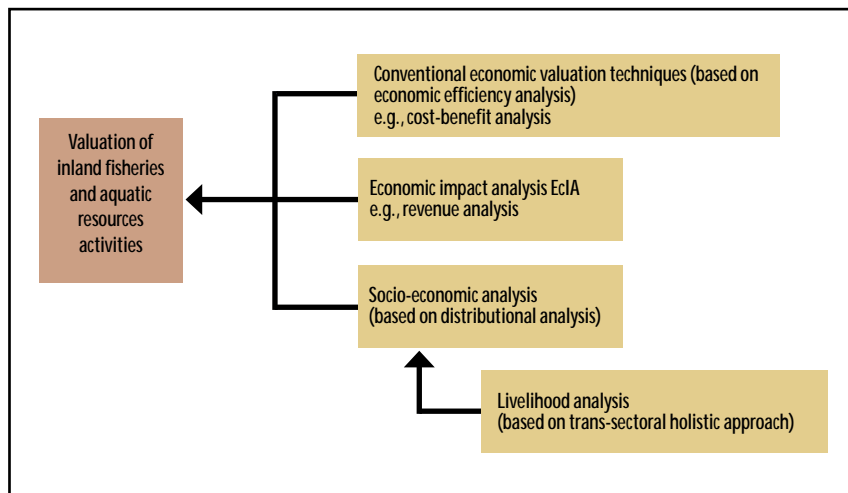


Fig. 2. Valuation techniques for aquatic resources within a multi-use context

benefit of such a framework is that it encourages analysts to take a broader and more systematic view of the factors that affect people's livelihoods – whether these are shocks and adverse trends, poorly functioning institutions and policies, or a lack of assets – and to investigate the relations between them (Scoones 1998).

Livelihood analysis in practice

The multi-use nature of the water upon which households rely for their inland fishing activities, and the multi-user context within which those activities take place, introduce a number of important methodological constraints. In particular, the intricacy of activities characterizing the livelihood strategies of the majority of fishing households implies that mono-sectoral approaches focusing on separate activities (e.g., fisheries or agriculture) are not appropriate. To correctly implement these valuation exercises, integrated (holistic) assessment analyses in which the different sectors of the local economy are viewed together as a joint production activity should be adopted.

The survey techniques and methods required for these trans-sectoral socio-economic valuations already exist. For many years they have been tested and applied in other domains (e.g., agro-pastoral and agro-forestry systems) and their respective methodological and analytical strengths and weaknesses are well known and documented (DFID 1998). Usually a

combination of participatory and non-participatory (passive) techniques is required. There is no unique “recipe” or best methodological combination. The only central condition is that the techniques must be trans-sectoral and holistic. They are, therefore, usually designed and implemented by multi-disciplinary teams. Table 1 presents some of them.

Conclusion

Adequate policies and processes for the effective management of natural resources require information about the exact economic value of these resources, and also about the ways in which people use these natural resources to sustain their livelihoods. It could be argued that to make an appropriate decision regarding the management of a natural resource, not only must information about its economic value be known but also the contribution that this resource makes to people's livelihoods: who uses the resources, when, and how?

A variety of techniques exist to answer these questions. It has been shown that the different approaches offer a set of complementary techniques that constitute a comprehensive analytical framework (Fig.2). This analytical framework, when properly applied, can help to improve understanding of the contribution of inland fisheries to national economic development and to the livelihoods of local populations.

As a final point, this article argues that the generation of more information on the economic and/or social values of small-scale fisheries is not in itself a sufficient condition to support more appropriate agenda-setting or to ensure the implementation of successful policies. Experience shows that the impact of social/economic information generated through a better evaluation process is not merely determined by the quality of that information, but also to a large extent, by the nature and quality of the policy environment. Better evaluation is nothing without improved governance, including political will and adequate policy processes.

References

Anon. 2001. Report of the Seminar on Contribution of Fisheries to Poverty Reduction in West Africa. Facilitated by the Sustainable Fisheries Livelihoods Program in West Africa, 14-15 February 2001, Dakar.

Béné, C. 2003. When fishery rhymes with poverty, a first step beyond the old paradigm on poverty in small-scale fisheries. *World Development* 31(6): 949-975.

Carney, D., M. Drinkwater, T. Rusinow, K. Neeffjes, S. Wanmali and N. Singh. 1999. Livelihoods approaches compared – a brief comparison of the livelihoods approaches of the UK DFID, CARE, Oxfam, and the UNDP. Department for International Development, London, 19 p.

Devereux, S. 1996. Fuzzy entitlements and common property resources: struggles over rights to communal land in Namibia. IDS Working paper 44. Brighton Institute of Development Studies, University of Sussex.

DFID. 1998. Socio-economic methodologies - Best practice guidelines. Department for International Development, London, published by the Natural Resources Institute.

European Commission. 2000. Communication from the Commission to the Council and the European Parliament. Fisheries and Poverty Reduction. COM (2000) 724 final. Commission of the European Communities, Brussels, 20 p.

Kaczynski, V. M. and S.W. Looney. 2000.

Coastal resources as an engine of economic growth and reduction of poverty in West Africa: Policy considerations. *Coastal Management* 28:235-248.

Kremer, A. 1994. Equity in the fishery: a floodplain in N.E. Bangladesh. Project Report No. R94E, Centre for Development Studies, University of Bath, UK.

LARS2. 2003. Statement and recommended actions. The Second International Symposium on the Management of Large Rivers for Fisheries – Sustaining Livelihoods and Biodiversity in the New Millennium. Mekong River Commission and Food and Agriculture Organization, Phnom Penh, 11-14 February 2003.

Leach, M., R. Mearns and I. Scoones. 1999. Environmental entitlements: dynamics and institutions in community-based natural resource management. *World Development* 27(2):225-247.

Neiland, A. (ed.). 2003. Valuation of tropical river fisheries: A global review. Report for the WorldFish Center, Penang, Malaysia.

Scoones, I. 1998. Sustainable rural livelihoods: a framework for analysis. IDS Working paper 72, Brighton Institute of Development Studies, University of Sussex.

Sen, A. 1981. Poverty and famines: an essay on entitlement and deprivation Clarendon Press, Oxford.

Table 1. Socio-economic technique suitable for livelihood analysis of fisheries

Type of analysis / assessment	Data collection techniques
<ul style="list-style-type: none"> Poverty profile Wealth ranking Income-expenditure survey Food security assessment 	<ul style="list-style-type: none"> Participatory / Consultative / Passive
<ul style="list-style-type: none"> Institutional analysis Stakeholder analysis Conflicts analysis Ethnic analysis Gender analysis Natural resource accessibility analysis 	<ul style="list-style-type: none"> Verbal / Visual / Analytic Quantitative / Semi-quantitative / Qualitative Rapid Appraisal / In-depth survey
<ul style="list-style-type: none"> Multi-sectoral activity analysis Household survey Activity ranking Seasonal calendar Oral histories 	<ul style="list-style-type: none"> Case study / Large-scale survey

C. Béné is from the Africa and West Asia Office of the WorldFish Center, P.O. Box 1261 Maadi, Cairo, Egypt; E-mail: c.bene@cgiar.org and **A.E. Neiland** is from the Institute for Sustainable Development and Aquatic Resources (IDDRA), Portsmouth Technopole, Kingston Crescent, Portsmouth PO2 8FA, UK; E-mail: neiland@iddra.org

River fisheries in Africa: their relationship to flow regimes

R.L. Welcomme

Abstract

River fisheries in Africa are important because of their contribution of animal protein to human diets. Such fisheries are highly dependent on hydrological regimes and show considerable year-to-year variation in response to natural climatic events. River flow regimes are being increasingly altered by withdrawals by man, principally for agriculture. The modification of hydrological regimes is leading to diminishing catches of fish and changes in the number and size of the species caught. Given that the trend to remove water from rivers for agriculture and power generation will continue, better appraisals of the impacts of such withdrawals are urgently needed so the policies for water allocation can be better defined. The development of tools to aid in such decision-making is equally important.

Introduction

Inland fisheries are fundamental to the livelihood of many African peoples. Freshwater fish contribute a considerable proportion of the animal protein in their diet, especially in areas close to streams and rivers. For example average fish consumption in Cameroon rainforests is around 47 kg/person/year, compared to 10 kg/person/year for the general population (Obam 1992) and in the Central Delta of the Niger fish consumption is about 10.5 kg/person/year versus to 7.8 kg/person/year for meat (Breuil and Quensièrè 1995). In 2000, the nominal catch of edible products on the continent, including fish from inland waters, was 2.2 million t, which represents about 25 per cent of the total world nominal production. About half of this probably came from rivers and their associated wetlands. It has been argued that real catches are much greater than the official estimates recorded in the nominal statistics because of under-reporting of subsistence catches from the many smaller streams (Welcomme 1976). A realistic value is probably double the nominal catch, implying that African rivers and streams produce about 2 million t of fish per year.

Information on fish and fisheries from as early as the 1970s shows that catches of fish from rivers are highly sensitive to hydrological regimes and, hence, to the many natural and human influences on

such regimes. Management of river fisheries has proved to be extremely difficult. The highly dispersed nature of the fisheries and the general lack of defined landings make a regular census problematic. They also hinder the regulation of fishers through the types of centralised management common until recently. More serious is the fact that the sensitivity of river fish populations to changes in the hydrological regime means that the fishery is effectively controlled by a number of users, other than the fishers, who impound, control and extract water for their own purposes. This has led to a situation where many fisheries have declined and, if unchecked, will lead to a more widespread impoverishment of river fish resources. Proper management of the river regime by providing for "environmental flows" requires a more thorough understanding of the ecology of the fish and their response to hydrological and fishing pressures.

Factors influencing fish production from rivers

Fish production from rivers is influenced by a number of factors, many of which are related. This paper focus on three key factors: hydrological regimes, fishing pressure, environmental degradation.

Hydrological regimes

Flood waters are important for most species of fish because the flooding of

lateral plains increases the area of food rich habitat and shelter from predators, and provides ideal sites for fish to develop and grow (Welcomme 1979, 1985). The annual hydrological cycle influences the migrations of many species of fish between floodplain and main channel habitats. The abundance and biomass of floodplain dependant species, and the fish catches that depend on them, fluctuate from year to year depending on the strength of flooding. Correlations between catches in a particular year and the intensity of flooding (usually represented by an index of flooding) in the same or preceding years have been found in a number of African rivers (University of Michigan (1971) for the Kafue River; Welcomme (1979) for the Shire River; Moses (1987) for the Cross River; Welcomme (1979) and Lae (1992, 1995) for the Niger River).

The delay between any flood event and the response in a fish community depends on the degree to which it is being exploited. Thus, the relationships between flood strength and catch in subsequent years for the Shire, Kafue and Niger Rivers (Welcomme 1985) showed the main correlations to be with floods in one to two previous years. Lae's 1992 data for the Niger show that in the late 1980s catches were more closely correlated with floods in the same year and that 69 per cent of the catch consisted of young-of-the-year fish, indicating a general increase in fishing

pressure. Some authors have also found correlations between catches and the amount of water persisting in the system over the low water period, notably the University of Michigan (1971) for the Kafue flats, although the best correlations were usually with the indices of flooding.

The situation in arid rivers has been less well described although, even during the drought years of the Niger River when the system was in an arid phase, good correlations with the strength of flooding were obtained (Lae 1992). All of this argues that in normal, humid African rivers the flood component of the hydrological regime is the most important factor affecting fish production, although the dry season component of the hydrograph cannot be ignored.

The effects of declining water levels on fish populations and catches were illustrated by the impact of the Sahelian drought from 1970 to 1985 when rainfall declined steadily in the Senegal, Niger and Chad basins. In this case there was no constraint to longitudinal migration, but flooding was much reduced or failed over a number of successive years. Catches declined from 90 000 t/yr to 45 000 t/yr in the Niger basin (Lae 1995). Some rheophilic and floodplain spawning species that like swift flowing water were depleted whereas lenitic and main channel spawning species that prefer still water, such as in lakes and slack water areas of rivers, became more common. These findings closely parallel those of Neiland et al. 1990 on the Benue River. In the Senegal River, catches rose from a pre-drought level of about 15 000 t to about 25 000 t in 1975 and then fell to 10 000 t in 1979. Catches in the Chad basin rose from pre-drought levels of about 100 000 t to 220 000 t in 1974 and fell to only about 35 000 t in 1985 (VandenBossche and Bernascek 1990). Chad basin catches included those from the lake as well as from the Chari-Logone river system, whose contribution became insignificant as the drought progressed. In all three systems, the early stages of the drought were marked by initial increases in catches due to an increased vulnerability of the fisheries and because the existing stocks were concentrated into smaller volumes of water, but in the later stages catches fell as the drought impacted biological production.

Fishing pressure

Most fisheries in African rivers exploit a large number of fish species by using a range of fishing gear (consisting of lines, nets and traps), each adapted to particular species, life stages and habitats. Use of the gear varies from season to season in such a way that nearly all life stages of species are vulnerable to capture. This type of multi-species, multi-gear fishery is especially difficult to survey and does not yield readily to standard mesh-dependent methods of control.

The growing population densities and increasing shortage of land means that many people have been forced into fishing as a means of livelihood. As a result, pressure on inland fish resources has tended to increase over the whole continent over the last twenty years (Welcomme 2003). As fishing effort increases, fishing impacts fish assemblages by successively eliminating the larger individuals and species from the multi-species communities and replacing them with smaller species and individuals. This process does not result immediately in lower catches as the greater productivity and reproduction rate of the smaller species compensates for the lower biomass (Welcomme 1999), but it does change the nature and the value of the fishery. While such intensive fishing pressure is now widespread, the Second International Symposium on the Management of Large Rivers for Fisheries (Phnom Penh, 11-14 February 2003) concluded that there are no proven cases of a river fishery as a whole having collapsed from fishing pressure alone. Where collapses have occurred, they have always been linked to degradation in environmental quality, usually because of altered hydrological regimes caused by dams. The impact of increased fishing pressure exacerbates the effects of such changes in the hydrological regime, but it is the changes to the flows that are of greatest importance.

Unfortunately the history of management of inland fisheries worldwide shows a generally low success rate in containing the growing pressures on fish stocks. This was mainly because of the centralized nature of traditional management whereby all the national waters were regulated by the central governments

with little attention to the differing biological and ecological needs of the fish stocks and the social and economic conditions of the fisheries. The recent trend to devolve management through co-management systems may prove more successful in that local communities will have more say in the management of their local resources. However, fisheries management is not only a question of managing the fishery, but also the environment on which the fishery depends and for this different approaches to management at the basin level have to be developed.

Environmental degradation

Most large rivers of Africa have at least one mainstem dam and some, such as the Nile and the Zambezi, have more. There are also a large number of medium-sized dams (reservoir sizes 10 - 100 km²) for irrigation, urban water supply and small-scale power generation. The larger dams are the major causes of degradation of the aquatic environment and disruption of the livelihoods of communities dependent upon farming, fishing and grazing along the river valley.

Although there have been attempts to develop large irrigated areas such as the Gezira in the Sudan and the *perimetre irrigée du Niger* in Mali, smaller irrigation projects are more common. As a result there are thousands of small dams (less than 10 km²) spread about the continent, particularly in the northern and southern semi-arid/arid Sahelian zones, that are installed for irrigation, drinking water for cattle and as a reserve for human use. Individually these small dams will have only minor effects on the watercourses downstream, which often dry out completely for part of the year. However, their cumulative effect is likely to be massive as they influence the hydrograph in many watercourses. They also alter stretches of rapids in smaller streams to form bodies of standing water for which resident fish species are ill equipped.

Dams have a major effect on fisheries downstream. They act as a barrier to upstream and downstream migration. They also regulate water flow so as to change the amount and timing of discharge and can prevent the regular inundation of downriver floodplains. The

loss of floodplains below major dams has been observed and recorded in a few cases. About 100 km² of the Phongolo River flats and associated lakes disappeared after the closure of the Phongolo-poort reservoir (Coke and Pott 1970). Much of the floodplain of the Senegal River has disappeared following the closure of the Manantali dam and a persistent failure of flooding has also been recorded below the Kainji dam on the Niger River (Sagua 1978). Post-impoundment flow values from the Benue River below the Lagdo reservoir show that peak river discharges have decreased by 44 per cent from 3 330 m³ to 1 870 m³, limiting the extent and duration of the flood (Neiland et al. 1990). Lae (1995) estimated the loss in catch caused by the Selingue and Markala dams at about 5 500 t at flood level, corresponding to catches of between 45 000 and 85 000 t/yr. The effect becomes more marked in systems already stressed by low water levels. Catches in the Niger River below the Kainji dam fell by about 50 per cent in three years (1967-69) in the Jebba - Lokoja reach (Otobo 1968) and by 60 per cent in the lower Anambra basin downstream.

The reduction in the catch is usually accompanied by changes in species composition, whereby flow loving and floodplain spawning rheophilic species are replaced by lenitic species that favor still waters and those that breed in the main channel. This change also often results in local loss of species.

Conclusion

Rivers in Africa are used for a number of human functions other than fisheries. The needs of high economic profile activities, such as power generation and irrigated agriculture, frequently result in conflicts of interest between extractive industries and the water requirements of the fish and the fisher communities. In such conflicts the interests of agriculture and power generation have invariably prevailed. Apart from the greater financial and political power of the agriculture and power sectors, an important reason for this is that the water requirements for power generation and agriculture are relatively well understood, whereas the requirements of fisheries are less clearly defined. It is, therefore, essential to better

refine our understanding of the ways in which fisheries respond to altered flow regimes in order to represent fishery interests more effectively in negotiations for the allocation of water to fish.

Much of the existing information and knowledge on the impact of changes in water flows on fisheries comes from the response of the Niger River to the Sahelian drought and to fisheries in such rivers as the Niger and the Senegal to dam building. Studies and experience in South Africa also give some indication of the costs of remedial activities in already modified systems. Here Heeg et al. (1980) estimated that the Phongolo floodplain [10 265 ha at peak flood and 2 700 ha of river and lakes at mean retention level] required 26 million m³/yr to maintain the mean retention level of its floodplain lakes and a further 100 million m³/yr to flood the whole plain. However, a model developed by Weldrick (1996) showed that the part of the floodplain could be submerged and the lakes could be filled by a discharge of 100 m³ s⁻¹ for five days (equivalent to a total discharge volume of 216 million m³/yr). However, this limited information is insufficient to describe the complex impacts that follow changes in the volume, form and timing of floods (Welcomme and Halls 2001; Bunn and Arthington 2002 for an analysis of impacts).

The various methodologies available for the assessment of impacts on fish and fisheries due to changes in river flows have been reviewed through the Comprehensive Assessment of Water Management in Agriculture. Two methodologies have emerged that provide a potential for analyzing impacts and projecting scenarios of environmental flows for the conservation of fish stocks and fish biodiversity in African rivers. The first is a generalized tool called DRIFT (Downstream Response to Imposed Flow Transformations) that has been developed in South Africa (King et al. In press) to analyse the impacts of a range of altered flows on river ecology and the social setting associated with it. The second is a model of fish populations alone, originally developed by Welcomme and Hagborg (1977), that was elaborated by Halls (2001) to describe the response of fish communities to various hydrological regimes and fishing pressures.

Such initiatives represent only the start of an important process. With the increasing demand for water across the African continent and the proposals to meet local deficits by exerting greater control of river flows and water abstractions, it is inevitable that the living aquatic resources that provide such an important source of protein to the people will be put under increasing stress. It is urgent to study further and improve the understanding of the response of these resources to altered flows so that informed decisions can be made about a better allocation of water. One initiative currently getting underway that should help achieve this is the CGIAR Challenge Program on Water and Food which is fostering research on environmental water flows (Box 1).

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References

- Bunn, S.E. and A.A. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30:492-507.
- Breuil C. and J. Quensière (1995). *Éléments d'une politique de développement durable des pêches et de la pisciculture au Mali*. MLI/91/005-PAMOS, FAO, Rome. 89 p.
- Coke, M. and R. Pott. 1970. *The Phongolo floodplain pans: A plan for conservation*. Pietermaritzberg, Natal Parks Board. 34 p.
- Halls, A.S. 2001. A dynamic pool model for floodplain river fisheries. *Ecology and Hydrobiology* 1:323-339.
- Heeg, J., C.M. Breen and K.H. Rogers. 1980. The Phongolo floodplain: a unique system threatened. *In* M. N. Bruton and K.H. Cooper (eds.) *Studies on the ecology of Maputaland*. Rhodes University and the Natal Branch of the Wildlife Society of

The CGIAR Challenge Program on Water and Food is launching an ambitious research, extension and capacity building program designed to significantly increase the productivity of water used for agriculture. The immediate objectives of the Program are to achieve:

- Food security for all at household level.
- Poverty alleviation, through increased sustainable livelihoods in rural and peri-urban areas.
- Improved health, through better nutrition, lower agriculture-related pollution and reduced water-related diseases.
- Environmental security through improved water quality as well as the maintenance of water related ecosystem service, including biodiversity.

Focusing geographically on nine river systems referred to as Benchmark Basins (Nile, Limpopo, Volta, Karkeh, Indo-Gangetic plains, Mekong, Yellow, Sao Francisco and a group of Andean basins) the Program will address five principal inter-related research themes: crop water productivity improvement, multiple use of upper catchments, aquatic ecosystems and fisheries, integrated basin water management systems, and the global and national food and water systems. The WorldFish Center will coordinate the aquatic ecosystems and fisheries theme on behalf of the Challenge Program.

The Aquatic Ecosystems and Fisheries theme has identified four main areas of research that will be given priority under the Program: Policies, Institutions and Governance; Valuation of Ecosystem Goods and Services, and the Costs of Degradation; Environmental Water Requirements; and Improving Water Productivity. Expected outputs from research in these areas will include:

1. Assessment of the factors determining access to aquatic resources by target communities and social groups and how these can be managed in each focal basin.
2. Specific guidance on the form of governance systems, policies and institutions, that foster equitable and sustainable management of aquatic ecosystems and their resources in each focal basin, and generic guidance on approaches that can be used in other basins.
3. Improved technical capacity and information systems that will support the development and application of such governance systems, policies and institutions.
4. Assessments of the ecological functions of key aquatic ecosystems, and valuations of the goods and services provided by these and the costs of ecosystem degradation.
5. Improved tools and methodologies for generating such information rapidly and in an accessible manner.
6. Projections of the impacts of specific degrees of hydrological change on the ecological functions of different aquatic ecosystems in selected basins and of the different goods and services they provide.
7. Improved methodologies for assessment of environmental water requirements of different aquatic ecosystems.
8. Quantification of the freshwater requirements of coastal ecosystems in selected basins.
9. River fisheries production models developed and applied in selected basins.
10. Assessment of the current and potential contribution of aquatic resources to water productivity in different farming systems, notably irrigated and flood-prone systems.
11. Quantification of the benefits that can be obtained by integrating fish production and harvest of other aquatic animals and plants into farming systems.
12. Improved technologies for integrating aquaculture and fisheries into different farming systems.

Those wishing to know more about or contribute to this program should visit www.waterforfood.org

- South Africa, Cape Town.
- King, J., C. Brown and H. Sabet. A scenario-based holistic approach to environmental flow assessments for rivers. *Rivers Research and Application*. (In press).
- Lae, R. 1992. Influence de l'hydrobiologie sur l'évolution des pecheries du delta centrale du Niger, de 1966 a 1989. *Aquatic Living Resources* 5:115-126.
- Lae, R. 1995. Climatic and anthropogenic effects on fish diversity and fish yields in the central delta of the Niger River. *Aquatic Living Resources* 8:43-58.
- Moses, B.S. 1987. The influence of flood regime on fish catch and fish communities of the Cross River floodplain ecosystem, Nigeria. *Environmental Biology of Fishes* 18(1):51-65.
- Neiland, A.E., J.P. Goddard and G. McGregor Reid. 1990. The impact of damming, drought and over-exploitation on the conservation of marketable fish stocks of the River Benue, Nigeria. *J. Fish Biol.* 37:203-205.
- Obam A. 1992. Conservation et mise en valeur de forêts au Cameroun. Imprimerie National, Yaounde, Cameroun.
- Otobo, F.O. 1968. Commercial fishery in the middle Niger, Nigeria. Committee of Inland Fisheries for Africa Tech. Pap. 5:185-208.
- Sagua, N.N. 1978. The effect of Kainji dam, Nigeria, upon fish production in the River Niger below the dam at Faku. CIFA Tech. Pap. 5:209-224.
- University of Michigan. 1971. The fisheries of the Kafue River flats, Zambia, in relation to the Kafue Gorge dam. Report prepared for the UN/FAO. Ann Arbor, Michigan. University of Michigan Press. FI:SF/ZAM 11:Tech. Rep. 1:161 p.
- VandenBossche, J.P. and G.M. Bernascek. 1990. Source-book for the inland fishery resources of Africa. 3 vols. CIFA Tech. Pap. 18/1, 411 p.
- Welcomme, R.L. 1976. Some general and theoretical considerations on the fish yield of African rivers. *J. Fish. Biol.* 8: 351-64.
- Welcomme, R.L. 1979. Fisheries ecology of floodplain rivers. Longman. 317 p.
- Welcomme, R.L. 1985. River Fisheries. FAO Fish. Tech. Pap. 262, 330 p.
- Welcomme, R.L. 1999. A review of a model for qualitative evaluation of exploitation levels in multi-species fisheries. *J. of Fish. Ecol. and Mgmt.* 6:1-20.
- Welcomme, R.L. 2003. Fisheries in Africa: Their past, present and future. In T.L. Crisman, L.J. Chapman, C.A. Chapman and L.S. Kaufman. *Aquatic Conservation and Management in Africa*. University Press of Florida, Gainesville. p. 145-175.
- Welcomme, R.L. and D. Hagborg. 1977. Towards a model of a floodplain fish population and its fishery. *Env. Biol. Fish.* 2(1):7-24.
- Welcomme, R.L. and A. Halls. 2001. Some considerations of the effects of differences in flood patterns on fish populations. *Ecohydrology and Hydrobiology* 1:313-321.
- Weldrick, S.K. 1996. The development of an ecological model to determine flood release options for the management of the Phongolo floodplain in Kwazulu/Natal (South Africa). MSc. Thesis, Rhodes University, Grahamstown. 81 p.

R.L. Welcomme is from RRAG, Imperial College, United Kingdom.
E-mail: welcomme@dial.pipex.com

FishBase species profile: *Clarias gariepinus* (Burchell, 1822)¹ North African catfish

Prepared by the FishBase team

In this issue *NAGA* introduces a new page on profiles of fish species. This page will be a permanent feature of the *NAGA* and will be based on information derived from FishBase (<http://www.fishbase.org>), the world's premier information system on fishes and a global public good. FishBase is being developed by the WorldFish Center and an International Consortium. The first species selected is the North African catfish *Clarias gariepinus*, one of the most important freshwater fish species in Africa. It has been chosen in honor of Prof Dr Guy Teugels of the Musée Royal de l'Afrique Centrale (MRAC) of Tervuren, Belgium, who recently passed away (see Announcement on page 39) and who spent many years investigating this species.

Common names: North African catfish (FAO English), Fig. 1; Poisson-chat nord-africain (FAO French); Pez gato (FAO Spanish); 80 names from 33 countries. **Importance:** fisheries, aquaculture (Fig. 2) and game. **Distribution:** almost Pan-African, absent from Maghreb, the upper and lower Guinea, the Cape province and probably also Nugal province. Asia: Asia Minor in Jordan, Israel, Lebanon, Syria and southern Turkey (Fig. 3). Widely introduced to other parts of Africa, Europe and Asia. Several countries report adverse ecological impact after introduction.

Ecology: occurs mainly in quiet waters, lakes and pools but may also occur in fast flowing rivers and in rapids. Widely tolerant of extreme environmental conditions. The presence of an accessory breathing organ enables this species to breath air when very active or under very dry conditions. Remains in the muddy substrates of ponds and occasionally gulps air through the mouth. Can leave the water at night using its strong pectoral fins and spines in search of land-based food or can move into the breeding areas through very shallow pathways. Nocturnal, feeding on the bottom and occasionally at the



O. Schneider

Fig. 1. *Clarias gariepinus*, 78cm TL, 3.5 kg

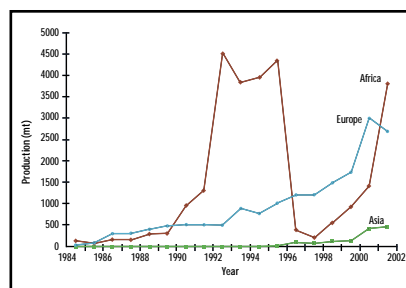


Fig. 2. Aquaculture production of *Clarias gariepinus* by continent from FAO statistics²

surface on a wide variety of prey.

Environment: benthopelagic; freshwater; 8-35°C; pH range: 6.5-8.0; dH range: 5.0-28.0; depth range: 4-80 m. **Danger/impact:** potential pest. **IUCN Red List status:** not in IUCN Red List. **Main food:** mainly animals (troph. 2.8 and up).

Trophic level: 3.15. **Food items:** bony fish; insects; benthic aquatic algae/weeds; terrestrial plants; zooplankton; phytoplankton; benthic crustaceans and mollusks. **Food consumption (Q/B):** 1.73 times the body weight per year.

Predator: *Crocodylus niloticus*.

Reproduction: dioecious; external fertilization; non-guarder; open water/ substratum egg scatterer. **Spawning season:** Sept-Dec in lake Chilwa, Malawi; July-Oct in Tapoa and small reservoirs in Burkina Faso; Mar-Aug in lake Manzala, Egypt; Feb-May in lake Awassa, Ethiopia. **Fecundity:** 36,805 (2,084 - 650,000). **Eggs:** benthic; spherical; 1.5 mm diameter.

Larvae: 4.4-4.8 mm hatching length.

Maturity: Lm=30.5-37.5 cm TL; tm=2 yrs.

Remarks: spawning takes place during the rainy season in flooded deltas. The fishes make a lateral migration towards the inundated plains to breed and return to the river or lake soon afterwards while the juveniles remain in the inundated area.

Growth/mortality parameters: Max. size: 170 cm TL (male/unsexed), 60.0 kg; L infinity = 139 cm TL; K = 0.09/yr; Phi prime = 3.24; t₀ = -1.27 yrs.; Natural Mortality (M) = 0.20/yr. **L/W relationship:** W = 0.0105 * L^{3.013}.

Chromosomes: 2n = 56; CF = 8m + 24-25sm + 23-24t; NF = 88-89. **Proximate analysis (%):** moisture (76.5); protein (19.0); fat (3.0); ash (1.5) based on 100 g edible weight.

For further information: contact the WorldFish Center FishBase Project Team, Los Baños, Philippines (fishbase@cgiar.org)



Clarias gariepinus
 ■ Native ■ Introduced and established
 □ Introduced but establishment uncertain

Fig. 3. Global distribution of *Clarias gariepinus* showing native³ and introduced ranges⁴

FishBase online sources used in producing the above species profile:

¹ <http://www.fishbase.org/Summary/SpeciesSummary.cfm?ID=1934&genusname=Clarias&speciesname=gariepinus>

² <http://www.fishbase.org/report/FAO/FAOaquacultureList.cfm?scientific=Clarias%20gariepinus>

³ <http://www.fishbase.org/Country/CountryList.cfm?ID=1934&genusname=Clarias&speciesname=gariepinus>

⁴ <http://www.fishbase.org/Introductions/IntroductionsList.cfm?ID=1934&GenusName=Clarias&SpeciesName=gariepinus&fc=139&stockcode=2130>

Using ReefBase to create customized maps







Prepared by the ReefBase team

One of the most popular sections of the ReefBase website is the online GIS that enables users to create an almost unlimited range of maps showing a wide variety of features. A new version of the GIS, offering an even larger array of facilities and data layers, is online as of early September. In this article, we will provide an introduction to the ReefBase GIS and also highlight some of the powerful but lesser used features of the system.

Basic features

The ReefBase GIS is accessed from the ReefBase homepage (www.reefbase.org) via the **Maps and Photos** menu link. Choosing "Online GIS" takes you to the introduction page where you can see an explanation of the components of the GIS screen. Click on **Start ReefBase GIS** to launch the mapping program. By default you are taken to the ReefBase World Map marked with country boundaries, coastlines and coral reefs. As you zoom in, mangroves and detailed map features such as rivers lakes and roads will automatically also become visible. The visible features are shown in the legend at the left of the screen (Fig. 1). A check box to the left of the layer name indicates that the layer has been turned on and is visible. You can make other layers such as coral bleaching or marine protected areas visible by clicking on the check box. The circular "radio button" to the left of the layer name indicates whether or not it is an "active layer" for the purposes of querying. If you would like to see more detailed legend information on a layer (such as the source of the data and an explanation of the symbol colors) just click on the name of the layer. By default, the Topography and Bathymetry layers are turned off, since they increase the time it takes for the map to be redrawn. However, these two features can dramatically increase the aesthetic appeal of the map, as long as you do not have too many other information layers turned on at the same time.


Table 1. Tools for moving and zooming a map

	Go to Lat-Long Clicking this button will open a small window where you can type the x and y (long./lat.) coordinates you would like to zoom in to. Coordinates must be in decimal degrees and separated by a comma.
	Zoom in Select this button and ((a) click on a point on the map or (b) draw a rectangle to zoom in.)
	Zoom out Click on the map after selecting this button to zoom out.
	Zoom all Click this button to zoom out to full extent of the map (e.g., entire world).
	Pan/move Select this button, then click on a point on the map and "move" it elsewhere (holding the mouse down). Once you release the mouse, the map will redraw and "move" as you indicated.
	Overview map Click this button to view a small overview map indicating the geographic extent of the map you are viewing.

Finding a particular area

Zooming in and moving around to a particular area of interest can be achieved through the zoom-in and pan tools from the column of icons at the right of the screen. Zooming back out can be achieved either by selecting a small area with the zoom out tool, or by clicking on the "show full extent" tool to go back to the full map of the world. If you know the latitude and longitude of the area you wish to view, simply click the pin icon and enter latitude and longitude in decimal degree format. If you are interested in going straight to a map of a particular country or region then use the drop down list in the top middle of the screen.


Getting information about a specific point

	Query map data
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Click this button, then click any data point or **draw a rectangle** (new!) on the map to find information on the point(s) or area(s) in the selected active layer (see above). After selecting data

points on the map, a popup window will display more detailed information on each record selected. A small pointing-hand indicates which data point on the map the information applies to.

Using a high resolution map in other applications

	Save map to disc
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Once you have the desired view and features displayed on the screen you can save this image for use in presentations or documents. A quick way is to right click on the map portion of the screen (option-click on a Mac) and choose **Copy**. You can then switch over to an application such as PowerPoint or Word and use **Paste** to insert the map. This method gives you an image that is the same resolution as your screen. However, by clicking on the save icon on the left hand toolbar you will be presented with a screen that lets you choose several higher resolutions, up to a maximum of about 2 000 x 2 000 pixels. This image is displayed in reduced size but can be copied or saved to your disc by "right clicking" on it and selecting "save image as".

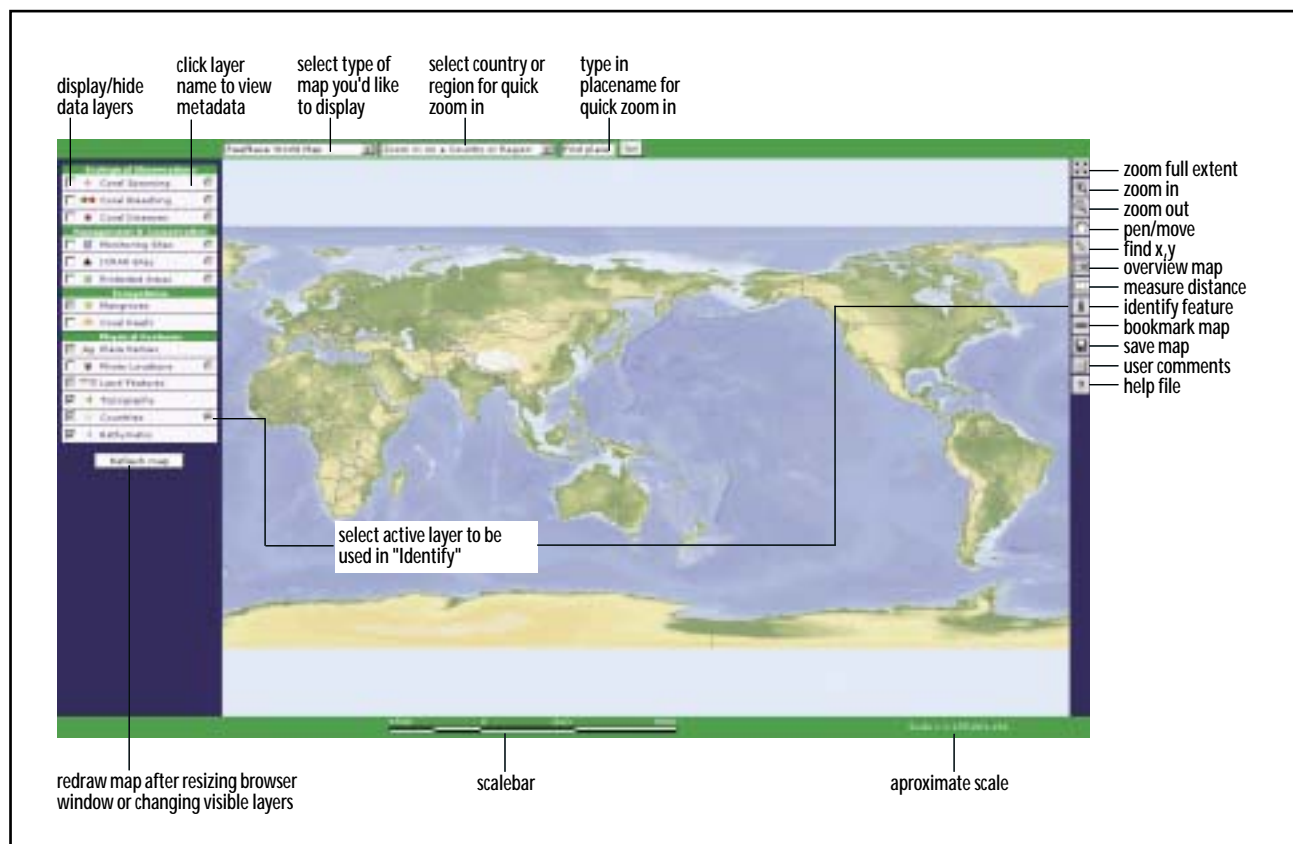
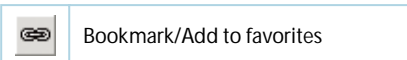


Fig. 1. Functions of the various tools and displays on the initial GIS screen

Saving your favorite map configuration



With this feature you can add the exact settings of the current map to your Favorites (IE) or Bookmarks (Netscape) folder. Next time you're online, simply select the saved link to send your browser to the exact same map.

Selecting other types of maps

While the ReefBase world map provides a great standard map onto which you can overlay a number of key datasets, there is a range of other special thematic maps that can be chosen from the pull down menu on the top right of the screen.

Reefs At Risk maps

These maps display the potential threats to coral reefs from human activities, as modeled by the Reefs At Risk project. You can select from the following views:

Coral reefs classified by overall (combined) threat:

- Overall threat (combined from the four individual threat layers)
- Threat: Overexploitation
- Threat: Coastal development
- Threat: Marine pollution
- Threat: Inland pollution and sedimentation

Reefs at Risk analyses have been completed at the global level at 4 km resolution, and at a more detailed resolution (1 km) for Southeast Asia. Currently, a regional Reefs at Risk analysis is being completed for the Caribbean and will be made available here in due time.

Reefs from space

NASA Imagery (New)

This new map enables you to see where ReefBase has photographs from space (Space Shuttle, International Space Station) and to zoom into these. The background global map is based on

MODIS satellite data from NASA. Reef data, such as monitoring and MPAs, can still be included on these maps.

NASA SEAWiFS bathymetry (New)

This satellite data has been passed through depth-algorithm, showing shallow water bathymetry. It also provides an attractive alternative backdrop for point data.

ReefCheck

All of the thematic maps in the ReefCheck reports of the last five years can be viewed at any scale. There are a total of 11 maps showing human impact, and 29 separate maps indicating the relative abundance of different reef organisms.

NOAA Degree Heating Weeks (New)

As a result of a collaborative effort between NOAA and ReefBase, these

maps bring together NOAA's Degree Heating Weeks (satellite-based maps indicating areas of thermal stress), and ReefBase's database on coral bleaching observations. A new map is added every month. You can select Degree Heating Weeks maps for any particular year and month and then display all bleaching records on top of this map for the same period.

World Ocean Atlas 2001 (New)

This is a collection of maps showing annual, seasonal, and monthly averages for various ocean variables: temperature, salinity, oxygen, nitrate, phosphate, silicate, and chlorophyll.


Statistical maps - Geographic areas

Color-coded marine areas indicate reef, continental shelf, marine, mangroves, and land areas, as well as coastline length per country.

Statistical maps - Socio-economics

Color-coded marine areas indicate total population, population living in the coastal zone, GDP/capita, and fish consumption per capita by country.

Giving us feedback on the ReefBase GIS



While we have included a number of new and improved features in the current version of the ReefBase GIS, we realize that there is always room for improvement. Users are encouraged to send comments on any particular map view using this tool. ReefBase will remember the exact area you have selected and the layers that are turned on. You can then provide comments on this map, including advice on errors, omissions, and additional data availability. With this feedback we will be able to continuously upgrade the ReefBase GIS.



Fig. 2. MODIS image of Cuba and southern Bahamas with NASA photos superimposed. Insert shows detail available for the NASA photos when zoomed in

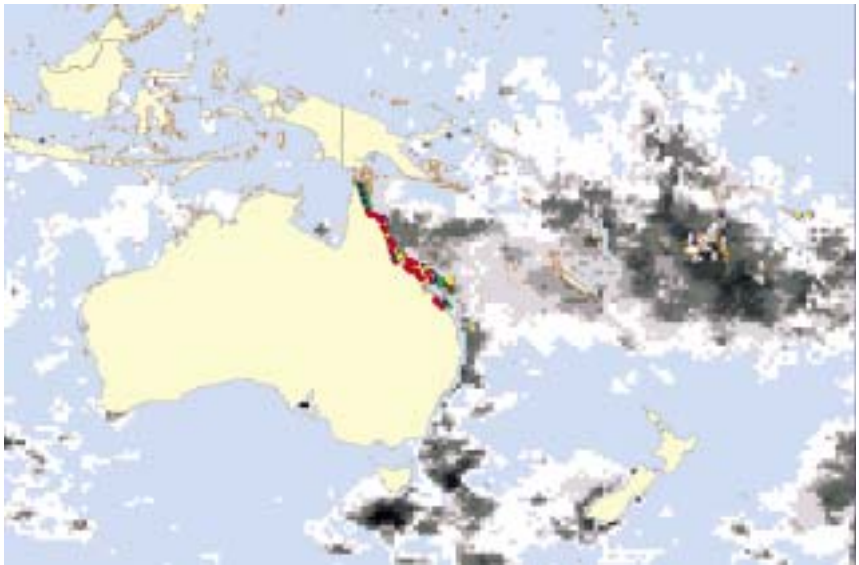


Fig. 3. Degree Heating Week map for April 2002 with coral bleaching records overlaid

ReefBase is a project by WorldFish Center and the International Coral Reef Action Network (ICRAN), with financial support from the United Nations Foundation (UNF). In addition, we would like to acknowledge support from the World Bank, who provided funds to strengthen ReefBase as a "Global Public Good". Much of the GIS data has been developed in collaboration with UNEP-WCMC, WRI, NASA, NOAA, ReefCheck, and others.

Potential of genetics for aquaculture development in Africa

W. Changadeya, L.B. Malekano and A.J.D. Ambali

Abstract

Aquaculture in Africa is fairly insignificant by world standards and accounts for a mere 0.4 per cent of global aquaculture production. The application of genetics can play an important role in efforts to increase aquaculture production in Africa through methods such as selective breeding, hybridization, chromosome manipulation and use of YY "supermales". Other issues that need to be addressed are limited genetic research facilities, funding, human capacity and suitable species for aquaculture.

Introduction

In comparison to the rest of the world, aquaculture in Africa is insignificant. The continent as a whole contributed a mere 0.4 per cent to the total world aquaculture production from 1984 to 1995 (Hecht 2000). Although currently undeveloped, aquaculture is expected to play an important role in future by providing food and employment for people in Africa (Miller et al. 2002).

The general characteristics of aquaculture production, its constraints and development potential differ considerably in North Africa and the sub-Saharan region. North Africa has a far greater potential. In Egypt, for instance, aquaculture has been practiced extensively for a long time, while in other countries of the continent it is a relatively new technology and has not yet been recognized as a consolidated food production sector in national economies. In terms of physical potential, North Africa has suitable locations that have been developed for farming of marine and estuarine species for export to the European markets. The new farms use more sophisticated, intensive production technologies that have been imported from Mediterranean countries. On the other hand, aquaculture in sub-Saharan Africa has been oriented to domestic markets and is mostly practiced by small-scale farmers. Although there is a physical potential for expansion of aquaculture in this region, factors such as the novelty of aquaculture, the generally poor economic conditions in many countries, and the

relative paucity of entrepreneurial skills and credit facilities hamper its development (FAO 1997).

Challenges and constraints

There is potential for a significant increase in aquaculture production in Africa through sustainable intensification and horizontal expansion into inland waters and coastal areas. Positive growth in aquaculture can be realized if a number of constraints and challenges facing the aquaculture sector are addressed. These include: (i) lack of localized knowledge systems on aquaculture among African farmers; (ii) prevalence of foreign aid programs organized on a top-down basis with inconsistent, short-term goals and excessive dependence on donor funded aquaculture development programs; (iii) low allocation for aquaculture development in national budgets; (iv) wholesale importation of traditional crop agriculture practices into aquaculture, such as seed recycling; (v) poor or slow growth of cultured species; (vi) poor broodstock management; (vii) loss of genetic diversity in culture system; (viii) contamination of the wild and indigenous gene pool; (ix) lack of baseline genetic data; and (x) poor species identification (Pullin and Capilli 1988). This paper discusses the potential of genetics in addressing some of the constraints and challenges identified above.

Several species are used in aquaculture in Africa (Table 1). The major ones are: *Oreochromis niloticus*, *O. aureus*, *Sarotherodon galilaeus* and *Tilapia zilli* in North and West Africa; *O. mossambicus*, *O. shiranus*, *T. rendalli*,

Clarias gariepinus (African catfish), and rainbow trout (*Salmo gairdneri* and *S. trutta*) in southern Africa; *S. melanotheron* is a relatively new, but important species in West Africa. The use of genetics in aquaculture development on the African continent has mainly focused on tilapia culture. Hence, the discussion in this paper uses tilapia to illustrate its case.

The tilapias (Cichlidae), some 870 species (Skelton 1993), are the major cultured species in Africa. They are suitable for culture and increasing the availability of protein and the quality of nutrition of poor fish farmers and consumers. Species of the genera *Oreochromis*, *Sarotherodon* and *Tilapia* have been widely exploited in aquaculture and natural fisheries. Within the *Oreochromis* genus, *O. mossambicus*, *O. niloticus* and *O. aureus* are considered the most important species for aquaculture.

Domestication of tilapias in Africa is still in the early stages. The genetic resources have been poorly managed during the past 40 years of intensive and extensive culture (Kocher 1997). Broodstock used in seed production are generally from the wild. Owing to small pond sizes and frequent droughts, the ponds generally dry out and seed or brood stock is easily lost. Hybridization and inbreeding in the ponds is also common as the strains recruited into the farms easily interbreed and genetic purity is lost. Kocher (1997) reports of a genetic survey that revealed heterozygosities of less than 10 per cent in several strains of farmed tilapia populations compared to their wild counterparts.

Genetic approaches used

Several approaches have been used to improve the performance of tilapias in aquaculture and these include genetic manipulation. These techniques have been very successful in other countries and seem to indicate an opportunity for increasing aquaculture production in Africa.

Selective breeding

In Africa, selective breeding of tilapias has been mainly aimed at increasing their growth rate so that a farmer can realize quicker and higher yields. In other parts of the world, selection has also been done for skin color, body conformation, fillet yield and cold tolerance (Behrends et al. 1982, 1990; Fitzsimmons 2000). Protocols used to develop the GIFT strain *O. niloticus* by the WorldFish Center and its partners in the Philippines and Norway are currently being used in national research institutions in Côte d'Ivoire, Egypt, Ghana and Malawi to improve local species and strains of tilapias through selective breeding (Gupta et al. 2001). Selective breeding can ameliorate the problem of poor or slow growth rate among cultured fish species. Most of the tilapia species cultured in Africa have not yet

been adequately domesticated and, therefore, the application of selective breeding in the domestication process can improve the performance of the strains. The GIFT strain *O. niloticus* is reported to grow 85 per cent faster than other farmed strains in the Philippines, have better survival rates, and can be grown without commercial feed in extensive systems (M. Gupta personal communication). Application of similar protocols on the stocks within Africa would improve the performance of local tilapias. However, selective breeding takes a long time to improve a strain and is expensive. The risks for selective breeding programs are that they are unlikely to receive long-term financial support from governments and donors for genetic research, and labor turn-over is high as trained personnel change jobs in search for better remuneration.

Hybridization

Hybridization has been used as a technique of improving yield of tilapias. The cultured tilapia species are closely related and readily produce viable hybrids. McAndrew et al. (1988) indicate that one popular strain may contain genes from as many as four species. Hybrids have also been produced to obtain

all-male fry that have better growth than mixed sex populations.

Most of the hybrids produced in aquaculture in Africa are unplanned and, hence, they have not been monitored adequately. For example, in Malawi, hybrids between *O. shiranus chilwae* and *O. shiranus shiranus*, and *O. shiranus* sp and *O. mossambicus* have been produced unwittingly (Ambali et al. 1999). There is a tendency to import improved strains developed from elsewhere, instead of concentrating on developing native genetic resources, e.g., *O. niloticus* has been introduced into Zambia and Zimbabwe because the species grows faster than indigenous species. Some of these introduced strains have escaped into the wild and hybridized with indigenous species because of poor management. In the Limpopo river in South Africa, *O. niloticus* has produced hybrids with *O. mossambicus* (Brink et al. 2002). Ecological risks have been reported from hybridization in some countries. While hybridization may bring about hybrids with a combination of desirable traits from different groups, the possibility of sterile and non-sterile hybrids may lead to introgression and breakdown of genetic distinctiveness (Penman 1999).

Table 1. Indigenous fish farmed in Africa

Species	Countries
<i>Anguilla anguilla</i>	Algeria, Morocco, Tunisia
<i>Chrysichthys nigrodigitatus</i>	Côte d'Ivoire, Nigeria
<i>Clarias anguillaris</i>	Burkina Faso, Egypt
<i>Clarias gariepinus</i>	Cameroon, Central African Republic, Ghana, Guinea, Lesotho, Malawi, Mali, Nigeria, Rwanda, South Africa, Swaziland, Tanzania, Zambia
<i>Dicentrarchus labrax</i>	Algeria, Egypt, Morocco, Tunisia
<i>Heterotis niloticus</i>	Gambia, Mali, Nigeria
<i>Lates niloticus</i>	Nigeria
<i>Liza ramada</i>	Tunisia
<i>Mugil cephalus</i>	Egypt, Tunisia, South Africa
<i>Oreochromis andersonii</i>	Zambia
<i>Oreochromis aureus</i>	Côte d'Ivoire
<i>Oreochromis macrochir</i>	Zambia
<i>Oreochromis mossambicus</i>	Malawi, Mozambique, South Africa, Swaziland
<i>Oreochromis niloticus</i>	Burkina Faso, Burundi, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Egypt, Gabon, Ghana, Kenya, Liberia, Mali, Mozambique, Niger, Rwanda, Sénégal, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Zambia
<i>Oreochromis shiranus</i>	Malawi
<i>Pomatomus saltator</i>	Tunisia
<i>Sarotherodon melanotheron</i>	Côte d'Ivoire
<i>Solea solea</i>	Algeria, Tunisia
<i>Sparus aurata</i>	Algeria, Egypt, Morocco, Tunisia
<i>Tilapia rendalli</i>	Malawi, Swaziland, Tanzania, Zambia
<i>Tilapia zilli</i>	Uganda

Source: FAO (1997); FishBase (1998)

Table 2. Genetic approaches used in Africa

Method	Countries
Selective breeding	Côte d'Ivoire, Egypt, Ghana, Malaŵi, Sénégal, South Africa
Hybridization	Côte d'Ivoire, Malaŵi, Egypt (unplanned)
Molecular marker	Côte d'Ivoire, Egypt, Ghana, Malaŵi, Nigeria
Gynogenesis	South Africa, Zambia
Genetic engineering	None

Crossing a female *Tilapia tholloni* with a male *O. mossambicus* yields 100 per cent females, and crossing female *O. spirulus* with male *O. leucostictus* yields 98 per cent males (Agnese et al. 1998). These introgressive hybridizations have led to loss of genetic purity of the indigenous stocks (Agnese et al. 1998; Ambali et al. 1999). In lake Ayami in Côte d'Ivoire, *T. busumana* and *T. discolor* have been reduced in numbers and even disappeared in catches. They have been replaced by *S. melanotheron*, an introduced species.

If hybridization is chosen as a technique for improving the performance of the indigenous population in aquaculture, there should be well-established genetic characterization records in order to monitor the long-term purity of the parental lines. Molecular markers can be employed to generate baseline genetic data of indigenous populations, which can be used later to check if there is contamination of wild and indigenous gene pools through hybridization. A great deal of effort is required to breed and maintain these parental lines, and most African countries cannot afford the costs involved.

Molecular marker-assisted selection

Use of genetic makers to identify loci that control quantitative traits (QTL) and to develop superior strains through marker-assisted selection is still in the early stages in tilapia improvement programs. Work on developing linkage maps for tilapia has been carried out at the University of New Hampshire, offering opportunity to track and select desirable genes from the map (Kocher 1997). Theoretically, marker-assisted selection takes a shorter period to improve performance of individuals in a population as compared to conventional breeding. The only constraint to the use of this technique is the cost involved in developing linkage maps.

Although feasibility of marker-assisted selection is yet to be demonstrated in Africa, molecular markers such as Randomly Amplified Polymorphic DNA (RAPD),

Restriction Fragment Length Polymorphism (RFLP), and microsatellites have been employed to generate genetic data for assessing genetic diversity, population structure, and migration among fish populations. For example, small-scale strain comparisons were carried out in Malaŵi during 1997-99 where wild populations of *O. shiranus* grew faster than domesticated stocks. Microsatellite DNA analysis of the populations revealed that farm populations had very low genetic diversity compared to their wild counterparts (mean number of alleles 4.4 ± 1.03 and 13.2 ± 3.31 , respectively) and there was introgression of *O. mossambicus* into the *O. shiranus* populations (Ambali et al. 1999). *O. mossambicus* populations from several water bodies in southern Africa have been recruited for genetic improvement at the University of Stellenbosch in the Republic of South Africa. Analysis of the genetic structure and diversity provided evidence for high levels of variation within and between the (12) populations (Brink et al. 2002). French scientists and the Institute of Aquatic Biology in Ghana have subjected West African cultured species like *S. melanotheron* to genetic investigation using various molecular markers. Some of the results showed that populations of *S. melanotheron* from Sierra Leone, Sénégal, Liberia, Ghana, Togo, Côte d'Ivoire, Benin and Congo-Brazzaville share a common ancestry (J.F. Agnèse personal communication to W. Changadeya).

Gynogenesis

"YY supermales" have been produced and assessed in South Africa through a collaborative project between the University of Stellenbosch (RSA) and the University of Wales Swansea (UK). Significant progress was made in the production of genetically male tilapia (YY males) in *O. mossambicus* with 20 YY males identified by the end of the project (Brink et al. 2002). *O. niloticus* YY males were introduced at Kafue fish farm in Zambia from the University of Wales Swansea (Jamu and Brummett 2002). Baseline data collected during the trials in South Africa

suggest that gynogenesis increased the yield and can thereby make a meaningful contribution to improving livelihoods from aquaculture (Brink et al. 2002).

Other genetic approaches

Three genetic techniques, namely, selective breeding, hybridization, and molecular markers application have been used in Africa (Table 2). Other genetic techniques have been successfully applied elsewhere to improve the performance of cultured fish. Such techniques may possess a potential for improving aquaculture production, but have not been widely tried.

Ploidy

This technique produces sterile polyploid, triploid or tetraploid organisms that do not invest energy into reproduction. Ploidy manipulation employs the same physical and chemical treatments used in the diploidisation phase of gynogenesis. Alternatively, triploidy can be obtained by mating normal diploid fish with tetraploids. Their main advantage is that they are sterile, but there is no increase in the growth rate. In tilapia, triploidy retards gonadal development and, hence, uncontrolled reproduction that causes stunted growth (Bramick et al. 1995). This technique has been employed in rainbow trout (Thorgaard 1992) and the Pacific oyster (Guo et al. 1996), but may not be feasible in several species of fish due to the low viability of induced tetraploids (Cassani et al. 1990; Cherfas et al. 1993).

Genetic engineering

Genetic engineering and production of transgenic organisms has become an active area of research and development in aquaculture. In tilapia, transgenics that contain the exogenous growth hormone (GH) gene construct derived from Chinook salmon have demonstrated growth enhancement (Rahman and Maclean 1997). Transgenic tilapia grow three times more than their non-transgenic siblings in a period of seven months. Transgenic common carp, catfish, Coho salmon, and tilapia have been produced and are being tried for commercial use (FAO 1997). Although transgenic fish have demonstrated increased growth and have the potential to raise aquaculture production, it will be some time before they will be commercially farmed because several issues against transgenic products must be addressed. These include: (i) transgenic fish

may escape into the wild and disrupt natural populations; (ii) the “transgenes” could be passed on to wild relatives; and (iii) consumers may not accept genetically modified fish.

Constraints to application of genetics

Application of genetics to aquaculture in Africa has been constrained by a number of factors.

Limited research facilities. Research facilities are limited and mostly state-owned in almost every African country where aquaculture is practiced. Many African universities also do research on aquaculture, with technology development and transfer coming mainly through donor-funded projects. Among the many aquaculture research centers in Africa, only a few are known for genetics research, namely, the WorldFish Center’s regional center in Abbassa, Egypt, and the University of Stellenbosch, Republic of South Africa. The availability of machinery and facilities for conducting genetic research is dependent on the donor community as national governments are unable to provide the funds and because research is given a low priority in most national budgets.

Limited funding. Although the majority of aquaculture systems in Africa were introduced through technology development and transfer projects, most research, development, and extension centers are non-functional at present. Even when there are funds for research in aquaculture, only limited amounts are allocated to research in genetics (Yapi-Gnaoré 2002).

Limited skills. Capacity to conduct aquaculture genetics research exists in most African universities, but very few experts are permanently based in research stations, which are usually government owned. It would be fruitful to enhance collaboration between universities with the capacity for genetics research and government departments with the infrastructure for undertaking research and a mandate to increase production. In addition, there is a need to train government personnel in aquaculture genetics.

Crop agriculture transplanted to aquaculture. In most African countries, aquaculture is new compared to

traditional agriculture. Most fish farmers are smallholder farmers who own small pond facilities on their farmlands. These farmers tend to transfer traditional practices from crop agriculture, such as seed recycling, into aquaculture and do not fully appreciate the importance of acquiring genetically improved strains. In areas where aquaculture is not on a commercial scale, the market for good quality fingerlings and broodstock is virtually nonexistent. This has compromised proper broodstock management.

Lack of suitable domesticated species. In Africa, *O. niloticus* appears to be the best candidate species, but it is not widely domesticated, except in North Africa. The introduction of non-indigenous species has led to hybridization with other related species and the production of unplanned hybrids. The management of introduced and translocated species is poor due to the lack of proper broodstock management and containment facilities. The introduction of the Nile perch (*Lates niloticus*) in lake Victoria led to the elimination of about 65 per cent of the endemic haplochromine fauna and caused the loss of about 200 taxa from the lake (Goldschmidt et al. 1993; Shumway 1999). Suitable domesticated species that could be genetically improved so as to enhance their performance in aquaculture should be identified for different regions. This process should be done simultaneously with the development of broodstock management protocols suitable for the specific species.

Capacity building

Aquaculture in Africa can make use of various technologies that have been used in other countries in North America and Asia. Capacity building through technology transfer is required. This is a dynamic process that involves creating, mobilizing, utilizing, enhancing or upgrading, and adjusting the existing capacities of individuals and local communities, institutions and the country-level policy framework in which individuals and institutions grow, operate and interact with their internal and external environment (Ngoile and Sarunday 2002). Aquaculture scientists from Africa should be trained in specific technologies in countries that have experience in employing these technologies. Since technology transfer is a continuous process, the networking with research institutions outside the continent has to be continuous so that Africa is not left behind

in technology. Linkages should also exist between aquaculture institutions in Africa and international facilities such as the WorldFish Center’s facility in Egypt and the International Network on Genetics in Aquaculture (INGA). Though isolated, the existing technical capacity in various aquaculture centers in Africa should be recognized and shared among African scientists through networking and other linkages. There should be linkages among universities, among research stations, and between research stations and universities.

Way forward

Genetic improvement has a role to play in increasing aquaculture production in Africa. The lack of suitable species has been identified as one of the key factors that have constrained the adoption of aquaculture in most African countries, even though environmental conditions are favorable and water is available. Promotion of such methods as selective breeding, hybridization, and chromosome manipulation will help in improving aquaculture production. The DNA probes, especially microsatellite DNA, should be employed in breeding programs to establish records of family relationships and pedigrees, and determine the genetic stock structure of the natural populations. Genetic improvement should not compromise conservation of biological diversity in aquaculture and in the wild. This is particularly important for most aquaculture species in Africa as these are indigenous and need to be conserved. Simple selective breeding of indigenous species within their natural zoogeographical zones would provide yield improvement without causing significant genetic deterioration of the wild populations. Import of genetically improved strains or other strains that do well in Asia should be discouraged, while encouraging improvement of native species. Lessons can be drawn from other continents, e.g., Europe where Atlantic salmon taken from the Baltic Sea to Norway infected Norwegian Atlantic salmon with a parasite to which it had no resistance (Bartley and Martin 2002).

References

- Agnese, J.F., B. Adepo-Gourene and L. Pouyou. 1998. Natural hybridisation in tilapias, p. 97-103. *In* J.F. Agnese (ed.) Genetics and Aquaculture in Africa. ORSTOM Editions.
- Ambali, A.J.D., R.W. Doyle and D.I. Cook. 1999. Genetic changes in *Oreochromis*

- shiranus* (Trewavas) associated with the early stages of national aquaculture development in Malawi. *Aquaculture Research* 30:579-588.
- Bartley, D.M. and F. Martin. 2002. Introduction of alien species strains and their impact on biodiversity. Nairobi, Kenya.
- Behrends, L., R. Nelson, R.O. Smitherman and N. Stone. 1982. Breeding and culture of the red-gold color phase of tilapia. *J. World Mar. Soc.* 13:210-220.
- Behrends, L., J. Kingsley and M. Bull. 1990. Cold tolerance in maternal mouth brooding tilapias: phenotypic variation among species and hybrids. *Aquaculture* 85:271-280.
- Bramick, U., B. Puckhaber, H. Langholz and G. Horstgen-Schwark. 1995. Testing of triploid tilapia (*Oreochromis niloticus*) under tropical pond conditions. *Aquaculture* 137:343-353.
- Brink, D., G.C. Mair, L. Hoffman and J.A. Beardmore. 2002. Genetic Improvement and Utilization of Indigenous Tilapia in Southern Africa. DFID Aquaculture and Fish Genetics Programme (R 7284). Final Technical Report, University of Stellenbosch, South Africa and University of Wales, Swansea, UK.
- Cassani, J.R., D.R. Maloney, H.P. Allaire and J.H. Kerby. 1990. Problems associated with tetraploid induction and survival in grass carp, *Ctenopharyngodon idella*. *Aquaculture* 88:273-284.
- Cherfas, N.B., B.I. Gomelsky, Y. Peretz, N. Ben-Dom, G. Hulata and B. Moav. 1993. Induced gynogenesis and polyploidy in the Israel common carp line Dor-70. *Isr. J. Aquacult. Bamidgheh* 45:59-72.
- FAO. 1997. Review of the state of world aquaculture. Fisheries Circular 886, Rev. 1. Food and Agriculture Organisation of the United Nations, Rome.
- FishBase. 1998. FishBase 1998 CD-ROM. ICLARM, Manila, Philippines.
- Fitzsimmons, K. 2000. Tilapia: the most important aquaculture species of the 21st century, p. 3-8. *In* K. Fitzsimmons and J.C. Filho (eds.) *Tilapia Aquaculture in the 21st Century*. Proceedings of the Fifth International Symposium on Tilapia in Aquaculture. 320 p.
- Goldschmidt, T., F. Witte and J. Wanink. 1993. Cascading effects of the introduced Nile Perch on the detritivorous/phytoplanktivorous species in the sublittoral areas of Lake Victoria. *Conservation Biology* 7(3):686-700.
- Guo, X., G.A. DeBrosse and S.K. Allen Jr. 1996. All-triploid Pacific oysters (*Crassostrea gigas* Thunberg) produced by mating tetraploids and diploids. *Aquaculture* 142:149-161.
- Gupta, M.V., B.O. Acosta, R. Dunham and P.R. Gardiner. 2001. Fish Genetics Research at the International Center for Living Aquatic Resources Management, p. 97-102. *In* M.V. Gupta and B.O. Acosta (eds.) *Fish genetics research in member countries and institutions of the International Network on Genetics in Aquaculture*. ICLARM Conf. Proc., 64, 279 p.
- Hecht, T. 2000. Consideration on African Aquaculture. *World Aquaculture* 31 (1): 12-19.
- Jamu, D. and R. Brummett. 2002. Opportunities and challenges for African aquaculture. Expert consultation on biosafety and environmental impact of genetic enhancement and introduction of improved tilapia strains/alien species in Africa. Nairobi, Kenya.
- Kocher, T.D. 1997. Introduction to the genetics of tilapia, p. 61-64. *In* K. Fitzsimmons (ed.) *Tilapia Aquaculture*. Proceeding from the Fourth International Symposium on Tilapia in Aquaculture, Northeast Regional Agricultural Engineering Extension, Ithaca, New York, Vol. 1, 433 p.
- McAndrew, B.J., F.R. Roubal, R.J. Roberts, A.M. Bullock and I.M. McEwen. 1988. The genetics and histology of red, blond and associated color variants in *Oreochromis niloticus*. *Genetica* 76:127-137.
- McAndrew, B.J., K.J. Rana, and D.J. Penman. 1993. Conservation and preservation of genetic variation in aquatic organism, p. 236-295. *In* J.F. Muir and R.J. Roberts (eds.) *Recent Advances in Aquaculture*. Blackwell Scientific Publications, Oxford.
- Miller, L.M., A.R. Kapuscinski and W. Senanan. 2002. A biosafety approach to addressing risks posed by aquaculture escapees. Expert consultation on biosafety and environmental impact of genetic enhancement and introduction of improved tilapia strains/alien species in Africa. Nairobi, Kenya.
- Ngoile, M. and W. Sarunday. 2002. Capacity for conservation of African aquaculture biodiversity. Expert consultation on biosafety and environmental impact of genetic enhancement and introduction of improved tilapia strains/alien species in Africa. Nairobi, Kenya.
- Penman, D.J. 1999. Biotechnology and aquatic genetics resources: Genes and genetically modified organism. *In* R.S.V. Pullin, D.M. Bartley and J. Kooiman (eds.) *Towards policies for conservation and sustainable use of aquatic genetic resources*. ICLARM Conf. Proc. p. 23-33.
- Pullin, R.S.V., and J.B. Capilli. 1988. Genetic improvement of tilapias: problems and prospects, p. 259-265. *In* R.S.V. Pullin, T. Bhukaswan, K. Tanguthai and J.L. Maclean (eds.) *The Second International Symposium on Tilapia in Aquaculture*. ICLARM Conf. Proc. 15, 623 p.
- Rahman, M.A. and N. Maclean. 1997. Growth enhanced transgenic tilapia (*Oreochromis niloticus*), p. 97-108. *In* K. Fitzsimmons (ed.) *Tilapia Aquaculture*. Proceeding of the Fourth International Symposium on Tilapia in Aquaculture, Northeast Regional Agricultural Engineering Extension, Ithaca, New York, Vol. 1. 433 p.
- Shumway, C.A. 1999. Forgotten waters: freshwater and marine ecosystems in Africa. Strategies for biodiversity conservation and sustainable development. Boston University. 168 p.
- Skelton, P. 1993. A complete guide to the freshwater fishes of southern Africa. Southern Book Publishers, Halfway House.
- Tacon, A.G.J. 1999. Trends in global aquaculture and aqua feed production. *Cahiers Options Méditerranéennes*, 37:107-122.
- Thorgaard, G.H. 1992. Application of genetic technologies to rainbow trout. *Aquaculture* 100:85-97.
- Yapi-Gnaoré, C.V., N.C. Kouassi, O.S. Assemien and Z.J. Otémé. 2002. Capacity (human and institutional) for developing and managing genetically improved strains of tilapia in Africa, including brood stock management and quarantine. Nairobi, Kenya. (In press).

W. Changadeya, L.B. Malekano and A.J.D. Ambali are from the Biotechnology-Ecology Research and Outreach Consortium (BioERO), PO Box 403, Zomba, Malawi.
E-mail: aambali@sdnp.org.mw

Expert consultation on ecological risk assessment of genetically improved fish

Studies undertaken in recent years on the genetic improvement of commercially important cultured fish species by selective breeding and other non-transgenic mechanisms have started to yield results and improved strains are now being disseminated by most member countries of the International Network on Genetics in Aquaculture (INGA). For example, improved carp and tilapia breeds now exist in Bangladesh, China, Fiji, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, and are being disseminated to farmers.

Improved strains are expected to bring significant economic and social benefits to poor people in developing countries. However, if not properly managed, these could also lead to risks to aquatic ecosystems and biodiversity once they escape into the natural environment. Hence, before the introduction and dissemination of improved strains are undertaken, it is imperative that relevant policies and protocols are reviewed, methods to assess the possible ecological risks formulated, and ways and means of averting any possible impacts identified, including measures to contain escapes.

With funding support from the Norwegian Agency of Development Cooperation (NORAD), the INGA/WorldFish Center, in collaboration with the Bangladesh Fisheries Research Institute, organized an *Expert Consultation on Ecological Risk Assessment of Genetically Improved Fish* during 4-8 August 2003 in Dhaka, Bangladesh. Fifty-four participants attended the meeting. These included

aquaculturists, geneticists, ecologists, biodiversity specialists, researchers, administrators and development workers from 20 countries representing national institutions in Asia, Africa, Europe, North America, and the Pacific, advanced scientific institutions and regional/international organizations (i.e., Food and Agriculture Organization of the United Nations - FAO, World Conservation Union - IUCN, Southeast Asian Fisheries Development Center - SEAFDEC, Secretariat for the Pacific Community - SPC, Network of Aquaculture Centres in Asia-Pacific - NACA, Asian Institute of Technology - AIT, and the WorldFish Center). The participants discussed the genetic and ecological risks of introducing improved breeds, as well as the methods and capacity of member countries in risk assessment. They also reviewed risk management and mitigation measures, the existing policy instruments, and gaps in their implementation. Then they formulated recommendations and drew up mechanisms to address the gaps in risk assessment and management, and the policy environment. The following is a summary of recommendations from the expert consultation:

- **Policies.** Relevant national and international instruments and non-binding Codes of Conduct related to introductions be reviewed and strengthened, taking into account national obligations under international instruments and agreements.
- Effective institutional frameworks, monitoring and enforcement mechanisms related to introductions



Ukil Abdus Sattar Bhuiyan, State Minister, Bangladesh Ministry of Fisheries, inaugurating the Expert Consultation on Ecological Risk Assessment of Genetically Improved Fish

of improved strains be established at national and local levels as appropriate.

- **Implementation.** Transparent, objective and practical methodologies be adopted and promoted for the assessment of risks associated with the dissemination of improved strains.
- **Capacity building.** Institutional capacity be strengthened at all levels to implement and enforce policies and regulations pertaining to the introduction and dissemination of improved strains of fish.
- International cooperative programs be undertaken to improve understanding and address ecological, social and economic issues related to improved strains.
- **Awareness.** The public and decision-makers be made aware of the benefits and potential risks of improved strains.
- Networking be promoted among all relevant institutions to address knowledge gaps and inform all stakeholders of issues related to research, use and management of improved strains.
- **Transboundary movements.** Countries initiate measures to fill policy gaps, and strengthen bilateral frameworks, where necessary, to cover transboundary movements, as provided for in the FAO Code of Conduct on Responsible Fisheries and pursuant Technical Guidelines on Aquaculture.

The main recommendations of the meeting will be published as a separate document, "Dhaka Declaration on Ecological Risk Assessment of Genetically Improved Fish."



Participants of the expert consultation on ecological risk assessment of genetically improved fish

Advanced course on quantitative genetics for INGA member country scientists

The WorldFish Center/INGA, with financial support from the Norwegian Agency for Development Cooperation (NORAD), is organizing a two-week training course on *Quantitative Genetics and its Application to Aquaculture* during 20-31 October 2003 in Penang, Malaysia. The objective is to strengthen the capacity of developing country scientists in the field of quantitative genetics, especially in the analysis and interpretation of genetic data. The course will bring together scientists from INGA member countries involved in the planning, design and implementation of genetic improvement programs for aquaculture species, expose them to high caliber lectures on the subject and teach them how to find solutions to problems in fish breeding and data analysis. The training program

will comprise lectures and practical exercises with an emphasis on hands-on analysis of actual breeding/genetic datasets. The course curriculum will cover the following topics: (i) general overview of the design and implementation of genetic improvement programs; (ii) strain choices and comparisons; (iii) estimation of phenotypic and genetic parameters (heritability, phenotypic and genetic correlations); (iv) breeding objectives and selection indices; (v) estimation of breeding values; (vi) incorporating DNA fingerprinting into selection schemes; (vii) mate allocation strategies in genetic improvement programs; (viii) importance of population size in selection programs; (ix) estimating genetic change; and (x) potential of biomolecular techniques in fish breeding.

INGA expands membership

The GIFT Foundation International Inc., Philippines, Asian Institute of Technology (AIT), Thailand, and University of Western Australia, Australia, have recently been admitted as Associate Members of INGA. With their expertise in the practical aspects of fish breeding and genetics research, they will make a valuable contribution to achieving the objectives of the network. To date, INGA has 13 developing countries as Members and 12 advanced scientific institutions, 1 private sector institution, and 3 regional and international organizations as Associate Members.

Workshop on public-private partnerships for the delivery of Tilapia genetic research outputs to Philippines farmers

Through the financial support of the International Development Research Centre (IDRC) of Canada, the WorldFish Center and Philippines institutions comprising the partners of the Tilapia Science Center (i.e., Freshwater Aquaculture Center, College of Fisheries and Phil-Fishgen of the Central Luzon State University; the National Freshwater Fisheries Technology Center, Bureau of Fisheries and Aquatic Resources of the Department of Agriculture; and the GIFT Foundation International, Inc.) are conducting research to evaluate the evolving public-private partnerships and determine their effects on the sustainability and achievement of development objectives in fish genetics research.

A workshop held in Angeles City, Philippines, during 25-27 June 2003, reviewed public-private partnerships in disseminating tilapia genetics research outputs to end-users and formulated recommendations that have policy implications. Thirty-seven participants representing various stakeholder groups (i.e., national aquatic research system-NARS, international organizations, advanced scientific institutions, the



Participants of the workshop on public-private partnerships for the delivery of tilapia genetic research outputs to end-users

private sector, hatchery operators, and farmers) participated in the workshop. The participants discussed and evaluated the effectiveness and efficiency of various systems for the distribution and dissemination of improved tilapia breeds; and analyzed issues, problems and constraints for the delivery and uptake of genetics-based technologies

and their outputs that need to be addressed. Based on the deliberations, the participants came up with recommendations that will be published as a formal document titled "Angeles Declaration: Public-Private Partnerships for Dissemination of Tilapia Genetic Research Outputs to End-Users."

Development of strategy for dissemination of improved Rohu in India

The Expert Consultation on the dissemination of improved strains of fish organized by INGA in Bangkok, Thailand, in June 2002 recognized the need for national plans and strategies for the effective dissemination of improved strains of fish to target beneficiaries without losing the genetic gains. The Central Institute of Freshwater Aquaculture (CIFA), India, in collaboration with the Institute of Aquaculture Research (AKVAFORSK), Norway, has undertaken research for the genetic improvement of Rohu (*Labeo rohita*), resulting in improvement in average growth of 17 per cent per generation after three generations of selective breeding and initiated dissemination through selected hatcheries. As part of the INGA's

strategy to assist member countries in effective dissemination of improved fish strains of fish, a mission comprising of INGA Research Coordinator Dr Modadugu Gupta and Dr Raul Ponzoni of the WorldFish Center, Mr Basilio Rodriguez, Jr. of the GIFT Foundation International and Dr P.V.G.K. Reddy, a well known geneticist and retired Principal Scientist of CIFA, was fielded in July 2003 to assist CIFA in developing a plan for disseminating the improved strain throughout the country. The mission held discussions with the Director and scientists of CIFA and extension officers, visited hatcheries in Andhra Pradesh, and reported to CIFA their suggestions and plans for the sustainable dissemination of the improved rohu strain.

INGA holds Steering Committee Meeting in Bangladesh

The Seventh Steering Committee Meeting of INGA was held on 6 August 2003 in Dhaka, Bangladesh, in conjunction with the Expert Consultation on Ecological Risk Assessment of Genetically Improved Fish. Members of the Steering Committee, senior scientists from 13 participating countries, representatives from advanced scientific institutions, and representatives from regional and international organizations attended. The participants, besides discussing the progress and follow-up actions since the 6th Steering Committee Meeting in Hanoi in 2001, also identified new initiatives that will be undertaken by the network over the next three to five years. Many member countries requested the WorldFish Center to initiate a regional project for genetic improvement of freshwater prawns (*Macrobrachium rosenbergii*) in view of the high demand in domestic and export markets.

NTAFP news

NTAFP member and ex-staff member of WorldFish Center's program in Bangladesh wins John Holliday student conservation award

Mr Debashish Mazumdar, a doctoral student at the Australian Catholic University, New South Wales, Australia, has won the 2002 New South Wales Fisheries' John Holliday Student Conservation Award for his research on the impact of saltmarshes on fisheries in Southeast Australia. The award program, in memory of the late Dr John Holliday who dedicated 26 years to working for New South Wales Fisheries, aims to encourage post-graduate students to share their research findings on topics of

interest to the department.

Mr Mazumdar's research shows that saltmarshes may be very important as a temporary habitat and as a food source, despite being infrequently inundated with salt water. His data indicate that the number of fish and fish species in saltmarshes are only slightly lower than in mangrove areas. The crabs that live in saltmarshes produce a very large number of offspring, especially in winter, and these are exported out of the saltmarsh areas

at high tide. Many fish species, including commercially important flat-tailed mullets, feed predominantly on crab larvae.

Mr Mazumdar's report was judged as being based on sound science and containing information relevant to managing and protecting saltmarsh areas in Australia.

Source: NSW Fisheries website (www.fisheries.nsw.gov.au Newsroom – 15 July 2003).

Indian scientist receives award in marine fisheries

The Indian Council of Agricultural Research (ICAR) conferred the prestigious Rafi Ahmed Kidwai Memorial Award for the biennium 2001-2002 in the area of marine fisheries to Dr V. Sriramachandra Murty, formerly the Head, Division of Demersal Fisheries, Central Marine Fisheries Research Institute, Cochin, India. ICAR instituted this award in 1956 to perpetuate the memory of Shri Rafi Ahmed Kidwai who was the President of the ICAR

from 1952 to 1954 and "to create an incentive for research workers in India and to recognize outstanding research work done in the fields of agriculture, animal husbandry and allied sciences." Dr Murty was recognized for nearly four-decades of pioneering research in fisheries biology, population dynamics and stock assessment of several groups of marine fish. The work has contributed significantly to marine fisheries development and management of

exploited demersal finfish stocks in India, besides providing valuable references for scientists involved in marine fisheries research. Dr Murty was also cited for his pioneering research on the assessment of marine ornamental fish resources of Lakshadweep. His contributions are of immense value in resource management and will help policy planners to devise and implement sustainable fisheries management policies relevant to the Indian situation.

Kyoto World Water Forum - a fisheries perspective

An estimated 24 000 participants gathered in Kyoto, Shiga and Osaka for the third World Water Forum (WWF) during 16-23 March 2003. Building on the achievements of the first Forum held in Morocco in 1997 and WWF 2 in The Hague in 2000, the Kyoto Forum provided an opportunity for the world's water community to debate and exchange information on recent developments and emerging issues concerning the management of the world's freshwater. While the WWF launched the World Water Vision in 2000, Kyoto provided an opportunity to assess the progress towards turning the vision into reality.

The Forum consisted of over 351 working sessions covering 33 themes and issues, such as: water and poverty, governance, climate, cities; water, food and the environment; and water, nature and the environment. It brought together water users, managers, researchers, NGOs, Ministers, CEOs, and youth from across the globe. The Forum allowed discussion on a remarkably rich diversity of current issues and initiatives at multiple levels in different parts of the world. Following the Forum, a Ministerial meeting resulted in a Ministerial Declaration that is available at www.world.water-forum3.com, together with the Forum's final Statement. The Declaration and Statement highlight the importance of governance, capacity-building, finance, water resources management and benefit sharing, drinking water and sanitation, water for food and rural development, water pollution prevention and ecosystem conservation, and disaster mitigation and risk management. They emphasize the importance being given to these issues in the current debates on water at the national and international levels.

In providing a forum, Kyoto was clearly a success. But as with most major conferences, many people will ask - what difference has Kyoto made to the lives of the poor people dependent upon freshwater? Kyoto certainly provided an important opportunity for discussion on concerns and for exchanging information - but will this help improve water management? By itself the Forum will not bring about change. The more important question is whether the international community will build upon Kyoto to develop new approaches to addressing the challenges and conflicts identified there. For those of us concerned with fisheries and aquaculture this raises the question of how we can build upon Kyoto to foster action to address our concerns.

At first glance, the discussions at Kyoto were not encouraging for fisheries. Fish, fisheries

and aquaculture were all largely absent from the technical debates. In sessions on water and food, and the environment and water, no papers on fish were presented and the fisheries community was very much in the minority in the discussions. However, in retrospect this is not surprising. How often do we discuss aquaculture development or fishery management in terms of water management, or how fisheries and aquaculture can improve water productivity? And when we do so - how effectively do we engage with the water management and research community? One of the messages from Kyoto is that the fisheries managers and researchers need to engage much more effectively with our colleagues concerned with water management in order to understand their perspectives and concerns, and learn how fisheries and aquaculture can relate to these.

In contrast, the Ministerial Declaration gives a high profile to fish in declaring that "Inland fisheries being a major source of food, freshwater fish production should be addressed through intensified efforts to improve water quality and quantity in rivers and protection or restoration of breeding areas." Interestingly, this was achieved as a result of the recommendations from the Second International Symposium on the Management of Large Rivers for Fisheries (held in Phnom Penh in February 2003) and the efforts of the Mekong River Commission (MRC) to promote wider awareness of these recommendations at Kyoto. Greater investment of this kind will do much to raise the profile of fisheries issues in these policy debates.

The central message from Kyoto is that the policy debate and technical discussions that are taking place around water are of central importance to fish and fisheries and, hence, there is an urgent need for much greater investment by the fisheries and aquaculture community to engage in these processes. As the international community seeks to identify ways by which to improve water productivity through more integrated approaches to water use, it will become increasingly important to understand and promote how best to integrate fisheries and aquaculture. Amongst the research areas where special attention is merited, four stand out:

Integrating fish into farm and water management. A wide range of opportunities exists for improving water productivity by integrating fish production into farming and water management systems. Practical technologies for doing so need to be developed through participatory research

and development approaches.

Ecosystems services. As the water community moves from defining water productivity in terms of more crop per drop to embracing a wider understanding of the role of water in supporting livelihoods at the basin level, more attention needs to be given to assessing ecosystem services and resource values that are sustained by water.

Environmental flows. If these values are to be sustained in the face of increasing competition for water, there is an urgent need to develop user-friendly methodologies for environmental flow assessment and build capacity to use these.

Governance. Work on all of these issues needs to be underpinned by a fundamental assessment of how aquatic resources and farming systems are governed and how the benefits are shared amongst stakeholders. In the absence of governance systems that foster improved engagement of fishers and farmers in water resource management decisions and improve benefit sharing, new technologies will be of little value.

The WorldFish Center is currently engaged in several initiatives that will help foster this work:

Fish for All has recognized water as a major priority and is building awareness of the importance of fish, fisheries and aquaculture in water management.

The Comprehensive Assessment of Water in Agriculture is supporting a number of projects to assess the current understanding of the contribution of fish and fisheries to agricultural productivity and highlighting future research needs.

The Challenge Program on Water and Food has given high priority to Aquatic Ecosystems and Fisheries as one of five central themes of the program. WorldFish will coordinate activities under this theme on behalf of the Challenge Program.

By pursuing these initiatives over the course of the next few years and working to develop a closer partnership with the water management and research communities, WorldFish hopes to see a much higher profile for fish at the next WWF in 2006 and greater tangible benefits to fishers and farmers from improved water management.

P. Dugan is from the WorldFish Center's Regional Research Center for Africa and West Asia, PO Box 1261, Maadi, Cairo, Egypt. E-mail: worldfish-egypt@cgiar.org

Dr. Aprilani Soegiarto awarded prestigious silver medal

The WorldFish Center is pleased to announce that **Prof Dr Aprilani Soegiarto**, a former Board Member of the WorldFish Center (1997-2003), was awarded a Silver Medal from the Wageningen University and Research Center, Wageningen, the Netherlands. The award was bestowed on him as the Chair of the Board of Trustees of the PROSEA (Plant Resources of Southeast Asia) Foundation during 1989-2003. More than 1 200 experts from all over the world are involved in PROSEA. Dr Aprilani helped to complete the 24-volume PROSEA Handbook in a successful joint venture between Wageningen University and six scientific institutions in Southeast Asia. The realization of the basic mission of PROSEA, i.e., the publication of a 24-volume Handbook on 7 000 species of useful plants of Southeast Asia over a

time-span of 16 years, is a formidable achievement. Congratulations on the hard work and rewarding experience.

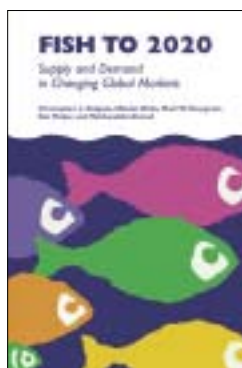
Dr Aprilani Soegiarto earned his Ph.D. in Marine Science from the University of Hawaii. He is an internationally recognized marine biologist, and has served as the fourth Vice Chair of the International Governmental Oceanographic Commission of UNESCO (1987-1990) and chair of the Association of the Southeast Asian Nations (ASEAN) Subcommittee on Marine Sciences (1984-1992). Later in his career he became involved in research management at the Indonesian Institute of Sciences (LIPI) in Jakarta, Indonesia.

He holds three concurrent positions: Research Professor at the Center for Research and Development in

Oceanology; Professor in Oceanology at the Bogor Agriculture University; and Chairman, Group II Natural Resources and Energy of the Indonesian National Research Council.



New publication



Fish to 2020 - Supply and Demand in Changing Global Markets

by Christopher L. Delgado, Nikolas Wada, Mark W. Rosegrant, Siet Meijer, and Mahfuzuddin Ahmed

Growing crises and controversy are plaguing the fish industry worldwide. With more people consuming more fish than ever before, the world's oceans are being overfished and fish farming is threatening surrounding waters and even wild fish stocks. Given this troubling picture, can an environmentally sustainable fish industry that also serves poor people be developed over the next two decades? To address this question, *Fish to 2020* presents the first comprehensive economic analysis of recent rapid changes in the fish sector and gives the outlook for fish in the global food system over the next two decades.

Using a state-of-the-art model of the world food system, *Fish to 2020* examines the pressing problems of fisheries in the context of changing global and national market forces. It reveals that developing countries will shape nearly all growth in the fish industry in the next two decades and describes how new technologies and improved policies in both developed and developing countries can help create a thriving sustainable fish industry. This book is essential for anyone who wishes to understand the future of the world food system and the crucial role that fish can play. Highlights of the book are available in a food policy report and a brief.

To order, please contact:
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Obituary: Professor Dr Ahyaudin Ali

Professor Ahyaudin Ali, Deputy Vice Chancellor (Research and Development) of Universiti Sains Malaysia, passed away on 5 July 2003 at the height of his career and at the relatively young age of 48 years. He was a member of the Network of Aquaculture and Fisheries Professionals (NTAFP), council member of the Asian Fisheries Society (AFS) and a close friend of the WorldFish Center. He had a distinguished career at the Universiti Sains Malaysia, which he joined as a lecturer in the School of Biological Sciences in April

1984. He was promoted to Associate Professor in 1990 and to full Professor in 1998. His research on limnology was particularly well recognized and he was the Chairperson for the Limnological Research Group on Paya Indah Sanctuary, Malaysian Wetlands Foundation during 1997-98. He chaired the Advisory Committee of the Ramsar Center, Japan from 1997 until his demise, and also chaired the training program on the "Rice-Macrobrachium Integrated Farming System" initiated by DFID-UK and CARE

Bangladesh in 1988. He was awarded the Biwako Ecology Prize (Japan) in 2001, and was appointed Deputy Vice Chancellor (Research and Development) of Universiti Sains Malaysia in October 2001. Despite his illness, he valiantly shouldered his heavy workload. He was a good friend and partner to the WorldFish Center and shared many of its visions and missions. He left behind his wife, Nor Aaini Haji Ismail, and four children. With his untimely demise, the world of aquaculture and fisheries has lost an eminent scientist.

Obituary: Professor Surapol Sudara, leading marine conservationist in Thailand

Thirty years pushing marine conservation

The Bangkok Post
http://www.bangkokpost.com/News/20Jul2003_news02.html

Prominent environmentalist Prof Surapol Sudara died on 19 July 2003 after being diagnosed with liver cancer in June. He was 64 years old.

Prof Surapol was an adviser to the Natural Resources and Environment Minister, Praphat Panyachartrak, as well as the House Committee on foreign affairs in Thailand. He specialized in marine biology and coastal-area management. Mr Praphat noted that Prof Surapol was a well-respected environment expert who played an important role in founding the Ministry of Natural Resources and Environment. "Prof Surapol was a key

adviser to the Ministry, especially on the government's policy for marine and coastal management," he said. "His death is a great loss to the nation's environmental movements."

Prof Surapol retired as lecturer at the Department of Marine Science in 1999. He became president of the Sueb Nakhasathien Foundation, one of Thailand's most active environment NGOs, in September 2001. "Prof Surapol was a pioneer in raising public awareness on the degradation of marine and coastal resources," said Sueb Nakhasathien Foundation President Vanchai Tantivitayapitak. "His work alerted state agencies and the public to threats to marine and coastal ecological systems."

Prof Surapol had worked toward promoting environmental conservation for more than three decades. He was a

key opponent of the Nam Chon dam project in Kanchanaburi and had recently warned the government to scrap a proposed potash mine in Udon Thani Province due to the potential for severe environmental consequences. He was also concerned about the impact of mass tourism on coral reefs and other aspects of marine ecology.

Before his death, Prof Surapol chaired a subcommittee working on the restructuring of EIAs in Thailand. Environment Institute President, Dr Thongchai Panswad said Prof Surapol's attempts to protect Thailand's natural resources had been hampered by state agencies that were more interested in economic development.

Prof Surapol was married to Taveetiya Sukharom and had three children.

Obituary: Professor Dr Guy Teugels, scholar, partner and friend

Professor Dr Guy Teugels, Senior Scientist and Curator of the Ichthyology Collection of the Royal Museum for Central Africa (Musée Royal de l'Afrique Centrale, MRAC) in Tervuren, Belgium, and Professor at the Catholic University of Louvain, passed away on 22nd July 2003. Prof Teugels was a leading international expert on African freshwater and brackishwater fishes, especially catfishes, and aquatic biodiversity. He led many projects, interacted with numerous institutions in Africa, and published widely, in a number of languages, on taxonomy, species

revisions and descriptions, genetics, biogeography, ecology, aquaculture, and effects of deforestation, dam construction and industrial pollution on fish populations. In particular, he contributed significantly to the development of a number of definitive and pioneering works on African fishes, notably the *Check-List of the Freshwater Fishes of Africa (CLOFFA)* in 1991 and *Faune des poissons d'eaux douces et saumâtres de l'Afrique de l'Ouest. Tome I and II. Collection Faune Tropicale* in 1990 and 1992. More recently, he extended his research interests to freshwater

fishes of Indonesia and Vietnam. Prof Teugels was a long time collaborator of the WorldFish Center with his involvement in the development of FishBase, partner in research projects, and as a resource person in training workshops in Africa. His collaboration with the WorldFish Center started in 1991-92 through MRAC's involvement in and support to the WorldFish Center for the development of FishBase and, subsequently, in the technical reviews of data on African fishes in FishBase. With his untimely demise, the scientific world has lost a scholar, a partner and a friend.

Bibliography

- 19452 - The role of aquaculture and living aquatic resources: priorities for support and networking.** 2003. Bangkok, Thailand. FAO. vii, 90 p. The Food and Agriculture Organisation of the United Nations (FAO), the Mekong River Commission (MRC), the Network of Aquaculture Centres in Asia-Pacific (NACA), the Southeast Asian Fisheries Development Center (SEAFDEC) and the WorldFish Center Regional Donor Consultation on the "Role of aquaculture and living aquatic resources: priorities for support and networking" convened in Manila, Philippines, 27-28 November 2002. SH151 R64 2002.
- 19453 - The double burden of malnutrition in Asia: causes, consequences, and solutions.** Gillespie, S.; Haddad, L.J. 2003. Delhi, India: Sage publications. xiv, 235 p. 81-7829-227-0. RJ399 M26G54.
- 19454 - Partnership as process: building an institutional ethnography of an inter-agency aquaculture project in Bangladesh.** Lewis, D.J. 2003. New Delhi, India: India Research Press. In Development as process: concepts and methods for working with complexity. p. 99-115. HD75 M67.
- 19455 - The effect of chromium picolinate on growth and carbohydrate utilization in tilapia, *Oreochromis niloticus* × *Oreochromis aureus*.** Qing Pan; Sheng Liu; Tan, Y.G.; Bi, Y.Z. 2003. Aquaculture 225(1-4): 421-429. Department of Aquaculture, School of Animal Science, South China Agricultural University, Canton 510642, PR China.
- 19557 - Reversing environmental degradation trends in the South China Sea and Gulf of Thailand: report of the First Meeting of the Regional Working Group on Fisheries.** 2002. Bangkok, Thailand: UNEP/GEF. iii, 10 p. Appendices. QH540 F57 2002.
- 19558 - Development of nursery and grow-out systems of local catfish, *Clarias batrachus*, in Bangladesh. Final report.** Hussain, M.G.; Khan, M.N.; Bhadra, A. 2001. Mymensingh, Bangladesh: Bangladesh Fisheries Research Institute. 42 p. SH167 C35H87.
- 19559 - Genetic improvement and conservation of carp species in Bangladesh.** Hussain, M.G.; Mazid, M.A. 2001. Mymensingh, Bangladesh: Bangladesh Fisheries Research Institute, ICLARM - The World Fish Center. 74 p. 984-31-1309-8. SH207 M5H87 2001.
- 19560 - Genetic management and improvement of exotic carp species in Bangladesh: proceedings of a DFID-AFGRP/BFRI workshop.** Penman, D.J.; Hussain, M.G.; McAndrew, B.J.; Mazid, M.A. (eds.) 2002. Mymensingh, Bangladesh: Bangladesh Fisheries Research Institute. 984-32-0288-0. SH167 C3G46 2002.
- 19561 - Report of the FAO working group on the assessment of small pelagic fish off northwest Africa, Nouadhibou, Mauritania, 24-31 March 2001.** 2001. FAO Fish. Rep. (657): 133 p. 92-5-004674-X. SH331 F36 #657.
- 19562 - Improving developing country food security through aquaculture development - lessons from Asia.** Ahmed, M.; Loric, M.H. 2002. Food Policy 27: 125-141. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (Email: worldfishcenter@cgjar.org) R 2002-37.
- 19563 - Towards food secure India: proceedings of the 88th session of the Indian Science Congress.** Paroda, R.S.;

This section contains a list of selected recent publications on fisheries, aquaculture and aquatic resources management available at the WorldFish Center Library. The subject, taxonomic and geographic indexes to this are given on pages 43-46.

Please write to the senior author if you require reprints of any article or monograph.

- Varma, A.; Gupta, N. (eds.) 2002. New Delhi, India: National Academy of Agricultural Sciences. xii, 222 p. 81-900426-1-0. HD9018 D44T68 2001.
- 19564 - Food insecurity atlas of rural India.** 2001. India: M. S. Swaminathan Research Foundation. xiv, 162 p. CD-ROM version available. HD9018 D44F66.
- 19565 - Food insecurity atlas of urban India.** 2002. India: M. S. Swaminathan Research Foundation. xv, 212 p. HD9018 D44F662.
- 19566 - A lasting catch.** Schioler, E. 2002. Penang, Malaysia: WorldFish Center. ix, 147 p. 983-2346-12-6. SH207 I5S33 2002.
- 19567 - Achieving water and fish for all in the Philippines.** Williams, M.J.; Choo, P.S. 2003. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-14.
- 19568 - Sulu - Sulawesi seas.** Freund, J. 2001. Manila, Philippines: Bookmark, Inc. and WWF Philippines-Kabang Kalikasan ng Pilipinas (KKP) 235 p. 971-569-426-8. QH541.5 S3F73.
- 19569 - Harmful algae management and mitigation: can WorldFish Center play a role?** Choo, P.S.; Williams, M.J. 2001. 9 p. Paper presented in International Symposium on Harmful Algae Management and Mitigation in the area of/nearby South China Sea, 9-12 December 2002, Taipei, Chinese Taipei. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-13.
- 19570 - 'Fish in hot water': the challenges facing fish and fisheries research in tropical estuaries.** Blaber, S.J.M. 2002. J. Fish Biol. 61 Suppl. A: 1-20. CSIRO Marine Research, P.O. Box 120, Cleveland, Queensland 4163, Australia (E-mail: steve.blaber@csiro.au)
- 19571 - A reassessment of the maintenance ration of red tilapia.** Richter, H.; Francis, G.; Becker, K. 2002. Aquacult. Int. 10(1): 1-9. Write to: K. Becker, University of Hohenheim, Institute for Animal Production in the Tropics & Subtropics (480), Dept. Aquaculture Systems & Animal Nutrition, 70599 Stuttgart, Germany (E-mail: inst480@uni-hohenheim.de)
- 19572 - Effects of dietary cottonseed meal protein level on growth, gonad development and plasma sex steroid hormones of tropical fish tilapia *Oreochromis* sp.** Rinchar, J.; Mbahinzireki, G.; Dabrowski, K.; Lee, K.J.; Garcia-Abiado, M.A.; Ottobre, J. 2002. Aquacult. Int. 10(1): 11-28.
- 19573 - Determination of dosage of Azotobacter and organic fertilizer for optimum nutrient release, net primary productivity and fish growth in fresh water fish ponds.** Garg, S.K.; Bhatnagar, A. 2002. Aquacult. Int. 10(2): 87-107. CCS Haryana Agricultural University, Dept. Zoology & Aquaculture, Laboratory of Aquaculture Management, 125 004, India (E-mail: gargsk@hau.nic.in)
- 19574 - A genetic fingerprint recapture technique for measuring growth in 'unmarkable' invertebrates: negative growth in commercially fished holothurians (*Holothuria nobilis*)** 2002. Mar. Ecol. Prog. Ser. 241: 221-226.
- 19575 - Settlement, movement and early juvenile mortality of the yellowtail snapper *Ocyurus chrysurus*.** Watson, M.; Munro, J.L.; Gell, F.R. 2002. Mar. Ecol. Prog. Ser. 237: 247-256. R 2002-36.
- 19576 - Combined culture of *Trochus niloticus* and giant clams (Tridacnidae): benefits for restocking and farming.** Clarke, P.J.; Komatsu, T.; Bell, J.D.; Lasi, F.; Oengpepa, C.P.; Legata, J. 2003. Aquaculture 215: 123-144. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-09.
- 19578 - Effect of stocking size and nutrient inputs on productivity of *Oreochromis shiranus* in ponds.** Chaula, K.; Jamu, D.; Bowman, J.R.; Veveřica, K.L. Nineteenth Annual Technical Report. Pond Dynamics / Aquaculture CRSP p. 161-165. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-10.
- 19579 - An annotated checklist of elasmobranchs of the South China Sea, with some global statistics on elasmobranch biodiversity, and an offer to taxonomists.** Froese, R.; Garilao, C.V. 2002. Elasmobranch biodiversity, conservation and management: proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. p. 82-85. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-11.
- 19580 - Modelling the Mekong fisheries: what can be done?** Baran, E. 2002. MRC Tech. Pap. 6: 70-73. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) SH328 M42 #6.
- 19581 - Choosing the appropriate spatial resolution for monitoring coral bleaching events using remote sensing.** Andrefouet, S.; Berkelmans, R.; Odriozola, L.; Done, T.; Oliver, J.; Muller-Karger, F. 2002. Coral Reefs 21: 147-154. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19582 - Comparative growth of Egyptian tilapia in response to declining water temperature.** Rezk, M.A.; Kamel, E.A.; Ramadan, A.A.; Dunham, R.A. 2002. Aquaculture 207: 239-247. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19583 - Developing optimal strategies for restocking sandfish: a collaborative project in New Caledonia.** Purcell, S.; Gardner, D.; Bell, J. 2002. SPC Beche-demer Info. Bull. (16): 2-4. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19584 - Spawning induction of three tropical sea cucumbers, *Holothuria scabra*, *H. fuscogilva* and *Actinopyga mauritiana*.** Battaglene, S.C.; Seymour, J.E.; Ramofafia, C.; Lane, I. 2002. Aquaculture 207: 29-47. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19585 - The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fishes.** Hair, C.; Bell, J.; Doherty, P. 2002. Responsible marine aquaculture: 327-353. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2002-39.
- 19586 - Predicting self-recruitment in**

- marine populations: biophysical correlates and mechanisms.** Sponaugle, S.; Cowen, R.K.; Shanks, A.; Morgan, S.G.; Leis, J.M.; Pineda, J.; Boehlert, G.W.; Kingsford, M.J.; Lindeman, K.C.; Grimes, C.; Munro, J.L. 2002. *Bull. Mar. Sci.* 70(1) Suppl.: 341-375. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19587 - Freshwater resources conservation: an action-oriented overview.** Baran, E.; Ponniah, A.G. 2003. UPWARD conservation and sustainable use of agricultural biodiversity: a resource book. 10 p. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-06.
- 19588 - SLODSTM: slow dissolving standards for water flow measurements.** Hart, A.M.; Lasi, F.E.; Glenn, E.P. 2002. *Aquacult. Eng.* 25: 239-252.
- 19589 - An organic matter and nitrogen dynamics model for the ecological analysis of integrated aquaculture/ agriculture systems: II. Model evaluation and application.** Jamu, D.M.; Piedrahita, R.H. 2002. *Environ. Modell. Softw.* 17: 583-592. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-04.
- 19590 - Village-based aquaculture ecosystems as a model for sustainable aquaculture development in Sub-Saharan Africa.** Brummett, R.E.; Costa-Pierce, B.A. 2002. In *Ecological aquaculture: the evolution of the blue revolution*, p. 145-160. Oxford, UK.: Blackwell Publishing. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-05.
- 19591 - The contribution of aquatic ecosystems and fisheries to food security and livelihoods: a research agenda.** Dugan, P.J.; Baran, E.; Tharme, R.; Prein, M.; Ahmed, R.; Amerasinghe, P.; Bueno, P.; Brown, C.; Dey, M.; Jayasinghe, G.; Niasse, M.; Nieland, A.; Smakhtin, V.; Tinh, N.; Viswanathan, K.; Welcomme, R. 2002. Challenge program on water and food: background papers to the full proposal, p. 85-113. Challenge program on water and food background paper 3. S494.5 W3C42 2002.
- 19592 - Meso-scale transboundary units for the management of coral reefs in the South China Sea area.** Ablan, M.C.A.; McManus, J.W.; Chen, C.A.; Shao, K.T.; Bell, J.; Cabanban, A.S.; Tuan, V.S.; Arthana, I.W. 2002. *NAGA* 25(3/4): 4-9. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19593 - Aquaculture in Jamaica.** Aiken, K.A.; Morris, D.; Hanley, F.C.; Manning, R. 2002. *NAGA* 25(3/4): 10-15. University of West Indies, Dept. Life Sciences (E-mail: kaaiken@uwimona.edu.jm)
- 19594 - Integration of freshwater prawn culture with rice farming in Kuttanad, India.** Kurup, B.M.; Ranjeet, K. 2002. *NAGA* 25(3/4): 16-19. Cochhin University of Science and Technology, School of Industrial Fisheries (E-mail: madhukurup@hotmail.com)
- 19595 - Length-weight relationship of mudskippers (Gobiidae: Oxudercinae) in the coastal areas of Selangor, Malaysia.** Khaironizam, M.Z.; Norma-Rashid, Y. 2002. *NAGA* 25(3/4): 20-22. University Malaya, Faculty of Science, Institute of Biological Sciences.
- 19596 - Diet composition of fish species from the southern continental shelf of Colombia.** Lopez-Peralta, R.H.; Arcila, C.A.T. 2002. *NAGA* 25(3/4): 23-29. Universidad Militar "Nueva Granada", Colombia (E-mail: rlopez@santander.umngedu.co)
- 19597 - Integrated coastal management - a new mega-term or a concept for the sustainable utilization of coastal regions?** Lohmeyer, U. 1998. *Anim. Res. Dev.* 48: 59-69. German Technical Cooperation (GTZ), GmbH, Abt. Viehwirtschaft und Fischerei, Dag-Hammarskjold-Weg 1-5, D-65760 Eschborn, Federal Republic of Germany, R 2003-12.
- 19598 - Fisheries of the Farasan Islands (Red Sea)** Gladstone, W. 2002. *NAGA* 25(3/4): 30-34. University of Newcastle, School of Science & Technology, Sustainable Resource Management & Coastal Ecology Unit, Central Coast Campus, PO Box 127, Ourimbah NSW 2258, Australia (E-mail: wgladsto@mail.newcastle.edu.au)
- 19599 - African freshwater fisheries: what needs to be managed?** Jul-Larsen, E.; van Zwieten, P. 2002. *NAGA* 25(3/4): 35-40. Chr. Michelsen Institute, Norway (E-mail: Eyolf.Jul-Larsen@CMI.NO)
- 19600 - Management of brookstock and quality control of fish seed in Hungary.** Varadi, L.; Gorda, S.; Bakos, J.; Jeney, Z. 2002. *NAGA* 25(3/4): 45-47. Research Institute for Fisheries, aquaculture & Irrigation, (HAKI), Szarvas, Hungary.
- 19601 - Genetic enhancement and conservation of aquatic biodiversity in Africa.** Gupta, M.V. 2002. *NAGA* 25(3/4): 48-49. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org).
- 19602 - The digital divide: your role in bridging the gap in aquatic library services for the disconnected.** Williams, M.J.; Choo, P.S. 2002. 13 p. Paper presented in the 28th IAMSLIC Conference, 5-11 October 2002, Mazatlan, Mexico. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-15.
- 19603 - Fisheries production in Asia: its role in food security and nutrition.** Williams, M.J.; Choo, P.S. 2003. 10 p. Paper presented in the 9th Asian Congress of Nutrition, February 23-27, 2003, New Delhi, India. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-17.
- 19604 - The role of information and knowledge management in fisheries development.** Williams, M.J.; Choo, P.S. 2003. 13 p. Paper presented in the National Fisheries Symposium, 18-20 February 2003, Kota Bharu, Kelantan, Malaysia. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-16.
- 19605 - Factors influencing migration of *Penaeus indicus* in the Negombo lagoon on the west coast of Sri Lanka.** Jayawardane, P.A.A.T.; McLusky, D.S.; Tytler, P. 2002. *Fish. Manage. Ecol.* 9(6): 351-363. MBRD, NARA, Crow Island, Mattakkuliya, Colombo 15, Sri Lanka (E-mail: paatj@hotmail.com)
- 19606 - Solarization of water hyacinth, *Eichhornia crassipes*, on Lake Victoria.** Ogari, J.; van der Knaap, M. 2002. *Fish. Manage. Ecol.* 9(6): 365-367. Lake Victoria Fisheries Research Project, PO Box 2145, Jinja, Uganda (E-mail: lvfrp@source.co.ug)
- 19607 - Growth, survival, and body composition of cage-culture Nile tilapia *Oreochromis niloticus* fed pelleted and unpelleted distillers grains with solubles in polyculture with freshwater prawn *Macrobrachium rosenbergii*.** 2000. *J. World Aquacult. Soc.* 31(4): 627-631.
- 19608 - Fishing skill in developing country fisheries: the Kedah, Malaysia trawl fishery.** Viswanathan, K.K.; Omar, I.; Jeon, Y.; Kirkley, J.; Squires, D.; Susilowati, I. 2002. *Mar. Resour. Econ.* 16: 293-314. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19611 - An organic matter and nitrogen dynamics model for the ecological analysis of integrated aquaculture/ agriculture systems: I. Model development and calibration.** Jamu, D.M.; Piedrahita, R.H. 2002. *Environ. Modell. Softw.* 17: 571-582. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-04.
- 19612 - Global overview of marine fisheries.** Garcia, S.M.; de Leiva Moreno, I. Responsible fisheries in the marine ecosystem, p. 1-24. SH329 S87R47 2001.
- 19613 - Anthropogenically induced changes in the environment: effect on fisheries.** Richardson, K. Responsible fisheries in the marine ecosystem, p. 275-289. SH329 S87R47 2001.
- 19614 - Fish culture in Cameroon: small scale commercial systems for rural poor.** Pouomogne, V.; Brummett, R. *Global Aquacult. Advocate*: 86-87. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-18.
- 19615 - Aquaculture and society in the new millennium.** Brummett, R.E. 2003. *World Aquacult.* 34(1): 51-59, 70. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-20.
- 19616 - Excess capacity and sustainable development in Java Sea fisheries.** Squires, D.; Omar, I.; Jeon, Y.; Kirkley, J.; Kuperan, K.; Susilowati, I. 2003. *Environ. Dev. Econ.* 8: 105-127. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-19.
- 19617 - C, N, P composition of suspended matter in Matang Mangrove Estuary, Malaysia.** Tanaka, K.; Sugahara, K.; Ohwaki, Y.; Choo, P.S. 1998. *JARQ* 32(2): 153-158. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-21.
- 19618 - Nutrient levels in ponds during the grow-out and harvest phase of *Penaeus monodon* during semi-intensive or intensive culture.** Choo, P.S.; Tanaka, K. 2000. *JIRCAS J. Sci. Pap.* (8): 13-20. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org) R 2003-23.
- 19619 - Variation in short-term survival of culture sandfish (*Holothuria scabra*) released in mangrove-seagrass and coral reef flat habitats in Solomon Islands.** Dance, S.K.; Lane, I.; Bell, J.D. 2003. *Aquaculture* 220: 495-505. Write to: WorldFish Center, PO Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19620 - Influences of nutrient outwelling from the mangrove swamp on the distribution of phytoplankton in the Matang Mangrove Estuary, Malaysia.** Tanaka, K.; Choo, P.S. 2000. *J. Oceanogr.* 56: 69-78. R 2003-24.
- 19621 - The use of mangrove wetland as a biofilter to treat shrimp pond effluents: preliminary results of an**

- experiment on the Caribbean coast of Colombia. Gautier, D.; Amador, J.; Newmark, F. 2001. *Aquacult. Res.* 32(10): 787-799. Auburn University, Dept. Fisheries & Allied Aquaculture, 203 Swingle Hall, Auburn, AL 36849, USA (E-mail: dgautier@acesag.auburn.edu)
- 19622 - Phosphatase activity with reference to bacteria and phosphorus in tropical freshwater aquaculture pond systems.** Barik, S.K.; Purushothaman, C.S.; Mohanty, A.N. 2001. *Aquacult. Res.* 32(10): 819-832. Central Institute of Fisheries Education, Seven Bungalows, Jai Prakash Road, Versova, Mumbai, Maharashtra, 400 061, India.
- 19623 - Marine protected areas in the eastern African region: how successful are they?** Francis, J.; Nilsson, A.; Waruinge, D. 2002. *Ambio* 31(7-8): 503-511. WIOMSA, P.O. Box 3298 Zanzibar, Tanzania (E-mail: julius@wioamsa.org)
- 19624 - Coastal resources and management systems influenced by conflict and migration: Mecufi, Mozambique.** Bryceson, I.; Massinga, A. 2002. *Ambio* 31(7-8): 512-517. Agricultural University of Norway, Noragric, Box 5001, N-1432 As, Norway (E-mail: ian.bryceson@noragric.nlh.no)
- 19625 - Marine fisheries in Tanzania. Jiddawi, N.S.; Ohman, M.C.** 2002. *Ambio* 31(7-8): 518-527. University of Dar-es-Salaam, Institute of Marine Sciences, P.O. Box 668, Zanzibar (E-mail: jiddawi@ims.udsm.ac.tz)
- 19626 - The artisanal fishery for *Octopus cyanea* Gray in Tanzania.** Guard, M.; Mgaya, Y.D. 2002. *Ambio* 31(7-8): 528-536. University of Aberdeen, Zoology Department, Tillydrone Road, Aberdeen AB24 2TZ, Scotland, UK (E-mail: martin.guard@lycos.com)
- 19627 - Coastal aquaculture development in eastern Africa and the western Indian Ocean: prospects and problems for food security and local economies.** Ronnback, P.; Bryceson, I.; Kautsky, N. 2002. *Ambio* 31(7-8): 537-542. Stockholm University, Department of Systems Ecology, SE-106 91 Stockholm, Sweden (E-mail: pat@system.ecology.su.se)
- 19628 - Effects of the 1998 coral mortality event on Kenyan coral reefs and fisheries.** McClanahan, T.; Maina, J.; Pet-Soede, L. 2002. *Ambio* 31(7-8): 543-550. The Wildlife Conservation Society, P.O. Box 99470, Mombasa, Kenya (E-mail: crcp@africaonline.co.ke)
- 19629 - Coral recruitment following a mass mortality event.** Tاملander, J. 2002. *Ambio* 31(7-8): 551-557. United Nations Environment Programme, Coral Reef Unit, P.O. Box 30552, Nairobi, Kenya (E-mail: jerker.tاملander@unep.org)
- 19630 - Environmental effects on the distribution of corallimorpharians in Tanzania.** Muhando, C.A.; Kuguru, B.L.; Wagner, G.M.; Mbiye, N.E.; Ohman, M.C. 2002. *Ambio* 31(7-8): 558-561. University of Dar-es-Salaam, Institute of Marine Sciences, P.O. Box 668, Zanzibar, Tanzania (E-mail: muhando@ims.udsm.ac.tz)
- 19631 - Population dynamics and movements of skipjack tuna (*Katsuwonus pelamis*) in the Maldivian fishery: analysis of tagging data from an advection-diffusion-reaction model.** Adam, M.S.; Sibert, J.R. 2002. *Aquat. Living Resour.* 15(1): 13-23. Joint Institute of Marine and Atmospheric Research, Pelagic Fisheries Research Program, 1000 Pope Road, MSB 312, Honolulu, HI 96822, USA (E-mail: msadam@soest.hawaii.edu)
- 19632 - Reproductive strategies of fishes in a tropical temporary stream of the Upper Senegal basin: Baoule River in Mali.** Paugy, D. 2002. *Aquat. Living Resour.* 15(1): 25-35. Antenne IRD, MNHN, laboratoire d'ichtyologie, 43 rue Cuvier, 75231 Paris cedex 5, France (E-mail: paugy@mnhn.fr)
- 19633 - The shift to smaller zooplankton in Lake Victoria cannot be attributed to the "sardine" *Rastrineobola argentea* (Cyprinidae)** Wanink, J.H.; Katunzi, E.F.B.; Goudswaard, K.P.C.; Witte, F.; van Densen, W.L.T. 2002. *Aquat. Living Resour.* 15(1): 37-43. Institute of Evolutionary and Ecological Sciences, Section Integrative Zoology, University of Leiden, P.O. Box 9516, 2300 RA Leiden, The Netherlands (E-mail: wanink@rulsfb.leidenuniv.nl)
- 19634 - ITQ: the assumption behind a meme.** Pauly, D. 1996. *Rev. Fish Biol. Fish.* 6(1): 109-112. Write to: WorldFish Center, P.O. Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgjar.org)
- 19635 - Regeneration status of mangrove forests in Mida Creek, Kenya: a compromised or secured future?** Kairo, J.G.; Dahdouh-Guebas, F.; Gwada, P.O.; Ochieng, C.; Koedam, N. 2002. *Ambio* 31(7-8): 562-568. Mangrove System Information Service, Kenya Marine & Fisheries Research Institute (KMFRI), P.O. Box 81651, Mombasa, Kenya (E-mail: jkairo@recoasscix.org)
- 19636 - Seagrass ecosystems in the western Indian Ocean.** Gullstrom, M.; de la Torre Castro, M.; Badeira, S.O.; Bjork, M.; Dahlberg, M.; Kautsky, N.; Ronnback, P.; Ohman, M.C. 2002. *Ambio* 31(7-8): 588-596. Kristineberg Marine Research Station, SE-450 34 Fiskebackskil, Sweden (E-mail: martin.gullstrom@kmrf.gu.se)
- 19637 - Support to marine research for sustainable management of marine and coastal resources in the western Indian Ocean.** Berg, H.; Francis, J.; Souter, P. 2002. *Ambio* 31(7-8): 597-601. SIDA, SE-105 25 Stockholm, Sweden (E-mail: hakan.berg@sida.se)
- 19638 - Marine biological research in Mozambique: past, present and future.** Badeira, S.; e Silva, R.P.; Paula, J.; Macia, A.; Herreroth, L.; Guissamulo, A.T.; Gove, D.Z. 2002. *Ambio* 31(7-8): 606-609. Department of Biological Sciences, Universidade Eduardo Mondlane, P.O. Box 257, Maputo, Mozambique (E-mail: sband@zebra.uem.mz)
- 19639 - Patterns in the distribution and abundance of hard corals around Zanzibar Island.** Mbiye, N.E.; Wagner, G.M.; Francis, J.; Ohman, M.C.; Garpe, K. 2002. *Ambio* 31(7-8): 609-611. National Museum of Tanzania, P.O. Box 511, Dar es Salaam, Tanzania (E-mail: mbiye@yahoo.com)
- 19640 - A review of water quality and pollution studies in Tanzania.** Mohammed, S.M. 2002. *Ambio* 31(7-8): 617-620. Institute of Marine Sciences, Zanzibar (E-mail: salim@ims.udsm.ac.tz)
- 19641 - Development of freshwater fish farming and poverty alleviation: a case study from Bangladesh.** de Graaf, G.; Abdul Latif. 2002. *Aquacult. Asia* 7(2): 5-7. Nefisco Foundation, Amsterdam, The Netherlands (E-mail: deGraaf@nefisco.org)
- 19642 - Conservation of endangered fish stocks through artificial propagation and larval rearing technique in west Bengal, India.** Mijkherjee, M.; Praharaj, A.; Das, S. 2002. *Aquacult. Asia* 7(2): 8-11. Office of the Deputy Director of Fisheries (Microbiology & Parasitology), Captain Bheri, P.O. Nawbhanga, E.M. Bypass, Kolkata-39, West Bengal, India.
- 19643 - Aquaculture fundamentals: the use of lime, gypsum, alum and potassium permanganate in water quality management.** Wilkinson, S. 2002. *Aquacult. Asia* 7(2): 12-14. ENACA, GPO Box 1040, Kasetsart University Post Office, Bangkok 10903, Thailand (E-mail: simon.wilkinson@enaca.org)
- 19644 - The utilizations of heterosis in common carp in China.** Dong, Z.J.; Yuan, X.H. 2002. *Aquacult. Asia* 7(2): 14-15. Freshwater Fisheries Research Centre of Chinese Academy of Fisheries Sciences, Wuxi, 214081, China (E-mail: dongz@bigfoot.com)
- 19645 - Progress of fish gene technology research in China.** Zhang, Y.; Zhu, X. 2002. *Aquacult. Asia* 7(2): 15-16. Pearl River Fisheries Research Institute, Guangzhou, 510380, P.R. China.
- 19646 - Seed production of Magur (*Clarius batrachus*) using a rural model portable hatchery in Assam, India - a farmer proven technology.** Das, S.K. 2002. *Aquacult. Asia* 7(2): 19-21. Assam Agricultural University, College of Fisheries, Raka, Nagaon, Assam, India (E-mail: skdas01@yahoo.com)
- 19647 - Supply of good quality fish seed for sustainable aquaculture.** Mair, G. 2002. *Aquacult. Asia* 7(2): 25-27. Aquaculture and Aquatic Resources Management Group, Asian Institute of Technology, Bangkok, Thailand (E-mail: gcmair@ait.ac.th)
- 19648 - Sewage fed aquaculture systems of Kolkata: a century-old innovation of farmers.** Nandeesha, M.C. 2002. *Aquacult. Asia* 7(2): 28-32. Department of Aquaculture, College of Fisheries, Central Agricultural University, PO Box No. 120, Agartala-799001, Tripura, India (E-mail: mcnrjai@yahoo.com)
- 19649 - Fish farming in rice environments of north eastern India.** Das, D.N. 2002. *Aquacult. Asia* 7(2): 43-47. Dept. of Zoology, Arunachal University, Itanagar-791 112, India.
- 19650 - A regional approach to assessing organic waste production by low salinity shrimp farms.** Szuster, B.; Flaherty, M. 2002. *Aquacult. Asia* 7(2): 48-52. Thailand Aquaculture Management Program, Department of Aquatic Science, Burapha University, Bang Saen, Chonburi, 20131, Thailand (E-mail: bszuster@uvic.ca)
- 19651 - Field guide to important commercial marine fishes of the South China Sea.** Isa, M.M.; Kohno, H.; Ida, H.; Nakamura, H.T.; Zainal, A.; Syed Abdul Kadir, S.A. 1998. Kuala Terengganu, Malaysia: Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center. xii, 287 p. 983-9114-05-0. QL623.56 F53.
- 19652 - Highlights of the SEAFDEC Interdepartmental Collaborative Research Program on Fishery Resources in the South China Sea, Area II. Waters of Sabah, Sarawak (Malaysia) and Brunei Darussalam.** 2000. Bangkok, Thailand: The Secretariat. vii, 54 p. 974-7604-63-9. SH327.5 S42 2000.
- 19653 - Proceedings of the Western Pacific Sea Turtle Cooperative Research and Management workshop.** Kinan, I. (ed.) 2002. Honolulu, Hawaii. Western Pacific Regional Fishery Management Council. viii, 289 p. "A forum to disseminate information and to promote greater regional collaboration for research and management of Pacific sea turtle populations". T.p. QL666 C5W47 2002.
- 19654 - The tuna fisheries statistics for the South China Sea area 1998.** Raha Hassan,

- R.B.; Awang, Z. (eds.) 2002. Kuala Terengganu, Malaysia: Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center. xii, 61 p. 983-9819-22-4. SH351 T8R34.
- 19655 - The catch-effort statistics for the South China Sea area 1996.** 2002. Kuala Terengganu, Malaysia: The Center. x, 151 p. SH214.56 S65 1996.
- 19656 - Report of the SEAFDEC - ASEAN Regional Workshop on Sea Turtle Conservation and Management.** 1999. Kuala Terengganu, Malaysia: Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center. 328 p. 983-9114-10-7. QL666 C5S43 1999.
- 19657 - Report of the First SEAFDEC Meeting on Regional Sea Turtle Data Management.** 2001. Kuala Terengganu, Malaysia: Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center. 122 p. 983-9819-19-4. QL666 C5S43 2000.
- 19658 - Educational reform for improved natural resource management: fisheries and aquaculture in Bangladeshi universities.** Allison, E.H.; McBride, R.J. 2003. Soc. Nat. Resour. 16: 249-264. School of Development Studies, University of East Anglia, Norwich, United Kingdom (E-mail: E.Allison@uea.ac.uk) R 2003-28.
- 19659 - Breeding and culture of the sea cucumber *Holothuria scabra* in Vietnam.** Pitt, R.; Duy, N.D.Q. 2003. Aquacult. Asia 8(1): 36-37, 39. Write to: WorldFish Center, P.O. Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgiar.org)
- 19660 - A preliminary study on the feasibility of using brushparks for fish production in Lake Chilwa, Malawi.** Jamu, D.M.; Chaula, K.; Hunga, H. 2003. Naga 26(1): 1-5. Write to: WorldFish Center, P.O. Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgiar.org)
- 19661 - The lowdown on world shrimp culture - II.** Yap, W.G. 2001. INFOFISH Int. 3: 20-23, 26-27. SEAFDEC Aquaculture Department, Tigbauan, Iloilo, Philippines.
- 19662 - Genetic applications in aquaculture.** Melamed, P.; Hew, C.L. 2001. INFOFISH Int. 3: 34-37. Department of Biological Sciences, National University of Singapore, Singapore.
- 19663 - Artisanal processing of sea snails in the Gambia.** Njie, M.; Tall, A. 2001. INFOFISH Int. 3: 48-52. Fisheries Department, The Gambia.
- 19664 - Marine parks of Malaysia - a management tool for fisheries resources.** Hiew, K.W.P. 2001. INFOFISH Int. 3: 57-61. Marine Parks Section, Department of Fisheries, Malaysia.
- 19665 - Aquaculture development in China.** Wang, Y. 2001. Aquacult. Asia 6(1): 4-10. Chinese Academy of Fisheries Sciences, Beijing, China.
- 19666 - Shrimp culture with a mild carnivore fish.** Mohan, C.V.; Shankar, K.M.; Ahmed, I.; Ramesh, K.S. 2001. Aquacult. Asia 6(1): 16-17. Fish Pathology Laboratory, Department of Aquaculture, College of Fisheries, Mangalore-575002, India (E-mail: cv_mohan@yahoo.com)
- 19667 - Probiotics in aquaculture - a fancy phrase? The Malaysian experience.** Devaraja, T.N. 2001. Aquacult. Asia 6: 18-21. Aquatic Animal Health Unit, Faculty of Veterinary Medicine, Universiti Putra Malaysia, Serdang 43400, Malaysia (E-mail: tdevaraja@yahoo.com)
- 19668 - Customary fisheries management and its effectiveness in the Solomon Islands.** Donnelly, R.; Davis, D.; Lam, M. 2001. Aquacult. Asia 6(1): 23-24. Southern Cross University, NSW, Australia.
- 19669 - Aquaculture education in Fiji.** Nandlal, S. 2001. Aquacult. Asia 6(1): 25-27. Ministry of Agriculture Fisheries and Forests, Naduruloulou, Aquaculture Station, P.O. Box 819, Nausori, Fiji (E-mail: S780189@student.usp.ac.fj)
- 19670 - Overview of sea cucumbers fisheries over the last decade - what possibilities for a durable management?** Conand, C. 2001. Echinoderms 2000. p. 339-344. Marine Ecology Laboratory, La Reunion, France. R 2003-29.
- 19671 - Aquaculture education in Pacific Island countries.** Pickering, T. 2001. Aquacult. Asia 6(1): 28-30. Marine Studies Program, The University of the South Pacific, Private Bag, Suva, Fiji Islands (E-mail: pickering_t@usp.ac.fj)
- 19672 - Reproductive cycle of two commercial species of sea cucumber (Echinodermata: Holothuroidea) from Caribbean Panama.** Guzman, H.M.; Guevara, C.A.; Hernandez, I.C. 2003. Mar. Biol. 142(2): 271-279. Smithsonian Tropical Research Institute, Apartado Postal 2072, Balboa, Panama.
- 19673 - Reproduction of the commercial sea cucumber *Holothuria scabra* (Echinodermata: Holothuroidea) in the Solomon Islands.** Ramofafia, C.; Byrne, M.; Battaglione, C.S. 2003. Mar. Biol. 142(2): 281-288. Department of Anatomy and Histology F13, University of Sydney, NSW 2006, Australia (E-mail: chris.ramofafia@fa.int)
- 19674 - Short-term temporal patterns of early recruitment of coral reef fishes in the tropical eastern Pacific.** Lozano, S.; Zapata, F.A. 2003. Mar. Biol. 142(2): 399-409. Departamento de Biología, Universidad del Valle, Apartado Aereo 25360, Cali, Colombia (E-mail: saloz@rocketmail.com)
- 19675 - Production and grow-out of the black-lip pearl oyster *Pinctada margaritifera*.** Lane, I.; Oengpepa, C.; Bell, J. 2003. Aquacult. Asia 8(1): 5-7. Write to: WorldFish Center, P.O. Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgiar.org)
- 19676 - Making saline wastelands productive through aquaculture.** Jain, K.K.; Diwan, A.D. 2002. INFOFISH Int. 6: 16-20. Central Institute of Fisheries Education, Versova, Mumbai, India.
- 19677 - Towards more free trade in fishery products in the Arab world.** Feidi, I. 2002. INFOFISH Int. (6): 26-31.
- 19678 - The status of Indian Ocean tuna stocks.** Ardill, D. 2002. INFOFISH Int. (6): 59-63. Indian Ocean Tuna Commission Secretariat, Victoria, Seychelles.
- 19679 - Regional guidelines for responsible fisheries in Southeast Asia: responsible fishing operations.** [1999] [Bangkok, Thailand]: The Center. 71 p. SH295 S67.
- 19680 - Length-weight relationship of fishes from coral reefs along the coastline of Jordan (Gulf of Aqaba).** Odat, N. 2003. NAGA 26(1): 9-10. Institute of Ecology, University of Jena, Dornburger Strasse 159, D-07743 Jena, Germany (E-mail: Nidal.Odat@uni-jena.de)
- 19681 - Shrimp disease management using bioactive marine secondary metabolites: an eco-friendly approach.** Selvin, J.; Lipton, A.P. 2003. NAGA 26(1): 11-13. Department of Biotechnology, Malankara Catholic College, Mariagiri, Kaliakavilai - 629165, Kanyakumari District, India (E-mail: selvinj@rediffmail.com)
- 19682 - Length-weight relationships of coral reef fishes from the Alacran Reef, Yucatan, Mexico.** Gonzalez-Gandara, C.; Perez-Diaz, E.; Santos-Rodriguez, L.; Arias-Gonzalez, J.E. 2003. NAGA 26(1): 14-16. Facultad de Ciencias Biológicas y Apdo, Postal 70, Tuxpan, Veracruz, Mexico.
- 19683 - An approach to estimate the natural mortality rate in fish stocks.** Cubillos, L.A. 2003. NAGA 26(10): 17-19. Departamento de Pesquerías, Instituto de Investigación Pesquera, Castilla 350, Talcahuano, Chile (E-mail: Lcubillos@inpesca.cl)
- 19684 - Genetic improvement of the herbivorous blunt snout bream (*Megalobrama amblycephala*).** Li, S.F.; Cai, W.Q. 2003. Naga 26(1): 20-23. Key Laboratory of Aquatic Genetic Resources and Aquacultural Ecosystem, Shanghai Fisheries University, 334 Jun Gong Road, Shanghai, 20090 China.
- 19685 - Nutritive value of palm kernel meal pretreated with enzyme or fermented with *Trichoderma koningii* (Oudemans) as a dietary ingredient for red hybrid tilapia (*Oreochromis* sp.).** Ng, W.K.; Lim, H.A.; Lim, S.L.; Ibrahim, C.O. 2002. Aquacult. Res. 33(15): 1199-1207. Fish Nutrition Laboratory, School of Biological Sciences, Universiti Sains Malaysia, Penang 11800, Malaysia (E-mail: wkng@usm.my)
- 19686 - The effects of shading on phytoplankton photosynthesis in rice-fish fields in Bangladesh.** Mustow, S.E. 2002. Agric. Ecosys. Environ. 90: 89-96. White Young Green Environmental Ltd., Arndale Court, Headingley, Leeds, LS6 2UJ, UK (E-mail: stephen.mustow@wyg.com) R 2003-31.
- 19687 - Capture and culture of presettlement coral reef fishes in Solomon Islands.** Hair, C.A.; Doherty, P.J.; Bell, J.D.; Lam, M. Proceedings 9th International Coral Reef Symposium, Bali, Indonesia 23-27 October 2000. Vol. 2. p. 819-827. Write to: WorldFish Center, P.O. Box 500, GPO, 10670 Penang, Malaysia (E-mail: worldfishcenter@cgiar.org) R 2003-33.
- 19688 - Management strategies associating batch-graded and size-graded postlarvae can reduce heterogeneous individual growth in *Macrobrachium rosenbergii* (de Man)** Ranjeet, K.; Kurup, B.M. 2002. Aquacult. Res. 33(15): 1221-1231. Write to: B. M. Kurup, School of Industrial Fisheries, Cochin University of Science and Technology, Fine Arts Avenue, Kochi-682 016, India (E-mail: madhukurup@hotmail.com)
- 19689 - Economic analysis of a pilot commercial production for spotted babylon, *Babylonia areolata* (Link 1807), of marketable sizes using a flow-through culture system in Thailand.** Chaitanawisuti, N.; Kritsanapuntu, S.; Natsukari, Y. 2002. Aquacult. Res. 33(15): 1265-1272. Aquatic Resources Research Institute, Chulalongkorn University, Bangkok, Thailand 10330 (E-mail: cnlajn@chula.ac.th)
- 19690 - Some aspects of fisheries of the Sylhet basin, north-east Bangladesh.** Alam, M.; Yousof Haroon, A.K.; Haldar, G.C.; Mazid, M.A. 2001. Bangladesh J. Fish. Res. 5(1): 1-12. Write to: M.A. Mazid, Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh.
- 19691 - Optimisation of stocking density of Thai silver barb (*Barbodes gonionotus***

- Bleeker) in the duckweed-fed four species polyculture system. Wahab, M.A.; Azim, M.E.; Mahmud, A.A.; Kohinoor, A.H.M.; Haque, M.M. 2001. Bangladesh J. Fish. Res. 5(1): 13-21. Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
- 19692 - Effects of organic manuring (chicken droppings) on growth of *Labeo rohita* Ham. spawn.** Khan, S.A.; Ahmed, G.U.; Ahmed, S.U. 2001. Bangladesh J. Fish. Res. 5(1): 29-35. Department of Fisheries Fisheries Research Institute, Mymensingh 2201, Bangladesh.
- 19693 - Growth and yield of GIFT (*Oreochromis niloticus*) and Thai silver barb (*Barbodes gonionotus* Bleeker) in rice fields and their effects on the yield of rice.** Uddin, M.J.; Dewan, S.; Ashrafuzzaman, M.; Haque, M.M. 2001. Bangladesh J. Fish. Res. 5(1): 29-35. Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
- 19694 - Toxic effects of dimecron to *Labeo rohita* Ham. fingerlings during acute and chronic exposures: histopathological changes.** Akhter, M.; Mollah, A.R.; Kadir, M.M.; Khaleque, M.A. 2001. Bangladesh J. Fish. Res. 5(1): 37-44. Write to: A. R. Mollah, Department of Fisheries, Dhaka, Bangladesh.
- 19695 - Proceedings of the Second National Workshop of Marine Molluscs.** 2003. Nha Trang, Vietnam: Research Institute for Aquaculture No. 3. 238 p. SH367 V5M37 2001.
- 19696 - Where there is water, there is fish.** 2003. Phnom Penh, Cambodia: MRC. 1 CD-ROM. Duration: 26 minutes. SH307 M42M44.
- 19697 - Sri Lanka freshwater fauna and fisheries: a guide to the freshwater fauna and the genesis of inland fisheries.** Fernando, C.H.; Weerewardhena, S.R. 2002. Ontario, Canada: Volumes Publishing. *A collection of scientific papers published by C.H. Fernando and collaborators from 1956-2002*-T.p. 955-97697-0-7. QL634 S75F47.
- 19698 - Incidence of epizootic ulcerative syndrome (EUS) in freshwater fishes in the endemic area of Punjab, Pakistan.** Abdul Rab, Afzal, M.; Akhtar, N.; Barlas, A.; Qayyum, M. 2001. Bangladesh J. Fish. Res. 5(1): 45-52. National Agricultural Research Center, Park Road, P.O. NIH Islamabad 45500, Pakistan.
- 19699 - Bacterial load in pond water and different organs of an Indian major carp *Cirrhinus mrigala* Ham.** Banu, A.N.H.; Islam, M.A.; Chowdhury, M.B.R. 2001. Bangladesh J. Fish. Res. 5(1): 53-58. Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh.
- 19700 - The potential of mixed culture of freshwater giant prawn *Macrobrachium rosenbergii* de Man and tiger shrimp *Penaeus monodon* Fab. at Khulna region, Bangladesh.** Azim, M.E.; Mazid, M.A.; Alam, M.J.; Nurullah, M. 2001. Bangladesh J. Fish. Res. 5(1): 67-74. Write to: M. J. Alam, Bangladesh Fisheries Research Institute, Mymensingh 2201, Bangladesh.
- 19701 - Resource productivity and economic performance of producing fish seeds in government and private farms in Bangladesh.** Kabir, M.H.; Malek, M.A.; Islam, M.S. 2001. Bangladesh J. Fish. Res. 5(1): 85-94. Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
- 19702 - Observation on some of the environmental parameters of selected shrimp farms in Khulna, Bangladesh.** Wahab, M.A.; Bergheim, A.; Braaten, B.; Islam, M.S.; Rahman, M.M. 2001. Bangladesh J. Fish. Res. 5(1): 75-84. Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh.
- 19703 - Economics of pond fish culture in some selected areas of Bangladesh.** Rahman, M.H.; Miah, T.H. 2001. Bangladesh J. Fish. Res. 5(1): 95-100. Bangladesh Institute of Nuclear Agriculture, P.O. Box 4, Mymensingh 2200, Bangladesh.
- 19704 - Cryopreservation in aquatic species.** Tiersch, T.R.; Mazik, P.M. (eds.) 2000. Baton Rouge, Louisiana, USA: World Aquaculture Society. xxviii, 439 p. 1-888807-02-4. QR69 C79T53.
- 19705 - Giant clams and seagrasses.** Anon. 2001. SEAFDEC Asian Aquacult. 23(5-6): 30-33, 40.
- 19706 - Co-management and marine reserves.** Anon. 2001. SEAFDEC Asian Aquacult. 23(5-6): 35-40.
- 19707 - International trade in aquaculture products - China.** Chen, S. 2002. INFOFISH Int. (1): 20-24. INFOYU, Room 203, Building 18, Maizidian Street, Chaoyang District, Beijing 100026, P.R. China (E-mail: infoyu@agri.gov.cn)
- 19708 - Tips for sustaining shrimp culture.** Srinivas, R. 2002. INFOFISH Int. (1): 28-32.
- 19709 - Mariculture in China.** Liu, S.; Hao, L. 2002. INFOFISH Int. (1): 33-38. Yellow Sea Fisheries Research Institute, Qingdao, P.R. China.
- 19710 - Live fish handling and marketing.** Singh, T. 2002. INFOFISH Int. (1): 49-52. INFOFISH, PO Box 10899, 50728 Kuala Lumpur, Malaysia (E-mail: infish@po.jaring.my)
- 19711 - Chloramphenicol in shrimp: legal aspects in the EU.** Hottlet, O. 2002. INFOFISH Int. (1): 53-56. NV Hottlet Frozen Foods, Belgium.
- 19712 - Discolouration of coastal waters and its significance in fisheries.** Rajesh, K.M.; Mendon, M.R.; Gupta, T.R.C.; Padiyar, A.; Chandramohan, K. 2002. INFOFISH Int. (1): 60-64. Department of Aquaculture, College of Fisheries, Mangalore, Karnataka, India.
- 19713 - FAO aquaculture activities: an example from Viet Nam.** van Anrooy, R.; Evans, B. 2001. FAO Aquacult. Newsl. (27): 4-7. FAO representation, Hanoi, Viet Nam (E-mail: FAO-VNM@fao.org)
- 19714 - Poverty alleviation through fish culture: homestead catfish culture in Bangladesh.** Marttin, F. de Graaf, G. 2001. FAO Aquacult. Newsl. (27): 8-11. Inland Water Resources and Aquaculture Services (FIRI), Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, Rome, Italy (E-mail: Felix.Marttin@fao.org)
- 19715 - Sustainable aquaculture for poverty alleviation (SAPA): a new rural development strategy for Viet Nam - Part 1.** Luu, L.T. 2001. FAO Aquacult. Newsl. (27): 12-17. Research Institute for Aquaculture (RIA1), Hanoi, Viet Nam.
- 19716 - Aquaculture and inland fisheries: fact sheet.** 2001. FAO Aquacult. Newsl. (27): 18-24.
- 19717 - Serum and tissue thiocyanate concentration in tilapia (*Oreochromis niloticus*), fed with cassava peel based diets supplemented with DL-methionine.** Oressegun, A.; Alegbeleye, W.O. 2002. J. Aqua. Trop. 17(2): 93-100.
- 19718 - Blood gasometric trends in hybrid-red tilapia *Oreochromis niloticus* (Linnaeus) X *O. mossambicus* (Peters) while adapting to increasing salinity.** Mena-Herrera, A.; Sumano-Lopez, H. 2002. J. Aqua. Trop. 17(2): 101-112. University of Colima, School of Marine Sciences, Manzanillo-Barra de Navidad, Km 20, Manzanillo, Colima, 28260, Mexico.
- 19719 - Utilization of enriched soybean flour by *Oreochromis niloticus*.** Sadiku, S.O.E.; Jauncey, K. 2002. J. Aqua. Trop. 17(2): 67-79. Department of Fisheries, Federal University of Technology, P.M.B. 65, Minna-Nigeria.
- 19720 - Substrate utilization in *Cirrhinus mrigala* under hypoxia and recovery conditions.** Padmavathy, P.; Ramanathan, N.; Francis, T. 2002. J. Aqua. Trop. 17(2): 81-92. Department of Fish. Farm Management, Fisheries College and Research Institute, Tamil Nadu Veterinary & Animal Sciences University, Thoothukkudi 628 008, India.
- 19721 - Status of research in hybridization and artificial insemination of decapod crustaceans in India.** Soundarapandian, P.; Shanmugam, A.; Kannupandi, T. 2002. J. Aqua. Trop. 17(2): 113-117. Centre of Advanced Study in Marine Biology, Annamalai University, Parangipettai 608 502, India.
- 19722 - Effect of dietary phosphorus on growth and phosphorus excretion in Indian white shrimp.** Ambasanar, K.; Ahamad Ali, S. 2002. J. Aqua. Trop. 17(2): 119-126. Central Institute of Brackishwater Aquaculture, 75, Santhome High Road, Chennai 600 028, India.
- 19723 - Growth and production of the balsam catfish, *Ictalurus balsanus* Jordan & Snyder, 1899, (Pisces: Ictaluridae), in earthen ponds.** Granados-Ramirez, J.G.; Arredondo-Figueroa, J.L.; Ponce-Palafox, J.T. 2002. J. Aqua. Trop. 17(2): 127-134. Facultad de Ciencias Biologicas, Universidad Autonoma del Estado de Morelos, Mexico.
- 19724 - Genetic structure of round scad mackerel *Decapterus macrosoma* (Carangidae) in the Indo Malay archipelago.** Borsa, P. 2003. Mar. Biol. 142(3): 575-581. Institut de Recherche pour le Developpement, UR 081 Genome Populations Environnement, BP A5, 98848 Noumea Cedex, New Caledonia (E-Mail: Philippe.Borsa@noumea.ird.nc)
- 19725 - Regional guidelines for responsible fisheries in Southeast Asia: responsible fishing operations.** 2003. [Kuala Terengganu, Malaysia]: [Marine Fisheries Resources Development and Management Department] v. 69 p. 974-537-297-8. SH295 S673.
- 19726 - Utilization of torula yeast (*Candida utilis*) as a protein source in diets for tilapia (*Oreochromis mossambicus* Peters) fry.** Olvera-Novoa, M.A.; Martinez-Palacios, C.A.; Olvera-Castillo, L. 2002. Aquacult. Nutr. 8(4): 257-264.
- 19727 - SEAFDEC/AQD's Dumangas Brackishwater Station takes centerstage in reviving the shrimp industry.** Aldon, E.T. 2000. SEAFDEC Asian Aquacult. 22(6): 10-12.
- 19728 - We are developing a simplified, farmer-oriented selection procedure for tilapia broodstock.** Frio, A.S. 2000. SEAFDEC Asian Aquacult. 22(6): 13-14.
- 19729 - The fishery resources of Indonesia.** Gasataya, E. 2000. SEAFDEC Asian Aquacult. 22(6): 17-18.
- 19730 - Silvofisheries in Indonesia.** Surtida, M.B. 2000. SEAFDEC Asian Aquacult. 22(6): 20-21, 28.
- 19731 - Rice-fish culture systems.** Surtida, A.P. 2000. SEAFDEC Asian Aquacult. 22(6): 22-23.
- 19732 - A glimpse at shrimp culture in Indonesia.** Surtida, A.P. 2000. SEAFDEC Asian Aquacult. 22(6): 24-25.

- 19733 - Technical efficiency of the driftnet and Payang seine (lampara)** Zen, L.W.; Abdullah, N.M.R.; Yew, T.S. 2002. *Asian Fish. Sci.* 15(2): 97-106. Fakultas Perikanan, Universitas Bung Hatta, Padang, Sumatra, Indonesia.
- 19734 - Development of hatchery techniques for the siver pomfret *Pampus argenteus* (Euphrasen)** Al-Abdul-Elah, K.M.; Almatar, S.; Abu-Rezq, T.; James, C.M.; El-Dakour, S. 2002. *Asian Fish. Sci.* 15(2): 107-121. Mariculture and Fisheries Department, Kuwait Institute for Scientific Research, P.O. Box 1638, Salmiya, Kuwait.
- 19735 - Joint mangrove management in Tamil Nadu: process, experiences and prospects: part 1: situation analysis: Pichavaram and Muthupet mangrove wetlands.** Selvam, V.; Ravichandran, K.K.; Karunakaran, V.M.; Mani, K.G.; Beula, G.E.J. 2003. Chennai, India: M. S. Swaminathan Research Foundation. 71 p. QH541.5 M27S44.
- 19736 - Farm size and aquaculture productivity relationship.** Roy, A.K.; Sahoo, K.N.; Saradhi, K.P.; Saha, G.S. 2002. *Asian Fish. Sci.* 15(2): 129-134. Technology Evaluation and Transfer Division, Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar - 751002, India.
- 19737 - Water quality and planktological approach to monitor eutrophication by cage-culture of red tilapia (*Oreochromis* sp.) at the Sermo Reservoir, Yogyakarta, Indonesia.** Rustadi; Kuwabara, R.; Kamiso, H.N. 2002. *Asian Fish. Sci.* 15(2): 135-144. Department of Fisheries, Faculty of Agriculture, Gadjah Mada University, Indonesia.
- 19738 - Vitamin C (ascorbyl 2 polyphosphate) requirement of freshwater prawn *Macrobrachium rosenbergii* (de Man)** Hari, B.; Kurup, B.M. 2002. *Asian Fish. Sci.* 15(2): 145-154. School of Industrial Fisheries, Cochin University of Science and Technology, Fine Arts Avenue, PB. No. 1791, Cochin Pin. 682 016, India.
- 19739 - Estimation of population parameters and stock assessment of *Penaeus indicus* (H. Milne Edwards) in the western coastal waters of Sri Lanka.** Jayawardane, P.A.A.T.; McLusky, D.S.; Tytler, P. 2002. *Asian Fish. Sci.* 15(2): 155-166. Marine Biological Resources Division, National Aquatic Resources Research and Development Agency, Crow Island, Mattakkuliya, Colombo 15, Sri Lanka.
- 19740 - Potential of feed pea (*Pisum sativum*) meal as a protein source in practical diets for milkfish (*Chanos chanos* Forsskal)** Borlongan, I.G.; Eusebio, P.S.; Welsh, T. 2003. *Aquaculture* 225 (1-4): 89-98. Aquaculture Department, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo 5021, Philippines.
- 19741 - Development of microsatellite markers in black tiger shrimp (*Penaeus monodon* Fabricius)** Wuthisuthimethavee, S.; Lumubol, P.; Vanavichit, A.; Tragoonrun, S. 2003. *Aquaculture* 224(1-4): 39-50. DNA Technology Laboratory, National Center for Genetic Engineering and Biotechnology, Kasetsart University, Kamphaengsaen Campus, Nakorn Pathom 73140, Thailand.
- 19742 - Influence of salinity on the developmental stages of African catfish *Heterobranchus longifilis* (Valenciennes, 1840)** Fashina-Bombata, H.A.; Busari, A.N. 2003. *Aquaculture* 224(1-4): 213-222. Department of Fisheries, Lagos State University, P.O. Box 96, Badagry, Lagos, Nigeria.
- 19743 - Detection of a chromosomal region with two quantitative trait loci, affecting cold tolerance and fish size, in an F2 tilapia hybrid.** Cnaani, A.; Hallerman, E.M.; Ron, M.; Weller, J.I.; Indelman, M.; Kashi, Y.; Gall, G.A.E.; Hulata, G. 2003. *Aquaculture* 223(1-4): 117-128. Institute of Animal Science, Agricultural Research Organization, Bet Dagan, P.O. Box 6, 50250, Israel.
- 19744 - Biochemical, physiological and hematological changes in white spot syndrome virus-infected shrimp, *Penaeus indicus*.** Yoganandhan, K.; Thirupathi, S.; Sahul Hameed, A.S. 2003. *Aquaculture* 221(1-4): 1-11.
- 19745 - An investigation of sex determination in the Mozambique tilapia, *Oreochromis mossambicus*, using synaptonemal complex analysis, FISH, sex reversal and gynogenesis.** Campos-Ramos, R.; Harvey, S.C.; McAndrew, B.J.; Penman, D.J. 2003. *Aquaculture* 221(1-4): 125-140. Write to: D.J. Penman, Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, Scotland, UK.
- 19746 - Culture-based fisheries: an underutilised opportunity in aquaculture development.** De Silva, S.S. 2003. *Aquaculture* 221(1-4): 221-243. School of Ecology and Environment, Deakin University, PO Box 423, Warrnambool, Victoria 3280, Australia.
- 19747 - Advanced nursing of mixed-sex and mono-sex tilapia (*Oreochromis niloticus*) fry, and its impact on subsequent growth in fertilized ponds.** Little, D.C.; Bhujel, R.C.; Pham, T.A. 2003. *Aquaculture* 221(1-4): 265-276.
- 19748 - Hematological and biochemical parameters in common carp, *Cyprinus carpio*, following herbal treatment for *Aeromonas hydrophila* infection.** Harikrishnan, R.; Nisha Rani, M.; Balasundaram, C. 2003. *Aquaculture* 221(1-4): 41-50. Department of Animal Science, Bharathidasan University, Tiruchirappalli 620 024, Tamil Nadu, India.
- 19749 - Antimicrobial resistance of intestinal *Aeromonas* spp. and *Enterococcus* spp. in fish cultured in integrated broiler-fish farms in Thailand.** Petersen, A.; Dalsgaard, A. 2003. *Aquaculture* 219(1-4): 71-82. Department of Veterinary Microbiology, The Royal Veterinary and Agricultural University, Stigbøjlen 4, 1870, Frederiksberg C, Denmark.
- 19750 - Spat collection of the pearl oyster (*Pinctada margaritifera cumingii*) in French Polynesia: an evaluation of the potential impact on genetic variability of wild and farmed populations after 20 years of commercial exploitation.** Arnaud-Haond, S.; Vonau, V.; Bonhomme, F.; Boudry, P.; Prou, J.; Seaman, T.; Veyret, M.; Goyard, E. *Aquaculture* 219(1-4): 181-192. Laboratoire d'Aquaculture tropicale, IFREMER/COP, BP 7004, 98719 Taravao, Tahiti, French Polynesia.
- 19751 - The acute toxicity of copper to blue tilapia in dilutions of settled pond water.** Straus, D.L. 2003. *Aquaculture* 219(1-4): 233-240. Agricultural Research Service, Harry K. Dupree—Stuttgart National Aquaculture Research Center, U.S. Department of Agriculture, P.O. Box 1050, Stuttgart, AR 72160, USA.
- 19752 - Collected papers on harmful algal blooms study in Bohai, Huanghai & east China Sea.** Zou, J.Z.; Zhou, M.J.; Yu, Z.M. (eds.) 2000. Qingdao, China: Department of Marine Environmental Science, Institute of Oceanology, Chinese Academy of Sciences. 765 p. in various pagings. Contains 124 articles in Chinese and English languages. SH177 R4Z68.
- 19753 - Use of coffee pulp as feed ingredient for tilapia culture.** Rojas, J.B.U. 2002. Wageningen, Netherlands: Wageningen Institute of Animal Sciences, Wageningen University. 133 p. Dissertation (Ph.D.)-Wageningen University. 90-5808-647-X. SH210 2002 R64.
- 19754 - Fish consumption and aquaculture in rural Bangladesh: nutritional contribution and production potential of culturing small indigenous fish species (SIS) in pond polyculture with commonly cultured carps.** Roos, N. 2001. Frederiksberg, Denmark: Research Department of Human Nutrition, The Royal Veterinary and Agricultural University. 177 p. in various pagings. Dissertation (Ph.D.)-The Royal Veterinary and Agricultural University, Denmark. 87-90505-08-5. SH210 2001 R66.

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 Malawi, Chilwa L. 19660
 Malaysia 19608, 19656, 19657, 19664, 19667
 Malaysia, Perak 19617, 19620
 Malaysia, Selangor 19595
 Maldive I. 19631
 Mali, Senegal basin 19632
 Mauritania 19561
 Mauritius 19623
 Mekong R. 19696
 Mexico, Alacran Reef 19682
 Morocco 19561
 Mozambique 19623, 19624, 19638
 Myanmar 19656, 19657
 New Caledonia 19583
 Pacific I. 19671
 Pacific Ocean 19653

Pakistan 19698
 Panama 19672
 Philippines 19567, 19656, 19705, 19727, 19728
 Reunion Island 19718
 Saudi Arabia, Farasan I. 19598
 Senegal 19561
 Seychelles 19623
 Solomon I. 19588, 19576, 19619, 19668, 19673, 19675, 19687
 South China Sea 19592, 19557, 19579, 19651, 19652, 19654, 19655
 Southeast Asia 19679, 19725
 Sri Lanka 19605, 19697, 19739
 Sulawesi Sea 19568
 Sulu Sea 19568
 Tanzania 19623, 19625, 19626, 19630, 19640
 Tanzania, Zanzibar I. 19639
 Thailand 19650, 19656, 19689, 19749
 Thailand, Gulf of 19557
 Victoria L. 19606
 Vietnam 19656, 19657, 19659, 19695, 19713, 19715

Selected Websites

Access

<http://www.wsp.org/english/access/intro.html>
 An e-newsletter for the Water and Sanitation Program (WSP) community. The WSP is an international partnership of the world's leading development agencies concerned with water and sanitation services for the poor.

ASEAN Review of Biodiversity and Environmental Conservation

<http://www.arbec.com.my/>
 A web-journal, dedicated to the study of Southeast Asian biodiversity.

Aquaculture Health Page

<http://www.geocities.com/CapeCanaveral/Lab/7490/index.html#home>
 The site contains useful information on fish diseases, drugs in aquaculture, water quality, molluscan diseases, aquaculture nutrition, crustacean diseases, diagnostic services, aquaculture organizations and relevant Internet resources.

The Center for Fisheries Enhancement

<http://www.mote.org/~kleber/>
 The objective of the Center for Fisheries Enhancement at Mote Marine Laboratory, Florida is to increase knowledge on how to preserve and responsibly enhance marine and estuarine fish populations, and to advance marine aquaculture in an environmentally sustainable manner. Three main areas of concern are: hatchery releases, habitat protection and fishing regulation.

The Commonwealth of Learning (COL)

<http://www.col.org/>
 COL is an intergovernmental organization created by Commonwealth Heads of Government to encourage the development and sharing of open learning/distance education knowledge, resources and technologies. COL aims to help developing nations improve access to quality education and training.

Convention on Biological Diversity

<http://www.biodiv.org/default.aspx>
 This booklet looks at the importance of biological diversity for the health of people and the planet. It explains the role of the Convention in protecting this biodiversity and ensuring that it is used for the benefit of all.

Danish Institute for Fisheries Research (DIFRES)

http://www.dfu.min.dk/uk/difres_fr.htm
 DIFRES carries out research, investigations and provides advice concerning sustainable exploitation of live marine and fresh water resources. It deals with chain considerations

from water to table. This includes interaction between the water environment and productivity and variation of the fish stocks, methods for assessment of the sizes of fish stocks, development of methods for sustainable fisheries management, and stock enhancement.

Danish Network for Fisheries and Aquaculture Research

<http://www.fishnet.dk/home/index.html>
A network of Danish fisheries and aquaculture scientists. It coordinates the activities within five research networks: Fisheries and Aquaculture Management and Economics FAME, Fish Physiology, Biochemistry and Food (FIBP), Maritime History and Marine Environmental Research School (MARINERS), Sustainable Control of Fish Diseases in Aquaculture (SCOFDA), Fisheries biology and modelling, and Scaling from Individual to Population (SLIP). These networks contain a number of research projects and each network has an associated research school.

The eSeFDee Marine Sciences Portal

<http://www.dvz.be/Portal/>
The eSeFDee Marine Sciences Portal for the North Atlantic and the Mediterranean is the continuation of the former links pages of the Sea Fisheries Department (CLO-SFD, Oostende, Belgium). The portal site is offered as a free service to the marine scientific community, to managers and decision makers, and in general, to anyone interested in the North Atlantic and the Mediterranean

The Fish Nutrition Research Lab

<http://www.uoguelph.ca/fishnutrition/index.html>
The Fish Nutrition Research Lab of the University of Guelph conducts basic and applied research in the field of fish nutrition and feeding with particular emphasis on bioenergetics, digestibility, nutrient requirements, feed formulation/evaluation, feeding systems and waste management.

Fishdisease.net

<http://www.fishdisease.net/>
A web community for aquatic animal health professionals. It provides links to user directory, upcoming conferences, aquatic disease related professional societies, journals or other publications, university or similar courses, and jobs.

Improved Assessments and Management of Shrimp Stocks Could Benefit Sea Turtle Populations, Shrimp Stocks and Shrimp Fisheries

<http://www.seaturtle.org/mtn/archives/mtn100/mtn100p22.shtml>
An article by C. W. Caillouet, Jr., extracted from Marine Turtle Newsletter, 100: 22-27, 2003. The focus of this paper is on over-fishing and the apparent flaws in shrimp stock assessments that have contributed to it.

The Institute of Aquaculture

<http://www.aqua.stir.ac.uk/index.htm>
An international research and post-graduate training centre, core-funded by the University of Stirling. It also receives research and project funding from the Department for International Development, the European Commission and from a wide variety of national and international research organizations, foundations and trusts and industry. The Institute has links with many other academic institutions, not only in Europe, but also with the Asian Institute of Technology and the Aquatic Animal Health Research Institute, Bangkok, Thailand, the Bangladesh Agricultural University, Mymensingh, the College of Fisheries,

Mangalore, India, the Centre for Aquaculture and Environmental Management in Mexico and Myazaki University, Japan.

Integrated Water-Resources Management in a River-Basin Context

<http://www.iwmi.cgiar.org/pubs/Proceedings/Malang/index.htm>
Proceedings of the regional workshop held in Malang, Indonesia, 15-19 January, 2001. It consists of the following: - Introduction
Part 1: Five-Country Regional Study-Framework and Comparative Analysis
Part 2: Five-Country Regional Study-Country Cases
Part 3: Study of Irrigation Investment, Fiscal Policy and Water-Resource Allocation in Indonesia and Vietnam
Part 4: Lessons from Some Best Practices in River-Basin Management
Part 5: Summary

The Japan Sea-Farming Association

http://www.jasfa.or.jp/english/en_index.html
The association is an alliance of the country's 39 prefectures having seacoast areas within their borders and their respective fishery cooperative associations. It is a national-level organization for sea farming.

Journal of Health and Population in Developing Countries

<http://www.jhpd.unc.edu/>
A semi-annual publication of the School of Public Health, Department of Health Policy and Administration, University of North Carolina. It is an interdisciplinary journal devoted to policy and management issues in health and population fields in developing countries.

Malaysia Nature Society (MNS)

<http://www.mns.org.my/>
Established in 1940, the MNS is the oldest scientific and non-government organization in Malaysia dedicated to nature conservation. It aims to promote the study, appreciation, conservation and protection of Malaysia's Natural Heritage, focusing on biological diversity and sustainable development.

Marine Parasitic Crustacea CD-ROM

<http://www.mala.bc.ca/parasite/>
This CD-ROM utilizes the latest in multimedia technology. The focus is on the biology of representative parasitic crustaceans of invertebrates and fish of coastal marine waters of British Columbia, Canada, including the parasitic Copepoda, Cirripedia, Isopoda and Amphipoda.

PovertyNet Newsletter

<http://www.worldbank.org/poverty/news/>
A monthly newsletter that contains updates on new information and resources available on the PovertyNet web site, covering: poverty reduction strategies, the World Bank's World Development Report (WDR) on poverty and development, poverty monitoring and evaluation, the impact of growth and inequality on poverty, the role of human capital development in the fight against poverty, safety nets and social capital.

Resource Utilization

<http://www.earthisland.org/map/lftrn.htm>
The website of the Mangrove Action Project (MAP). It contains articles on earth resources, resource management, and other news updates.

The Sea Fish Industry Authority (Seafish)

<http://www.seafish.org/index.asp>
Seafish works across all sectors of the UK seafood industry to promote good quality, sustainable seafood. Their research and projects are aimed at raising standards, improving efficiency and ensuring that the

industry develops in a viable way.

Seaweed Site

<http://seaweed.ucg.ie/defaultmonday.html>
This website has a lot of information on all aspects of seaweeds and marine algal biology.

Smithsonian Institution Marine Science

<http://www.si.edu/marinescience/>
Marine Science at the Smithsonian Institution is uniquely positioned to study the patterns and mechanisms of change in ocean environments and is a major force in the effort to conserve key coastal resources. It operates a unique network of coastal laboratories and long-term marine research sites in the western Atlantic Ocean that extends along the east coast of North and Central America, bridging the Panamanian isthmus from the Caribbean Sea to the Pacific Ocean.

The Stock Enhancement and Sea Ranching Homepage

<http://www.efan.no/was/>
The website aims to increase awareness about stock enhancement and sea ranching by highlighting programs and groups that are working in this field, focusing on various successes around the world, pointing to networks of researchers and focus groups, informing about symposia, meetings, and publications in the field, and providing a discussion forum on all aspects of hatchery releases into aquatic environments.

Voices of the Poor Reports

<http://www.worldbank.org/poverty/voices/reports.htm>
Voices of the Poor consist of three books, which bring together the experiences of over 60,000 poor women and men. The first book, *Can Anyone Hear Us?*, gathers the voices of over 40,000 poor women and men in 50 countries from the World Bank's participatory poverty assessments; the second book, *Crying Out for Change*, draws material from a new 23 country comparative study. The final book, *From Many Lands*, offers regional patterns and country case studies.

Guidelines for Authors

The purpose of these guidelines is to assist NAGA contributors in the preparation of articles for submission to *NAGA, WorldFish Center Quarterly*. The presentation of your manuscript is the critical first stage in the successful publication of your article and the instructions below will assist you in ensuring that your article is reviewed and published as efficiently as possible.

If you can prepare your article on a computer it will enable us to work more quickly and easily. However, if you do not have access to a computer, hard copies of your manuscript should be submitted to: The Editor, NAGA, Communications Unit, WorldFish Center, PO Box 500 GPO, 10670 Penang, Malaysia.
E-mail: naga@cgjar.org

Manuscript

Please ensure that the manuscript is clear enough to work on, and adheres to the following:

- Paper size: A4
- Font size: 12 points
- Your text should be double-spaced with a 2.5 cm margin all around.
- Your manuscript must be paginated.
- Articles submitted should be between 1 500-2 000 words.
- Include an abstract in approximately 50 words, stating what was done, found and concluded.
- Submit one hard copy; and one soft copy and keep one copy for reference
- The **electronic/soft copy** should be in Microsoft Word for Windows. The soft copy must be an exact printout of the hard copy. The soft copy should be sent by e-mail to: naga@cgjar.org. If you do not have access to e-mail, send the soft copy in a 3 ½ inch disk to the WorldFish Center.
- The **hard copy** should only be printed on one side and sent to WorldFish.

House style

- **Spelling** should conform to the new edition of the Concise Oxford English Dictionary. Alternatives will be accepted provided they are consistent.
- Use **italics** for scientific names, and words/phrases in foreign languages.
- To check all **fish species names**, refer to FishBase at www.fishbase.org.
- **Justification** of text – the text

should be left justified. Do not use hyphenation except for hyphenated words.

- **Headings** – where there are several levels of heading, each one should be differentiated from the other as below:
Title of article – (Upper and Lower Case, Bold, 14 pts, Centered)

Heading – Level One (Upper and Lower Case, Bold, 12 pts, Centered)

Heading – Level Two (Upper and Lower Case, Bold, 11 pts, Flush Left)

Heading – Level Three (Upper and Lower Case, Bold, 10 pts, Flush Left)

Heading – Level Four (Upper and Lower Case, Italics, 10 pts, Flush Left)

- **Space after punctuation marks** – use single (and not double) space after full stops, commas, colons, semicolons, etc.
- **Quotation marks** – use double quotation marks for dialogue and quoted material. Single quotation marks are used only for quote within quotes.
- **Units of measure** – The International System of Units (SI) for measurements and weights is recommended.
- **Numerals** – spell out numerals smaller than 10, e.g. eight fish. However numerals smaller than 10 should not be spelled out when accompanied by a standard unit of measure, e.g. 3 kg.
- **Dates** – should be written as 'day month year', e.g. 8 May 2001.
- **Abbreviations** – Any word or words to be abbreviated should be written in full when first mentioned followed by the abbreviation in parenthesis.

Illustrations

- Illustrations can be photographs, line drawing, maps or graphs. Bear in mind that the quality of printed illustrations is dictated by the quality of the originals you supply;
- Line drawings submitted should be originals, drawn in black ink on white paper. These should be mailed to the WorldFish Center flat or rolled, never folded;
- If drawings are digitally produced, they

must be of high quality;

- One color (black) line drawing should be produced at 500-800 dpi and saved as a bitmap tiff file;
- Tone illustrations or illustrations in color should be produced at 250-300 dpi and saved in grayscale as tiff files.
- Maps should include indicators of latitude and longitude.
- Check to ensure that figures are numbered correctly as they are cited in the text. Position figure numbers and headings at the bottom of the illustration.

Tables

- Key in your tables using the Table Menu in Word.
- Ensure that your tables are numbered correctly and that they tally with the numbering cited in your text.
- Position table numbers and headings above the table. The headings should be clear, complete and informative.
- Place sources and notes immediately below the table.

References (examples)

Book:

- Gupta, M.V. and B.O. Acosta (eds.). 2001. Fish genetics research in member countries and institutions of the International Network on Genetics in Aquaculture. ICLARM Conf. Proc. 64, 170 p.
- Longhurst, A. and D. Pauly. 1987. Ecology of tropical oceans. Academic Press, San Diego.

Chapter or part of a book or published conference proceedings:

- Christensen, V. and D. Pauly. 1993. On steady-state modeling of ecosystems, p. 14-19. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

Journal article:

- Hillman, S. 1994. Environment on trial. *NAGA, ICLARM Q.* 17 (1): 8-10.

- **Notes on authors** should be included at the end of the article:
A. Shaleesha and V.A. Stanley are scientists at the J.R.D. Tata Ecotechnology Center, M.S. Swaminathan Research Foundation, Chennai – 600 113, India.