editorial

This issue of *NAGA*, Vol. 27, Nos. 1 and 2, is a special volume focused on coral reefs. We picked the coral reef focus for a bumper issue to coincide with the 10th International Coral Reefs Symposium (ICRS) held this July in Okinawa, Japan. Some 1 450 participants attended the symposium including several WorldFish Center scientists and partners whose latest research is also summarized in this volume of *NAGA*.

In this issue, we would also like to announce some important changes at WorldFish Center. In March, our new Director General, Dr Stephen Hall, assumed his position, succeeding Dr Meryl Williams. WorldFish is poised on the crest of a new wave of change as we review our mission, vision and strategy in seeking to deliver the best of aquatic and fisheries science with our partners to reduce poverty and alleviate hunger. As part of this overall review, *NAGA* is also undergoing a revamp as we strive to cater to the interests of our readers and renew the mission of WorldFish. Over the years, *NAGA*'s readership has expanded to nearly 5 000, the number of articles submitted have grown beyond our capacity to publish them all despite increasing the number of pages. All this success of course comes at a price - in terms of printing and mailing as well as the time taken for scientific review and approval by our technical editors.

The time has come then for a serious re-look at the purpose of *NAGA* within a changing research and publishing climate. Starting in 2005, we will commission articles for each issue of *NAGA* and will no longer be able to accept unsolicited papers. We are also exploring the possibility of transforming *NAGA* into an e-journal that could be circulated in a variety of formats, including email. The print journal will be circulated to institute and university libraries while individual subscribers will be encouraged to receive free e-copies.

As we move in this direction, we encourage our readers to write to us with their views on what you think *NAGA*'s future direction should be. Please send us your comments c/o The Communication Unit, P.O. Box 500, GPO, 10670 Penang, Malaysia or email to worldfish-naga@cgiar.org

The *NAGA* Editorial Team

contents

articles

news

NAGA
WorldFish Center Quarterly
Volume 27, No. 1 & 2 JANUARY - JUNE 2004

Cover photo by J. Oliver:
Gorgonians on reef slope.

Editors
Modadugu V. Gupta, Ilona C. Stobutzki, Kuperan K. Viswanathan
Assistant Editors
Belen Acosta, Len Garces

Copy Editor
Rita Kapadia
Coordinator
Catherine Tan, Salina Mustaffa

Cover Designer and Layout Artist
Garrick Tan
Printed by
INTACT Communications

Note of apology from the *NAGA* editorial team:
The photo of *Macrobrachium rosenbergii* used in the article "Genetic diversity in wild stocks of the giant freshwater prawn (*Macrobrachium rosenbergii*): Implications for aquaculture and conservation" by P.B. Mather and M. de Bruyn on page 4 in *NAGA*, Vol. 26, No. 4, was courtesy of F. Herman/Ocean-SA of OCEAN-SA, Les plaines, 97116 Guadeloupe F.W.I. (ocean@outremer.com). The *NAGA* editorial team would like to extend their apology to the contributor for not including the credits in the issue itself.

Community-based marine protected areas in the Bohol (Mindanao) Sea, Philippines

J.D. Indab and P.B. Suarez-Aspilla

Abstract

This paper discusses the status, direction and management issues in the marine protected areas (MPAs) of the Bohol (Mindanao) Sea, Philippines. The MPAs in the study area have increased through the years. Many of them were established and managed by the local government units (LGUs) in collaboration with national government agencies (NGAs), academic institutions, people's and non-governmental organizations (NGOs). Several management issues and problems were cited by the MPA managers such as insufficient funds and facilities, lack of support from NGAs/NGOs and lack of education among the people. Nevertheless, lessons for sustainability can be learned from the experience of some well-managed MPAs in the Bohol Sea. These include strong support from the political leadership, community participation and networking among the concerned sectors. Although the best practices are being followed in a number of MPAs in the Bohol Sea, success is still fragmented. The MPAs are currently managed independently although there are ongoing initiatives to network their efforts. However, it can be observed that, as a management tool, MPAs are gaining popularity and support, not only among the fisherfolk but also among local communities and LGUs in the Bohol Sea area.

Introduction

The Philippines has more than two decades of experience with community-based coastal resources management initiatives in which marine sanctuaries have played an important role (Crawford et al. 2000). A number of projects have been undertaken by government agencies, academic institutions, and non-government organizations, with marine sanctuary as either the main development effort or as a component of larger coastal management programs. At the turn of the millennium, there are now many marine reserves located in the different coastal regions of the country (Crawford et al. 2000).

In spite of the increase in the number of marine sanctuaries, not much has been written about them, particularly on how they are established, managed and monitored, or the issues/problems experienced by the day-to-day managers. This paper discusses the status, direction, and management issues of the marine protected areas of the Bohol (Mindanao) Sea. It also presents some possible solutions to the issues from the perspective of the resource managers themselves.

Brief Background of Philippine Coastal Resources

The Philippines is one big coastal community of about 80 million people (NSO Quickstat 2003). The country's coastline stretches to more than 18 000 km and its coastal waters cover an area of 266 000 sq km. The coastline is one of the longest in the world and, in Asia, it is second only to that of Indonesia (Our Seas, Our Life 1998). Sixty per cent of the country's 78 provinces as well as the municipalities are situated in the coastal areas (La Viña 1999).

However, the current reality is a continued degradation of the coastal resources. It is estimated that in 1918 there were approximately 500 000 ha of mangroves in the Philippines. By the1990s, about 60 per cent of these had been lost (La Viña 1999). The Philippines has about 27 000 sq km of coral reefs, of which about 70 per cent were considered to be in poor or fair condition and only 5 per cent were in excellent condition by 1991 (Our Seas, Our Life 1998). According to the Food and Agriculture Organization (FAO), unless coastal resource management efforts are undertaken urgently, the country's fish supply will drop to 940 000 t from the present level of 1.95 million t, and the per capita annual consumption of fish will plunge to 10.45 kg by 2010 when the population is expected to reach 94 million (Ferrer et al. 1996). The deteriorating condition of the coastal resources can be attributed to a number of factors, such as over-fishing, use of destructive fishing methods, pollution, conflicting government policies and non-enforcement of laws. A major cause is the open access policy that leads to what Garrett Hardin described as "The Tragedy of the Commons" (Hardin 1968). This is aggravated by the country's resource management system, generally considered to be centralized, top down and non-participatory (Sajise 1995).

Community-Based Coastal Resource Management

With the continuing deterioration of the country's coastal resources, it has been realized that it is not possible to attain sustainable development under a centralized and non-participatory system. Consequently, there has been a shift to policies and strategies that advocate resource management and conservation through community-based initiatives. Community-based approaches have been used in the management of agricultural resources in many parts of the world, but these initiatives were not applied to marine and coastal ecosystems until much later (Pomeroy 1994). In the Philippines, community-based management of coastal resources (CBCRM) started in the early 1980s (Pomeroy et al. 1999). CBCRM as an effective approach for sustainable management of coastal resources has gained popularity in the last two decades, especially among local government units (LGUs), people's organizations (POs), academic units, and finally in the government sector. The superiority of this approach is indicated by the fact that most successful programs on coastal resource management are community-based. CBCRM provides the resource users with a sense of ownership through full participation, cooperation and empowerment of the stakeholders. This is conducive to the proper management of coastal resources by local communities (Alcala in Ferrer et al. 1996).

Marine Reserves as Management Tools

Marine reserves, or no-take marine areas, are areas of the marine environment protected from various forms of human or extractive exploitation, especially fishing (Alcala 2001a). In this context, the term is synonymous with marine protected areas, marine harvest refugia, and marine sanctuaries. The marine areas outside of reserves are referred to as non-reserves or fished areas, where fishers are allowed to fish using traditional, non-destructive fishing gear (Alcala 2001b). Marine protected areas as management tools are designed to help arrest the depletion of marine resources especially fish. They are established to protect fish and other marine organisms, increase fishery yields, allow build-up of fish biomass in the reserve, and reduce conflicts between groups of stakeholders in the fishery (Alcala 2001a).

According to some biologists, the idea of marine reserves can be traced back to the remote past (Alcala 2001a). Before the 1970s, marine parks were established for conservation purposes (Alcala 2001b). In 1987 there were only 19 parks and reserves in the Philippines, including the fish sanctuaries at Apo Island, Balicasag Island and Pamilacan Island, all in the central Philippines. In the late 1980s, fish sanctuaries were established in Luzon (San Salvador Island, Zambales) and in Misamis Occidental, northern Mindanao (Alcala 1988). During the 1990s, the number of marine reserves or marine protected areas increased, especially with the establishment of the Coastal Environment Program (CEP) of the DENR in 1993 (Alcala 2001b). In 2001, Alcala pointed out that based on a recent count, there are an estimated 500 marine reserves or marine protected areas in the Philippines. However, only about 10 per cent are properly managed and protected (Alcala 2001a). Although only a few of these reserves are truly effective, the concept is becoming popular, especially among local communities and many local government units, non-governmental organizations and academe.

Status of Marine Protected Areas in the Bohol Sea

The Bohol Sea covers 29 000 sq km, stretching from the Sulu Sea to the Pacific Ocean. It is surrounded by the islands of Mindanao (southeast), Negros, Bohol and Leyte (northwest). It was formerly called the Mindanao Sea (Fig. 1).

The total number of marine protected areas in the Bohol Sea is hard to determine due to lack of information and the difficulty in defining the exact attributes of these reserves (Alcala 2001a). The Silliman University Angelo King Center for Research and Environmental Management reported that there are more than 30 marine reserves in the Bohol Sea at present, seven of which have been studied and monitored by the office for some years, the oldest for 27 years (Fig. 1). A Workshop on the Role of Marine Protected Areas and Coral Reef Related Research and the Conservation of Fisheries and Marine Biodiversity in the Bohol (Mindanao) Sea was held from May 28 to 30, 2003. Thirty resource managers representing 26 MPAs attended and shared their experiences.[1] Twenty-two of them came from Mindanao while eight were from the Visayas. They were mostly male, married and Roman Catholic in religious affiliation. In terms of age level, 19 participants were in the 31 to 50 years category, 10 were above 50 while only one was below 30 years of age. As regards educational attainment, five were college graduates, nine had some college education, five were high school graduates, six had some secondary education and five were elementary graduates. Most of the resource managers have lived in their respective barangays for more than 20 years and only a few had lived in other places for short periods. About 50 per cent of the participants were barangay captains (local officials) and a majority of participants were members and officers of local fishermen's groups and related people's organizations.

The area of the MPAs managed by the participants varied, with many in the 6-15 ha category. The smallest was less than one ha while the biggest was more than 20 ha. Most of the MPAs were of the coral reef type. Many of these MPAs were

[1] This Workshop was a joint effort of the Silliman University Angelo King Center for Environment and Management (SUAKCREM) through the Pew Fellowship in Marine Conservation granted to A.C. Alcala, G.R. Russ, the WorldFish Center, the Center for Ecological and Natural Science Research of the De La Salle University, the Institute of Fisheries Research and Development of the Mindanao State University at Naawan, and the School of Environment Science and Management of the University of the Philippines at Los Baños.

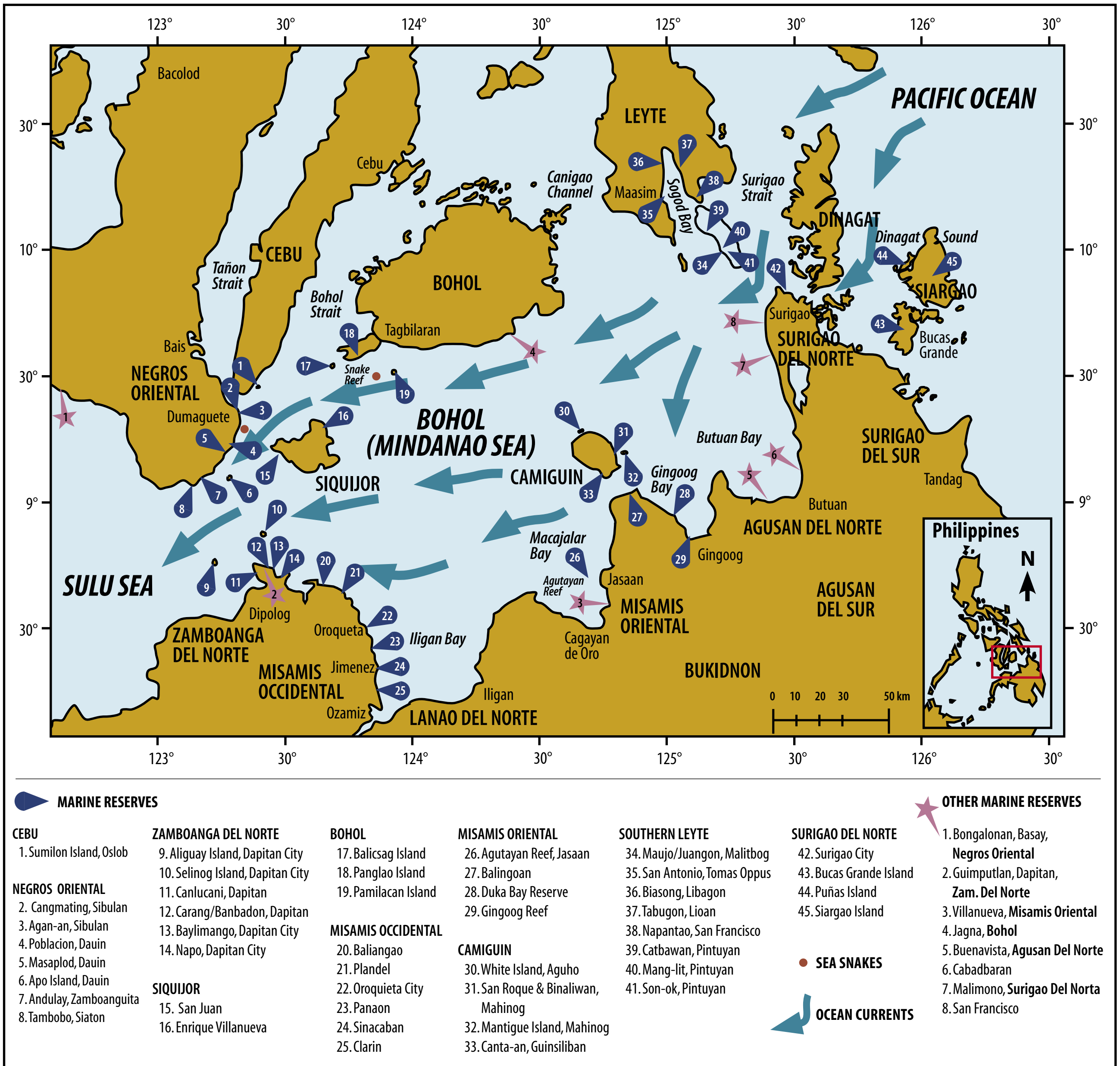


Fig. 1. Map of Bohol Sea showing some of the marine reserves of the area. (Source: SUAKCREM)

newly established - about 12 of them were created since 2000. Eight were established in the 1990s and three in the 1980s, with Apo Island Marine Reserve in Negros Oriental being the oldest.

The establishment and management of the MPAs was reported to be more of a joint endeavor involving their LGUs (particularly the barangays), line agencies like Bureau of Fisheries and Aquatic Resources (BFAR), people's organizations, Bantay Dagat (local people deputized as fish wardens) and some non-governmental organizations (NGOs)/academic institutions like Silliman University. Prior to the establishment of the MPAs, they carried out surveys of the area, public consultations and enactment of an ordinance. In a number of cases there was opposition, not only from fellow fishermen but also from their local barangay and municipal officials. However, in many cases the negative reactions turned into acceptance as people started to see the beneficial effects of the MPAs. Only a few of these MPAs had been regularly monitored and assessed due to lack of skills and resources available locally.[2] The managers of the MPAs that are protected and monitored, like Apo Island, attested to the increase in the fishery yield and improvement in the

[2] Monitoring is usually done by staff of NGOs/academic institutions like Silliman University, personnel of government agencies like BFAR and some trained local residents.

biodiversity of the marine resources in their coastal waters.

Many of the managers claimed that their MPAs were successful, based on their personal knowledge of the increase in the volume of fish catch and biodiversity. Some noted that due to inadequate enforcement facilities and lack of support from local officials they were unable to protect their MPAs from fishermen who violate the law. Two of the MPAs in the Bohol Sea that are considered to be successful are Apo Island Marine Reserve in Dauin, Negros Oriental and Selinog Island in Dapitan City, Zamboanga del Norte. In the case of Apo Island Marine Reserve, created in 1982, the fishers reported enhanced fishery catches from the adjacent non-reserve area as well. The reserve now brings more income to the local people from increased fishery yield and tourism. It was also observed that there have been significant improvements in both mean density and species richness of large predatory coral reef fishes during the period of reserve protection in both reserve and non-reserve areas in Apo Island (Russ and Alcala 1996). Apo Island Marine Reserve is the oldest MPA in the Philippines. As a model of marine conservation, it is essentially a partnership among the local community (Apo Island residents), local government units (Barangay Apo and Dauin town) and academic/non-governmental organizations (Silliman University Marine Laboratory) (Alcala 2001a).

The other well-managed MPA is Selinog Island, established in 2001 under the Pew Fellowship in Marine Conservation awarded to A.C. Alcala and G.R. Russ. This marine reserve was established after less than one year of collaborative effort by the local community (residents of Selinog Island and people's organizations), the local government units (Barangay Selinog and Dapitan City), and the academe/non-governmental organizations (Silliman University Angelo King Center for Research and Environmental Management) (Alcala 2001a). Selinog Island Marine Reserve is expected to follow the experience of Apo Island, which served as inspiration to the local community and the LGUs to protect and manage their coral reef and fishery resources.

A number of success factors and lessons for sustainability can be learned from the experience of Apo Island and Selinog Island MPAs. These include: 1) strong support from the political leadership at the barangay and municipal levels; 2) active involvement of the community in the management of the MPA; 3) clear legal basis; 4) intensified information and education campaign; and 5) networking between LGUs, national government agencies (NGAs) and NGOs/academe.

In spite of the best practices being followed in a number of MPAs in the Bohol Sea, success is still fragmented. The MPAs are currently managed independently, although there are ongoing initiatives to network their efforts. There is no uniformity in the guidelines and rules in the establishment and management of these MPAs. However, it can be observed that, as a mangement tool, MPAs are gaining popularity and support, not only among the fisherfolk but also among local communities and local government units in the Bohol Sea area.

Management Issues and Proposed Solutions

A number of management issues were identified by the resource managers for the Bohol Sea MPAs. The following were considered to be the most common problems that managers experienced, ranked by them in order of importance:

1. Insufficient funds and facilities for enforcement;
2. Lack of support from NGOs/NGAs and municipal/barangay local government units;
3. Political intervention and threats;
4. Lack of information/education among the people;
5. Illegal fishing/commercial fishing;
6. Boundary disputes and incomplete implementation of the law on delineation of municipal waters;
7. Lack of skills among local people for resource assessment and monitoring;
8. Inactive Bantay Dagat;
9. Influx of tourists contributing to the problem of waste disposal and coral reef destruction; and
10. Conflicting laws and agencies.

To address the management issues and problems identified, the following solutions were proposed by the resource managers:

1. Solicit financial assistance from line agencies, NGOs and funding institutions, which involves project proposals, enactment of ordinances allocating LGU funds for MPAs, fund-raising activities and implementation of a fee system.
2. Establish or restore good relations with local leaders (mayors, barangay captains, etc.) through improved communications, lobbying, and constant visits to show support of leadership. Representatives of NGAs, LGUs and NGOs should be invited to MPA-related activities, including assemblies and meetings.
3. Establish linkages with the National Federation of Fish Wardens and organizations of local fisherfolk.
4. Strengthen legal basis through enactment and implementation of ordinances that promote MPAs.
5. Promote community participation and intensify information campaigns at the local level through seminars, symposia, radio programs, brochures, posters and the holding of festivals and caravans.
6. Support representation of fisherfolk organizations in local special bodies (LGUs).
7. Write a position paper requesting National Mapping and Resource Information Authority (NAMRIA) to facilitate delineation of municipal waters, specifically in the Bohol Sea.

As regards the role of science and research in improving management of marine protected areas, the resource managers pointed out the need for researchers and research institutions to simplify their findings to be understood and used at the community level and ensure that they reach the communities. They also identified two areas where the researchers can assist them. One is an information and education campaign to increase awareness and support for MPAs and related issues among local people.

The other is in providing resources and technical skills for training, monitoring, resource assessment and reporting to the managers and local communities.

To be able to consolidate their efforts and work together in the implementation of the proposed solutions, the participants decided to form themselves into one organization known as the Hugpong Tagdumala sa Sangtuaryo sa Kadagatan sa Bohol (HUTASAKAB). This roughly translates to Association of MPA Resource Managers in the Bohol Sea. The birth of such an association was a historic event and welcomed with much enthusiasm by the resource managers and researchers (Annex 1). It is a major step towards the goal of forging a partnership between the resource managers and the other concerned sectors.

Future Direction

The vision is to make all marine protected areas in the Bohol Sea work and to create a fully functioning network of marine reserves in the area. To this end, efforts will be directed towards the implementation of a uniform set of principles and guidelines for a sound management of marine protected areas. Environment-friendly activities, including alternative livelihood projects that do not destroy the coastal environment, will be encouraged. Initiatives will be undertaken to strengthen local organizations and to promote capacity building in local communities. A network of linkages will be established, not only among resource managers but also with researchers/scientists and other coastal stakeholders. Ultimately, these will contribute to the attainment of the goal, not only of protecting the marine resources in the area for this generation and the next but also of improving the living conditions of the people in this area.

References

Alcala, A.C. 1988. Effects of marine reserves on coral fish abundances and yields of Philippine coral reefs. Ambio 17(3):194-199.

Alcala, A.C. 1997. Role of community-based fisheries management and marine reserves in coastal fisheries. Silliman Journal 38:159-169.

Alcala, A.C. 2001a. Marine reserves in the Philippines: historical development, effects and influences on marine conservation policy. The Bookmark Inc., Makati City.

Alcala, A.C. 2001b. Marine reserves as tools for fishery management and biodiversity conservation: natural experiments in the central Philippines, 1974-2000. Paper presented at the UNEP Conference Blue Millenium: Managing Global Fisheries for Biodiversity, June 24-27, 2001. Victoria, BC, Canada.

Crawford, B., M. Balgos and C. Pagdilao. 2000. Community-based marine sanctuaries in the Philippines: A Report on focus group discussions. Coastal Management Report #2224. PCAMRD Book Series No. 30. Coastal Resource Center, University of Rhode Island, Narragansett, RI, USA, and Philippine Council for Aquatic and Marine Research and Development, Los Baños, Laguna, Philippines.

Ferrer, E.M., L.P. de la Cruz and M.A. Domingo. (eds). 1996. Seeds of hope. College of Social Work and Community Development, University of the Philippines, Quezon City, Philippines.

Hardin, G. 1968. The tragedy of the commons. Science 162:1243-1248.

La Viña, A.G.M. 1999. Management of fisheries, coastal resources and the coastal environments in the Philippines: policy, legal and institutional framework. PRIAP-ICLARM Work. Pap. Ser 5. NSO Quickstat. July 2003. http://www.census.gov.ph/data/quickstat/index.html

Our Seas, Our Life 1998. USAID CRMP, Cebu City, Philippines.

Pomeroy, R. S. (ed.) 1994. Community management and common property of coastal fisheries in Asia and the Pacific: Concepts, Methods and Experiences. ICLARM Conf. Proc. 45, Manila.

Pomeroy, R.S., B.M. Katon, E. Genio and I. Harkes. 1999. Fisheries co-management in Asia: Phase I project report. ICLARM, Manila.

Russ, G.R. and A.C. Alcala. 1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, Central Philippines. Mar. Ecol. Prog. Ser. 132:1-9.

Sajise, P.E. 1995. Community-based resource management in the Philippines: perspectives and experiences. Paper presented during the Training Course and Co-Management of Living Coastal Resources in ASEAN: Theory, Practice and Implication for Vietnam. Ministry of Fisheries, Hanoi, Vietnam.

J.D. Indab is from Silliman University Angelo King Center for Research and Environmental Management (SUAKCREM) Dumaguete City and the History-Political Science Department, Silliman University, Dumaguete City. **P.B. Suarez-Aspilla** is from Silliman University Angelo King Center for Research and Environmental Management (SUAKCREM) Dumaguete City and the Chemistry Department, Silliman University, Dumaguete City. Email: indab@eudoramail.com and suakcrem@yahoo.com

Annex 1. Officers of the HUTASAKAB

Name of Association: HUGPONG TAGDUMALA SA SANGTUARYO SA KADAGATAN SA BOHOL (HUTASAKAB)

President	MARIO T. PASCOBELLO (Negros Oriental)
Vice-President for Mindanao	EDNA C. ABAD (Zamboanga del Norte)
Vice-President for Visayas	CRISTITO G. JAMISOLA (Bohol)
Secretary	NARCISO T. ROMERO (Negros Oriental)
Treasurer	CESARIO O. ALCALA, Jr. (Siquijor)
PRO for Mindanao	CONSTANTINO M. RUIZ (Surigao del Norte)
PRO for Visayas	FERMIN B. ADIM (Southern Leyte)

Length-weight relationship of commercially important marine fishes and shellfishes of the southern coast of Karnataka, India

K.P. Abdurahiman, T. Harishnayak, P.U. Zacharia and K.S. Mohamed

Abstract

The parameters of the length-weight relationship of the form $W = aL^b$ are presented for 51 species of commercially important marine fishes and shellfishes caught along the southern coast of Karnataka, India. Samples from commercial (trawl, purse seines, gill nets) and artisanal gears were taken during August 1999 to May 2001. The 'b' value ranged between 1.942 and 3.616 with a mean of 2.80, standard deviation of 0.32, and mode of 3.

Introduction

The length-weight relationship (LWR) is an important factor in the biological study of fishes and their stock assessments. The LWR is particularly important in parameterizing yield equations and in estimations of stock size. This relationship is helpful for estimating the weight of a fish of a given length and can be used in studies of gonad development, rate of feeding, metamorphosis, maturity and condition (Le Cren 1951). Methods to estimate the length-weight relationship of fishes are described by Pauly (1983).

Karnataka state, in southwest India, has a coastline of 300 km and a shelf area of about 25 000 km^2 (Fig. 1). Mohamed et al. (1998) studied marine fisheries and the state of commercially exploited species in this region. Karnataka's contribution to total marine fish production in India has varied between 6 per cent and 14 per cent. Pelagic and demersal finfishes, prawns and cephalopods are landed at 28 landing centers along the coast. The average annual production in the state was estimated at 112 500 t/year during 1950 to 1990. Mechanized boats employing purse seines and trawl gears

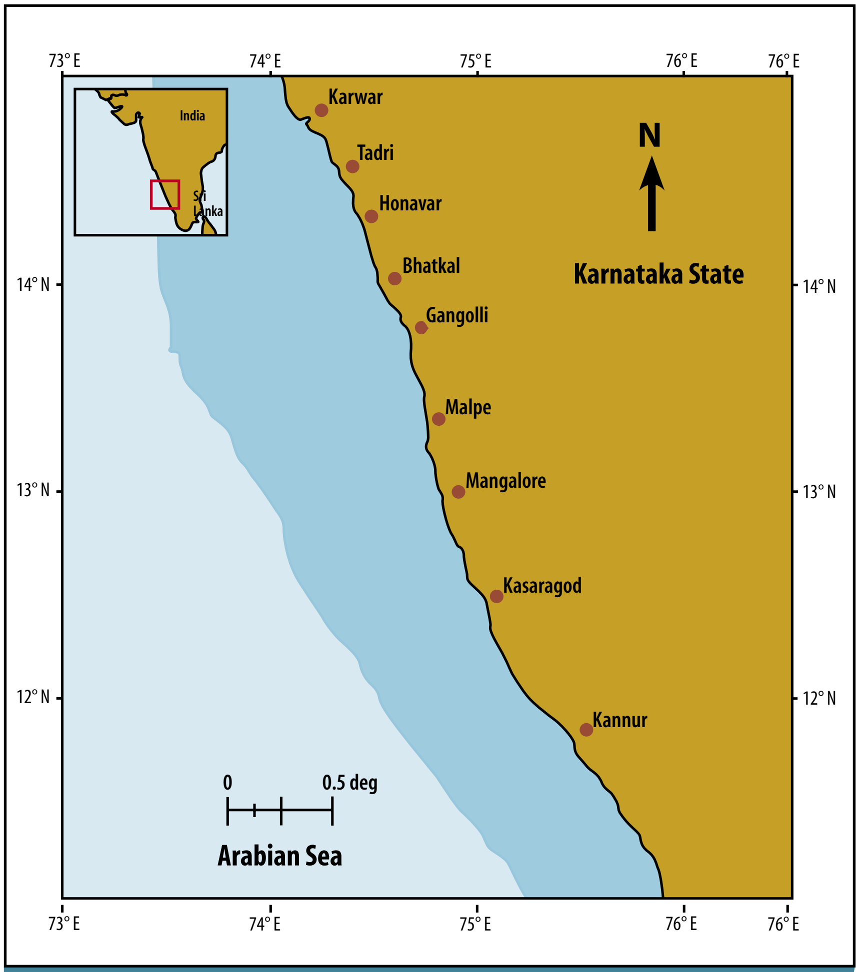


Fig. 1. Map of the southern coast of Karnataka, India.

obtained more than 95 per cent of the annual average catch in Karnataka during 1990-95.

There are a limited number of studies on the LWR of the commercially important fishes from the southern Karnataka region (Dulkhed 1963; Muthiah 1994; Rao 1997, 1988; Mohamed and Rao 1997; Kalitha and Jayabalan 1997; Sukumaran and Neelakantan 1997; Zacharia 1998). As part of an Indian Council of Agricultural Research (ICAR) project on application of trophic modelling to the marine ecosystem of southern Karnataka, biological data on length, weight, length-frequency and diet composition of all major commercial species occurring in the region was collected. Here we report on the LWR of key species in the region.

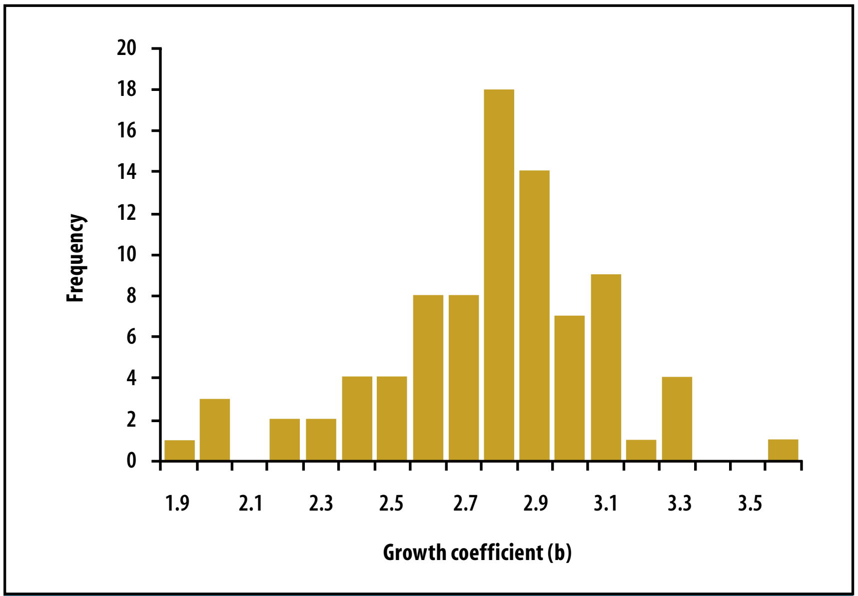


Fig. 2. Frequency distribution of allometric growth coeffiecients for 51 marine species from southern Karnataka, India.

Materials and Methods

The fishes used for the study were collected during the period August 1999 to May 2001 from the Mangalore and Malpe fishing harbors, two important landing centres on the southern coast of Karnataka. The fishing gears used in this region include trawl, purse seines, gillnets and indigenous gears. Total length (TL) was measured from the tip of the snout (mouth closed) to the extended tip of the caudal fin. Fork length (FL) was measured from the tip of the snout to the end of the middle rays of the caudal fork. Body weight of individual fish was measured to the nearest gram with an electronic balance after removing the adhered water and other remains from the surface of body. Species identification was made based on Smith and Heemstra (1986) and FAO Species Identification sheets (Fischer and Bianchi 1984).

The length–weight relationship (LWR) was estimated by using the equation

$$W = aL^b$$

where W = weight in grams, L = total length in centimeters, a is a scaling constant and b the allometric growth parameter. Alogarithmic transformation was used to make the relationship linear:

$$\log W = \log a + \log b\ L$$

For each species a regression was used to estimate the intercept (Log a) and the regression coefficient or slope (b), using Microsoft Excel™. For species with sufficient data the LWR was determined separately for each sex. LWR parameters for additional species were obtained from the literature, as part of the preparation for the trophic modeling study.

Results

The parameters of the length–weight relationship estimated for 51 species belonging to 29 families comprising a total of 19 726 individuals are presented in Table 1. The LWR pertaining to 11 species comprising cephalopods and crabs were taken from published data. Most of the parameters were based on large samples and thus may be considered reasonably representative and reliable. The estimated values of b ranged between 1.94 (*Loligo duvauceli*) and 3.62 (*Portunus pelagicus*) (Fig. 2). The mean value for all species was 2.80 (SD = 0.32). The median and mode values of b were 2.85 and 3, respectively. The sample size ranged from 20 individuals for *Carcharhinus limbatus* to 2 819 for *Saurida tumbil*. The parameters as shown in Table 1 can be used for studying growth and population dynamics for any of the 51 species of fish exploited from this coast.

Acknowledgements

We are grateful to the Director, CMFRI, Cochin and Dr C. Muthiah, Officer in Charge for providing facilities and encouragement. Funds provided by the Indian Council of Agricultural Research (ICAR), New Delhi through a Cess Fund Scheme on trophic modelling (064/004) are gratefully acknowledged.

References

Dhulkhed, M. H. 1963. The length-weight and volume relationship of the Indian oil sardine, *Sardinella longiceps* Valenciennes. Indian. J. Fish. 10(A): 40-47.

Fischer, W. and G. Bianchi (eds.) 1984. FAO. Species identification sheets for fishery purpose - Western Indian Ocean (Fishing Area 51). Food and Agricultural Organization of the United Nations, Rome. Vol. I-IV.

Table 1. Sex-wise length-weight relationship parameters and minimum and maximum length and weights. The source is from the present study unless otherwise stated.

Taxa	Sex	Length (cm)		Weight (g)		n	a	b	r	Source
		min	max	min	max					
Rock Cods (Serranidae)										
Epinephelus diacanthus	Pooled	14.7	38.7	156.0	720.0	200	0.058	2.516	0.87	
Flatheads (Platycephalidae)										
Grammoplites suppositus	M	14.3	26.9	19.0	139.0	200	0.013	2.798	0.88	
	F	17.9	27.9	37.0	171.0	193	0.012	2.846	0.88	
Bulls Eye (Priacanthidae)										
Priacanthus hamrur	M	17.0	26.8	57.5	237.0	38	0.017	2.905	0.97	
	F	15.8	28.5	48.0	275.0	165	0.02	2.787	0.90	
Seer Fish (Scombridae)										
Scomberomorus commerson	Pooled	25.0	100.0	150.0	7200.0	232	0.016	2.802	0.99	
Scomberomorus guttatus	Pooled	32.0	51.0	310.0	1500.0	200	0.023	2.782	0.93	
Tunas (Scombridae)										
Euthynnus affinis	Pooled	19.5	70.0	134.0	3900.0	253	0.026	2.836	0.96	Muthiah (1985)
Thunnus tonggol	Pooled	32.0	79.0	460.0	4600.0	260	0.055	2.636	0.98	"
Auxis thazard (*Auxis thazard thazard**)	Pooled	22.3	45.0	146.0	1800.0	261	0.008	3.228	0.92	"
Barracudas (Sphyraenidae)										
Sphyraena jello	M	16.6	27.0	27.5	187.0	177	0.005	3.059	0.96	
	F	16.7	28.2	25.0	189.0	188	0.004	3.170	0.95	
Sphyraena obtusata	M	16.6	27.0	27.5	142.0	175	0.004	3.120	0.94	
	F	16.7	28.2	25.0	152.0	191	0.004	3.110	0.96	
Sharks (Sphyrnidae)										
Sphyrna lewini	M	43.5	52.5	350.0	700.0	21	0.002	3.285	0.95	
	F	46.0	56.5	460.0	790.0	22	0.046	2.417	0.88	
Sharks (Carcharhinidae)										
Rhizoprinodon acutus	M	27.0	53.5	92.0	763.0	19	0.003	3.108	0.98	
	F	32.6	144.0	52.4	640.0	22	0.002	3.142	0.98	
Scoliodon laticaudus	Pooled	34.0	52.0	150.0	510.0	37	0.010	2.745	0.84	
Carcharhinus limbatus	Pooled	56.0	68.0	790.0	1500.0	20	0.221	2.070	0.66	
Ribbon Fish (Trichiuridae)										
Trichiurus lepturus	M	36.0	90.0	28.0	466.0	200	0.001	2.819	0.91	
	F	39.0	103.0	36.0	960.0	200	0.001	3.029	0.95	
Sardines (Clupeidae)										
Sardinella longiceps	Pooled	11.5	21.2	13.5	77.0	259	0.021	2.669	0.93	
Mackerels (Scombridae)										
Rastrelliger kanagurta	Pooled	6.6	28.2	2.5	241.0	266	0.005	3.261	0.99	
Carangids (Carangidae)										
Megalaspis cordyla	M	15.5	37	46.5	731.0	200	0.032	2.582	0.85	
	F	15.6	43.0	36.0	810.0	200	0.020	2.748	0.98	
Decapterus russelli	M	8.3	22.9	6.2	111.0	199	0.073	2.306	0.86	
	F	14.0	22.5	27.0	100.0	150	0.024	2.647	0.93	

*Valid name on FishBase (www.fishbase.org)

continue >

< continued

Taxa	Sex	Length (cm)		Weight (g)		n	a	b	r	Source
		min	max	min	max					
Caranx kalla (Alepes djedaba)*	M	6.3	15.7			196	0.064	2.871	0.92	Kalitha and Jayabalan 1997
	F	6.3	15.7			361	0.009	3.026	0.93	"
Scomberoides tol	M	14.3	41.0	17.1	490.0	59	0.007	2.937	0.99	
	F	14.0	43.0	18.7	520.0	66	0.007	2.955	0.99	
White Fish (Lactariidae)										
Lactarius lactarius	M	8.5	20.5	8.3	10.3	250	0.018	2.853	0.93	Zacharia unpublished
	F	10.0	26.5	9.2	200.0	274	0.015	2.905	0.96	"
Thread Fin Breams (Nemipteridae)										
Nemipterus japonicus	Pooled	9.5	30.8	20.0	350.0	408	0.039	2.664	0.99	Zacharia (1998)
Nemipterus mesoprion	M	14.5	25.5	41.0	189.0	210	0.035	2.673	0.96	Zacharia unpublished
	F	12.9	22.7	27.0	180.0	200	0.018	2.898	0.96	"
Rays & Skates (Rhinobatidae)										
Rhinobatos granulatus	M	30.0	78.0	70.0	1750.0	89	0.004	2.910	0.94	
	F	23.4	72.0	30.0	1630.0	85	0.005	2.889	0.97	
Snappers (Lutjanidae)										
Pristipomoides filamentosus	M	15.2	54.9	40.1	1450.0	42	0.014	2.898	0.99	
	F	15.5	49.5	37.5	1150.0	25	0.013	2.910	0.99	
Pomfrets (Stromateidae)										
Pampus argenteus	M	9.0	25.5	23.0	289.0	90	0.120	2.485	0.96	
	F	10.3	28.2	33.4	382.0	54	0.387	2.036	0.98	
Pomfrets (Carangidae)										
Formio niger (Parastromateus niger)*	M	17.2	35.0	90.0	644.0	23	0.053	2.655	0.98	
	F	19.3	36.3	130.0	734.0	12	0.069	2.573	0.96	
King Fish (Rachycentridae)										
Rachycentron canadum	M	29.4	55.0	132.0	960.0	16	0.010	2.876	0.93	
	F	26.0	53.6	95.0	920.0	22	0.004	3.092	0.99	
Other Clupeids (Clupeidae)										
Kowala coval	M	7.5	11.5	3.8	16.9	178	0.006	3.213	0.93	
	F	7.5	11.4	3.7	16.0	149	0.006	3.187	0.92	
Dussumieria acuta	M	11.0	20.4	9.8	58.9	162	0.009	2.938	0.98	
	F	11.4	20.2	11.6	64.9	177	0.010	2.894	0.97	
Wolf Herring (Chirocentridae)										
Chirocentrus dorab	M	26.4	61.0	59.0	700.0	109	0.007	2.801	0.97	
	F	29.0	58.0	77.0	585.0	76	0.003	2.990	0.97	
Anchovies (Engraulidae)										
Stolephorus commersonii	M	9.5	14.0	6.2	20.3	80	0.004	3.351	0.95	
	F	9.1	14.4	5.1	24.9	82	0.004	3.326	0.97	
Stolephorus devisi (Encrasicholina devisi)*	M	5.5	9.7	1.5	8.0	216	0.031	2.307	0.87	
	F	6.0	10.0	1.5	7.5	228	0.035	2.249	0.82	
Thryssa mystax	M	10.0	19.0	7.0	60.7	184	0.008	2.954	0.91	
	F	12.0	20.5	12.0	70.0	199	0.007	3.019	0.92	

continued >

< continued

Taxa	Sex	Length (cm)		Weight (g)		n	a	b	r	Source
		min	max	min	max					
Sciaenids (Sciaenidae)										
Johnieops sina (Johnius dussumieri)*	M	10.0	215.0	11.2	49.2	150	0.052	2.420	0.85	
	F	10.0	19.3	10.9	75.7	229	0.017	2.869	0.94	
Otolithes cuvieri	M	11.2	29.5	13.6	300.0	108	0.014	2.897	0.98	
	F	11.3	35.3	12.0	353.5	177	0.011	2.961	0.94	
Silver Bellies (Leiognathidae)										
Leiognathus bindus	M	7.3	11.0	6.0	22.0	149	0.044	2.521	0.85	
	F	7.6	10.7	8.0	19.8	141	0.126	2.054	0.67	
Secutor insidiator	M	6.6	10.4	4.3	16.6	101	0.023	2.782	0.94	
	F	7.0	11.3	5.0	18.0	101	0.018	2.907	0.94	
Lizard Fishes (Synodontidae)										
Saurida tumbil	Pooled	101.0	480.0			2819	3.432-6E	3.142	0.99	Muthiah (1994)
Saurida undosquamis	Pooled	72.0	316.0			2774	1.34-6E	3.306	0.99	"
Flat Fishes (Paralichthyidae)										
Pseudorhombus arsius	M	13.7	30.0	23.0	260.0	147	0.004	3.256	0.98	
	F	14.0	31.5	22.4	313.0	160	0.003	3.378	0.99	
Pseudorhombus natelensis	M	14.0	26.5	33.0	175.0	28	0.019	2.839	0.93	
	F	13.2	21.7	30.0	131.0	46	0.029	2.708	0.92	
Flat Fishes (Cynoglossidae)										
Cynoglossus macrostomus	Pooled	10.5	15.8	7.8	24.9	199	0.027	2.420	0.88	
Prawns (Penaeidae)										
Metapenaeus monoceros	M	7.0	14.6	2.4	23.1	96	0.004	3.240	0.98	
	F	7.5	18.0	3.5	53.0	105	0.006	3.084	0.98	
Crabs (Portunidae)										
Portunus pelagicus	M	Carapace width				111	3.2-6E	3.616	0.98	Sukumaran and Neelakantan
		Carapace length				111	3.52-4E	3.178	0.98	(1997)
	F	Carapace width				106	1.63-5E	3.253	0.98	"
		Carapace length				106	8.874-4E	2.930	0.98	"
Portunus sanguinolentus	M	Carapace width				86	3.62-5E	3.099	0.98	"
		Carapace length				86	3.974-4E	3.172	0.99	"
	F	Carapace width				84	6.58-5E	2.960	0.98	"
		Carapace length				84	8.287-4E	2.953	0.97	"
Stomatopods (Squillidae)										
Oratosquilla nepa	M	4.0	11.2	1.0	15.5	107	0.017	2.786	0.97	
	F	6.0	11.4	2.3	15.3	109	0.014	2.884	0.97	
Cephalopods (Sepiidae)										
Sepia aculeata	M					363	0.001	2.649	0.95	Rao (1997)
	F					462	0.001	2.855	0.98	"
Cephalopods (Loliginidae)										
Loligo duvauceli	M	5.8	36.6			580	0.005	1.942	0.98	Rao (1988)
	F	6.7	22.8			595	0.001	2.242	0.96	"
	Pooled	3.0	34.0			372	0.003	2.105	0.97	Mohamed and Rao (1997)

Kalitha, B. and N. Jayabalan. 1997. Length-weight relationship and relative condition factor of the Golden Scad, *Caranx kalla* Cuv. from Mangalore coast. Indian. J. Fish. 44(1):87-90.

Le Cren, C.P. 1951. Length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). Journal of Animal Ecology 20(2): 201-219.

Mohamed, K.S., C. Muthiah, P.U. Zacharia, K.K Sukumaran, P. Rohit and P.K. Krishnakumar. 1998. Marine fisheries of Karnataka state, India. *Naga*, ICLARM Q. 21(2):10-15.

Mohamed, K.S. and G.S. Rao. 1997. Seasonal growth, stock-recruitment relationship and predictive yield of the Indian squid *Loligo duvauceli* exploited off Karnataka coast. Indian J. Fish. 44(4):319-329.

Muthiah, C.1985. Fishery and bionomics of tunas at Mangalore. CMFRI Bull. 36: 51-70.

Muthiah, C. 1994. Studies on the fishery and biology of the Lizardfish, *Saurida* sp. from the Karnataka coast. Ph. D. Thesis, Univ. of Karnataka. 185 p.

Pauly D. 1983. Some simple methods for the assessment of tropical fish stocks. FAO. Fisheries Technical Pap. No. 234. FAO, Rome.

Rao, G. S. 1997. Aspects of biology and exploitation of *Sepia aculeata* Orbigny from Mangalore area, Karnataka. Indian. J. Fish. 44(3):247-254.

Rao, G. S. 1988. Biology of inshore squid, *Loligo duvauceli* Orbigny with a note on its fishery of Mangalore. Indian. J. Fish. 35(3):121-130.

Smith, M. M. and C.P. Heemstra. 1986. Smiths Sea Fishes. 6th ed. Springer-Verlag, Berlin.

Sukumaran, K.K. and B. Neelakantan. 1997. Length-weight relationship in two marine portunid crabs; *Portunus (Portunus) sanguinolentus* (Herbst) and *Portunus (Portunus) pelagicus* (Linnaeus) from the Karnataka coast. Indian J. Mar. Sci. 26:39-42.

Zacharia, P.U. 1998. Dynamics of the thread fin bream, *Nemipterus japonicus* exploited off Karnataka. Indian. J. Fish. 45(3):265- 270.

K.P. Abdurahiman, **T. Harishnayak**, **P.U. Zacharia** and **K. S. Mohamed** are from the Research Center of Central Marine Fisheries Research Institute, P. B. No. 244, Bolar, Mangalore- 575001, Karnataka, India.
For correspondence contact
Dr K.S. Mohamed, CMFRI, PO Box 1603, Cochin 682018, Kerala , India.
Email: ksmohamed@vsnl.com

Corals, fishermen and tourists

A. Kunzmann

Abstract

Two major anthropogenic activities that disturb coral reefs are fishing and tourism, even though coral reefs are important for both fishing and tourism. Already more than 60 per cent of all reefs worldwide are endangered. The use of explosives and poison by small-scale fishers, to supply the market for live fish for aquariums and for human consumption, cause irreversible damages to reefs. Similarly, rapid and unmanaged coastal development for marine tourism negatively affects coral reefs in many ways. Though marine parks and marine protected areas are being promoted all over the world, developing countries need assistance in establishing and assessing such reserves and for taking appropriate actions for rehabilitation of reefs. These can be accomplished through partnership projects.

Introduction

Coral reefs are one of the most productive ecosystems on earth, although they usually occur in waters that are relatively low in nutrients. Reef communities lying along tropical coasts are a rich and indispensable source of renewable goods. The importance of coastal environments as a source of protein and foreign exchange is steadily increasing, particularly for tropical countries. At the same time, these countries are confronted with exploding growth of coastal population as well an alarming rate of coastal degradation. For these countries, the sustainable use of reefs and other tropical marine ecosystems will soon be a question of survival for the coastal population.

In recent years the press has frequently reported that reefs are endangered worldwide (e.g., Der Spiegel 1999; National Geographic 1999) due to natural and anthropogenic reasons. This paper concentrates on two manmade factors leading to reef destruction: fishermen and tourists. The issue has been neglected in the past and public awareness is still low. Furthermore, this paper concentrates regionally on examples from Southeast Asia and the Red Sea.

Why do we need reefs

Coral reefs are a rich meadow for fishermen, while for the scuba divers they are a pleasure for the eyes. But reefs have several additional important functions. They are indispensable and invaluable. Indispensable, because they protect coasts from erosion by waves and currents and because they make them safe[1] for navigation, fishing and tourism. They are also invaluable as effective coastal protection, because they re-grow and repair damage to a certain extent[2]. They also provide goods with a high value. Worldwide, reefs yielded a value of about US$ 375 billion per year (Costanza et al. 1997), of which US$ 100 billion was food from reefs or reef environments. In some developing countries, food from reefs provides for 25 per cent of the total food supply and 60 per cent of the total protein intake.

Reefs are known for an enormous diversity of species. There are about 4 000 species of fish and 800 species of coral identified. It is estimated that about 9 million species occur in reefs, not counting the microbial species (Reaka-Kudla 1997). Therefore, reefs are a genetic treasure box. They host a number of bioactive substances that are increasingly used in pharmacology and medicine. They provide moulds for anti-cancer medication and raw material for implant surgery.

In spite of this global importance, reefs are endangered worldwide. According to a report by the World Resources Institute (Bryant et al. 1998), almost 60 per cent of all reefs are endangered through human disturbance or activities, such as coastal development, overexploitation, destructive fishing methods, increasing sedimentation and eutrophication, and pollution from domestic and industrial sewage. Climatic variations with abnormal high or low water temperatures (e.g., El Niño) and so-called "red-tides" (toxic phytoplankton booms) are often the last straw for stressed reefs. For example, in 1997 (the International Year of the Reef) and in 1998 (the International Year of the Ocean), a worldwide bleaching of corals was observed (Wilkinson and Hodgson 1999). Almost 10 per cent of all reefs were destroyed beyond repair.

[1] Although reefs are usually known as obstacles for shipping, the leeward side of very long reefs, paralleling the coast, offers safe navigation because waves are broken and swell is minimized (e.g., in Indonesia).

[2] This capacity for self-repair has natural limits that are frequently overstepped by unwise exploitation.

The major negative effects on coral reefs can differ from area to area. In Southeast Asia, it is mainly sedimentation and destructive fishing practices that destroy reefs, while in the Red Sea and the Caribbean, tourism is the main factor. This paper presents the effects of fishing and tourism, with selected examples from Indonesia, the Philippines and the Red Sea.

Misuse of reefs

Coral reefs in Southeast Asia are known for their extraordinary species richness. As with rainforests, Southeast Asia represents the global centre for biodiversity, i.e., there are many species per unit area. For example, some 400 reef-building corals, more than 3 000 coral fish species and about 1 700 species of molluscs are known in the region. Coral reefs in Southeast Asia account for some 160 000 km^2, which corresponds to approximately 25 per cent of all reefs worldwide. Unfortunately the status of reefs in Southeast Asia is already critical. Thirty five per cent of Asian reefs are considered disturbed and less than five per cent are categorised as original or "excellent" (Cesar et al. 1997). The main reasons for this are overexploitation, unsustainable use, and rapidly increasing coastal development.

Fishing with destructive methods

The use of dynamite and various poisons for fishing has been banned in Indonesia since 1972. Nevertheless, up to 50 per cent of fishermen use explosives and poison from time to time, although they are aware of the ban and realise that this practice destroys corals (Kunzmann 1997).

Fishing with explosives is done in several ways. Large bombs target large areas in order to catch baitfish for the long liners that catch the highly sought after and expensive tuna. Smaller bombs, on the other hand, catch reef fish for supplying to local fish markets and tourist restaurants. Both methods severely destroy corals and the reef structure. Only coral rubble remains and is soon overgrown by algae. The organisms in the vicinity of the explosion are killed or badly injured (Figs. 1-4). Human victims of self-made explosives can take months or even years to recover, while the recovery of reefs through resettlement with corals can take decades. In many cases the destruction is permanent (Cornish and McKellar 1998).

Cyanide and CN-insecticides are used in order to catch valuable ornamental fish for the lucrative aquarium trade. Expensive napoleon wrasses, groupers and crayfish are caught for live export to Hong Kong and Taiwan. These markets demand up to 25 000 t live reef fish annually, with a value of more than US$ 1 billion (Johannes and Riepen 1995).

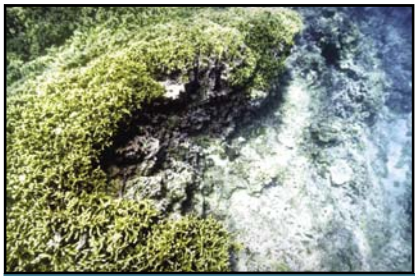


Fig. 1. Pulau Pandan, West Sumatra: destroyed reef crest in ca. 12 m depth. A big bomb has left a crater with a diameter 6 m in the middle of a healthy reef so that part of the reef has broken off and fallen down the slope.

Fig. 2. Pulau Pandan, West Sumatra: destroyed reef crest at ca. 7 m depth. Smaller, hand-made explosives have left crates of 1-2 m diameter. The resulting rubble of this Acropora formation move back and forth with the swell and work like a caterpillar, destroying large areas of the reef over the next few days.

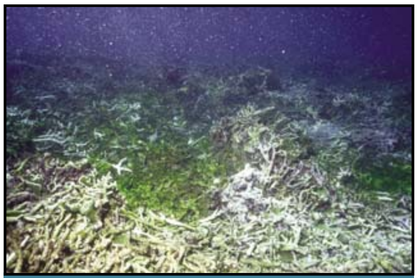


Fig. 3. Pulau Pandan, West Sumatra: destroyed reef crest at ca. 7 m depth. Photo taken seven days after Fig.2. Green, slimy algae overgrow the Acropora fragments and prevent a resettlement by corals.

Fig. 4. Pulau Pandan, West Sumatra: destroyed reef immediately under the surface. These Pachyseris specimens have been destroyed by a bomb and look like they are cut with a sharp knife.

Groupers are traded for several hundred US$ each and a napoleon wrasse can fetch several thousand US$ (Lee and Sadovy 1998). For prestige reasons, rich Chinese businessmen are willing to pay up to US$ 2 000 for a pair of napoleon wrasse lips! (Fig. 5).

The market share of the Philippines in the global export of ornamental fish is 80 per cent, with a value of more than US$ 100 million per year. More than two-thirds of ornamental fish are caught with cyanide and up to 75 per cent of the poisoned fish die upon capture. Another 60 per cent of the survivors die during transport. The very same cyanide also kills coral colonies and small animals (like worms, gastropods, bivalves and crustaceans) in the vicinity. Unfortunately, fishing with poison is practiced all over Southeast Asia, the driving force being a large market (Johannes and Riepen 1995; Fig. 6)

Fig. 5. Head of a Napoleon Wrasse (*Cheilinus undulatus*). In top restaurants in Hong Kong, prices of up to 80 US$ per kg are accepted and for a pair of lips even up to 2 000 US$.

The local fishermen receive only a very small share of the market value of the fish, but for a little additional income they are willing to take the small risk of being caught using poison. Usually the fishermen are protected by the navy or the fisheries authorities, who accept bribes in return for turning a blind eye.

Aquarium fish can die even weeks after capture due to the long-term, chronic damage caused by the poison. However, the buyer does not know the real reason the fish die. Very little is known about the potential impact of the residue of the poison in fish consumed as food. The long-term damage results in endless coral cemeteries underwater.

Tourism

Tourism can damage reefs in many ways. Long coastal stretches are plastered with hotels, sewage is discharged straight into the sea and visitors pour by the hundreds into the water, either with water-vehicles or by diving. Frequently hotels or the hotel roads are built with coral blocks that have been cut out of the reef in front of the hotel. At the same time, more and more tourists require larger airports, whose runways are sometimes even built on reef-tops (Fig. 7).

Many hotels have tried to save large amounts of money by systematically destroying reefs in front of their door to use as cheap building materials. But more and more of them pay a large price. When the increasing coastal erosion due to the missing protective reef starts to reach and erode the hotel walls, millions of dollars are needed for artificial constructions to break the waves (Clark 1996). Furthermore, tourists keen on snorkelling around unspoilt reefs do not return.

Unfortunately tourism also supports a very lively trade in corals, bivalves and shells of gastropods. Thousands of tons are traded every year and the global market share of the Philippines is 90 per cent. Protected species like the tritons trumpet and the giant clam, which are in danger of extinction, are traded illegally. Tropical shells also find their way to Germany and are sold on the beaches of North and Baltic Sea.

Growing tourism is also the driving force behind rapid coastal development and

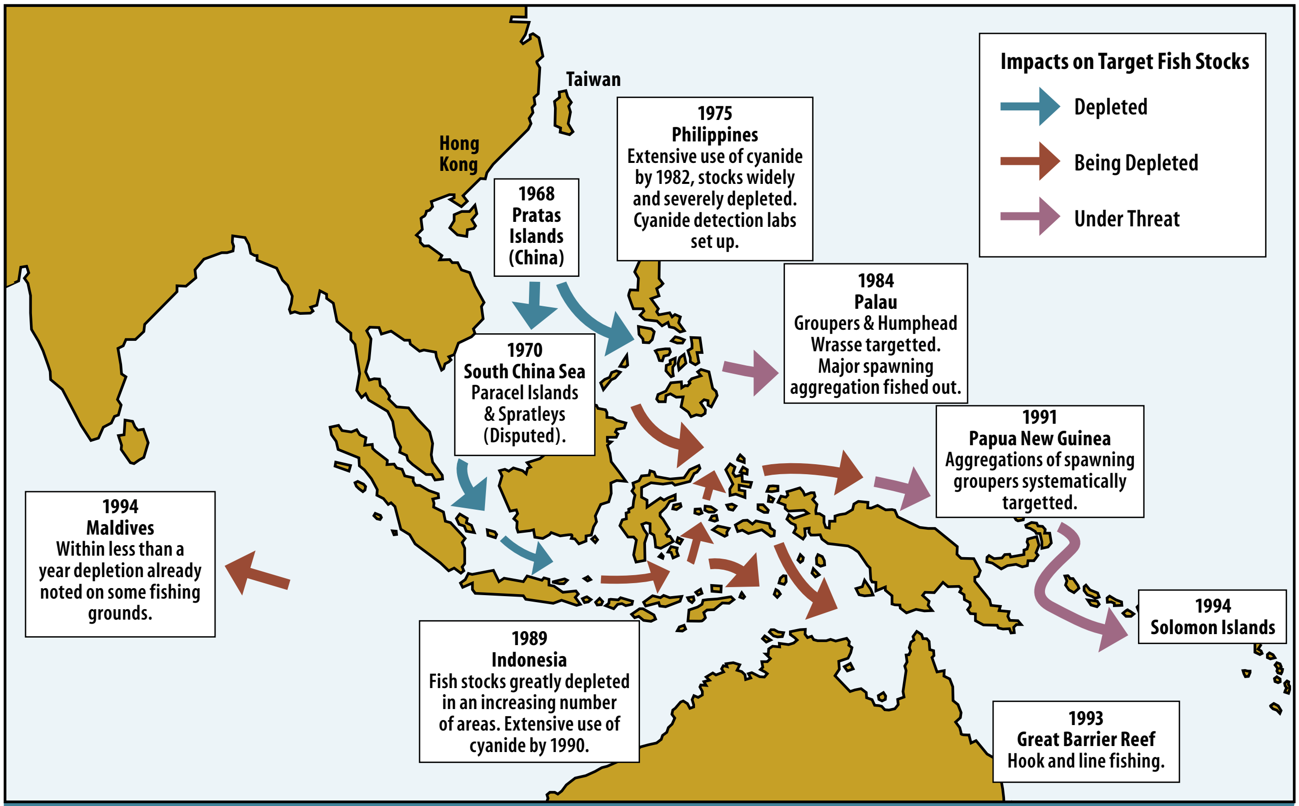


Fig. 6. Fishing with poison in Southeast Asia. After the Philippines and Indonesia have been over exploited, the illegal practices move on to the Maldives in the west and to the Pacific Islands in the east.

Fig. 7. International Airport Bali: the runway has been extended by several hundred meters to the west, in order to provide for large aircraft like the 747. A beautiful reef, right in the tourist centre Kuta, has been sacrificed.

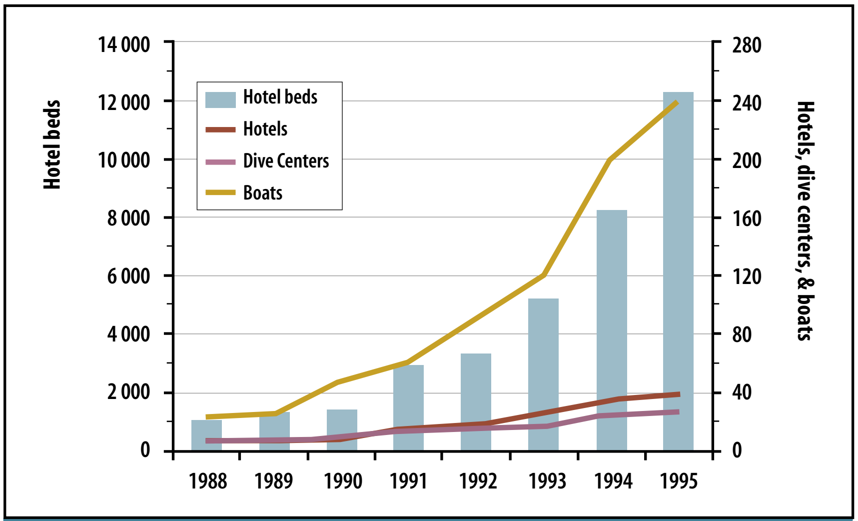


Fig. 8. Development of tourism at the Red Sea. The number of hotel beds and diving tourists has sharply increased since 1988.

construction on coasts worldwide (Caribbean and Southeast Asia), but particularly at the Red Sea (Fig. 8). In the Caribbean, where the total turnover from tourism is calculated at some US$ 9 billion per year, tourism contributes 50 per cent of the GNP in some countries. The Florida Keys, for example, had a gross turnover of US$ 1.6 billion from marine tourism in 1997 (Bryant et al. 1998).

Adventure holidays, often sold as "soft-tourism", and the diving business have a much stronger impact than has previously been assumed, according to three new studies from the Great Barrier Reef in Australia, the Red Sea and the Caribbean (Harriot et al. 1997; Hawkins and Roberts 1994). For example, the number of divers is increasing steadily and so also the number of contacts of divers with corals (about 35 to 100 contacts per dive) that harms corals. In the Red Sea more than 30 per cent of all reefs are already negatively affected. This is particularly true for Egypt, where plans have been drawn up to intensify marine tourism tenfold within the next five years!

There are natural and anthropogenic factors that threaten reefs, e.g., rapidly increasing sedimentation and eutrophication caused by unwise agriculture and forestry practices (Fig. 9). The number of disturbance factors are increasing and the intervals between individual disturbances are becoming shorter and shorter, so that even the strongest reef system does not have a chance to recover from injuries. Periodically occurring natural irregularities, e.g., ENSO in 1997-1998, have such a catastrophic impact that reefs bleach and subsequently die on a global scale.

Ways out?

Fortunately the number of marine parks and marine protected areas (MPs and MPAs) have increased worldwide and also in developing countries. In Indonesia there are plans to double the area by 2005 (Kunzmann 1998, 2002). Large international programs like the International Year of the Reef (IYOR 1997) or the International Year of the Ocean (IYO 1998) have contributed massively to increasing the awareness of these issues among the local populations. Finally development banks have initiated several large projects for the protection and rehabilitation of marine systems, e.g., the Coral Reef Rehabilitation and Monitoring Project (COREMAP) in Indonesia, financially supported by the World Bank, the Asian Development Bank and Japan.

Management of tourism, destructive fishing practices and coastal development have to be regulated and should be

Fig. 9. Padang, West Sumatra: The dirty plumes of the rivers Kuranji and Banjir are clearly visible. After heavy rainfall they can be traced up to 15 km in front of the coastline. The sediment and fertiliser from uncontrolled agriculture and forestry harm reefs.

subordinated under a concept of sustainable development of marine ecosystems. Otherwise coral reefs, a source of income and food for millions of people, will have little chance of survival. In order to achieve this, it is necessary to inform politicians, decision-makers and economic leaders of all potential commercial aspects of marine systems. Some of these are:

Potential function of the reef	Potential yield per year and km² reef[3]
Coastal Protection	50 Mio. US$[4]
Fisheries (10-30 t/km²)	0.1 to 0.15 Mio. US$[5]
Tourism	20 Mio. US$
Marine natural products/pharmacology	? US$[6]
Biodiversity/ gene pool	? US$[7]

Final remarks

The World Resources Institute Report 1998 summarizes as follows:

- Fifty-eight per cent of all reefs worldwide are endangered through anthropogenic influences.
- In Southeast Asia, 80 per cent of all reefs are negatively impacted.
- The main factors are over-extensive and destructive use, as well as an increasing coastal development.
- Globally there are more than 400 MPAs, but many are only on paper and about 150 are smaller than one km².
- 40 countries with reefs do not have a single MPA.

This is a reason for concern. The sum of factors and their cumulative effects have destroyed many reefs beyond repair. There are still isolated reefs in excellent condition, for example, in the South Pacific and these should be protected. It is recommended that tropical countries should be given assistance for this. Moreover, we should no longer use short-term economic reasons as excuses not to implement partnership projects. Many times it has been discovered too late that this is short-sighted, because in the end we all have to pay the price.

Acknowledgements

Marc Kochzius from the Center for Tropical Marine Ecology (ZMT) contributed Figs. 5 and 8 and unpublished data. Sabine Kadler from ZMT prepared the slides.

References

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. Reefs at risk. World Resources Institute, Washington. 56 p.

Cesar, H., C. G. Lundin, S. Bettencourt and J. Dixon. 1997. Indonesian coral reefs - an economic analysis of precious but threatened resource. Ambio 26(6): 345-350.

Clark, J.R. 1996. Coastal zone management handbook. CRC Lewis Publishers, New York, London, Tokyo.

Cornish, A.S. and D. McKellar. 1998. A history of fishing with explosives and poisons in Hong Kong waters. Naga 21(3): 4-9.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Der Spiegel. 1999. Paradies unter grünem Teppich. Spiegel No. 4:168-172.

FAO 1996. Yearbook of fishery statistics - fishery commodities. FAO Fisheries Series 83:1-179.

Harriott, V.J., D. Davis and S.A. Banks. 1997. Recreational diving and its impact in marine protected areas in eastern Australia. Ambio 26(3):173-179.

Hawkins, J.P. and C.M. Roberts. 1994. The growth of coastal tourism in the Red Sea: present and future effects on coral reefs. Ambio 23(8):503-508.

Johannes, R.E. and M. Riepen. 1995. Environmental, economic and social implications of the live reef fish trade in Asia and the Western Pacific. Unpublished by TNC-Washington (sponsored by SPC, AIDAB).

Kunzmann, A. 1997. The coral reefs of West Sumatra, p.1249-1262. ***In*** T. Tomascik, A.M. Mah, A. Nontji, M. Kasim Moosa (eds.) The ecology of the Indonesian Seas. Part two. Periplus Editions (HK) Ltd. Singapore.

Kunzmann, A. 1998. "Management" of marine ecosystems in West Sumatra: theory and everyday practice. Image of Indonesia IV(5):19-22.

Kunzmann, A. 2002. On the way to management of West Sumatra's coastal ecosystems. Naga 24(1):4-10.

Lee, C. and Y. Sadovy. 1998. A taste for live fish: Hong Kong´s live reef fish market. *Naga* 21(2):38-42.

National Geographic. 1999. Coral in peril. Nat. Geogr. 1:2-30.

Reaka-Kudla, M.L. 1997. The global biodiversity of coral reefs: a comparison with rain forests, p 83-108. ***In*** M.L. Reaka-Kudla, D.E. Wilson, E.O. Wilson (eds.) Biodiversity II. Joseph Henry Press, Washington, D.C.

Wells, S. and N. Hanna. 1992. Das Greenpeace Buch der Korallenriffe. Beck, München.

Wilkinson, C. and G. Hodgson. 1999. Coral reefs and the 1997-1998 mass bleaching. Nature and Resources 35(2):16-25.

A. Kunzmann is from the Centre for Tropical Marine Ecology (ZMT), Bremen. E-mail: akunzmann@zmt-bremen.de

[3] Figures are from real projects in the Caribbean, Indonesia and Australia.
[4] Wells and Hanna 1992; assumed longevity of manmade coastal protections is 100 years.
[5] FAO 1996; reef catches of 9 million t/yr represent about 12 per cent of the total world catch.
[6] Figures still unknown
[7] Figures still unknown

Length-weight relationships of marine fishes from the central Brazilian coast

L.O. Frota, P.A.S. Costa and A.C. Braga

Abstract

Parameters of the length-weight relationship are presented for 85 fish species from the marine and estuarine regions of the central Brazilian coast (latitude 13° to 23° S). Three different methods were used. A non-linear iterative process using the quasi-Newton algorithm yielded a better fit for all data sets analyzed. The length-weight allometry coefficient *b* estimated from standard length data tended to be lower than from total length data. The difference between these estimates was significant for some species.

Introduction

The relationship between body length and weight is of great importance in fishery biology (Sparre et al. 1989; Gulland 1983). Biomass estimates obtained from the widely used analytical models, such as virtual population analysis (Pope 1972), require the calculation of mean weight of individuals per age or length class through the length-weight relationship (LWR). Therefore, obtaining accurate LWR parameter estimates is an important factor in the assessment of fish stocks.

Length-weight relationships are usually calculated through linear regression on log-transformed data. The ordinary least squares or "predictive" regression (Zar 1984) is the most commonly applied method for the estimation of LWR parameters. Ricker (1973) suggested the use of geometric mean (GM) functional regression in order to circumvent the problem that the independent variable (i.e., length) is subject to natural variability. In recent years, the use of non-linear procedures for the estimation of LWR, as well as other population parameters, has been increasing among researchers.

The parameter *b* of the LWR equation ($W = a.L^b$), also known as the allometry coefficient, has an important biological meaning, indicating the rate of weight gain relative to growth in length. Marked variability in estimates of *b* is usually observed among different populations of the same species, or within the same population at different times. On the one hand, this may reflect changes in the condition of individuals related to feeding, reproductive or migratory activities (King 1995). On the other hand, sampling related factors or calculation methods may often account for the significant difference in estimates. Among the first we quote sample size, length distribution in the samples and type of length measure, and among the second, regression models used for parameter estimation.

The central coast of Brazil is characterized by a generally narrow continental shelf (about 25 km) with bottom composed of calcareous sediment (Nonaka et al. 2000; Fig.1). The southward flow of the Brazil Current in this region represents a typical western boundary current regime (Castro and Miranda 1998) and brings warm, saline and oligotrophic waters to the coast. Sea surface temperatures between 24.0° to 26.4°C and 26.0° to 28.3°C have been recorded at 10 m depth over the Abrolhos Bank during winter-summer and autumn, respectively. The Royal Charlotte Bank and Abrolhos Bank (Fig.1) are offshore extensions of the shelf where coral and calcareous algal reef habitats predominate and that represent important fishing grounds for the snapper and grouper line fishery.

The main objective of this paper is to provide the LWR for a wide variety of fishes from the central Brazilian coast, including both the target species and by-catch species in commercial, recreational or subsistence fisheries. A secondary objective is to analyze the influence of fitting methods, sample size and types of length measure in the estimation of LWR parameters.

Materials and Methods

Samples were obtained during the period 1993-2000 using various fishing gears, such as hand lines, long lines, bottom trawls, gill nets and beach seines. Fishes were measured lying on their right side on a scaled board and different types of length measures were taken. Smaller species were measured to the nearest mm and larger species to the nearest five mm. Fishes up to 10 kg were weighed to the nearest decigram on a digital balance and heavier specimens were weighed to the nearest 100 g using a dynamometer. Three different methods were used to estimate the parameters of the length-weight equation: (i) ordinary "predictive" linear regression, based on log-transformed data; (ii) GM functional linear regression, also based on log-transformed data; and (iii) a non-linear iterative procedure using the quasi-Newton algorithm. Weights that differed more than 20 per cent from the predicted

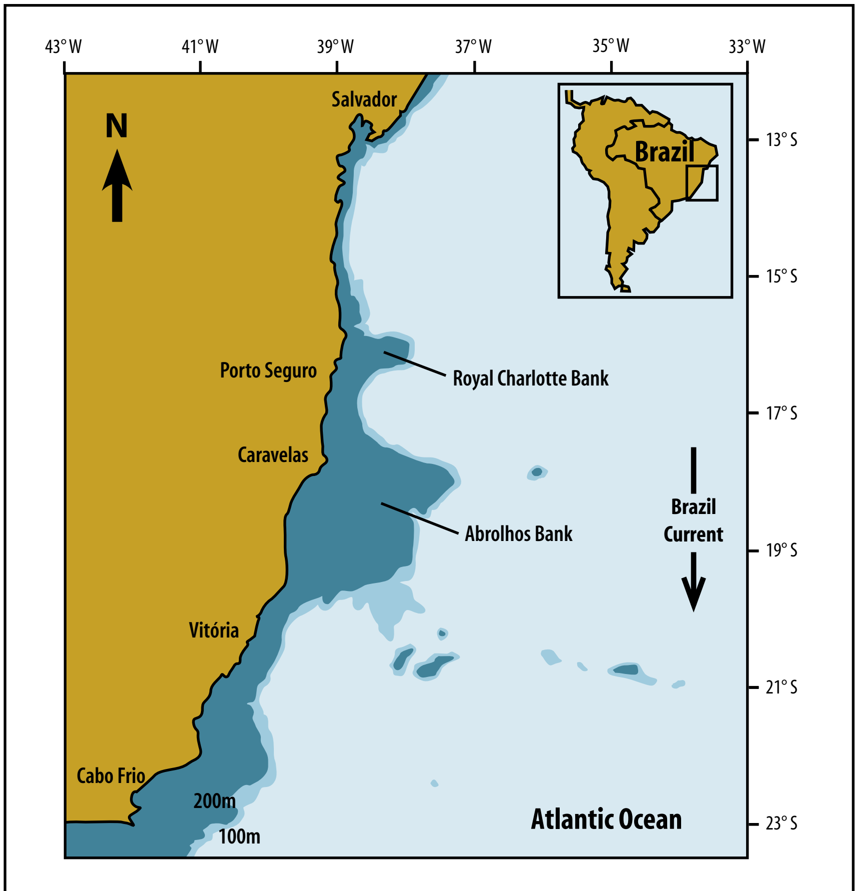


Fig. 1. Map showing central Brazilian coast, continental shelf and upper slope.

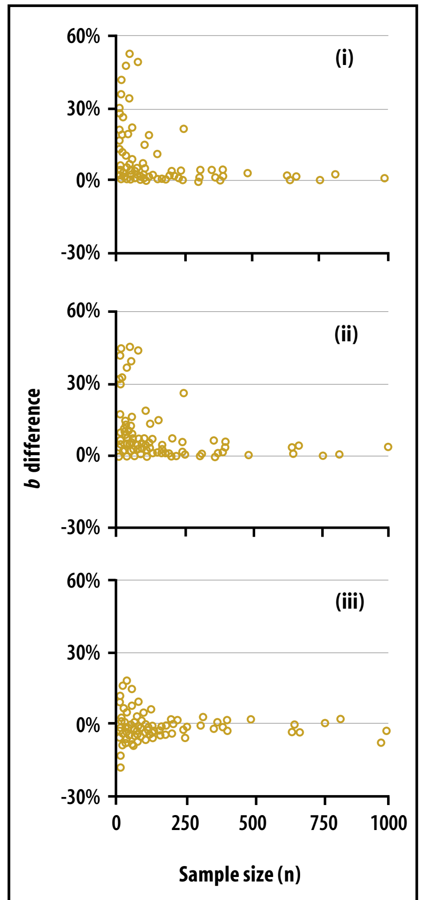


Fig. 2. Percentage difference between residual sum of squares (RSS) of three regression methods for 139 sets of length-weight data plotted against sample size. **(i)** ordinary - non-linear; **(ii)** functional - non-linear; **(iii)** ordinary -functional.

value in a preliminary ordinary regression were considered outliers and excluded from the analyses. Fits obtained from the different methods were compared in regard to their residual sum of squares (RSS).

The influence of length type on estimates of the LWR allometry coefficient *b* was investigated for 39 species. First we excluded outliers from the regressions on total length (TL), fork length (FL) and standard length (SL). Length-weight relationships were then calculated for each length type and data sets were composed of the same individuals for each species. Estimates of *b* obtained from different length types were compared using Wilcoxon matched pairs test (Zar 1984). For each species, covariance analysis was used to check whether values of *b* obtained from using different length types were statistically similar.

Results

The LWR was estimated for 139 data sets corresponding to 85 fish species (80 teleosts and 5 elasmobranchs) from 41 families. Sample size ranged from 10 to 986 individuals (mean = 114). Sample size, length and weight ranges, parameter estimates and determination coefficients (r^2) from non-linear regressions for each species are presented in Table 1.

For all 139 data sets, RSS yielded by the non-linear procedure was lower than those from both the ordinary and functional regression methods. Non-linear RSS was on average 5.5 per cent and 6.3 per cent lower than that from the ordinary and functional regression methods, respectively. The difference was greater for the smaller sample sizes (Fig.2). For n<100, the mean difference between non-linear RSS and either the ordinary or the functional RSS was around 7 per cent, dropping to less than 2 per cent for n>300. Ordinary regression yielded a better fit than functional regression for 93 data sets and a Wilcoxon test indicated a significant difference in residuals from these linear methods (P = 0.0032).

For 104 data sets, the allometry coefficient *b* calculated by functional regression was higher than that of the non-linear procedure and a Wilcoxon test showed a highly significant (P < 0.0001) difference in estimates of *b* between these methods. As predicted by Ricker's model (1973), values of *b* obtained by functional regression were always

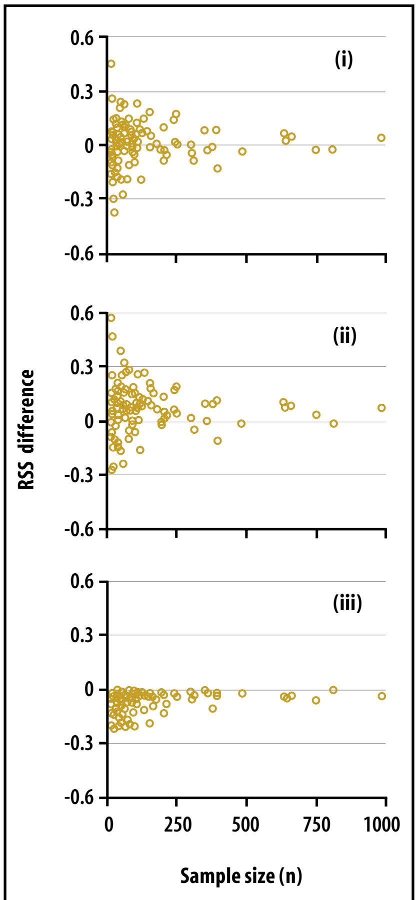


Fig. 3. Absolute differences between estimates of LWR allometry coefficient *b* from three regression methods for 139 sets of length-weight data plotted against sample size. **(i)** ordinary - non-linear; **(ii)** functional - non-linear; **(iii)** ordinary - functional.

higher than those obtained by ordinary regression. No statistical difference was detected between values of *b* estimated by ordinary regression and by the non-linear method. Differences among values of *b* estimated by the different regression models were greater for smaller sample sizes (Fig.3).

In terms of the influence of length type, SL data yielded a lower allometry coefficient *b* than TL data for 23 out of 39 species analyzed, and estimates obtained from these length types differed significantly ($P = 0.0075$). The Wilcoxon test did not show significant statistical difference between estimates of *b* obtained from FL and either TL or SL data. Allometry coefficients calculated from different length types are plotted in Fig.4.

The estimate of *b* obtained from SL data was statistically different from that of TL data for four species, namely *Dermatolepis inermis* ($P < 0.0001$), *Malacanthus plumieri* ($P = 0.0012$), *Holocentrus ascensionis* ($P = 0.0102$) and *Pseudopercis numida* ($P = 0.0171$). When comparing *b* obtained from TL and FL data, significant differences were found for *Balistes capriscus* ($P < 0.0001$), *M. plumieri* ($P < 0.001$), *Ocyurus chrysurus* ($P = 0.0075$), *P. numida* ($P = 0.0202$) and *Lopholatilus villarii* ($P = 0.0458$). Only for *Balistes vetula* we found a significant difference between estimates of *b* obtained from FL and SL data ($P < 0.0001$).

Discussion

When comparing LWRs available in the literature, one might find wide variability in parameter estimates for a single species. This is due to the fact that the LWR is greatly affected by many factors related to population variability and to sampling and estimation methods. Sampling related factors include sample size, length distribution in the sample and type of length measure, while nutritional conditions account for intrinsic biological variability (Ricker 1975). Parameter estimates are only good enough for the population studied and awareness of time of sampling is essential. Efficient sampling must include the widest possible range of lengths, generally obtained with large samples and non-selective fishing techniques. In this study, we estimated the LWR for some data sets with small sample size and homogeneous length distribution in order to analyze variability in parameter estimates related to sample characteristics.

Different mathematical models used for the calculations may also significantly affect LWR parameter estimates. For all data sets analyzed in this study, a non-linear method (using the quasi-Newton algorithm) yielded lower RSS when compared to both ordinary and functional linear regressions. Our results are in accordance with those reported by Haimovici and Velasco (2000) and strongly suggest that, whenever possible, the LWR should be calculated using non-linear procedures.

The GM functional regression model predicts that the resulting estimate of the slope *b* will always be higher than that of the ordinary regression (Ricker 1973). In the present study, we found that functional regression estimates of *b* were also significantly higher than those yielded by the non-linear method. As the non-linear method always produces a better fit and, therefore, best represents the relationship between the variables length and weight, this result suggests that the GM functional regression may lead to overestimation of the LWR allometry coefficient *b*, especially when sample size is small.

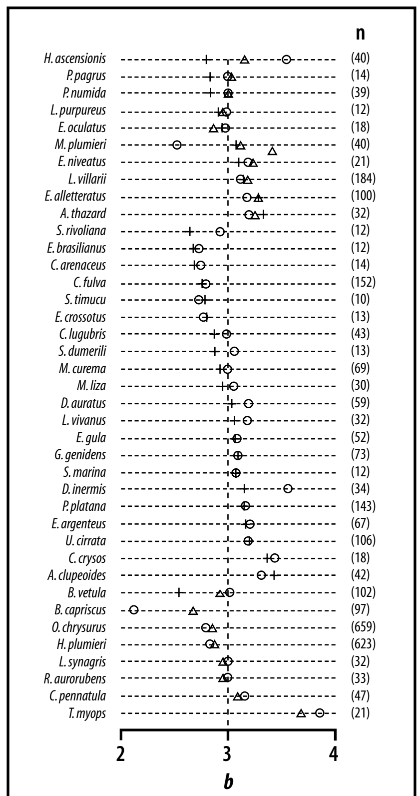


Fig. 4. LWR allometry coefficients *b* calculated based on (o) TL data, (Δ) FL data and (+) SL data for 39 species of marine fishes from the central Brazilian coast (n).

Table I. Non-linear length-weight relationships of 85 species of marine fishes from eastern Brazil.

Family	Species	*n	Length	Length (cm)		Total weight (g)		LWR		
			Type	min.	max.	min.	max.	a	b	r²
Triakidae	*Mustelus canis*	121	TL	57.0	111.0	586,2	4789.7	0.0034	3.006	0.967
Carcharhinidae	*Prionace glauca*	74	TL	183.0	288.0	24000.0	100000.0	0.0110	2.828	0.885
	Carcharhinus signatus	10	TL	95.5	230.3	4391.0	59700.0	0.0091	2.886	0.998
Squalidae	*Squalus megalops*	24	TL	49.5	79.0	486.6	2342.0	0.0038	3.042	0.955
	Squalus mitsukurii	34	TL	59.4	89.8	838.1	3301.8	0.0021	3.176	0.943
Elopidae	*Elops saurus*	16	SL	16.2	36.3	34.5	573.0	0.0040	3.290	0.988
Muraenidae	*Gymnothorax moringa*	212	TL	51.0	103.0	200.0	2287.4	0.0003	3.431	0.957
	Gymnothorax polygonius	22	TL	55.2	80.8	298.7	988.0	0.0011	3.113	0.949
Engraulidae	*Anchoa januaria*	35	SL	5.0	6.9	1.9	4.3	0.0396	2.412	0.842
	Anchovia clupeoides	200	SL	9.8	15.2	12.4	54.2	0.0081	3.219	0.891
	A. clupeoides	47	TL	13.8	17.9	15.4	38.1	0.0045	3.149	0.884
	Cetengraulis edentulus	17	SL	9.2	10.9	15.6	25.4	0.0149	3.123	0.889
Clupeidae	*Opisthonema oglinum*	75	TL	7.5	25.3	3.0	125.6	0.0140	2.790	0.987
	Platanichthys platana	240	SL	2.5	9.7	0.3	16.1	0.0198	2.945	0.955
	P. platana	144	TL	3.5	11.0	0.3	12.2	0.0072	3.102	0.946
	Sardinella brasiliensis	40	FL	15.8	18.5	51.7	88.9	0.0086	3.155	0.891
Ariidae	*Genidens genidens* (juvenile)	153	SL	5.0	8.8	1.8	9.4	0.0179	2.888	0.971
	G. genidens	92	SL	9.0	26.2	9.9	335.5	0.0089	3.198	0.990
	G. genidens	77	TL	8.3	32.3	4.1	267.0	0.0042	3.190	0.995
Synodontidae	*Trachinocephalus myops*	21	FL	20.6	30.0	88.7	394.1	0.0007	3.881	0.976
	T. myops	21	TL	22.5	32.6	88.7	394.1	0.0004	3.972	0.981
Polymixiidae	*Polymixia lowei*	10	TL	25.2	46.3	204.3	1398.5	0.0119	3.039	0.981
Ophidiidae	*Genypterus brasiliensis*	41	TL	35.4	96.2	306.0	4637.7	0.0147	2.766	0.996
Phycidae	*Urophycis cirrata*	251	TL	24.0	53.5	95.4	1191.6	0.0042	3.166	0.968
	U. cirrata	108	SL	22.5	48.0	116.5	1294.3	0.0059	3.177	0.975
Merlucciidae	*Merluccius hubbsi*	151	TL	16.6	50.5	26.8	955.0	0.0090	2.937	0.967
Lophiidae	*Lophius gastrophysus*	19	TL	41.0	67.5	1040.0	4340.0	0.0086	3.140	0.973
Mugilidae	*M. curema* (juvenile)	246	SL	2.1	8.4	0.2	17.7	0.0262	3.004	0.994
	Mugil curema (adult)	200	SL	10.3	28.3	23.9	489.4	0.0493	2.710	0.970
	M. curema (adult)	72	TL	17.4	35.7	58.7	489.4	0.0108	2.969	0.974
	Mugil liza	104	SL	13.9	37.1	42.7	816.5	0.0398	2.767	0.966
	M. liza	32	TL	17.5	42.2	42.7	657.8	0.0078	3.032	0.991
Belonidae	*Strongylura marina*	24	SL	35.3	73.4	62.3	674.8	0.0011	3.108	0.990
	S. marina	12	TL	37.6	78.3	62.3	674.8	0.0007	3.175	0.993
	Strongylura timucu	10	SL	34.0	47.4	62.5	161.7	0.0037	2.769	0.964
	S. timucu	10	TL	36.7	51.4	62.5	161.7	0.0043	2.672	0.955
Holocentridae	*Holocentrus ascensionis*	67	TL	26.5	37.9	213.0	613.7	0.0079	3.076	0.847
	H. ascensionis	60	FL	20.1	31.1	137.5	650.0	0.0121	3.147	0.911
	H. ascensionis	55	SL	17.5	28.4	137.5	605.1	0.0734	2.682	0.878
Dactylopteridae	*Dactylopterus volitans*	11	TL	35.2	44.0	496.4	802.6	0.0851	2.424	0.959
Scorpaenidae	*Pontinus rathbuni*	17	TL	21.6	33.4	126.6	641.6	0.0039	3.398	0.977
Triglidae	*Prionotus nudigula*	11	TL	26.6	38.1	226.3	887.4	0.0010	3.738	0.966
Serranidae	*Cephalopholis fulva*	751	TL	16.5	40.0	75.8	1177.3	0.0114	3.128	0.950
	C. fulva	165	SL	15.7	32.7	141.0	919.3	0.0755	2.727	0.928
	Dermatolepis inermis	56	TL	42.3	92.5	1236.1	15700.0	0.0015	3.551	0.973
	D. inermis	47	SL	33.1	79.0	1236.1	15700.0	0.0111	3.243	0.994
	Epinephelus adscensionis	11	SL	31.5	46.0	847.0	3044.8	0.0125	3.224	0.966

continue >

< continued

Family	Species	*n	Length	Length (cm)		Total weight (g)		LWR		
			Type	min.	max.	min.	max.	a	b	r²
	Epinephelus marginatus	19	TL	53.3	93.5	2431.5	15000.0	0.0107	3.126	0.991
	Epinephelus morio	69	FL	49.0	84.0	2000.0	8000.0	0.0606	2.661	0.892
	Epinephelus niveatus	120	TL	34.5	121.6	595.6	23030.0	0.0259	2.867	0.978
	E. niveatus	25	SL	28.3	95.5	595.6	20000.0	0.0249	2.990	0.980
	Mycteroperca bonaci	359	FL	42.2	143.0	1016.6	46000.0	0.0069	3.153	0.979
	Mycteroperca acutirostris	23	FL	32.7	46.2	543.3	1457.2	0.0130	3.033	0.957
	Mycteroperca interstitialis	22	FL	44.5	75.5	911.5	5000.0	0.0009	3.582	0.956
Malacanthidae	*Caulolatilus chrysops*	10	TL	38.9	55.4	604.5	1920.0	0.0065	3.130	0.955
	Lopholatilus villarii	483	TL	37.5	98.0	603.0	12500.0	0.0054	3.181	0.988
	L. villarii	193	FL	40.9	89.8	874.4	10474.1	0.0054	3.216	0.991
	L. villarii	192	SL	35.0	79.0	874.4	10474.1	0.0111	3.155	0.984
	Malacanthus plumieri	51	TL	35.4	69.5	313.1	1879.8	0.0206	2.692	0.926
	M. plumieri	45	SL	42.2	60.5	556.3	1879.8	0.0047	3.147	0.946
	M. plumieri	44	FL	46.2	69.5	556.3	1879.8	0.0240	2.655	0.918
Pomatomidae	*Pomatomus saltatrix*	67	TL	48.0	75.5	977.8	3143.8	0.0595	2.509	0.968
Coryphaenidae	*Coryphaena hippurus*	302	FL	54.0	138.5	1417.1	21500.0	0.0202	2.799	0.940
Carangidae	*Alectis ciliaris*	11	FL	84.5	114.0	7000.0	16300.0	0.0786	2.579	0.851
	Caranx crysos	380	FL	23.3	43.1	242.4	1485.4	0.0306	2.861	0.938
	C. crysos	18	SL	31.5	48.2	630.0	3002.1	0.0043	3.465	0.980
	C. crysos	16	TL	34.5	43.2	463.4	830.1	0.0459	2.593	0.913
	Caranx latus	300	FL	34.1	89.0	780.1	10400.0	0.0674	2.668	0.987
	Caranx lugubris	48	SL	32.7	61.5	922.9	5655.6	0.0572	2.794	0.982
	C. lugubris	48	TL	42.0	73.0	922.9	4484.3	0.0187	2.900	0.966
	Seriola dumerili	313	FL	60.0	150.5	3000.0	40400.0	0.0363	2.771	0.973
	S. dumerili	22	TL	43.6	140.0	937.9	29500.0	0.0144	2.949	0.987
	S. dumerili	16	SL	43.5	77.5	2094.3	11363.0	0.0159	3.089	0.982
	Seriola rivoliana	87	FL	47.5	93.0	1500.0	11000.0	0.0359	2.801	0.958
	S. rivoliana	18	TL	51.0	98.4	1351.5	9649.1	0.0122	2.957	0.993
	S. rivoliana	12	SL	41.9	69.4	1351.5	5565.3	0.0409	2.783	0.974
Lutjanidae	*Etelis oculatus*	27	TL	56.5	99.5	1590.5	8476.8	0.0128	2.908	0.975
	E. oculatus	26	SL	41.7	74.0	1590.5	8476.8	0.0495	2.783	0.962
	E. oculatus	22	FL	45.8	80.5	1590.5	8476.8	0.0198	2.937	0.975
	Lutjanus analis	393	FL	37.0	83.0	972.4	10500.0	0.0282	2.890	0.967
	Lutjanus jocu	392	FL	24.5	81.1	278.3	12100.0	0.0057	3.287	0.969
	Lutjanus purpureus	17	FL	27.3	44.9	340.2	1608.8	0.0084	3.186	0.977
	L. purpureus	17	TL	30.4	49.8	340.2	1608.8	0.0072	3.143	0.972
	L. purpureus	12	SL	29.0	36.7	677.6	1352.4	0.0348	2.928	0.917
	Lutjanus synagris	86	FL	20.0	48.5	145.6	1881.8	0.0216	2.917	0.987
	L. synagris	34	TL	26.2	51.5	225.6	1812.1	0.0113	3.031	0.987
	Lutjanus vivanus	242	FL	26.2	54.0	333.7	2601.0	0.0191	2.966	0.974
	L. vivanus	65	TL	41.5	76.8	945.5	6687.7	0.0169	2.948	0.956
	L. vivanus	34	SL	32.0	56.0	945.5	4753.5	0.0232	3.051	0.929
	Ocyurus chrysurus	986	FL	23.0	53.5	214.5	2145.3	0.0328	2.812	0.975
	O. chrysurus	661	TL	28.0	63.8	214.5	2119.6	0.0235	2.740	0.973
	Rhomboplites aurorubens	46	FL	25.3	46.5	260.3	1495.9	0.0232	2.894	0.977
	R. aurorubens	33	TL	36.0	51.5	525.8	1495.9	0.0168	2.896	0.957
Gerreidae	*Eucinostomus argenteus*	350	SL	2.0	10.7	0.2	32.9	0.0313	2.919	0.986
	E. argenteus	77	TL	3.7	12.6	0.6	26.0	0.0113	3.045	0.986

continue >

< continued

Family	Species	*n	Length	Length (cm)		Total weight (g)		LWR		
			Type	min.	max.	min.	max.	a	b	r²
	Eucinostomus gula	110	SL	3.8	11.0	1.3	33.8	0.0209	3.122	0.972
	E. gula	59	TL	5.0	14.2	1.3	33.3	0.0124	3.015	0.977
	Eugerres brasilianus	21	SL	10.9	17.5	39.9	182.4	0.0200	3.176	0.981
	E. brasilianus	12	TL	14.6	19.5	39.9	85.6	0.0309	2.686	0.945
	Diapterus auratus	105	SL	5.9	14.4	6.9	105.7	0.0423	2.932	0.974
	D. auratus	60	TL	12.1	17.4	21.0	66.5	0.0185	2.896	0.945
Haemulidae	*Haemulon plumieri*	635	FL	15.2	34.6	81.3	891.8	0.0417	2.809	0.962
	H. plumieri	639	TL	17.1	39.1	81.3	891.8	0.0335	2.772	0.959
	Orthopristis ruber	152	TL	16.9	24.4	65.6	183.1	0.0265	2.748	0.872
Sparidae	*Calamus pennatula*	50	TL	17.3	31.2	80.0	510.0	0.0119	3.093	0.986
	C. pennatula	48	FL	14.8	28.0	80.0	510.0	0.0463	2.810	0.984
	Pagrus pagrus	809	TL	17.0	64.5	76.0	3781.3	0.0206	2.898	0.991
	P. pagrus	14	FL	24.8	42.3	336.2	1711.8	0.0160	2.965	0.989
	P. pagrus	14	SL	21.7	38.0	336.2	1711.8	0.0307	2.910	0.984
Sciaenidae	*Menticirrhus americanus*	33	TL	12.3	33.2	22.8	428.0	0.0068	3.157	0.991
	Umbrina canosai	84	TL	24.7	41.5	222.8	981.2	0.0275	2.804	0.949
Mullidae	*Mullus argentinae*	95	TL	13.6	26.0	32.2	235.7	0.0086	3.129	0.857
Pinguipedidae	*Pseudopercis numida*	97	TL	44.8	98.7	862.9	9674.5	0.0125	2.954	0.991
	P. numida	45	FL	44.2	95.8	1036.1	9674.5	0.0152	2.939	0.988
	P. numida	45	SL	38.3	86.0	1036.1	9674.5	0.0562	2.715	0.985
Percophidae	*Percophis brasiliensis*	90	TL	41.6	68.5	328.4	1501.3	0.0046	3.000	0.911
Sphyraenidae	*Sphyraena barracuda*	77	FL	58.3	139.0	1234.3	18000.0	0.0070	2.972	0.944
Gempylidae	*Lepidocybium flavobrunneum*	35	TL	71.0	180.0	4400.0	60000.0	0.0255	2.840	0.962
Trichiuridae	*Trichiurus lepturus*	111	LPA	21.4	63.0	115.0	2275.0	0.0338	2.653	0.966
Scombridae	*Acanthocybium solandri*	43	FL	82.6	176.0	2900.6	36000.0	0.0016	3.275	0.978
	Auxis thazard	34	SL	23.0	29.3	214.8	511.2	0.0080	3.273	0.944
	A. thazard	34	TL	26.9	34.8	214.8	511.2	0.0060	3.194	0.951
	A. thazard	33	FL	24.6	31.7	214.8	511.2	0.0089	3.170	0.926
	Euthynnus alletteratus	104	TL	25.9	39.5	192.2	691.6	0.0065	3.153	0.966
	E. alletteratus	103	FL	23.4	35.2	192.2	691.6	0.0072	3.225	0.968
	E. alletteratus	103	SL	22.0	32.7	192.2	691.6	0.0094	3.216	0.966
	Scomberomorus cavalla	100	FL	55.7	151.0	1217.9	23000.0	0.0164	2.821	0.974
Scombridae	*Thunnus albacares*	71	FL	82.0	136.5	8000.0	39700.0	0.0147	3.013	0.967
	Thunnus atlanticus	130	FL	45.5	90.0	1799.4	12500.0	0.1250	2.551	0.883
Xiphiidae	*Xiphias gladius*	31	LJF	90.0	226.0	7500.0	150000.0	0.0056	3.150	0.985
Paralichthyidae	*Citharichthys arenaceus*	36	SL	3.5	9.6	0.7	16.1	0.0101	3.280	0.989
	C. arenaceus	14	TL	4.3	5.5	0.7	1.5	0.0127	2.760	0.885
	Etropus crossotus	14	SL	3.8	6.8	1.1	6.3	0.0162	3.092	0.983
	E. crossotus	13	TL	4.7	8.6	1.1	6.3	0.0111	2.937	0.989
Balistidae	*Balistes capriscus*	119	FL	19.7	36.9	165.0	1005.0	0.0240	2.942	0.974
	B. capriscus	97	TL	21.3	46.7	165.0	895.0	0.1823	2.215	0.962
	Balistes vetula	174	FL	26.2	49.0	520.1	3345.0	0.0205	3.064	0.956
	B. vetula	102	SL	21.2	43.0	520.1	3101.8	0.2328	2.513	0.923
Tetraodontidae	*Lagocephalus laevigatus*	11	SL	25.9	38.9	360.1	1102.8	0.3382	2.223	0.910

* n - sample size; TL - total length; FL - fork length; SL - standard length; LPA - pre-anal length; LJF - lower jaw-fork length; a, b - regression coefficients; r^2 - determination coefficient

The LWRs have been computed using different types of length and weight measures. The combination most frequently used in fishery studies is FL and fresh total body weight (Ricker 1975). In this study, we found that different length types can lead to statistically different estimates of the LWR allometry coefficient *b* and SL data tended to yield lower values of *b* than TL data. Choosing the use of TL, FL or SL for fish population studies means choosing total or partial inclusion or exclusion of the caudal fin in the length measure, and this can be a controversial matter.

Fins are highly compressed structures, devoid of muscle. Therefore, there is a considerable difference in growth allometry and relative weight gain of the caudal fin as compared to the rest of a fish body. This becomes even more significant if we consider fishes with odd shaped caudal fins. We found significant differences in estimates of *b* from TL and either SL or FL data for species such as *B. capriscus, M. plumieri* and *L. villarii*, all characterized by a filamentous prolongation in the distal tips of the caudal fin. The same occurred for *O. chrysurus* and *H. ascensionis*, which have deeply forked caudal fins with relatively long lobes.

Fishery researchers must be aware that the LWR can be significantly affected by sampling and computational procedures, and efforts should be made to obtain appropriate and comparable parameter estimates.

Acknowledgements

This work was supported by the REVIZEE Program (Living Resources of the Economic Exclusive Zone), including funds from the Ministry of the Environment and the Ministry of Science and Technology, Brazilian Government. One of the authors received a research fellowship from CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico). The authors are indebted to many captains, fishermen and fishing plant personnel of the Porto Seguro harbor, whose cooperation made this study possible. We specially thank Domingos Almeida Carvalho and José Carlos Thomy Dultra, from the Cooperativa Mista de Pescadores do Sul da Bahia (COPESSULBA), for providing all the support and assistance at Porto Seguro. We also thank Mr. Tinho, from Frigorífico Rio Buranhém ltda., and José Paes Leme Marçano, from Peixaria Beira Mar ltda., for their valuable help.

References

Castro, B.M. and L.B. Miranda. 1998. Physical oceanography of the western Atlantic continental shelf located between 4° N and 34° S coastal segment (4,W). The Sea 11:209-251.

Gulland, J.A. 1983. Fish stock assessment: a manual of basic methods. FAO/Wiley Series on Food and Agriculture, Rome.

Haimovici, M. and G. Velasco. 2000. Length-weight relationships of marine fishes from southern Brazil. *Naga*, ICLARM Q. 23(1):19-23.

King, M. 1995. Fisheries biology, assessment and management. Fishing New Books, Blackwell Science Ltd., Cambridge.

Nonaka, R.H., Y. Matsuura and K. Suzuki. 2000. Seasonal variation in larval fish assemblages in relation to oceanographic conditions in the Abrolhos Bank region off eastern Brazil. Fish. Bull. 98(4):767-784.

Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Int. Comm. Northwest Atl. Fish. Res. Bull. 9:65-74.

Ricker, W.E. 1973. Linear regressions in fisheries research. J. Fish. Res. Board Can. 30:409-434.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191.

Sparre, P., E. Ursin and S.C. Venema. 1989. Introduction to tropical fish stock assessment. Part 1. Manual. FAO Fisheries Technical Paper. No. 306.1. Rome, FAO.

Zar, J.H. 1984. Biostatistical analysis. Prentice Hall, New Jersey.

L.O. Frota[1], **P.A.S. Costa**[2] and **A.C. Braga**[2] are from Depto. de Ciências Naturais, Lab. de Dinâmica de Populações Marinhas. Fundação Universidade do Rio de Janeiro (UNI-RIO). Av. Pasteur, 296 – Urca, Rio de Janeiro, Brasil. 22290-240
Email: [1]lofrota@uol.com.br; [2]pcarr@uol.com.br

Use of a fishery independant index to predict recruitment and catches of the spiny lobster

R. Cruz and R. Adriano

Abstract

This paper presents a review of recruitment and catch predictions based on an index of abundance of juveniles and pre-recruits (fishery independent index) in the Cuban lobster fisheries. This methodology can provide information based on fisheries data that can improve the management of the fishery.

Introduction

The Caribbean spiny lobster (*Panulirus argus*) supports economically important fisheries throughout its distribution from Bermuda and North Carolina in the United States, to Rio de Janeiro in Brazil. The Cuban archipelago supports the most valuable fishery for *P. argus* in the Caribbean that accounts for 30 to 35 per cent of the sold commercial catches in the region. The Cuban fishery involves 250 boats and 1 300 fishermen who operate 300 000 fishing gears during a nine-month fishing season. The fishing methods for *P. argus* are unique: 70 per cent of fishing gear is artificial shelters (*pesqueros*) made from the trunks of a coastal tree or from fibrocement sheets and palm trunks.

Spiny lobsters are distributed widely in shallow waters with seagrass beds. Measurements of the juvenile, pre-adult, and adult spiny lobster abundance can be easily undertaken by collecting them from the artificial shelters. The juvenile abundance indices for lobsters in artificial shelters have been used successfully in the forecast of recruitment and catches of the lobster in Cuba and in Australia. The juvenile index is a measure of abundance independent from the fisheries data. Although the recruitment can be measured with the catch and effort data (González 1991; Medley and Ninnes 1997), the measurement in Caribbean spiny lobster fishery is complex because the lobsters are caught by a range of fishing gears which make it difficult to obtain a single measure of effort.

The objective of this paper is to summarize the data on artificial shelters collected over more than a decade and use it as an alternative tool to predict recruitment and catches of the juveniles and pre-recruit Caribbean spiny lobster in Cuba.

Materials and Methods

This study was done in the Gulf of Batabanó which lies in the southwestern part of the Cuban archipelago (Fig. 1).

Fig. 1. Map of the Cuban western archipelago showing the locations of monitoring sites in the Gulf of Batabanó (Bocas de Alonso and Coloma).

Study of the abundance of juveniles (16 to 50 mm Carapace Length - CL) began in 1980 at selected sites at Bocas de Alonso, located southeast of the Isla de la Juventud. The study of mature and pre-recruit lobsters (50 to 77 mm CL) was carried out in the fishing grounds of the west Coloma region.

Artificial shelters of concrete blocks were used to sample juveniles (Fig. 2). The shelters consisted of two layers of eight blocks placed on top of one another forming a square of 16 blocks measuring 118 x 30 cm. A total of 60 artificial shelters were positioned in the nursery area, separated by 25 to 30 m, covering an area of 0.25 km^2. Lobsters were caught by SCUBA divers (using hand bully nets or lobster nets). They were classified and then returned to the same shelter from which they were caught. Monthly sampling of juveniles was conducted over 180 months during the period 1982 to 1996. The annual index of abundance of juveniles was calculated as the mean numbers per block per month (January to December) and per station.

Sampling of mature and pre-recruit lobsters was carried out using artificial shelters (*pesqueros*), also known as Cuban casitas in Mexico (Fig. 2). The index of abundance of pre-recruits in the fishery was calculated as the average number of undersized lobsters per *pesquero* noted by the researchers every month. Further details of the concrete blocks and *pesqueros* used as shelters and the sampling methods have been described by Cruz and Phillips (2000) and Cruz (2002).

Four models for the predictions of the lobster catch were used: 1) full year model (January-December); 2) natural year model (June-February); 3) *recalo* model (October-February); and 4) *levante* model (June-September). The catches were calculated using the following equations:

1) Full year model:

$$\text{Catch} = 5203+64.83\ Ij_{(t-1)}$$

2) Natural year model:

$$\text{Catch} = 5003+73411\ Ij_{(t-1)}$$

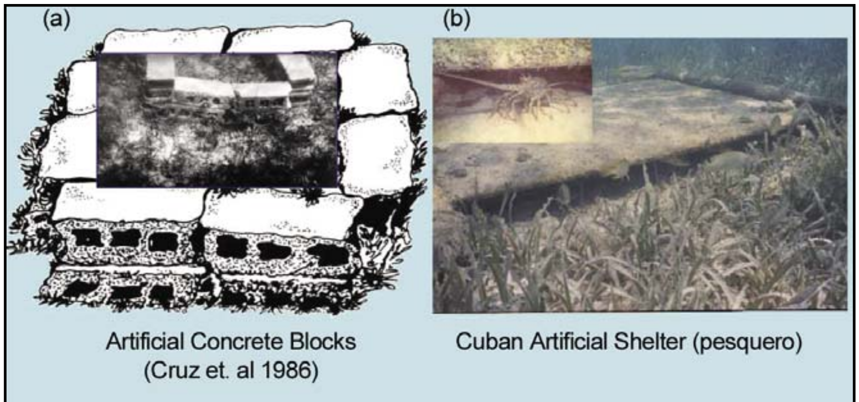


Fig. 2. (a) Schematic representation of the artificial concrete blocks; and (b) Cuban artificial shelter (*pesquero*) used for sampling juvenile and pre-recruit lobsters.

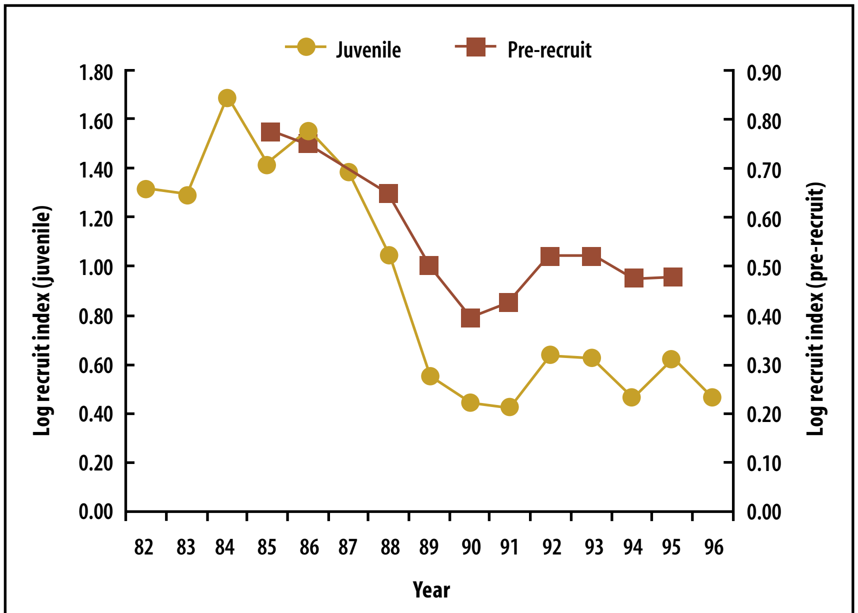


Fig. 3. Annual log juvenile index (1982-1996) at Bocas Alonso and log pre-recruit index (1984-1995) at the Coloma region, Gulf of Batabanó, Cuba.

3) *Recalo* model:

$$\text{Catch} = 3.9701(Ij_{(t-1)}\text{\^{}}0.1111)(ft\text{\^{}}0.6767)$$

4) *Levante* model:

$$\text{Catch} = 3987+40.89Ij_{(t-1)}-0.49\ \text{Catch}_{(recalo)(t-1)}$$

where, $Ij_{(t-1)}$ = index juvenile previous year (t-1); $\text{Catch}_{(recalo)(t-1)}$ = recalo catch in the previous season (t-1); ft = number of fishing days, during the months of October to February, in the year t.

Results and Discussion

Between 1982 and 1994, 21 047 lobsters were caught, ranging in size from 12 to 77 mm (CL) in the nursery area of Bocas de Alonso. Altogether 69 979 adult lobsters were measured between 1985 and 1990, of which 35 542 were male and 34 437 were female, in the fishing ground of Coloma.

Indices of the abundance of juveniles and pre-recruits varied considerably from year to year (Fig. 3). In each area, recruitment indices declined over time from 1982 to 1996. The catches of juveniles in the concrete blocks reached their highest levels between 1982 and 1988 and their lowest levels between 1989 and 1996. The difference was highly significant (t =9.1985, p <0.001). These two periods

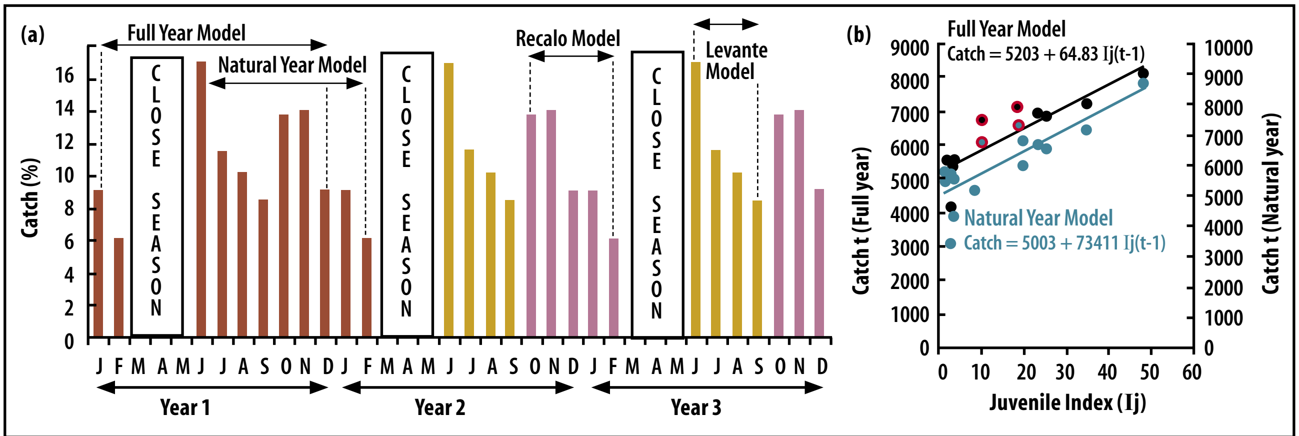


Fig. 4. Summary of seasonal models for predictions of the lobster catch in the Gulf of Batabanó, Cuba: (a) schematic representation of the period used for the prediction of the lobster catch; (b) relationship between annual juvenile index and the catch of Panulirus argus one year later using the full year and natural model.

also differed significantly in terms of catch rates of pre-recruits (t = 3.2152, p <0.001). The index of abundance of juveniles was significantly correlated with that of pre-recruits (sub-legal) lobsters in the following year at location of Coloma (n = 9; R^2 = 0.8573, p <0.01). This result confirms that the juvenile and pre-recruit abundance indices are associated with the recruitment levels of lobsters to the fishery at those stations. The lower juvenile numbers during 1988 to1990 were reflected in the lower numbers of the pre-recruits to the fishery.

The seasonal pattern of average catches (%) from 1978 to 1996, the methods and the equations of each model for predicting the lobster catch in the Gulf of Batabanó are summarized in Fig. 4. The full year prediction model (January-December) of recruitment in the fishery is based on the high correlation between the commercial catch in any year and the juveniles abundance index, before the lobsters are recruited to the fishery. A highly significant relationship was observed between the juvenile abundance index of a particular year and the lobster catch (t) in the following year in the Gulf of Batabanó (n =14; R^2 = 0.77, p <0.001) (Cruz et al. 1995; Cruz et al. 2001). This model predicted lobster catch for the period 1983 to1996 from the annual index of juvenile abundance one year earlier (1982 to 1995).

The natural year (June-February) prediction model (Fig. 4) of recruitment in the fishery is based on the highly significant relationship between the juvenile abundance index and the lobster catch for the following natural year (n =14; R^2 = 0.67, p <0.001). Methods have also been developed that predict the catch from the *puerulus* settlement indices (Phillips 1986) and/or juvenile abundance (Caputi et al. 1991, 1995; Phillips et al. 2000) of the western rock lobster, *Panulirus cygnus*.

In Cuba, separate predictions of the lobster catch are made for the two parts of the fishery (Fig. 4): the season of the massive migrations or *recalo* (October-February) and the *levante* season (in June), just after the beginning of the fishing season, because the lobsters enter the artificial shelters in the fishing area during the closed season in March to May). By examining these two phases of the fishery separately, Cruz et al. (2001) have shown that the catch during massive lobster migrations is dependent on the intensity of recruitment and the number of fishing days. In the *levante* season (June-September), it depends on the juvenile index and the catches during the previous *recalo*).

The poor prediction of the lobster catches in 1984 and 1989 (pointed with red ring, in the full year and natural year model as seen in Fig. 4) resulted from the very few data points of the juvenile index in 1983 and 1988, respectively. This discrepancy may be the result of fluctuations in annual catches induced by environmental conditions that affect the catch of legal-sized lobsters or the levels of recruitments (Cruz and Adriano 2001).

The independent recruitment index model provides a good basis for assessing the lobster stock. In particular, it permits new management options to be developed to plan for fluctuations in recruitment. The current results suggest that the stock is largely self-recruiting and the spawning stock requires careful management.

Acknowledgments

We express our gratitude to the research staff of Cerntro de Investigaciones Pesqueras and Centro de Investigaciones Marinas de la Universidad de la Habana, who supported and helped the monthly monitoring program.

References

Cruz, R. 2002. Manual de métodos de muestreo para la evaluación de las poblaciones de langosta espinosa. Fao Documento Técnico de Pesca. No. 399. Roma.

Cruz, R. and R. Adriano. 2001. Regional and seasonal prediction of the

Caribbean lobster (*Panulirus argus*) commercial catch in Cuba. Mar. Freshwater Res. 52**:**1633–1640.

Cruz, R., E. Díaz, M. Báez and R. Adriano. 2001. Variability in recruitment at multiple life stages of the Caribbean spiny lobster, *Panulirus argus*, in the Gulf of Batabanó, Cuba. Mar. Freshwater Res. 52**:**1263–1270.

Cruz, R. and B.F. Phillips. 2000. The artificial shelters (*pesqueros*) used for the spiny lobster (*Panulirus argus*) fisheries in Cuba, p. 400-419. ***In*** B. F. Phillips and J. Kittaka (eds.) Spiny Lobster Management: Fisheries and Culture. Second Edition. Fishing News Books, Oxford.

Cruz, R. M.E de León & R. Puga (1995): Prediction of comercial catches of the spiny lobster *Panulirus argus* in the Gulf of Batabanó. Fourth International Workshop on Lobster Biology and Management, 1993. Crustaceana Vol 68(2):238-244.

González, C. J. 1991. Migration and refuge in the assessment and management of the spiny lobster *Panulirus argus* in the Mexican Caribbean. Ph.D. Thesis, Imperial College, University of London, UK. 448 p.

Medley, P.A.H. and C. H. Ninnes. 1997. A recruitment index and population model for spiny lobster (*Panulirus argus*) using catch and effort data. Canadian Journal of Fisheries and Aquatic Sciences 54**:**1414-1421.

Phillips, B. F., R. Cruz, N. Caputi and R. Brown. 2000. Predicting the catch of spiny lobster fisheries. p357-375. ***In*** B.F. Phillips and J. Kittaka (eds.) Spiny Lobster Management: Fisheries and Culture. Second Edition. Fishing News Books, Oxford.

Phillips, B.F. 1986. Prediction of commercial catches of the western rock lobster *Panulirus cygnus* George. Canadian Journal of Fisheries and Aquatic Sciences 43:2126-2130.

Caputi, N., R.S. Brown and C. F. Chubb. 1995.Regional prediction of the western rock lobster, *Panulirus cygnus*, commercial catch in Western Australia. *Crustaceana* 68:245-256.

Caputi,N., R. S. Brown and B. F. Phillips. 1991. Prediction of the catches of the western rock lobster (*Panulirus cygnus*) based on indices of puerulus and juvenile abundance. Revista de Investigaciones Marinas 12(1–3): 57-65.

R. Cruz and **R. Adriano** are from the Centro de Investigaciones Marinas de la Universidad de la Habana. Calle 16 # 114 entre 1era y 3era. Miramar, Ciudad de la Habana, Cuba.
Email: rcruz@comuh.uh.cu

Indicators for management of coral reefs and their applications to marine protected areas

M.C.A. Ablan, J.W. McManus and K. Viswanathan

Abstract

Informed planning and decision-making in the management of natural resources requires an ability to integrate complex interactions in ecosystems and communicate these effectively to stakeholders. This involves coping with three fundamental dilemmas. The first comes from the irregular pulse of nature. The second is the recognition that there are no strictly objective criteria for judging the "well-being" of an ecosystem. The third is posed by the quest for indicators with some integrative properties that may be used to analyze an ecosystem and impart the information to the relevant resource users. This paper presents some examples of indicators used to: 1) assess the status of a coral reef and, in particular, the state of its fisheries resources; 2) identify reefs that are most threatened by human activities; and 3) evaluate the likelihood of success of management interventions. These indicators are not exhaustive, but illustrate the range of options available for the management of coral reef ecosystems.

Introduction

Man has barely come to grips with understanding how ecosystems function and is now struggling to manage its finite resources in a sustainable manner. Science and research play a major role in providing the information required to plan and decide on management actions. This involves making some sense out of the complexities of interactions in the ecosystem and communicating the knowledge and its implications efficiently to multiple stakeholders (Hovgard et al. 2001).

There are three fundamental dilemmas that have to be dealt with in understanding these complexities. The first comes from the irregular pulse of nature. Natural variability in an ecosystem may prevent the recognition of substantive changes or give false alarms. Though ecosystem processes such as nutrient cycling, primary productivity and recruitment into the system are cyclical. They are also highly irregular. They display variations annually, seasonally and diurnally. Recognition of abnormalities is subject to the temporal scale of observations and the availability of long term monitoring information. False alarms may be easily sounded because of poor understanding of the dynamics of the system and the interactions among its components.

Secondly, one must recognize that there are no strictly objective criteria for judging the well being or ideal state of an ecosystem. The ideal state is inevitably based on some combination of desirable attributes that are not objectively selected. Several components in the ecosystem may actually have opposing definitions. More often than not, no single configuration of the ecosystem meets the biological, social, ecological and economic needs in the system.

The third dilemma is posed by the quest for indicators. A choice of what to monitor among the many components and processes occurring in the system has to be made. The chosen indicators must have some integrative properties that will reflect changes in more than one aspect of the system (Garcia and Staples 2000). These indicators must not be based on overly simplistic assumptions about the nature of the biological and ecological processes and human and ecosystem behavior. Indicators must be used in simple but robust systems of tracking instability. It must, however, be noted that indicator-based systems are not a complete substitute for more comprehensive sets of information that are needed and conventionally used to manage natural resource systems. However, indicator-based systems will greatly reduce the constant need for a comprehensive information base for making resource management decisions.

In all these, the issue of scale has to be addressed. Local communities and local government units are recognized as the primary stakeholders and participants in the management of natural renewable resources. However, the natural boundaries of ecosystems and the processes that support and stress these ecosystems may transcend the boundaries of these local management units. This is especially true for aquatic ecosystems where the concept of a continuum is well appreciated. Thus, efforts to arrest the decline in resources and loss of biodiversity for ecosystems such as coral reefs demand that research and assessment activities, and management interventions are carried out at the local, national and regional scales.

Indicators and the management of aquatic ecosystems

The development of indicators has been called for in Chapter 40 of the Earth Summit Agenda 21. The Conference on Sustainable Development (1993 and 1994) took this further by emphasizing the need for a "Menu of Indicators" that will serve as the basis for early warning systems, establishing cost effective data collection, monitoring and assessment of trends, and informed decision-making, particularly for natural resource systems (Garcia and Staples 2000). Carefully selected indicators may facilitate the processes and increase the effectiveness of the awareness-building efforts. Trends in indicators may also trigger changes in policies as well as approaches to managing ecosystems.

Potential applications of indicators

Indicators are useful in several ways. It may be worthwhile to mention a few types of indicators and their applications. This list is not exhaustive, but rather illustrative of the sorts of indicators that need to be identified as part of the menu of indicators for coral reef ecosystems.

Assessment indicators – are useful in choosing priority areas that need management interventions. Continuous monitoring of these indicators assists in evaluating the success of the implementation of the management programs and signifies when corrective action in the management plan is necessary.

Indicators of threat or risk – provide a means of anticipating and possibly preventing potential disasters. Indicators may help understand the complex interactions and assist in dealing with the sources of threats.

Success-likelihood indicators – are means of optimizing the results of a management intervention. Successful rehabilitation and sustainability of degraded aquatic ecosystems will depend on a number of biophysical and socio-economic factors (e.g., availability of fish, invertebrates and algae to replenish the system, their success in restoring the natural resources, potential for changes in human behavior that have initially led to the ecosystem decline, etc.). Indicators of these preconditions for success are useful in designing and implementing management initiatives.

For indicators to be effective, they must bring about a change in the behavior of users of the resource. In response to indicators, users of the resource must be willing to change their behavior, for example by reduction in harvest or compliance to regulations to improve habitats (e.g., the establishment of "no take zones").

Examples of static and dynamic uses of indicators in aquatic resources management

The use of indicators for management is a recent development for aquatic ecosystems and most have focused on the biophysical aspects of the system. Indicators may be used as static measures to assess the state of ecosystems. A simple example would be the adoption of the lake trout (*Salvelinus namaycush)* as an indicator of health of offshore oligotrophic waters in the intensively studied Lake Superior and Huron of the Great Lakes (Edwards et al. 1990). The continued presence of this environmentally sensitive species was an indication of the absence of man-made stresses from eutorphication, toxic substances, and harvesting.

Another example would be the Index of Biological Integrity (IBI). This set of indicators was widely adopted by state and federal agencies as a tool for water resources management in the US. The method employs an array of biological metrics derived from individual fish, fish populations and fish community assemblages in the rivers and lakes. Biological metrics are akin to economic indicators used in econometric analyses. Twelve metrics were identified under three categories: 1) species richness and composition; 2) trophic composition; and 3) fish abundance and condition. Scores given to each of the 12 metrics are summed and used to rate the condition (i.e., excellent, good, fair, poor or very poor) of the ecosystem (Karr and Chu 2000).

For coral reef ecosystems, several indicators have been developed for rapid assessment techniques for the purpose of management. Percentage of live coral cover, abundance and diversity of both coral and reef fish species, production from the fisheries, and the presence of various forms of stress to the ecosystem are some of the ones identified for biophysical conditions. Such indicators are generally used to report the status of reef ecosystems (Wilkinson 1999).

Maximum Sustainable Yield (MSY) and the Maximum Economic Yield (MEY) used by the fisheries sector are also examples of dynamic indicators used in natural resources management. MSY is defined by Caddy and Csirke (1983) as the limit reference point beyond which immediate and substantial action should be taken to protect harvested stock. MEY (Gulland 1969) is the point where the community derives the greatest net profit from the fishery. More recently, ESY or Ecologically Sustainable Yield has been identified as desirable. ESY is the yield an ecosystem can sustain without shifting to an undesirable state (Zabel et al. 2003). These are indicators of fishery potential as well as a development and management target. Unlike the indicators previously mentioned, MSY, MEY and ESY are more robust in that they integrate biophysical and socioeconomic aspects of the system.

Sets of indicators collected over a time period may be used dynamically. For instance, the trajectory of fish catch values after the imposition of gear restrictions may be compared with a trajectory set as a management goal. Dahl (1996) gives an example for populations of fish and pollution indicators. The deviations in trajectories may be used to make correction in either the management activity or the management goal. Linton and Warner (2003) present examples of indicators used for integrated coastal zone management in the Caribbean.

Marine protected areas and the management of coral reefs

Of the management approaches available for coral reefs, the designation of marine protected areas (MPAs) or fisheries reserves are conservation strategies that have received much interest and support globally. In fact, the designation of such reserve areas has expanded dramatically over the last few decades (Alder et al. 2002). Marine reserves are strongly advocated by many resource managers and biologists because they offer potential benefits to coastal fisheries and marine resources management, including the enhancement and restoration of fishery yields, protection of reproductive potential and maintenance of biological diversity (Hoagland et al. 2001). For fisheries that target highly mobile single species with little or no by-catch or habitat impact, MPAs provide few benefits compared to conventional fishery management tools (Hilborn et al. 2004).

The success stories of community-based management of reefs such as Sumilon and Apo islands in the Philippines further highlight this point. The designation of 20 per cent of a reef area as a "no take" zone resulted in a rehabilitation of the reef and increased fisheries yield (Alcala and Russ 2002). Designation of MPAs has become an intrinsic part of fisheries management pursued within the framework of integrated coastal zone management (ICZM) efforts.

To illustrate the importance of indicators for coral reef management, we present some examples of the applications of indicators for the designation and management of MPAs. The issue of scale needs to be highlighted because MPAs focus on local communities, yet the benefits and the risks of these marine reserves (e.g., sources of pollution, destructive harvesting of resources, poverty and environment policies, sources of recruits into the system, etc.) may not be strictly limited to the local communities. Furthermore, management units are defined relative to the scale of the reef areas being considered.

Indicators of levels of fishing on reefs

Coral reef fisheries provide food and livelihood to tens of millions of people throughout tropical and subtropical seas. A large proportion of these people survive on marginal incomes. Studies on the effect of fishing on coral reef resources published by Polounin and Roberts (1996), Birkeland (1997), McManus (1997), Hollingworth (2000), and Alcala and Russ (2002) all agree that declining catches from reef fisheries result from over-fishing.

Indicators of levels of fishing

There are hundreds of types of coral reef fisheries, and various combinations of methods and effort levels affect reefs in complex ways. However, it is possible to roughly classify the status of many reef fisheries into three stages (Table 1) with the following indicators.

Characteristic market species. This is probably the most immediate indicator of the state of a reef fishery. Relatively unstressed coral reefs support numerous large species that are easy to harvest. Because these species are generally of high value, it is desirable to maintain their populations and to ensure that large individuals are perpetually available for harvesting. Many species common on near-pristine reefs, such as giant clams, conchs and sharks, are characteristic of fisheries classified as by Stage I.

In more heavily fished reef systems (Stage II), large, high-value predatory fish such as groupers and snappers become uncommon, and there is a tendency for lower value species, such as parrotfish, wrasses and rabbitfish to predominate. The shift from high-value to lower-value species, both within the ecosystem and on the market, indicates "ecosystem overfishing" (Pauly 1979).

In some situations, a reef fishery becomes an employer of last resort. Under intense coastal crowding, open access to fisheries, and the absence of alternative livelihoods, the numbers of participants in coastal fisheries tends to increase until the average fisher receives little or no net income (Pauly et al. 1989; Pauly 1990). This is a situation that predominates in reefs in a Stage III fishery. Immature parrotfish, wrasses and butterfly fish are species characteristic of this stage. Reef and market species have not only shifted from high to lower value species, but fish that were not initially caught for consumption have been included in the regular catch (e.g., very small juveniles and butterflyfish).

In a Stage III fishery (McManus et al. 1995) there is a decline in the *median size of the catch*, in the *value per fish* and in the *catch per unit effort (CPUE)* based on legal means of fishing. CPUE is recorded, for example, as the weight of the fish caught per hour of fishing. Additionally, one can often identify the *use of destructive fishing methods*, which are harmful to the environment (e.g., blasting and poisoning) or the fishers themselves (e.g., make-shift hookah devices).

Two other indicators for levels of fishing may be identified with the availability of remotely sensed data. These are:

Devegetated haloes. The presence and size of haloes may be used as an indicator of the stage of a fishery. The haloes are areas around coral patches that are kept clear of vegetation by herbivorous fish or invertebrates such as sea urchins (Randall 1965; Pennings 1998). They are particularly visible on reef flats, where seagrass predominates and where interspersed patches of coral may be subject to coral-algal phase shifts. Fishing of piscivorous fish is expected to result in larger haloes, as herbivorous fish range farther from coral shelter and/or become more abundant under reduced predation.

Harvest of herbivorous fish and/or invertebrates in a Stage III fishery may lead to the disappearance of the haloes as vegetation closes in on the coral patches. This is particularly evident on the heavily fished Bolinao reef flat in the Philippines, where aerial photographs clearly show former halos filled in with various densities of seagrass (McManus et al. 1992).

Type of algae settling on coral. On near-pristine reefs, dead coral generally becomes covered with calcareous encrusting algae that appear to encourage coral settlement and growth (Yap and Gomez 1988). However, in the absence of the normal suite of large herbivorous fishes in Stage III fishing, green filamentous algae (e.g., *Enteromorpha*) tend to proliferate on dead coral. This process may be followed by the settlement of brown frondose algae (McClanahan 1997). The spectral signatures for zooxanthellae in living coral, recently dead coral, encrusting red calcareous algae, green algae and brown algae are markedly different and can be detected by multispectral scanners (McManus and Noordelos 1998).

Many examples of each of these stages of coral reef fisheries are to be found in major coral reef regions of the world. Some Pacific Islands and the Great Barrier Reef in Australia are in Stage I, although some overfishing may still occur, e.g., in parts of Fiji. Stage II fisheries predominate in the Caribbean and in east Africa. Stage III coral reef fisheries are most common in South Asia and Southeast Asia.

Application of this assessment indicator to the management of MPAs

Some MPAs are established for the purposes of rehabilitating a coral reef and increasing yield from the fishery. By designating a "no take" zone, fishers sacrifice a part of their fishing ground on the assumption that this will improve the yield and sustainability of the remaining fishing areas. The indicators described above are useful to evaluate the success of the MPA by initially assessing a fishery before the establishment of a protected area and subsequently monitor its changes.

Indicators of threats to coral reefs

The Reefs at Risk analysis of threats to coral reef systems is a map-based indicator analysis of threats to the world's coral reefs (Bryant et al. 1998). These same indicators were used for Southeast Asia and published in Burke et al. (2000). The Reefs at Risk analysis considers information from four major potential sources of threats to reefs: coastal development; overexploitation and destructive fishing practices; inland pollution and erosion; and marine pollution. These data are used to rate the level of threat to coral reef areas.

The analysis also considers the presence or absence of management initiatives in classifying reefs to different threat categories. The indicators used in the Reefs at Risk analysis are explained in more detail below.

Threat indicators

Coastal development. Increased human activity in the coastal zone, a condition that translates into greater levels of stress to a reef system, is associated with the rate of coastal development. Population size is a primary indicator of human impact. The presence of infrastructure and activities (e.g., airports, military bases, tourist zones and mining activity) that escalate erosion, siltation and eutrophication in an area are included in the analysis.

Marine pollution. Spillage from ocean vessels are a major threat to coral reefs. Oil spills expose coral reef habitats to toxic substances and slowly smother organisms that inhabit them. The size of ports is an indication of the size of ships and the frequency of their visits to an area. Data on shipping lanes and sites known to have narrow passages also help identify locations where grounding accidents are likely to occur. The presence of oil tanks and wells are noted.

Table 1. Characteristics of a coral reef fishery according to the three main stages.

	Stage I	Stage II	Stage III
Characteristic species	Snappers, groupers, sharks, moray eels, giant clams, conch	Mature parrotfish, wrasses, siganids	Immature parrotfish, wrasses, siganids, butterfly fish
Median sizes	> 100 cm	25-100 cm	8-25 cm
Presence of passive gear (e.g., hooks, traps, etc.)	Frequent	Moderate	Rare
Occurrence of blasting or poisoning	Occasional	Common	Frequent
CPUE (legal methods)	High	Moderate	Low
Value per fish	High	Moderate	Low
Occurrence of devegetated haloes	Moderate	Large	Small
Algae on dead coral	Calcareous	Calcareous and green filamentous	Green filamentous
Examples	Australia	Kenya	Philippines, Jamaica

Over-exploitation. This term is used interchangeably with overfishing. The previous discussion on coral reef fisheries has detailed the relationship between the condition of a reef fishery and the associated consequences on the reef coral, algae and fish communities. Given the close relationship between the level of exploitation and eventual reef condition, an indicator of threat based on over-exploitation is included. The information in the analysis is based on the opinion of experts who were asked to identify where destructive fishing practices occur.

Inland pollution and erosion. Agriculture, logging and mining activities inland can affect reefs. The relative erosion potential (REP) is used as the primary indicator for this threat. REP is computed based on satellite data giving the relative slope, land cover class and precipitation in an area. The values are adjusted based on information on river flows.

The results of the Reefs at Risk analysis are based on a series of distance relationships correlating mapped locations of human activity (e.g., ports, towns, oil wells, coastal mining activities and shipping lanes) with predicted risk zones of likely environmental degradation. Detailed sub-national statistics on population density, size of urban areas, land cover type, rainfall and topography are included to help estimate potential runoff within watersheds from inland deforestation, land clearing and agriculture.

Distance rules defining threat zones have been established for each component indicator using information on the known locations of more than 800 reef sites documented as degraded by human activity through one of the four factors considered in this analysis. Minimum distances are established through expert review and input and by determining the most conservative set of rules that, when taken in aggregation for any one of the four threat categories, include at least two-thirds of all known degraded sites affected by

Table 2. Threat indicators and decision rules used to classify reefs for the Reefs at Risk analysis.

THREAT FACTOR: COASTAL DEVELOPMENT			
Indicator	**Qualifier**	**High**	**Medium**
Cities	Population over 5 million	Within 30 km	30-60 km
Cities	Population over 1 million	Within 20 km	20-40 km
Cities	Population over 100 000 with little sewage treatment	Within 10 km	10-25 km
Cities	Population over 100 000 with moderate sewage treatment	-	Within 10 km
Settlements	Any size	-	Within 8 km
Airport/ military bases	Military and civilian airports	-	Within 10 km
Mines	Any type	Within 10 km	-
Tourist resorts	Including diving facilities	-	Within 8 km
THREAT FACTOR: MARINE POLLUTION			
Indicator	**Qualifier**	**High**	**Medium**
Ports	Large size	Within 20 km	Within 50 km
Ports	Medium size	Within 10 km	Within 30 km
Ports	Small size	-	Within 10 km
Oil tanks and wells	Any size	Within 4 km	Within 10 km
Shipping threat areas	Known major shipping routes with areas of relatively narrow passage	-	Defined zone
THREAT FACTOR: OVEREXPLOITATION AND DESTRUCTIVE FISHING			
Indicator	**Qualifier**	**High**	**Medium**
Population density	Coastal population density exceeds 100 persons per sq km	Within 20 km	-
Population density	Coastal population density exceeds 20 persons per sq km	-	Within 20 km
Destructive fishing	Expert identified areas where blast or cyanide fishing occurs	Within 20 km	-
THREAT FACTOR: INLAND POLLUTION AND EROSION			
Indicator	**Qualifier**	**High**	**Medium**
Model Relative Erosion Potential (REP)	Based on the relative slope, land cover class and precipitation in an area	Scaled to model river flow	Scaled to model river flow

Source: Bryant et al. 1998.

activities related to the category. Table 2 presents the component indicators used and the decision rules established to grade any one reef as under "medium" or "high" threat. Areas not defined as under high or medium threat default to low threat.

Reefs are initially classified by individual threat factors. Results from the four factors are further integrated using the decision rules in Table 3. Draft risk maps were revised and scrutinized at a global workshop attended by coral reef experts from around the world. Scientists also mapped areas under high threat from destructive fishing practices and areas of intense shipping with narrow passages or "shipping threat areas" – two additional data sets incorporated into this analysis. Overall, the Reefs at Risk indicators accurately classifies as "at risk" over 80 per cent of sites identified by ReefBase 2.0 (McManus and Ablan 1997) to be degraded by humans. In some cases reefs mapped as "at risk" were relatively healthy due to good planning and management by local governments and people, or because natural factors rendered these reefs less sensitive to the impact of human activity. In other cases, a review of the literature and expert opinion show that degradation is actually more severe than the indicator suggests.

Application of this map-based indicator of threat to the management of MPAs

This initial indicator-based assessment of threats to reefs was conducted on a global scale. The information is intended to raise awareness of the need for proper management to ensure the survival of coral reefs. By superimposing the threat maps on the locations of protected areas, the study has concluded that globally, more than 400 marine parks, sanctuaries and reserves contain coral reefs but most of these sites are very small. If protection is considered as an insurance against total destruction, reefs are inadequately insured globally. More than 150 MPAs are less than one square kilometer in size and at least 40 countries lack any marine protected areas for conserving their coral reef systems (Bryant et al. 1998).

For Southeast Asia, a finer scale analysis indicates that, on average, 8 per cent of a country's reef area is inside a MPA. Only 7 per cent of these are managed well. The management status of almost half of the 646 MPAs is unknown (Burke et al. 2000). Similar analyses are on-going for other regions (i.e., the wider Caribbean, East Africa and the Pacific). The results are relevant to trans-boundary coral reef management issues (e.g., pollution, destructive fishing, legislation, incentives, sources of recruits into the system, biodiversity, etc.) and plans to manage reef areas sustainably.

Success-likelihood Indicators

Difficulties in defining reef ecosystem boundaries

There may be a disparity between boundaries of reef resources and the jurisdiction limits of resource managers. The natural boundaries of reef resources, like all aquatic resources, are difficult to define. They depend on the physical structure of the reef, the distribution of particular species of interest and the variable scales at which processes and interactions that support the ecosystem operate. However, management boundaries correspond to existing political and administrative systems.

In most cases, the natural boundaries are wider than those of the local management units and the hierarchy of jurisdiction boundaries do not match the boundaries defined by nature. Exploitation of resources may not be solely due to activities of the local residents, given the open access nature of most coral reef fisheries. Therefore, the issue of scale becomes highly relevant in evaluating success-likelihood indicators.

Indicators of connectivity and vulnerability of reef areas

Recovery of reefs subject to intense fishing pressure hinges on the availability of new recruits and their success in replenishing resources removed from a reef. Resource managers need information on the dynamics of the source and eventual sink of recruits to design marine reserves, estimate the potential contribution of restocking to rehabilitation efforts, understand mechanisms that maintain biodiversity, and maximize gains from a fishery. A reef, which is highly dependent on other reefs, will be managed differently from one that is primarily self-recruiting (Tuck and Possingham 2000).

Connectivity among reef systems may lead to situations where different local or national groups harvest the same stock of resources. Thus, management regimes in one area may be ineffective because of competing uses for the resource elsewhere. Such connectivity also has implications for the vulnerability of sink reefs when the relative sources which supply recruits experience massive damage.

A combination of information from genetic markers, growth and reproductive characters of populations, current patterns, tagging experiments and an analysis of otolith microstructures provide the best set of biological indicators for reef connectivity and vulnerability. Complementary information on fish movements may be obtained from tagging experiments and age structure analyses. The following indicators of connectivity have been identified.

Estimated numbers of migrants per generation (N_{em}) or some other measure of exchange. Values of estimates of exchange, such as N_{em}, are derived from genetic markers. The frequencies of alternative forms of a gene are calculated for each population. Comparisons between these frequencies from two different populations are the basis for the estimates of the

Table 3. Decisions rules used to integrate the results from the four threat factors in the Reefs at Risk analysis.

Threat category	Decision Rule
High	High threat in at least one of the threat factors
Medium	Medium threat in at least one of the threat factors
Low	Low threat in all four threat factors

Source: Bryant et al. 1998.

number of migrants (N_{em}) between them. Average N_{em} for marine organisms is quite low (Ward 2000). However, caution must be exercised in the interpretation of genetic data since this will be greatly dependent on the assumptions used in the analysis and the sampling strategy.

More recently, genetic data analysis methods have been developed to select or exclude populations of origin of individuals (Cornue et al. 1999; Davies et al. 1999). Though untested for marine species, they have the potential to provide estimates of connectivity between reef areas.

Duration of pre-settlement stage, mode of reproduction and mode of existence as adults of target species. The currents do not passively transport larvae (Leis and McCormick 2000). The available data suggest that reef linkage is highly dependent on the life history strategies of an organism (Ablan et al. 2002) and must thus be interpreted with respect to species or life history strategy which is of primary interest to management (e.g., sea turtles, groupers, primary reef building species, etc.). General conclusions on linkage relationships between reefs should be possible with sufficient data from several model organisms.

Entrainment. Natural or man-made structures may produce coastal eddies that significantly reduce transport of eggs or larvae and increase mortality (Cowen et al. 2000).

Condition of possible source reefs. Velocity and direction of currents vary with changes in wind velocity during different times of the year. Seasonal averages are used as the primary indicator of the distance and direction of transport from one reef area to another and identify possible source reefs (McManus and Menez 1998). Assessments of the condition of source reefs are essential to design marine reserves and to estimate the potential contribution of restocking to rehabilitation efforts.

Applications of connectivity indicators to the management of MPAs

Information on the origins, sources and sinks of larval recruitment and genetic heritage that drive coral reef populations and maintain ecosystem biodiversity is crucial for management, particularly because the natural boundaries of these ecosystems are difficult to define. The data are essential to design marine reserves, to decide if restocking or transplantation to augment natural populations is necessary to rehabilitate a system, understand mechanisms that maintain biodiversity, maximize gains and promote sustainability of the resource from the local to the national and regional scales.

Indicators of compliance and legitimacy and their importance to management of MPAs

In addition to the biological and ecological based success-likelihood indicators, the social and behavioral indicators of compliance and enforcement are important for successful management of any natural resource. Most MPAs are developed through community effort or in agreement with communities. The extent to which affected individuals and communities are willing to comply with the "no take" or "limited take" restrictions placed on the reefs or fishing areas can strongly affect the outcome of management regimes.

Evidence from social behavior indicates that morality and moral norms may sometimes influence behavior and economic outcomes more than just drives for personal gains (Etzioni 1988; Frank 1988; Mansbridge 1990; Thaler 1991). For example, a large number of experiments have shown that people do not automatically act as free riders when the opportunity to do so presents itself. Instead, many people persist in investing a substantial proportion of their resources into public goods, despite conditions designed to maximize free riding. The opportunities for free riding by harvesting illegally in "no take" zones is very real in the case of MPAs, but people do not always take advantage.

Many fishermen comply with regulations despite large potential illegal gains and small expected penalties (Kuperan and Sutinen 1998). The extent to which the forces of morality and legitimacy motivate compliance to regulations for managing coral reef resources may be effectively used as success-likelihood for the management of coral reefs. Two such indicators are the levels of *legitimacy* of an MPA and the *extent of non-compliance with the rules* by members.

Legitimacy. It may be measured as the percentage of the community that accepts the management initiative and the respects the authority that implements it.

Extent of non-compliance. Indications of non-compliance include records of violations over time and the percentage of the community who choose to act as free riders.

Conclusion

Resource and ecosystem management is increasingly seen to be as much about managing human behavior as about the ecology and biology of the ecosystem. Integrated natural resource management involves an understanding of the linkages between natural resource systems and socioeconomic systems. Socioeconomic systems impose pressure on natural resources through various extraction and contamination processes. Given the complexities of natural resource systems, the concept of indicators has grown out of the notion that resource managers and other stakeholders need a relatively simple way of assessing the impacts that humans have on natural resources and factoring these into management decisions and plans for sustainable development.

This paper presents some means by which indicators may be used to: a) assess the condition of a resource; b) actively know and respond to threats; and c) evaluate the success-likelihood of management interventions for sustainable management of coral reef ecosystems. It is clear that indicators are support tools. They can also be used to improve communication, accountability and transparency between multiple stakeholders involved in benefiting from the use of a natural resource system. For indicators to be useful for management there must be a clear linkage between the indicators themselves and the objectives of sustainable natural resource management (Metzner 2001; Garcia and Staples 2000). Thus, indicators for the management of coral reefs need to be developed within the framework of management objectives and in cooperation with the major stakeholders.

Indicator-based systems are not a complete substitute for more comprehensive sets of information used to manage natural resource systems. However, indicator-based systems will greatly reduce the constant need for a very detailed information base for making management decisions.

The issue of different stakeholders promoting their own interest is an important problem. Each stakeholder will typically stress the issues of relevance, appropriateness and legitimacy to them and require an accommodation process. This will often entail a need for sustainability indicators capturing a broad mix of the qualities required by the different stakeholders if indicators are to serve as an efficient communication and management tool acceptable to all stakeholders (Hovgard et al. 2001). There is a large range of indicators that can be developed and used for the management of coral reefs in the context of integrated natural resource management. The indicators to be used will depend on the resources required to develop them, acceptability by stakeholders, the objectives of the management plan for the various natural resources, and the regulatory instruments to be used.

Acknowledgements

The information included in this paper is part of a research that was funded under grants from the European Commission, the Dutch Government, Swedish International Development Agency; USAID, the John D Catherine T MacArthur Foundation.

References

Ablan, M.C., J.W. McManus, C.A. Chen, K.T. Shao, A. Cabanban, J. Bell, V.S. Tuan and W. Arthana. 2002. Meso-scale trans-boundary units for the management of coral reef areas in the South China Sea and adjacent areas. *Naga* the WorldFish Center Quarterly 25: 4-9.

Alcala, A.C., and G.R. Russ. 2002. Status of Philippine coral reef fisheries. Asian Fisheries Science 15(2002):177-192.

Alder, J., D. Zeller, T. Pitcher and R. Sumaila. 2002. A method for evaluating marine protected area management. Coast. Manage. 30(2):121-131.

Birkeland, C. (ed.) 1997. Life and death of coral reefs. Chapman and Hall, New York.

Burke, L., E. Selig and M. Spalding. 2000. Reefs at risk in Southeast Asia. World Resources Institute. Washington, USA.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. Reefs at risk: a map-based indicator of threats to the world's coral reefs. World Resources Institute. Washington, USA.

Caddy, J.F., and J. Csirke. 1983. Approximations to sustainable yield for exploited and unexploited stocks. Oceanog. Trop. 8:3-15.

Cowen, R.K., K.M.M. Lwiza, S. Sponaugle, C.B. Paris and D.B. Olson. 2000 Connectivity of marine populations: open or closed. Science 287:857-859.

Cornuet, J.M., S. Piry, G. Luikart, A. Estoup and M. Solignac. 1999. New methods employing multilocus genotypes to select or exclude populations of origins of individuals. Genetics 153: 1989-2000.

Davis, N., F.X. Villablanca and G.K. Roderick. 1999. Determining the source of individuals: multi-locus genotyping in non-equilibrium populations. TREE 14(1):17-21.

Dahl, A. 1996. Measuring the unmeasurable. Our Planet 8: 29-33 UNEP.

Hoagland, P., U.R. Sumaila and S. Farrow. 2001. Encyclopedia of Ocean Sciences 3:1654-1659.

Edwards, C.J., R.A. Ryder and T.R. Marshall. 1990. Using lake trout as a surrogate of ecosystem health for oligotrophic waters of the great lakes. J. Great Lakes Res. 16(4): 591-608.

Etzioni, A. 1988. The moral dimension. London, Free Press. Collier MacMillan.

Frank, R.H. 1988. Passions within reason. New York: W.W. Norton.

Garcia, S.M. and D.J. Staples. 2000. Sustainability reference systems and indicators for responsible capture fisheries: a review of concepts and elements for a set of guideline. Mar. Freshwater Res. 51:385-426.

Gulland, J.A. 1969. Manual of methods for fish stock assessment. Part 1. Fish population analysis. FAO Man. Fish. Sci. 4.

Hilborn, R., K. Stokes, J. Maguire, T. Smith, L.W. Botsford, M. Mangel, J. Orensanz, A. Parma, J. Rice, J. Bell, K. L. Cochrane, S. Garcia, S. J. Hall, G. P. Kirkwood, K. Sainsbury, G. Stefansson, and C. Walters. When can marine reserves improve fisheries management? Ocean and Coastal Management. (In press).

Hollingworth, C.E. (ed.) 2000. Ecosystem effects of fishing. Proceedings of an ICES/SCOR Symposium. ICES Journal of Marine Science Symposium Edition 57.

Hovgard, H., S. Reeves and J.R.Nielsen. 2001. Indicators and their use for communicating information between the major stakeholders in the fisheries systems. Paper presented at the FAO and SEAFDEC Regional Technical Consultation on Indicators for Sustainable Fisheries Management in ASEAN Region, Haiphong, Vietnam, 2-5 May.

Karr, J.R., and E.W. Chu. 2000. Sustaining living rivers. Hydrobiologia 422/423: 1-14.

Kuperan, K., and J.G. Sutinen. 1998. Blue Water Crime: Deterrence, Legitimacy, and Compliance in Fisheries. Law & Society Review 32(2) 309-337.

Leis, J. M., and M.I. McCormick. 2002. The biology, behavior and ecology of the pelagic, larval stage of coral-reef fishes, p. 171-199. ***In*** P.F. Sale. (ed.). Coral reef fishes: dynamics and diversity in a complex ecosystem. Academic Press, San Diego.

Linton, D.M. and G.F. Warner. 2003. Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. Ocean Coast. Manage. 46(3-4): 261-276.

Mansbridge, J. (ed.) 1990. Beyond self-interest. Chicago & London: The University of Chicago Press.

McClanahan, T. 1997. Primary succession of coral-reef algae: Differing patterns on fished versus unfished reefs. Journal of Experimental Marine Biology and Ecology 218:77-102.

McManus, J.W., C.L. Nanola, R.B. Reyes and K.N. Kesner. 1992. Resource Ecology of the Bolinao Coral Reef System. ICLARM Stud. Rev 22. ICLARM, Manila.

McManus, J.W., C.L. Nanola, and R.B. Reyes. 1995. Effects of some destructive fishing methods on coral cover and potential rates of recovery. Environmental Management, 21:69-78.

McManus, J.W. 1997. Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia. Coral Reefs 16. Suppl: S121-127.

McManus, J.W. and M.C.A. Ablan (eds.) 1997. ReefBase: a global database of coral reefs and their resources. Ver. 3.0. ICLARM Manila, Philippines.

McManus, J.W. and L.A. B. Menez. 1998. The proposed international Spratly Island marine part: ecological considerations. ***In*** H. Lessios (ed.) Proceedings of the 8th International Coral Reef Symposium 2:1943-1948.

Metzner, R. 2001. The Usefulness of Indicators for Fisheries Management. Paper presented at the FAO and SEAFDEC Regional Technical Consultation on Indicators for Sustainable Fisheries Management in ASEAN Region, Haiphong, Vietnam, 2-5 May. Frank, 1988.

Pauly, D. 1979. Theory and management of tropical mutli-species stocks: a review with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies Review 1.

Pauly, D., G. Silvestre and I.R. Smith. 1989. On development, fisheries and dynamite: a brief review of tropical fisheries management. Nat. Resources Modeling 3:307-329.

Pauly, D. 1990. On Malthusian overfishing. *Naga* the ICLARM Quarterly 13(1): 3-4.

Pennings, S.C. 1998. Indirect interaction on coral reefs, p. 249-297. ***In*** C. Birkeland (ed.) Life and Death of Coral Reefs. Chapman and Hall. New York.

Polunin, R.B. and C. Roberts. 1996. Reef fisheries. Chapman and Hall. London.

Randall, J.E. 1965. Grazing effects on seagrasses by herbivorous reef fish in the West Indies. Ecology 46:255-260.

Thaler, R. 1991. Quasi Rational Economics. New York: Russel Sage Foundation.

Tuck, G.N. and H.P. Possingham. 2000. Marine protected areas for spatially structured exploited stocks. Marine Ecology Progress Series 192:89-101.

Ward, R.D. 2000. Genetics in fisheries management. Hydrobiologia 420: 191-201.

Wilkinson, C.R. 1999. Global and local threats to coral reef functioning and existence: review and predictions. Mar. Frewshwat. Res. 50(8):867-878.

Yap, H.T., and E.D. Gomez. 1988. Aspects of benthic recruitment on a northern Philippine reef. Proceedings of the 6th International Coral Reef Symposium. Townsville 2:279-283.

Zabel, R.W., C.J. Harvey, S.L. Katz, T.P. Good and P.S. Levin. 2003. Marine conservation requires a new ecosystem-based concept for fisheries management that looks beyond sustainable yield for individual fish species. American Scientist (on-line). http://www.americanscientist.org/template/AssetDetail/assetid/17216?fulltext=true

---

M.C.A. Ablan and **K. Viswanathan** are from the WorldFish Center, Jalan Batu Maung, Batu Maung, Bayan Lepas, Penang, Malaysia. **J.W. McManus** is from the Department of Marine Biology and Fisheries, Rosensteil School of Marine and Atmospheric Sciences, 4600 Rickenbacker Causeway, Florida, USA. Email: m.ablan@cgiar.org

The GCRMN - Coordinating coral reef monitoring efforts for effective management

K. Tun and C. Wilkinson

Coral reefs, one of our earth's most valuable and fragile of resources, are being damaged and destroyed at an increasing rate worldwide. The Status of Coral Reefs of the World: 2000 report estimates that at least 27 per cent of the world's reefs have been effectively lost, including 16 per cent that were severely damaged during the massive El Niño and La Niña climate changes of 1998. The world may lose another 14 per cent of its coral reefs in 2 to 10 years, and a further 18 per cent in 10 to 30 years, unless effective management of these valuable resources is implemented soon.

Not all is doom and gloom, however, as the report indicated that about half of the 16 per cent of reefs damaged in 1998 are showing encouraging recovery, with the best recovery occurring within marine protected areas (MPAs) or at isolated reefs. The report also highlighted many examples of successful coral reef conservation around the world, and many outstanding efforts by international agencies to conserve biodiversity of coral reefs.

K. Tun

Diver conducting Line Intercept Transect (LIT) surveys at a reef in North Sabah, Borneo.

Coral reefs have been, and continue to be, a difficult ecosystem to monitor and assess. Because coral reefs are underwater and often very remote, it is difficult to gather precise information on their status. Coupled with limited resources available for monitoring efforts, this makes the task of procuring and synthesizing information a difficult one. To address this issue, the Global Coral Reef Monitoring Network (GCRMN), an operational unit of the International Coral Reef Initiative (ICRI), was established in 1995 to provide data and information on the global status of coral reefs, assess how people use and interact with reefs, assist coral reef management, and raise awareness among all stakeholders of the status of reefs and the need for urgent action. The GCRMN is maintained by the Australian Institute of Marine Science (AIMS), drawing on its expertise in monitoring. GCRMN also works in association with the U.S. National Oceanic and Atmospheric Administration's (NOAA) and the WorldFish Center.

The GCRMN constitutes a global network of people, governments, institutes and NGOs monitoring coral reefs and the communities that use them.

The GCRMN works in partnership with existing global and regional monitoring programs like Reef Check, and provides coordinating mechanisms for publishing results for decision makers and the public. The GCRMN encourages and coordinates monitoring at various levels: from grassroots level (communities, schools, tourist operators, tourists, etc.) to governmental departments, NGOs, and global, regional and national institutions of higher learning and research.

K. Tun

Divers working in pairs to establish survey transects for Reef Check and LIT surveys.

The GCRMN provides its network with a range of monitoring methods and protocols, monitoring training, basic equipment, and help with data analysis and report writing. GCRMN also assists in linking all levels of monitoring and monitoring programs/projects into regional nodes, providing data and information on coral reef health and status of reef fishes, and data storage facilities and assistance through ReefBase. GCRMN encourages and assists countries and regions to produce their national and regional Status of the Coral Reefs reports. It also produces global reports on the status of coral reef every two years and ensures that this information receives wide publicity and distribution.

The major features and products of the GCRMN are: a network of people trained to look closely at coral reefs and to monitor their status; nodes of countries cooperating to monitor reefs in their region and report on their status; manuals and protocols for the assessment of ecological and socioeconomic aspects of coral reefs; and National, Regional and Global Status of the Coral Reef reports every two years.

Currently, the GCRMN is represented by 17 regional nodes, with overall coordination by a global coordinator based at AIMS. At the 10th International Coral Reef Symposium (ICRS) held in Okinawa in June 2004, the GCRMN showcased the coral reef monitoring efforts of its members and highlighted the key role that monitoring plays in the overall understanding of coral reef function and management.
For more information about GCRMN, please contact Clive Wilkinson, the global coordinator of GCRMN at dive.wilkinson@impac.org.au.

Regional Nodes:

1) Middle East - Red Sea and Gulf of Aden (PERSGA) Region
2) Middle East - Regional Organisation for the Protection of the Marine Environment (ROPME) Sea Region
3) Southwest Indian Ocean Islands
4) Eastern African
5) South Asia
6) Southeast Asia
7) Northeast Asia
8) Australia and PNG
9) South West Pacific
10) SE and Central Pacific (Polynesia Mana)
11) Micronesia (MAREPAC)
12) Hawaiian Islands
13) US Caribbean
14) Northern Caribbean and Atlantic
15) North Central America and Mesoamerican Barrier Reef System
16) Eastern Caribbean
17) Southern Tropical America

Catching and rearing postlarval cleaner shrimp for the aquarium trade: results from a WorldFish Center project in Solomon Islands

C. Hair, R. Warren, A. Tewaki, C. Haro and W. Phillips

Abstract

Between 1999 and 2003, the WorldFish Center in Solomon Islands conducted research into the feasibility of a new fishery based on the capture and culture of postlarval coral reef fish for the live fish trade. The work was carried out in two phases: a research phase from late 1999 to the end of 2002; and a "fine-tuning" phase in 2003. Most of the species were of value to the marine aquarium trade, with very few live reef food fish recorded. The most valuable ornamentals were the banded cleaner shrimp, *Stenopus* species. Cleaner shrimp were harvested using crest nets, the method being modified with the addition of a solid, water-retaining cod-end designed to increase survival at capture. Grow-out techniques were improved by rearing the shrimp separately in jars to prevent aggression. The jars were painted black to protect the shrimp from sunlight. An economic model using experimental catch data and farm gate prices indicates that the fishery based on shrimp, supplemented with small numbers of lobster and fish is economically viable. The next step will be setting up a demonstration farm in a village in the Western Province of Solomon Islands.

Introduction

Coral reef fish species form the basis of two markets that utilize live individuals. The live reef fish food trade targets mostly serranids with some lutjanids and a labrid species. The major markets are in Hong Kong and mainland China. The marine aquarium industry trades in hundreds of species from dozens of families, for markets in the UK, Japan and the US. Both trades have been associated with over-harvesting and the use of destructive techniques to harvest fish (Sadovy and Vincent 2002; Sadovy et al. 2003). On the other hand, there is also an urgent need for alternative sustainable livelihoods in the Asia Pacific region. Between February 1999 and December 2003, the WorldFish Center investigated the feasibility of a new artisanal fishery based on the capture and rearing of pre-settlement coral reef fish for both these markets. Sustainable methods were used to capture postlarval fish as they settled from the plankton and simple aquaculture techniques were used to grow these fish to marketable size. The rationale for harvesting fish at this stage of their lifecycle is that postlarvae are very abundant before settlement, but the process of settlement is accompanied by very high mortality (Carr and Hixon 1995; Doherty et al. in press). This is primarily due to high predation rates when naïve postlarvae return to reefs following their planktonic dispersal phase (Hixon 1991). Harvesting pre-settlers should not affect natural replenishment to the reefs because they are removed immediately prior to this high mortality. The project was funded by the Australian Centre for International Agricultural Research (ACIAR) and based at the WorldFish Center station in the Western Province of Solomon Islands. The Australian Institute of Marine Science (AIMS) played an important collaborative and advisory role. Officers from the Solomon Islands Department of Fisheries and Marine Resources (DFMR) also participated in the study.

The study was divided into two phases. The first comprised research into the feasibility of the concept and ran from 1999 to 2002. During this period, two methods of fish harvest were investigated: light traps and crest nets. Both of these were originally developed for scientific sampling of competent late stage fish and invertebrate larvae (Doherty 1987; Dufour and Galzin 1993). Routine monthly sampling using both techniques was carried out for two years. Light traps caught almost 93 000 individuals belonging to 52 families. Crest nets caught over 150 000 individuals from 83 families. Of these, only a small part of the catch was of value to the aquarium trade (15 per cent for light traps and 5 per cent for crest nets) and a negligible number of live reef food fish species were recorded. Marine ornamental species included juvenile painted lobster (*Panulirus versicolor*) and angelfish (*Pomacanthus* and *Centropyge* species). However, by far the most valuable and abundant ornamentals were the banded cleaner shrimp from the genus *Stenopus*. These were taken almost exclusively from crest nets. *Stenopus* and *Lysmata* shrimp are amongst the ten most traded invertebrates worldwide (Wabnitz et al. 2003). They are attractive, relatively easy to maintain in a tank and perform a beneficial cleaning and scavenging role (Wabnitz et al. 2003). Although the life cycle of several cleaner shrimp species has been closed, there are a number of constraints to commercial production of *Stenopus* species (Calado et al. 2003). Hence, most are still collected from the wild, despite some concern that over-fishing could have detrimental effects on natural reef ecosystems (Wabnitz et al. 2003).

At the conclusion of the first phase, we recognized that there was potential to develop an economically viable fishery based on postlarval reef species, primarily crustaceans. The second phase was through 2003 and was devoted to "fine-tuning" the capture and culture methods, specifically for high value species. Given that crest nets caught more and higher value species and were cheaper, easier to operate and more reliable than light traps, a modified form of this technique was developed for the new fishery. In this article, we describe efforts to catch, rear and market banded cleaner shrimp reared from postlarvae in Solomon Islands.

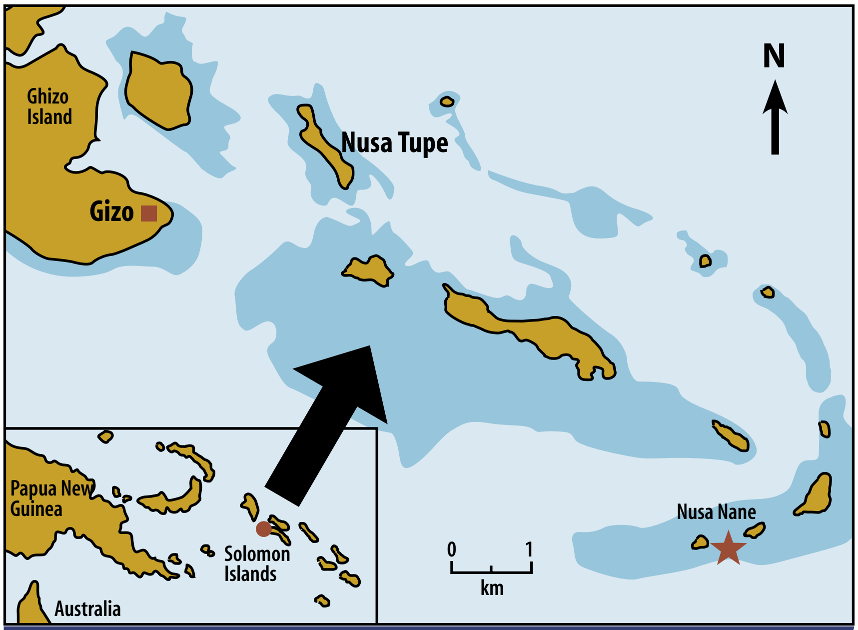


Fig. 1. Location of the WorldFish Center (Nusa Tupe) and the reef crest (Nusa Nane).


Fig. 2. Reef crest at Nusa Nane.

Materials and Methods

Study site

The WorldFish Center in Solomon Islands is located at Nusa Tupe near Gizo in the Western Province (Fig. 1). The crest net sampling site was approximately 6 km from the field station on a two-kilometre long reef crest that was exposed at low tide.

Capture of shrimp

Crest nets are small mesh nets fixed on a shallow outer reef crest, immediately behind the surf zone (Hair et al. 2002a, Fig. 2). They sample fish coming through the surf zone from the open sea into the lagoon (Dufour and Galzin 1993). Nets were deployed in the week leading up to and following the new moon each month, when the highest number of fish are leaving the plankton (Milicich and Doherty 1994; Dufour et al. 1996). The catch was retrieved early each morning.

From November 1999 to September 2001, two crest nets were set during every new moon period. In 2002 and 2003, only some months were sampled. Two types of net were used during the first research phase: (i) 1.5 mm plankton mesh nets, mouth size 1x1.5 m and 3 m long with a detachable soft cod-end (Doherty and McIlwain 1996), provided by AIMS (Fig. 3a) were used until February 2001 (Hair et al. 2002a); and (ii) 3 mm knotless mesh nets, mouth size 1 x 1.5 m and 3.5 m long, also with a soft cod end, were used until the end of sampling in September 2001 (Fig. 3b). Shrimp catches from the old and new

nets were compared during the months of February and April 2001, and no significant difference was found in the number of shrimp collected (Hair et al. 2002b).

In the fine-tuning phase of the work in 2003, a third catching device was developed. The crest nets were modified by replacing the soft cod end with a rigid, water retaining cod-end in order to reduce mortality and improve the condition of harvested postlarval shrimp (Fig. 3c). During both phases of the project, some cleaner shrimp were retained for aquaculture. However, most grow-out trials were carried out in 2003.

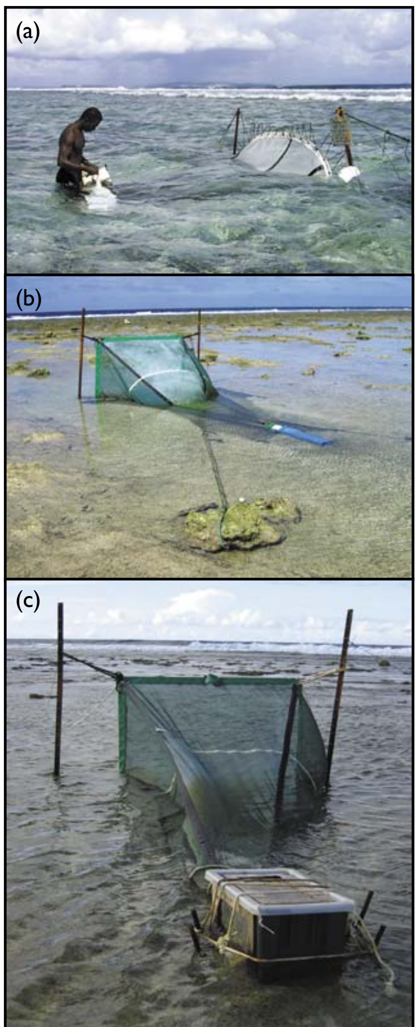


Fig. 3. Sampling gear used in the study: (a) original AIMS crest net with soft cod-end; (b) green knotless mesh crest net with soft cod-end; and (c) green crest net with solid cod-end.

Grow-out of shrimp

Cage culture

Due to variable nightly catches and the uncertainty of catching enough shrimp for experimental treatments, cleaner shrimp were classed as a single cohort for rearing if they were caught within three successive nights. During 2003, different types of cages were filled with live rock and placed on trestles to keep them off the sea floor (Fig. 4). Banded cleaner shrimp were grown *en masse* in cages for periods of 21 days in plastic prawn trays (56 x 31 x 10 cm) lined with 1.5 mm net mesh to prevent escape and predation, stick frames covered with mesh, and plastic wastepaper baskets with mesh lids (56 cm high x 31 cm diameter). Shrimp were fed twice daily on a diet of minced fish, crustacean and mollusc flesh.

As mortality was generally high in *en masse* cage culture, a series of experiments were designed to investigate why. Shrimp were grown in prawn trays in deep versus shallow water and in trays with separate compartments and with pipe shelters. In another experiment, shrimp were reared using different feeding regimes: (i) feeding at two-hourly intervals; (ii) feeding twice daily; and (iii) not fed at all. Survival of shrimp in these various treatments was compared after three weeks of culture.

Jar culture

Our observations of cleaner shrimp indicated that their aggressive nature contributed to the high mortality recorded during *en masse* grow-out. To investigate this, shrimp were grown individually in 200 ml clear plastic jars (Fig. 5). All jars had holes drilled in them to facilitate water flow but minimize food loss. The jars were positively buoyant. Food was placed in the jars, with uneaten food removed and new food added twice a day initially. Twice-daily feeding was found to be very labor intensive, so the feeding regime was reduced to once daily with little change in survival.

Although intraspecific fighting was eliminated, a new problem emerged as shrimp reared in jars developed algal growth on their exoskeleton (Fig. 6). After moulting the shrimp would regain normal coloration but quickly start to look "green" again. In addition, an individual fouled with algae often lost appendages or died during moulting. This problem appeared to be directly related to the amount of algal fouling.

Two experiments investigated the role of light as a determinant of algal growth on the shrimp exoskeleton. First, shrimp were reared in jars in the sea at the surface (in shaded and unshaded cages) and near the sea floor (in shaded and unshaded cages). Second, shrimp were reared in jars that were painted black. During these trials, shrimp were checked

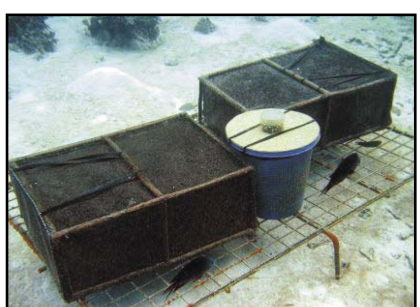


Fig. 4. Examples of baskets used to rear shrimp *en masse*.

Fig. 5. Jars used for rearing shrimp individually.

for the amount of algal fouling on their exoskeleton and mortality recorded daily.

Marketing of shrimp

The cultured shrimp were shipped by air to an exporter in Honiara, then exported to the US for sale in retail aquarium stores. During the initial research phase, specimens were sent to the exporter for feedback on their value and condition. In 2003, fish were sold to the marine aquarium company to verify the quoted prices for these species.

Economic model of the fishery

An economic model of the postlarval fish capture/culture operation was developed by B. Johnston (Queensland Department of Primary Industries and Fisheries). The model used a discounted cash flow analysis to determine the annual cost structure and the likely profitability of the operation. The model assumed a project life of 20 years and used a real discount rate of 8 per cent to calculate the net present value (NPV). The budget also incorporated the initial capital and establishment costs. The variables input into the model included the number of traps, catch rates of banded cleaner shrimp (plus small numbers of lobster and teleosts), landed value of each of the valuable species and costs of capital items (nets and traps), maintenance and labor. A risk analysis was carried out to determine the robustness of the financial result to variations in yield (catch) and market value.

Results

Identification

Most cleaner shrimp were from the genus *Stenopus*, family Stenopidae. Most small *Stenopus* postlarvae looked similar at capture (Fig. 7a), although larger individuals were distinctive (Fig. 7b). All individuals could be positively identified by the third day after capture at the latest. During the research phase, only *Stenopus hispidus,* banded cleaner shrimp (Fig. 8a) were recorded. During 2003, *S. zanzibaricus* (gold-banded coral shrimp Fig. 8b) and *S. tenuirostris* (blue-banded coral shrimp Fig. 8c) were also captured. The identification of extra species was attributed to improvements in capture techniques in this second phase of the project. The rare and highly sought-after banded cleaner shrimp, *S. pyrsonatus,* was not recorded during this study, although a small number of *Lysmata amboinensis* (Indo-Pacific white-striped cleaner shrimp, family Hippolytidae) were captured and reared. Identification is important since different species have different growth characteristics and commercial value.

Catch data

Temporal variation in crest net catches (1999-2003)

Mean monthly crest net catches of cleaner shrimp per night for all new moon periods fished between November 1999 and November 2003 are shown in Fig. 9. Catches varied greatly, ranging from almost zero in November 1999 and March 2001 to almost 20 shrimp per net night in September 2003.

Comparison of gear types– (2003)

Crest nets with solid cod-ends caught similar or greater numbers of cleaner shrimp compared to crest nets with soft cod-ends (Fig. 9). The best survival was recorded in the solid cod-ends in all months (Table 1).

Fig. 6. Banded cleaner shrimp with algal fouling on its exoskeleton.

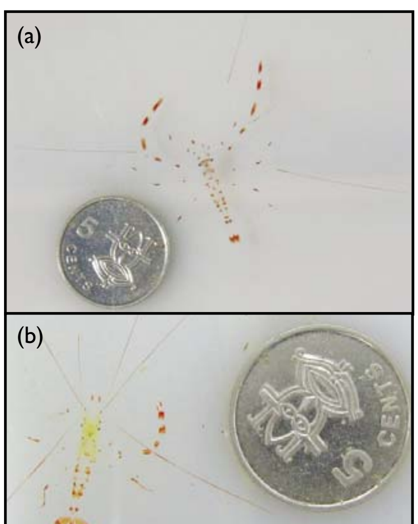


Fig. 7. Postlarval *Stenopus* species: (a) unidentified postlarvae; and (b) *Stenopus zanzibaricus*.

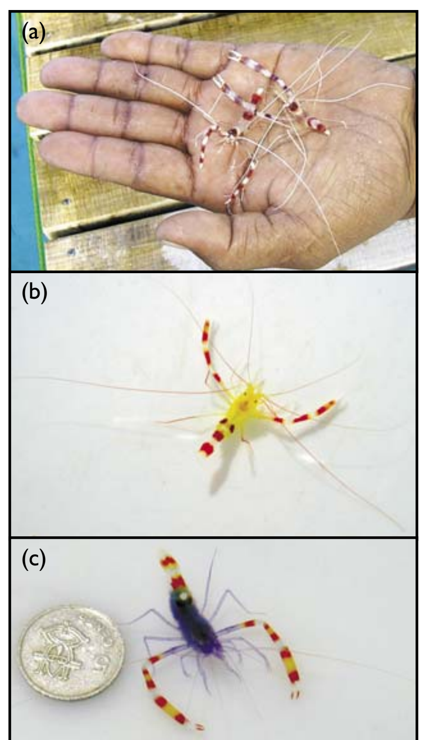


Fig. 8. Adult (export size) *Stenopus* species: (a) *Stenopus hispidus*; (b) *S. zanzibaricus*; and (c) *S. tenuirostris*.

Table 1. Average shrimp survival (%) in solid con-ends versus soft cod-ends during sampling in 2003.

Treatment	Jul.	Aug.	Sep.	Oct.	Nov.
Solid cod-end	90%	95%	100%	95%	100%
Soft cod-end	60%	60%	60%	75%	80%

Grow-out trials

Benthic cages

Mortality of shrimp grown *en masse* in cages on the sea floor was calculated weekly. Very high mortality (between 40 and 80 per cent) was experienced in the early, unreplicated trials. Furthermore, manipulating depth, type of shelter and frequency of feeding did not improve survival rates: mortality remained between 60 and 88 per cent. Generally, the greatest number of shrimp died or were lost in the first week after capture. Mortality continued throughout grow-out, albeit at a lower rate than the first week. Mortality remained at similar levels, regardless of shrimp densities in the cage.

Jars

Results of effects of shading on shrimp in jars are shown in Table 2. Mortality of shrimp in unshaded jars was at least twice that of the shaded jars at either depth. Although slightly higher survival occurred in surface treatments, this factor was less important than shading. Surface treatments had higher algal levels than sea floor treatments in both cases and unshaded shrimp grew more algae than shaded shrimp at each depth.

Table 2. Overall mortality (%) during shrimp jar shading experiments in 2003.

Treatment	% mortality	Av. algal level
Sea floor shaded Surface shaded	30-40% 20-30%	0.4-0.5 0.7-0.8
Sea floor unshaded Surface unshaded	60-100% 60-70&	0.4-0.8 1.1-1.2
Black jars Clear jars	0-20% 30-40%	0-0.1 0.3-0.6

(n=10 jars in each treatment. Algal level was estimated as 0= nil algae; 1=small amount on legs only; 2=small amount on legs and body; 3=dark algae on full body).

Once jars were painted black to further reduce light, mortality of shrimp fell further and was lower than that experienced in clear jars (Table 2). Levels of algae on the shrimp exoskeletons was also reduced in black jars.

S. hispidus grew well in jars and were ready for export after about four weeks at around 25 mm body length. Unfortunately, the other species did not grow well in jars and did not reach export size, even after two months of grow-out.

Value of the catch

Based on prices quoted by the exporter, the estimated value of the crest nets catch from October 1999 to September 2001 was $2 777[1]. Cleaner shrimp accounted for 65 per cent of the potential total value for that period despite making up only 13.5 per cent of ornamentals by number. The farm gate price for cleaner shrimp was $1.00 each.

During 2003, 10 shipments of fish, worth a total of $245 were sold. The highest value came from banded cleaner shrimp with $144 for 146 shrimp. Eighty lobsters netted $79, and 97 fish (mostly angelfish, puffers and butterflyfish) were worth $21. These were taken from about 75 night's fishing using three nets each night.

Economic model

The economic model was run using a range of values in order to confirm its robustness to variations in production (either due to variable catches or fluctuations in survival during culture) and market price. The parameter values were based on actual catches of shrimp, while lobsters and teleosts were included as a supplementary component of the fishery. Capital costs included two traps at $175 each and $140 for rearing facilities. A small labor cost was included ($280 per annum) and $700 paid to the owner/operator per annum (although it is likely that in the early stages of operation, the fish-farmer will depend on unpaid family labor, only occasionally withdrawing funds). Experience with village giant clam farming in Solomon Islands indicated that paid labor might be employed once the operation is established and profitable (C. Oengpepa, pers. comm). The model indicated that the fishery was profitable over a wide

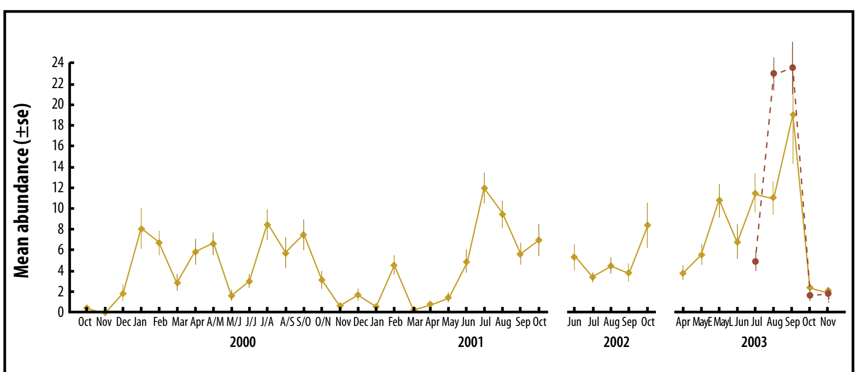


Fig. 9. Mean nightly abundance per net (±se) per month of banded cleaner shrimp and lobster for all sampling periods from 1999 to 2003. Solid line denotes catches in soft cod-ends and broken line denotes catches in the solid cod-ends.

[1] All values are in US$.

range of inputs and debt could be recovered in the first year.

Discussion

The marine aquarium trade generates $200 to $330 million worldwide each year (Wabnitz et al. 2003). As most valuable fish are sourced from tropical seas in developing countries, it provides an important source of income to coastal communities in the Asia Pacific region. Unfortunately, specimens are often collected using cyanide or destructive fishing techniques and there are fears that over-fishing is occurring for some species in some areas (Sadovy and Vincent 2002). When this project commenced, it was envisaged that harvesting pre-settlers might take pressure off existing coral reef populations by providing an alternative to the collection of large juveniles and adults for the trade. Our final results, however, suggest this is unlikely. The small range and relatively low abundance of target species harvested using crest nets (and light traps) means that the new fishery is more likely to complement the existing dive fishery, not replace it. Nevertheless, it could positively impact the socio-economic situation by providing a sustainable livelihood in the region.

The final year of the project was devoted to "fine-tuning" the catching and rearing methodology to a stage where it could be introduced to coastal communities. The effectiveness of the solid, "fish friendly" cod-end was well demonstrated by the improvement of survival in the catch. Average survival of shrimp was 10 per cent between 1999 and 2001 (Hair et al. 2002b). In 2003, with fish friendly cod-ends, survival rose to 97 per cent. Survival of other target species and by-catch also improved markedly with solid, water-retaining cod-ends. Shrimp could be maintained in good condition between collection at the reef crest and delivery to their grow-out habitat by handling them gently and separating them at retrieval from the cod-end. *S. hispidus* is naturally aggressive and in the ornamental fish trade adults are maintained in tanks as mated pairs or isolated in jars (L. Squire, pers. comm.). The observed drop in mortality when the shrimp were isolated in jars suggested that aggression occurs from around the time of settlement. One drawback of the jar rearing method is the increased likelihood of shrimp growing algae on their exoskeleton since banded cleaner shrimp are nocturnal and cryptic in the wild yet exposed to strong sunlight when grown out in jars. The algal growth was controlled with black jars and shade over the grow-out cages. Growing shrimp in jars is more labor intensive but is a simple procedure and can be handled by most age groups. This is an advantage for a family run operation in a village.

Cleaner shrimp were the most abundant and valuable species we collected throughout the study. The value of the ornamental catch from light traps and crest nets from October 1999 to September 2001 was $598 and $2 777, respectively. Low-value damselfish, predominantly caught in light traps, made up nearly 80 per cent of ornamentals by number but only 21 per cent of the value. Cleaner shrimp made up only 13.5 per cent by number but accounted for 65 per cent of the total value. Economic modeling of the fishery using actual catch abundances and their real value indicates that banded cleaner shrimp could support a fishery. There is potential to increase profitability if grow-out of the blue-banded and gold-banded cleaner shrimp can be improved and if other species (e.g., *Lysmata*) can be targeted. Juvenile painted crayfish and a small range of ornamental teleosts (finfish) would provide extra income. Additionally, recognition of the techniques as a sustainable, responsible fishery may lead to certification by the Marine Aquarium Council with subsequent market advantages (Holthus 1999).

The next step involves the establishment of a village demonstration farm in the Western Province of Solomon Islands. If the operation is a success, the techniques will be transferred to other countries in the region. Funding for this activity is again being provided by ACIAR as part of a larger project that supports sustainable aquaculture in the Pacific region. The lead agency is the Department of Primary Industries and Fisheries in Queensland (DPI), working in close collaboration with the WorldFish Center in the Pacific and Secretariat of the Pacific Community (SPC).

Acknowledgements

This research was funded by the Australian Centre for International Agricultural Research. Special thanks to Dr P. Doherty of AIMS for supervision and guidance. We acknowledge the logistical support and advice provided by I. Lane and the WorldFish Center's Nusa Tupe staff for assistance with field sampling. M. Rimmer provided helpful comments on the draft manuscript.

References

Calado, R., L. Narciso, S. Morais, A.L. Rhyne, and J. Lin. 2003. A rearing system for the culture of ornamental decapod crustacean larvae. Aquaculture 218: 329-339.

Carr, M.H. and M.A. Hixon. 1995. Predation effects on early post-settlement survivorship of coral reef fishes. Marine Ecology Progress Series 124:31-42.

Doherty, P.J. 1987. Light traps: selective but useful devices for quantifying the distributions and abundances of larval fishes. Bulletin of Marine Science 41: 423-431.

Doherty, P.J. and J. McIlwain. 1996. Monitoring larval fluxes through the surf zones of Australian coral reefs. Marine and Freshwater Research 47: 383-390.

Doherty, P.J., V. Dufour, R. Galzin, M.A. Hixon, M.G. Meekan and S. Planes. 2004. High mortality during settlement is a population bottleneck for a tropical surgeonfish. Ecology (in press).

Dufour, V. and R. Galzin. 1993. Colonization patterns of reef fish larvae to the lagoon at Moorea Island, French Polynesia. Marine Ecology Progress Series 102:143-152.

Hair C.A., P.J. Doherty, J.D. Bell and M. Lam. 2002a. Capture and culture of presettlement coral reef fishes in Solomon Islands. ***In*** M. Kasim Moosa, S. Soemodihardjo, A. Soegiarto, K. Romimohtarto, A. Nontji, Soekarno, Suharsono (eds.) Proceedings of the Ninth International Coral Reef Symposium, Bali, 23-27 October 2000. Ministry of Environment, Indonesian Institute of Sciences and the International Society for Reef Studies. Vol. 2:819-827.

Hair, C.A., J.D. Bell and P.J. Doherty. 2002b. Development of new artisanal fisheries based on the capture and culture of postlarval coral reef fish. WorldFish Center Final Report to ACIAR, December 2002.

Hixon, M.A. 1991. Predation as a process structuring coral-reef fish communities, p. 475-508. ***In*** P.F. Sale (ed.) The ecology of fishes on coral reefs. Academic Press, San Diego.

Holthus, P. 1999. The Marine Aquarium Council, certifying quality and sustainability in the marine aquarium industry. SPC Live Reef Fish Bulletin 5:34-35.

Milicich, M.J. and P.J. Doherty. 1994. Larval supply of coral reef fish populations: magnitude and synchrony of replenishment to Lizard Island, Great Barrier Reef. Marine Ecology Progress Series 110:121-134.

Sadovy, Y.J. and A.C.J. Vincent. 2002. Ecological issues and the trades in live reef fishes, p391-420. ***In*** P.F. Sale. (ed.) Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem. Academic Press, San Diego.

Sadovy, Y.J., T.J. Donaldson, T.R. Graham, F. McGilvray, G.J. Muldoon, M.J. Phillips, M.A. Rimmer, A. Smith and B. Yeeting. 2003. While stocks last the live reef food fish trade. ADB Pacific Studies Series.

Wabnitz, C., M. Taylor, E. Green and T. Razak. 2003. From ocean to aquarium. UNEP-WCMC, Cambridge, UK.

Wood, E. 2001. Collection of coral reef fish for aquaria: global trade, conservation issues and management strategies. Marine Conservation Society, UK.

C. Hair is from the Queensland Department of Primary Industries and Fisheries, Northern Fisheries Centre, PO Box 5396, Cairns QLD 4870, Australia. Email: cathy.hair@dpi.qld.gov.au. **R. Warren**, **A. Tewaki** and **C. Haro** are from the WorldFish Center, PO Box 77, Gizo, Solomon Islands; and **W. Phillips** is from the Solomon Islands Department of Fisheries and Marine Resources, PO Box 77, Gizo, Solomon Islands.

A global protocol for monitoring of coral bleaching

J. Oliver, N. Setiasih, P. Marshall and L. Hansen

Abstract

Coral bleaching and subsequent mortality represent a major threat to the future health and productivity of coral reefs. However a lack of reliable data on occurrence, severity and other characteristics of bleaching events hampers research on the causes and consequences of this important phenomenon. This article describes a global protocol for monitoring coral bleaching events, which addresses this problem and can be used by people with different levels of expertise and resources.

Introduction

Coral bleaching is considered to be one of the most significant and widespread threats to coral reefs. When predicted temperature increases due to global warming over the next 100 years are compared to the known temperature bleaching limits of corals, the depressing conclusion is that, by 2020, coral reefs in many parts of the world may suffer bleaching and mortality every year. Unless corals are able to adapt to rising temperatures, reefs may suffer progressive deterioration and species loss, resulting in major ecological impacts and consequent social and economic impacts on the human communities in many countries that depend on reefs for their livelihoods. Global warming and greenhouse gas emissions represent a relatively new and severe threat to the sustainability and productivity of coral reefs, and the services they provide to humans.

Accurate and precise estimates of the severity, timing and spatial patterns of coral bleaching and their subsequent mortality are essential if we are to gauge the level and immediacy of the threat and to develop appropriate management actions to alleviate the ecological and social impacts. Unfortunately, lack of standardized protocols has led to a proliferation of survey methods, surveyed variables and varying definitions for coral bleaching in different regions. Most reports are anecdotal and many are provided by people with limited training in quantitative ecological assessments. This makes comparison between areas exceedingly difficult. In addition, there is considerable variability in the effectiveness of the various monitoring procedures that have been used. Consequently, some surveys have not made effective use of personnel and time while others have collected data of limited use due to problems in observational bias and lack of standardization between observers.

There is an urgent need to obtain better information on bleaching events around the world. This information is crucial to a scientific understanding of the fate of coral reefs and to the feasibility and practicality of developing management strategies to increase the resistance and resilience of reefs to bleaching and associated mortality events. The World Wide Fund for Nature (WWF), the WorldFish Center and the Great Barrier Reef Marine Park Authority have recently developed a protocol for monitoring coral bleaching and for managing the resulting data. This protocol aims to provide a simple yet consistent set of procedures to document the extent and severity of bleaching events, and to collect information on other issues such as the causes and impacts of these events. This paper summarizes the key components of the protocol and is intended to raise awareness of its existence as well as promote its use in all regions.

Who will use the Protocol?

It is assumed that this guide will be used by people wishing to record the basic features of a bleaching event and to document overall impacts and possible causal relationships. The two primary aims are, firstly, to document global patterns and, secondly, to understand smaller-scale patterns and variations that may have local management implications. This protocol is designed to produce more quantitative data on the global distribution, severity, and frequency of bleaching events so that a more rigorous analysis of the relationship between coral reef status and climate change/global warming can be carried out.

The protocol will serve as:

- a quick guide on what to do if bleaching is observed;
- a guide on how to use time and resources most effectively to observe and record bleaching;
- an introductory resource on what bleaching is and how to recognize it;
- an aid in making immediate reports on coral bleaching when seen in the field;

- a guide for the development of structured and detailed assessments of bleaching as well as its causes and consequences.

Quick Guide

This section should be used if you want some quick guidance on what to do if you have seen (or think you have seen) coral bleaching. In addition to providing an introduction on how to distinguish bleaching from other phenomena which cause coral to go white, this section takes you through the steps needed to decide what type of measurements and monitoring activities would be most appropriate for the circumstances you have observed.

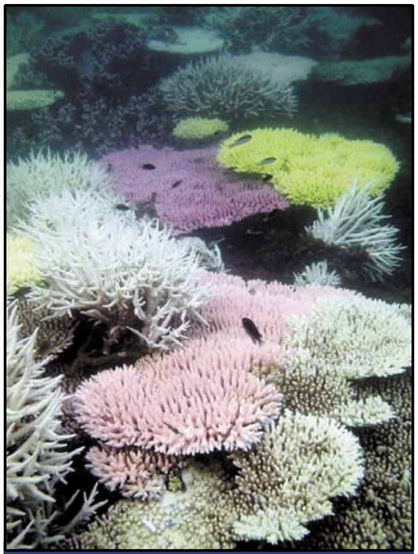
Box 1 below sets out the basics steps that should be followed if you observe coral bleaching.

How do I identify coral bleaching?

Coral bleaching occurs when corals lose the single celled algae (zooxanthellae) that live within their tissues. These golden brown coloured algae occur in varying densities in reef corals (and other reef invertebrates) and give them a light tan to deep chocolate brown colour. Where additional pigments exist within the animal cells, this brown colour can be overlaid by different hues, such as blue, green, purple or yellow (Fig. 1). When corals lose their zooxanthellae, the white skeleton can be seen through the transparent animal tissue, making the corals look bleached white. In cases where the corals possess additional animal pigments, bleached corals take on vivid fluorescent hues, with no trace of the normal brown background colour.

Corals which have bleached are not initially dead. On close inspection it may be possible to see the transparent polyps and tentacles of bleached colonies. However corals cannot remain bleached indefinitely. If the stress is not too severe or prolonged, they can slowly regain or regrow their zooxanthellae and survive. But in severe bleaching events many corals subsequently die, causing major changes in the structure and function of the reef ecosystem, with a possible cascading impact on other organisms.

Recently-dead corals are also white and can sometimes be confused with bleached corals. Bleached corals can be distinguished from dead corals by a careful examination of the coral surface. Completely bleached corals look extremely clean and almost glow when seen underwater. If the surface is sediment free and if you can see minute transparent tentacles when you view the colony from the side, the coral is



Ray Berkelmans/ReefBase

Fig. 1. In some corals, loss of their zooxanthellae reveals underlying colors in the animal tissue (pink, yellow, blue, green, orange) that can be very vivid. These corals are still considered bleached.

Box 1. What do I do if I see bleaching?

1. Record your observation and fill out a NOAA/ReefBase Questionnaire (www.reefbase.org/input/bleachingreport/index.asp) and contact local experts (if any).
2. If bleaching is widespread or severe, send out a message on coral-list to advise others.
3. If you cannot fill out most of the basic information in the questionnaire, consider returning to the site as soon as possible for a reconnaissance visit to get additional general information. Ask around and get other people who regularly visit the reef to indicate if they have seen bleaching and where. Get them to fill out a ReefBase/NOAA Questionnaire – or make a note of these observations yourself and send them to ReefBase.
4. Ask yourself why you are interested in this event. If you are not interested in formally answering the above questions (or any others you can think of) then continue to record the basic information on the Questionnaire and send it to ReefBase.
5. If you want to formally answer questions similar to those in step 4, then you will need to design a monitoring program (see below).
6. If you decide to implement a monitoring program, choose the methods and sampling protocol that best suits the questions you wish to answer, and the resources you have available to you; or pick a scenario that comes closest to your situation and either follow the protocol suggested or modify it to suit your situation.
7. Take photographs to illustrate conditions that you see and any unusual features. If using a digital camera, try to use one with a resolution of at least 3 megapixels.
8. Store your data in a safe place and then share it with others by publishing it yourself or sending the summary data to ReefBase.

not dead. Dead or dying colonies are unable to actively remove the sediment that rains down in all but the clearest reef environments. So any accumulation of even small amounts of sediment is a sign of mortality. Algae rapidly colonise dead coral surfaces, so a thin film or haze of green, brown or yellow is also a sure sign that the coral is dead rather than bleached. In the case of some fleshy corals, you can detect the presence of live tissue by gently touching the coral surface.

Bear in mind that bleached corals may ultimately die and dead colonies may be a final stage in the bleaching process. If your first observation is of large numbers of recently dead corals, you may have to look for other evidence to determine if this has been caused by bleaching. Other common causes of recently dead corals are crown-of-thorns starfish (COTS), disease and freshwater flooding.

Designing a program for your needs

In this protocol we use three resource scenarios (Box 2) to illustrate the activities that might be possible under different resource constraints.

Before undertaking the detailed procedures for making the recommended measurements, it is important to take time to consider what questions you wish to address, what measurements are most appropriate and where and how often they should be taken. While a set protocol in which everyone records the same measurements might seem to be the best approach, this is not likely to work in practice. The unique circumstances and sets of questions faced by different organizations and teams will require different monitoring programs. In many cases people have specific methods or procedures that they prefer because of their skill or experience. These can still provide data that are comparable across programs. Thus, the most effective approach is to carefully identify the objectives of the monitoring initiative and to then design a program that draws from a list of commonly used and comparable procedures, to best suit the locally specific questions, environment, resources and logistics.

The design of a monitoring and assessment program for coral bleaching should be approached in the same way as any monitoring program. A logical top-down approach should be used, beginning with the identification of the specific objectives (often phrased in the form of a question) and area under consideration (global, national, a reef, a dive spot). This should be followed by the selection of: variables to be measured; methods of measurement; sampling site; and sampling frequency. Fieldwork should commence only after all these factors have been specified. This is especially important when a substantial investment in time and resources is to be made in monitoring a bleaching event or events. Careful thought about objectives and spatial scales will also result in more relevant and reliable information being gathered even when assessment is limited to casual observations and questionnaires.

In theory, an unlimited number of questions could be posed in relation to coral bleaching. The more specific the question, the more specific the design of the monitoring program. This will result in data that can be used to answer the questions unambiguously. A monitoring program can be designed to address more than one question, but there is a risk that if questions are not specific enough the result will be a monitoring program that may not answer any of the questions.

Picking a monitoring program to suit your situation

It is not possible to fully specify all monitoring activities that should be carried out under every possible situation. Table 1 provides a guide to the type and frequency of monitoring that should be considered for different resource scenarios, and for two typical questions. Further guidance on other questions can be found in the full protocol. It is important to invest time in designing the monitoring to suit your specific situation and to use the points in Table 1 as a guide only.

Box 2. Resource scenarios.

Resources, in terms of funding, staffing and expertise, are an important constraints on the capacity of an organization or team to respond to a coral bleaching event. Recognizing these constraints and working within them to maximize the quality and relevance of data is essential to a successful monitoring program. Three generalized resource scenarios are described below as a guide in selecting a set of monitoring tools that are most suitable to the circumstances.

Low Resources	Moderate Resources	High Resources
• No dedicated funds • No or limited numbers trained staff • Active volunteers available (with diving qualifications) • Concern over plight of local reefs	• Some levels of dedicated funding available for bleaching work • Formal bleaching monitoring program exists or will be established • Trained staff available (or funding exists to train new staff) • Moderate level of logistic support (boats, computers, labs, scientifically qualified staff, good communications)	• Substantial funding available • Dedicated bleaching monitoring program exists • Highly qualified scientific team • High level logistic support • Strong community and government commitment to program

Table 1. Monitoring activities for various scenarios.

Question	Resource scenarios		
	1. Low	**2. Medium**	**3. High**
A. What is the general extent and severity of the current bleaching event?	**A1** • Record variables from questionnaire when visiting any sites (affected and non-affected) • Circulate questionnaires amongst local divers and other reef users • Submit information to ReefBase	**A2** • Carry out tasks in A1, plus synoptic surveys of representative sections throughout the area you are interested in (timed swims or manta tow) • Identify major species affected (take photos or specimens)	**A3** • Carry out tasks in scenario A1 and A2, plus conduct detailed surveys of representative sites using transects and some precise measure of percentage of coral affected (line transect, photo-transect) • Use aerial surveys (if water clarity and tides permit) or dedicated ship time to obtain synoptic estimates over wider geographic area
D. What are the ecological impacts on the reef system?	**D1** • Carry out tasks in A1 • Conduct before (if possible) and after bleaching observations including mortality/recovery • General estimates of coral cover over time	**D2** • Carry out tasks in A1, A2 and D1 • Monitor tagged corals – track mortality/recovery through visual estimates • Collect measured estimates of benthic cover through time (transects/quadrats)	**D3** • Carry out tasks in A1, A2, D1 and D2 • Monitor tagged corals and quadrats – measure mortality and recovery using video or photographic records • Collect measured estimates of benthic cover through time at higher taxonomic resolution (transects/quadrats) • Survey transects for other macro-invertebrates • Conduct surveys of fish abundance and diversity

A - Severity and Extent of Bleaching
D - Ecological Impacts

Outline of a typical monitoring plan

The following example outlines how one might develop a program to address questions A and D with moderate resource levels.

Prior to any bleaching being observed

If you are concerned about a particular area even before any bleaching has occurred, it is important to carry out some surveys before bleaching occurs to allow for specific before and after comparisons to be able to gauge ecological impacts.

- If visibility and local conditions permit, carry out manta tows of the whole area of interest to determine the distribution of habitats and the general characteristics of each habitat and zone.
- Choose replicate sites that are representative of the area (if more than one habitat or reef zone is being investigated, choose replicate sites in each of these). Sites can be selected using the results of the manta tow, local charts or aerial photographs.
- Using timed swims (15 minutes around an area of about 50m x 20m) or manta tows (5 x 2 minute tows), estimate hard coral cover (HCC), bleaching, and any other major indicators of coral stress.
- If further detailed information is needed, carry out replicate Line Intercept Transect (LIT) surveys at each site to measure percentage cover of principal benthos.
- If accurate data on the percentage of bleached corals which die or survive are needed, tag at least 20 corals at each site and record species, bleaching and mortality (presumably none at this stage).
- Regularly check the NOAA CHAMP website (http://orbit-net.nesdis.noaa.gov/orad/coral_bleaching_index.html) or the ReefBase hotspot/bleaching maps for hotspot reports during the high temperature season to anticipate bleaching events.

After onset of bleaching is observed (during peak of bleaching)

- Fill out the ReefBase questionnaire and distribute it to other divers or scientists in the area to do the same.
- Carry out extensive manta tow and/or timed swims to determine the extent/severity/variability of bleaching.
- Determine if existing sites adequately represent the areas bleached. If not,

add additional sites to cover a range of levels of bleaching intensity.

- Carry out belt transects (or LIT if the bleaching is very frequent) to get accurate estimates of the percentage of corals bleached at different levels of intensity.
- Record condition of all tagged corals. If there is not a reasonable number of bleached corals at each site (at least 10) then additional bleached corals should be tagged and their condition recorded.

Further monitoring during and after bleaching

- Repeat synoptic surveys (manta tow or timed swims) at regular intervals. Suggested optimal regime would be at 2 months, 6 months, 12 months and 24 months after initial bleaching. Full post-bleaching LIT surveys should be repeated once bleaching is no longer present and all corals have either died or recovered. If resources permit, further recovery LIT surveys should be conducted annually or every two years.

Key Variables to Monitor

The most important variable to monitor in all bleaching surveys is the percentage of the total living coral cover that is bleached. While line transects, photographic transects and other detailed survey methods yield this data from direct measurements, broad-scale surveys such as timed swims and manta tows, and questionnaires, generally provide only subjective estimates that are often grouped into categories. In order to be able to compare surveys from different locations and times, we recommend a standard set of bleaching categories for all such surveys (Table 2).

Table 2. Standard bleaching categories for use in broad-scale assessments.

Index	%*	Description	Visual Assessment
0	< 1	No bleaching	No bleaching observed, or only very occasional, scattered bleached colonies (one or two per dive)
1	1-10	Low or mild bleaching	Bleached colonies seen occasionally and are conspicuous, but vast majority of colonies not bleached
2	10-50	Moderate bleaching	Bleached colonies frequent but less than half of all colonies
3	50-90	High bleaching	Bleaching very frequent and conspicuous, most corals bleached
4	>90	Extreme bleaching	Bleaching dominates the landscape, unbleached colonies not common. The whole reef looks white

* Estimated % of total coral cover bleached

Standardization is also important in estimating the percentage of other coral reef benthic organisms. We recommend that the categories established by the Australian Institute of Marine Science and the Global Coral Reef Monitoring Network (GCRMN) be followed. The full protocol sets out the details for several other key variables that should be monitored in bleaching studies.

As part of the protocol, a series of data sheets has been created to assist in recording standard information in a consistent format. In addition, a Microsoft Access database with data entry forms designed to resemble the data sheets has been constructed. Both data sheets and a blank copy of the database can be downloaded from ReefBase at www.reefbase.org/bleachingdatabase.

Conclusions

In this summary paper, we highlight the objectives and many of the key components of the coral bleaching protocol. In the protocol we have assembled a virtual toolbox of methods and measurement tools which will, hopefully, cover a wide range of scenarios while at the same time promoting the collection of more standardized data. If the protocol is successful in this, we should be able to carry out much more meaningful analyses of the global and regional patterns of coral bleaching over the next decade and test the various predictions that have been made regarding the fate of coral reefs in the face of continuing global warming.

J. Oliver is from the World Fish Center, PO Box 500, GPO, 10670 Penang, Malaysia. **N. Setiasih** is from the World Wide Fund for Nature (WWF) Indonesia, Wallacea Program, Jl. Hayam Wuruk 179, Denpasar 80235, Bali, Indonesia. **P. Marshall** is from the Great Barrier Reef Marine Park Authority, 2-68 Flinders Street, PO Box 1379, Townsville, Qld. 4810 Australia. **L. Hansen** is from the World Wildlife Fund (WWF), 1250 24th Street, NW Washington, DC 20037, USA.
Email: j.oliver@cgiar.org

SEACORM NET - Southeast Asia's coral reef monitoring network

K. Tun and Chou LM

The Coral reefs of Southeast Asia (SEA) are globally the most species-rich and also the most threatened. Covering an area of over 100 000 km^2, they make up almost 34 per cent of the world's total coral reef area. They are home to more species of hard corals than any other region - 75 per cent of the 800 odd reef-building coral species occur in the region. This richness has been both a blessing and a curse to the reefs. The rich bounty of reef resources has sustained the livelihoods of generations of coastal communities. However, unregulated over-exploitation and destructive fishing over the past few decades has resulted in unprecedented damage and widespread degradation, posing a threat to coastal communities that are heavily dependent on reef resources. Despite this widespread damage, the associated economic benefits remain substantial – their importance to food security, employment, tourism, pharmaceutical research, and shoreline protection cannot be over-emphasized. The value of the region's sustainable coral reef fisheries alone is estimated at US$ 2.4 billion annually (Burke et al. 2002).

Since the mid-1980s, increased awareness of reef degradation has led to a growing realization that monitoring and management play a critical role in preventing further and perhaps irreversible loss in reef biodiversity and productivity. Numerous efforts to assess the status and arrest the decline have been initiated in recent decades at the local, national and regional scales. The level of expertise in reef monitoring and management varies among countries and in each country it is influenced by the individual needs of the country, availability of funding, capacity to undertake research and monitoring, and political willingness to implement management measures.

A recent positive development is the adoption of specific regulations and establishment of Marine Protected Areas (MPAs). Most countries have also initiated monitoring programs to regularly and systematically document reef status (both inside and outside MPAs). Despite the increasing data generated by these programs, there is insufficient cross-country coordination and information sharing. This is not due to a lack of willingness to collaborate but because of the lack of a permanent and structured mechanism to facilitate cooperation and coordination. Over the last two decades, numerous regional initiatives, starting with the ASEAN-Australia Living Coastal Resources (LCR) Project, have brought reef scientists together and established a strong network among them. However, the network remains an informal arrangement and coordination is still on a voluntary basis.

The year 2004 marks a new chapter for coral reef monitoring in SEA. With the appointment of a SEA regional coordinator for the Global Coral Reef Monitoring Network (GCRMN) in February, the country coordinators have come together and supported the establishment of a formal regional network of coral reef monitoring groups. The region's scientists recognize the need to work together and to spearhead regional initiatives that will allow for better integration of information and resources. Named SEACORM Net (Southeast Asia Coral Reef Monitoring Network), the group intends to establish a strong working relationship between member countries, share information and lessons learnt, inform and update each other on research and monitoring activities in each country, and provide a mechanism for cross-country assistance and collaboration.

The first major initiative of SEACORM Net was to take a unified approach at the 10th International Coral Reef Symposium (ICRS) held in Okinawa in June 2004. To enable more efficient networking between member countries, SEACORM Net has also established a website using the Windows SharePoint Services platform, to enable more efficient information sharing and collaboration.

Currently, SEACORM Net has members from Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. For further information about SEACORM Net, please contact Karenne Tun (k.tun@cgiar.org)

Reference

Burke, L., E. Selig and M. Spalding. 2002. Reefs at Risk in Southeast Asia. World Resources Institute.

Use of enriched live prey in promoting growth and maturation of Tiger Shrimp (*Penaeus monodon*)

A. Yong Seok Kian, S. Mustafa and R.A. Rahman

Abstract

This study was undertaken to determine the effect of nutritional management of broodstock of *Penaeus monodon* on growth and maturation. Test specimens were obtained from a grow-out pond before attainment of maturity and were reared in hatchery tanks. Four types of dietary treatments (M1–M4) were given to separate batches that were run in duplicate. Feeding trials continued for five months. A diet with live bloodworm, bioencapsulated to contain tricalcic phosphate as its major component, was found to be the most efficient. Specimens of this particular batch assimilated food more efficiently, grew at a faster rate and attained maturity earlier than other groups. Bloodworm provided the lipid fractions for which there is no *de novo* synthesis in shrimp. The enrichment product acted by promoting somatic growth and increasing transfer of biochemical constituents needed by the ovary for development.

Introduction

Penaeus monodon is the most widely used species of penaeid shrimp in aquaculture (Fig. 1). Supply of high quality broodstock is often a major constraint in the production of good quality seed. Most hatcheries depend on wild stocks, whose supply and quality are variable. Inducing maturation and spawning in captivity provides a more dependable means of seed production. The results are promising if the specimens are nourished properly and provided with enriched live prey. A survey of literature reveals that a sustained rearing of shrimp for production of seed in tropical countries is rare. The easier method of holding wild-caught shrimp in captivity for spawning is widely practiced. An attempt was made in this study to collect pond-reared *P. monodon* and grow them in hatchery tanks to maturity. The results outlined in this paper are based on experiments that involved four feeding regimes, with two consisting of bioencapsulated diets. The performance of all the four batches of feeding treatments in terms of growth and maturity is presented.

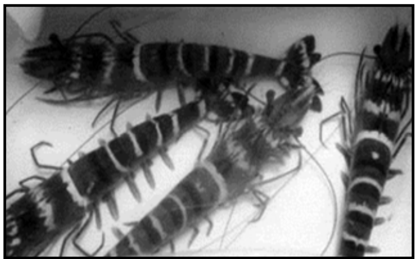


Fig. 1. Tiger prawn (*Penaeus monodon*) broodstock.

Materials and Methods

The *P. monodon* used in this experiment were procured from grow-out ponds and sorted according to size. The average initial weights of the females and males were 34.2±8.6 g and 32.6±5.2 g, respectively. After acclimation to hatchery conditions for a week, the specimens were individually weighed and stocked in black fiberglass tanks of 3.8 t capacity. The specimens were divided into four groups and stocked in eight maturation tanks at a density of six specimens/m^2 with a 1:1 male to female ratio as suggested by Bray and Lawrence (1992). The specimens were exposed to a natural photoperiod which was almost 12 h light and 12 h dark. Water depth of approximately 1 m was maintained throughout the experiment. Water was renewed daily and aerated. The physico-chemical parameters of water routinely monitored on a daily basis included temperature, salinity, pH and dissolved oxygen. The average values of water temperature, salinity, pH and dissolved oxygen were 28.1±1.5 °C, 29.8±1.7 ppt, 7.33±0.25 and 6.43±0.88 mg/L, respectively. These values are within the ranges suitable for *P. monodon* in a hatchery (Rosly 1990; Sabah Fisheries Department 1991).

Test specimens were offered four different dietary treatments (Table 1) with two replicates each. The experiment was continued for five months. The feeding regime consisted of four feedings/day at the rate of 10 per cent body weight/day (wet weight basis) at fixed intervals (0800 h, 1300 h, 1800 h and 2300 h). At these times, feeding represented 30, 40, 20 and 10 per cent of total food supplied in a 24 h period, in that order. During feeding, the water renewal process was suspended for one hour to avoid loss of feed through the effluent water.

Table 1. Composition of the test diets.

Dietary treatment	Feed component
M1	Squid (40 %)+ mussel (30 %) + trash fish (30 %)
M2	Squid (30 %)+ mussel (25 %) + trash fish (25 %) + enriched bloodworm (20 %)
M3	Squid (30 %)+ mussel (25 %) + trash fish (25 %) + Madmac (20 %)
M4	Squid (30 %)+ mussel (25 %) + trash fish (25 %) + enriched artemia (20 %)

The fresh feeds were rinsed, drained and manually sliced into 1 to 1.5 cm pieces. The appropriate amounts for each tank were weighed and labeled before putting them into the freezer. The feeds were partially thawed and rinsed before they were offered to *P. monodon* (Robertson et al. 1993).

Artemia cysts were incubated in an artemia tank for 14 to 16 h. Newly hatched artemia were harvested, rinsed with clean seawater and transferred into a bucket. Live bloodworms and newly hatched artemia were enriched by the bioencapsulation technique. They were exposed to a suitable volume of filtered seawater containing tricalcic phosphate to a concentration of 1 per cent for one hour.

When the stocked *P. monodon* attained a body weight of some 60 g, unilateral eyestalk ablation was performed. One of the eyestalks was ligatured at the base by a surgical thread and just anterior to this portion the stock was cut off with scissors. After eyestalk ablation, the condition of the ovary was monitored once every two days between 1800 h and 1900 h using an underwater dive torch light. Gravid spawners were identified by the dark outline of the abdominal portion (Chwang et al. 1986). Each gravid spawner was transferred to a 250-liter tank for spawning, following the recommendation of Millamena et al. (1986). Gentle aeration was maintained throughout.

The specimens in each treatment group were individually weighed every month to estimate the food conversion ratio (FCR), food conversion efficiency (FCE %), body specific growth (BSG %), specific growth rate (SGR per day) and daily growth rate (mg/day/individual). These parameters were calculated as described by Mustafa and Ridzwan (2000).

Results

Data pertaining to growth and reproductive performance of *P. monodon* given different types of diets are summarized in Table 2. The body weight increased in all the treatment groups, but differences were evident between the groups.

Table 2. The FCR, FCE, BSG, SGR and daily growth of *P. monodon* fed four different diets.

Parameters	Diet			
	M1	M2	M3	M4
Average initial weight (g)	38.88 ± 1.68	37.12 ± 3.09	37.98 ± 3.74	38.03 ± 2.26
Average final weight (g)	60.54 ± 4.72[a]	71.81 ± 10.63[b]	68.39 ± 6.26[b]	58.84 ± 4.54[a]
FCR	5.24[a]	3.55[b]	3.78[b]	5.72[a]
FCE (%)	3.81[a]	5.65[b]	5.45[b]	3.48[a]
BSG (%)	55.70[a]	93.50[b]	80.10[b]	54.50[a]
SGR (%)	0.30[a]	0.44[b]	0.39[b]	0.29[a]
Daily growth rate (mg/day/individual)	144.40[a]	231.30[b]	202.70[b]	133.60[a]
Maturation rate	1/24	6/24	3/24	2/24

Values in the same row that are denoted by different superscripts are significantly different (P<0.05).

Growth and FCR were influenced by dietary composition and ration size, while FCR was affected by the quality of feed. Not all the food is converted to body mass. A certain proportion is eliminated from the body in the form of metabolic waste. Generally, in aquaculture, efforts are made to establish a more efficient feeding system that accelerates growth without increasing the FCR. Any rise in FCR beyond an established 'normal' profile is a matter of concern and calls for in-depth analysis of the whole feeding regime as well as the culture system. Feeding in excess of appetite wastes feed, fouls the culture medium, increases FCR and raises the production cost. Underfeeding reduces growth and also increases the FCR for a different reason. Examination of these relationships is important in developing feeding and growth models and in the interpretation of production data. When growth profiles are established using data from underfed specimens, or feeding models are developed on the basis of the data pertaining to FCR values from either underfed or overfed batches of shrimp, the information derived will be faulty (Talbot 2002).

In this experiment, the highest weight gain (231 mg/day) was recorded in the treatment with the diet that was supplemented with bioencapsulated bloodworm (M2). These specimens also showed a higher value of BSG (93.5 per cent) and SGR (0.44 per cent) and a lower value of FCR (3.55), indicating better assimilation of food into body tissues and faster growth in biomass as compared with other dietary treatments. The performance of dietary treatment M3 in terms of growth was next to M2. Test specimens maintained on M3 diet grew at a rate of 202.7 mg/day. No significant difference in growth was seen between M2 and M3 treatments (P<0.05). *P. monodon* fed the other two diets showed slower growth rate: 144.4 mg/day (M1) and 133.6 mg/day (M4). Treatment M2 also gave better results in reproductive efficiency in addition to supporting the highest growth out of all the test groups. In this batch the first sign of maturity was observed four weeks after the eyestalk ablation and the number of individuals with mature gonads was also the highest.

For managing growth and optimizing FCR, an analysis of good growth with low FCR or low growth with high FCR is required. The real cause of slow growth and high FCR can be determined by growth-ration analysis. Increase in SGR with ration size, and decline in FCR in a rearing system when specimens are given a particular dietary treatment requires attention for increasing the nutritional status by manipulation of quality or quantity of the diet.

Discussion

Nutrition is a major factor in growth (Fenucci et al. 1980, 1981; Piedad-Pascual 1986; Bautista and Subosa 1997; Deering et al. 1997; Sudaryono et al. 1999; Davis and Arnold 2000) and reproductive performance of penaeid shrimps in captivity (Harisson 1990; Bray and Lawrence 1992; Naessens et al. 1997). However, comprehensive information on nutrient requirements of *P. monodon* is limited and is urgently needed for a successful management of broodstock in hatcheries. Products such as squid, mussel, bloodworm, clam and trash fish in raw form have demonstrated their role in nourishing the captive stock of *P. monodon,* but there is no explicit indication of their direct or specific influence on reproduction. Generally, well-nourished shrimps are expected to be more fertile. It is unknown if any of these or other natural food items selectively act on the reproductive system to stimulate the cycle of maturation and increase the fertility. A diet that contains substances which can target the gonads is, therefore, of great importance in broodstock management. It can reduce the duration of broodstock rearing and cost of hatchery operations. Bioencapsulation offers a means of developing such a diet. Results of this study suggest that this approach can be employed to develop a diet for manipulating the fertility of shrimp in hatcheries for high quality seed production.

Noticeable differences in the FCR in *P. monodon* fed different diets indicated the essential differences in the efficacy of assimilation of feed components and accomplishing growth of the animal. In fish culture, an FCR value of up to 2.0 is considered suitable for commercial feeding. In the case of *P. monodon*, such a generalized scale has not been established, but FCR values ranging from 1.58 to 1.71 (wet weight) and 5.49 to 6.62 (dry weight) have been reported (Higano and Pichitkul 2000) from commercially viable shrimp farms. Sarac et al. (1993) observed that FCR values varied with the stage of growth: 8.18 to 12.25 in larger *P. monodon* (32 g) and 1.69 to 2.98 in smaller animals (1.5 g) given the same diet. In adult *P. monodon,* intake of feed was consistently high but the FCE was low as compared to their juvenile stage. Evidently, small animals show an accelerating growth pattern with time, while the large-sized ones grow at a slower rate on similar diets. Similar results were obtained for other species of shrimp. Choe (1971) found that growth declined in *P. japonicus* with size and age. Wyban et al. (1995) reported that growth and feeding rate were directly related to temperature but varied inversely with size in *P. vannamei.* Obviously, at the younger stage shrimps assimilate nutrients more efficiently than the older individuals and this accounts for their lower FCR. In the light of these findings, the determination of economic feasibility of feeding requires a consideration of a multitude of factors, including FCR, stage of growth and total cost of compound rations, among others. In addition to the type of food, the physiological efficiency and utilization of diets also influence the FCR and FCE in *P. monodon*. Piedad-Pascual (1986) noticed that the FCR values varied from 7.46 to 13.72 in an experiment that involved supplementing lecithin and lipid in the diet offered to *P. monodon* juveniles. Buchanan et al. (1997) obtained FCR values in the range of 1.98 to 3.06 for juveniles of this species given canola meal mixed with enzymes. Significantly lower FCR values (2.3 to 2.9) were observed in *P. monodon* when fed with different types of legume meals (Sudaryono et al. 1999).

The growth rate of adult *P. monodon* maintained entirely on fresh natural food (M2) was higher than that reported for juvenile penaeid shrimp fed artificial diet (Surdayono et al. 1999). Previous studies have shown that the growth rate and FCR are greatly influenced by the type of food, life stage of the animal and the rearing environment. Sudaryono et al. (1999) noticed that juvenile *P. monodon* (4.1 g) gained an average of 83.5 mg/day when fed with soybean and lupin based diet. A higher growth rate was noted in juvenile penaeid prawns supplied with artificial diet that contained a higher concentration of protein (Dominy and Ako 1988; Sudaryono et al. 1995). Furthermore, Cruz-Suárez et al. (1992) demonstrated that the addition of 10 per cent squid meal into juvenile *P. monodon* diets consistently improved the growth rate of the shrimps that were reared in ponds and tanks. This study also indicated that FCR was lower (1.7) in specimens that were cultivated in ponds as compared to those reared in tanks (2.8).

The higher growth rate and FCE obtained from the M2 group in this investigation could be attributed to the phosphate enrichment and the bloodworm supplement. Bloodworm is known to be a natural forage organism that supports maturation in penaeid prawns due to its highly unsaturated fatty acids (HUFAs) that help in the process of gonad maturation (Middleditch et al. 1979). The better growth performance exhibited by *P. monodon* fed enriched bloodworm was probably caused by the HUFAs and certain essential nutrients needed to build body tissues. Published data have indicated the role of variable proportions of lipid and protein in growth and food conversion (Ketola 1982; Sarac et al. 1993; Merican and Shim 1996; Glencross et al. 2002), but the quantitative requirements of the fractions of these nutrients (amino acids in the case of protein and HUFAs in the case of lipid) are not properly understood. Diets poor in essential fatty acids retard growth in tiger prawn (Sarac et al. 1993; Merican and Shim 1996). It has also been shown that not only the total quantity of lipid but also the source from where it is derived influences the growth of shrimps (Peidad-Pascual 1986; Deering et al. 1997). In fish, it is possible to reduce the protein level of the diet without growth suppression if the caloric content is maintained at a high level with lipid (Watanabe 1982), but such studies have not been reported in shrimps. It will be potentially interesting in diet formulation if information on this aspect is available.

Observations on maturation resulted in interesting information. The first spawning occurred four weeks after the eyestalk ablation in the most nourishing dietary treatment (M2). This was faster than the spawning time reported by Bray and Lawrence (1998) where unilaterally eyestalk-ablated female *P. monodon* took five weeks to spawn. Supply of HUFAs and cholesterol from bloodworm to broodstock obviously contributed to the development of gonads. Without having an intrinsic biosynthesis of these substances despite their physiological requirement, captive broodstock would obviously depend on the availability of these lipid fractions in the diet. Presence of both cholesterol and HUFAs is, therefore, a critically important factor in the reproductive processes. Incorporation of the phosphate compounds apparently facilitated transfer of cholesterol and HUFAs to the developing ovary, either by strengthening the capacity of somatic organs (especially the hepato-pancreas) to store them for subsequent transfer to ovaries, or by directly influencing the ovary to increase the uptake. An understanding of the exact mechanism requires more physiological investigations designed to elicit information on these aspects.

Conclusion

Growth and maturation of *P. monodon* are influenced by nutrition. Live prey in the form of bloodworm is quite effective in nourishing *P. monodon* broodstock. Bioencapsulation of bloodworms with tricalcic phosphate strengthens the capacity of somatic tissues to support development of the ovary. The enrichment product may also act on the ovary to facilitate the uptake of required chemical substances such as cholesterol and highly unsaturated fatty acids required for the development of ovaries and formation of high quality eggs. An understanding of the exact mechanism of action of the bioencapsulated phosphorylating compound requires further investigation.

References

Bautista, M.N. and P.F. Subosa. 1997. Changes in shrimp feed quality and effects on growth and survival of *Penaeus monodon* juveniles. Aquaculture 151:121-129.

Bray, W.A. and A.L. Lawrence. 1992. Reproduction of *Penaeus* species in captivity, p.93-170. ***In*** A.W. Fast and A.J. Lester (eds.) Marine Shrimp Culture: Principles and Practices Vol. 23. Amsterdam, The Netherlands.

Bray, W.A. and A.L. Lawrence. 1998. Successful reproduction of *Penaeus monodon* following hypersaline culture. Aquaculture 159:275-282.

Buchanan, J., H.Z. Sarac, D. Poppi and R.T. Cowan. 1997. Effects of enzyme addition to canola meal in prawn diets. Aquaculture 151:29-35.

Choe, S. 1971. Body increases during molt and molting cycle of the oriental brown shrimp *Penaeus japonicus*. Marine Biology 9:31-37.

Chwang, N.L.M., P. Chiang and I.C. Liao. 1986. Evaluation of shrimp (*Penaeus monodon*) hatchery methods practiced by Taiwanese technicians, p. 39-43. ***In*** J.L. Maclean, L.B. Dizon and L.V. Hosilos (eds.) The First Asian Fisheries Forum. Manila, Philippines.

Cruz-Suaárez, L.E., D. Ricque and AQUACOP. 1992. Effect of squid meal on growth of *Penaeus monodon* juveniles in pond pens and tanks. Aquaculture 106:293-299.

Davis, D.A. and C.R. Arnold. 2000. Replacement of fish meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*. Aquaculture 185:291-298.

Deering, M.J., D.R. Fielder and D.R. Hewitt. 1997. Growth and fatty acid composition of juvenile leader prawn, *Penaeus monodon* fed different lipid. Aquaculture 151:131-141.

Dominy, W.G. and H. Ako. 1988. The utilization of blood meal as a protein ingredient in the diet of the marine shrimp *Penaeus vannamei.* Aquaculture 70:289-299.

Fenucci, J.L., A.L. Lawrence and Z.P. Zein-Eldin. 1981. The effects of fatty acid and shrimp meal composition of prepared diets on growth of juvenile shrimp, *Penaeus stylirostris*. Journal of the World Mariculture Society 12(1): 315-324.

Fenucci, J.L., Z.P. Zein-Eldin and A.L. Lawrence. 1980. The nutritional response of two penaeid species to various levels of squid meal in a prepared feed. Proceedings of the World Mariculture Society 11:403-409.

Glencross, B.D., D.M. Smith, M.R. Thomas and K.C. Williams. 2002. The effects of dietary lipid amount and fatty-acid composition on the digestibility of lipids by the prawn, *Penaeus monodon*. Aquaculture 205:157-169.

Harrison, K.E. 1990. The role of nutrition in maturation, reproduction and embryonic development of decapod crustaceans: a review. Journal of Shellfish Research 9 (9):1-18.

Higano, J. and P. Pichitkul. 2000. Water quality and carbon and nitrogen budgets in intensive prawn farms in freshwater areas of Thailand. Newsletter No. 22. Japan International Research Center for Agricultural Sciences.

Ketola, H.G. 1982. Amino acid nutrition of fishes: Requirements and supplementation of diets. Comparative Biochemistry and Physiology 73B (1):1-17.

Merican, Z.O. and K.F. Shim. 1996. Qualitative requirements of essential

fatty acids for juvenile *Penaeus monodon*. Aquaculture 147:275-291.
Middleditch, B.S., S.R. Missler, D.G. Ward, J.P. McVey, A. Brown and A.L. Lawrence. 1979. Maturation of penaeid shrimp: dietary fatty acids. Proceedings of the World Mariculture Society 10: 472-476.
Millamena, O.M., J.H. Primavera, R.A. Pudadera and R.V. Caballera. 1986. The effect of diet of the reproductive performance of pond-reared *Penaeus monodon* Fabricius broodstock, p. 593-596. ***In*** J.L. Maclean, L.B. Dizon and L.V. Hosilos (eds.) The First Asian Fisheries Forum. Manila, Philippines.
Mustafa, S. and A.R. Ridzwan. 2000. Sustainable marine aquaculture recent developments with special reference to Southeast Asia. Kota Kinabalu, Malaysia.
Naessens, E., P. Lavens, L. Gomez, C.L. Browdy, K. McGovern-Hopkins, A.W. Spencer, D. Kawashigashi and P. Sorgeloos. 1997. Maturation performance of *Penaeus vannamei* co-fed *Artemia* biomass preparations. Aquaculture 155:87-101.
Piedad-Pascual, F. 1986. Effect of supplemental lecithin and lipid sources on the growth and survival of *Penaeus monodon* juveniles. p615-618. ***In*** J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds.) The First Asian Fisheries Forum. Manila, Philippines.
Robertson, L., B. Bray, T. Samocha and A.L. Lawrence. 1993. Reproduction of penaeid shrimp: an operations guide, p. 107-132. ***In*** J.P. McVey (ed.) CRC Handbook of Mariculture, Crustacean Aquaculture. 2nd edition. Vol. 1. Boca Raton.
Rosly, H. 1990. Garis panduan mutu air untuk ternakan ikan dan udang laut. Risalah Perikanan Bil. 43. Jabatan Perikanan, Kementeraian Pertanian Malaysia.
Sabah Fisheries Department, 1991. Water quality requirements for *Penaeus monodon* culture. Fisheries No. 3/91.
Sarac, Z., H. Thaggard, J. Saunders, M. Gravel, A. Neill and R.T. Cowan. 1993. Observations on the chemical composition of some commercial prawn feeds and associated growth responses in *Penaeus monodon*. Aquaculture 115:97-110.
Sudaryono, A., M.J. Hoxey, S.G. Kailis and L.H. Evans. 1995. Investigation of alternative protein sources in practical diets for juvenile shrimp *Penaeus monodon*. Aquaculture 134:313-323.
Sudaryono, A., E. Tsvetnenko, J. Hutabarat, Supriharyono and L.H. Evans. 1999. Lupin ingredients in shrimp (*Penaeus monodon*) diets: influence of lupin species and types of meals. Aquaculture 171:121-133.
Talbot, C. 2002. Growth and feeding models and their application in management decision support, p. 93-98. ***In*** M. Sargolia (ed.) Aquaculture Europe 2002: Seafarming Today and Tomorrow, Brussels.
Watanabe, T. 1982. Lipid nutrition in fish. Comparative Biochemical and Physiology 73B (1):3-15.
Wyban, J., W.A. Walsh and D.M. Godin. 1995. Temperature effects on growth, feeding rate and feed conversion of the Pacific white shrimp (*Penaeus vannamei*). Aquaculture 138:267-279.

A. Yong Seok Kian is currently a Lecturer, **S. Mustafa** is an Associate Professor and **R.A. Rahman** is a Professor at Borneo Marine Research Institute. Corresponding author: A. Yong Seok Kian, Borneo Marine Research Institute, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, Malaysia
Email: yongannita@yahoo.com.sg

Feasibility of fisheries co-management in Africa

A.S. Khan, H. Mikkola and R. Brummett

Abstract

The current, highly centralized approach to fisheries management seems to be incapable of coping with escalating resource depletion and environmental degradation. Co-management has been identified as an alternative. This paper compares various approaches to fisheries management and discusses their performance in relation to the nature of the fishery. It is concluded that in African fisheries, stringent institutional arrangements, poor human, technical and financial resources, and a limited time frame often thwart co-management approaches. However, with the right conditions and prerequisites, co-management can be successful in improving compliance with regulations and maintaining or enhancing the quality of the resource. The paper brings out the issues that require further research.

Introduction

As in many parts of the world, over-exploitation of fisheries is common in Africa. Traditionally, fishery management was entrusted to community leadership, typically a Chief working with the support of a council of elders. The fishery resource was often perceived as a gift from nature or various deities who made their wishes known through the elders. Rituals and sacrifices were often associated with traditional African fisheries management.

Ownership and access to the resource was communal. Family members inherit the resource and access is granted by kinship. Fishing communities have strong social and religious values with ethics and norms, which creates room for collective communal co-operation. Participation in such traditional institutions is often based on age and gender. Women, for example, are typically involved in fish processing and marketing. Adult men fish while older men spearhead decision-making based on their experience and knowledge. Youths are mostly involved in communal development projects.

Traditional management measures widely employed in African fisheries include, *inter alia*:

- Forbidding of fishing in certain areas.
- Closed days or seasons.
- Restrictions on fishing gears or techniques.
- Limiting access.

Offenders are punished through sanctions, fines or expulsion from the community. Such management practices seem to have worked well mostly because of strong group cohesion, emphasis on social obligations, consensus-based decision making and a high degree of social conformity (Horemans and Jallow 2000). Recently, these systems have been weakened by the erosion of traditional beliefs, disrespect for elders and the disintegration of social structures as a result of urbanization.

Since colonial times, centralized institutions have been in place to increase government control over resources. Policies are usually embodied in a Fisheries Act, Decree or Master Plan, which defines the authority and administration for management. The Department of Fisheries, in consultation with scientists, extension agents, community representatives and/or donor agencies, formulates policy and legislation. Fishery regulations mostly take the form of:

- Effort regulation (total allowable catch, limited fleet size etc.);
- Technical regulation (mesh size restrictions, gear specifications);
- Entry limitations (permits, licenses etc.); and
- Monitoring and surveillance (confiscation, fines, etc.).

The success of such centralized planning and regulation depends upon a government's ability to correctly analyze problems and enforce its will. Unfortunately, inadequate infrastructure, expertise and funding have resulted in: 1) a serious lack of data upon which to base effective policy and 2) the inability to enforce regulations. Together, these problems have rendered most modern fishery management policies meaningless. In many African countries, increased community involvement through co-management programs is being seen as a potential solution to this problem.

Fisheries co-management is the sharing of responsibility and cost for the sustainable management of a fishery between the government and the local community (Berkes et al. 1991; West and Brechin 1991; Pomeroy and Williams 1994; Jentoft and McCay 1995; Borrini-Feyerabend 1996; Raakjaer Nielsen et al. 1996; Sen and Raakjaer Nielsen 1996; Kuperan et al. 1998; Schreiber 2001; Hara et al. 2002). The concept of co-management is now synonymous with co-operative management, community based management, joint management and/or participatory management, but should not be confused with cooperative fisheries management which aims to establish coordinated joint management programs between states (Munro 1987, 2002). The key objective of co-management is the development of a strategy for collaborative decision-making that can lead to agreement on management roles and responsibilities that generate local incentives for sustainable resource use (Hara 1999).

Co-Management in Africa

The basic challenge of co-management is the reshaping of government thinking to institutionalize collaboration between administration and resource users in order to end unproductive situations where they are pitted against one another as antagonistic actors (Baland and Platteau 1996). Devolution of some authority to manage fisheries away from central administrations to user groups may be one of the most difficult tasks of co-management (Raakjaer Nielsen et al. 1996). Government resource managers are often reluctant to share their authority or even part of it (Kuperan et al. 1998). Allowing fish harvesters to manage fisheries is felt to be almost as sensible as turning the hen house over to the fox, with harvesters lacking both the necessary knowledge about resources and capability of reaching consensus (Davies and Jentoft 2001). Population increases in fishing communities, market integration and technological innovations in gear and crafts as well as corruption and other patterns of human behavior can undermine co-management arrangements (McCay and Jentoft 1996). In addition, co-management is associated with high program design costs necessary to ensure effective participation (Hanna 1995) and these may outweigh the expected benefits (Kuperan et al. 1998).

On the other hand, long-term costs for monitoring and enforcement are low (Hanna 1995) as many recurring costs to government, such as patrols, record keeping and facilities maintenance, can be shifted from the central government to user groups. In addition, user participation draws upon the experience and expertise of fishers and increases the likelihood of compliance with rules and regulations (Jentoft 1989; Jentoft and McCay 1995). The institution of co-management regimes has reportedly helped strengthen small-scale fishing communities by increasing community cohesion and an elevation of pride in cultural identity and optimism about the future (McGoodwin 2001). To look at how the various costs and benefits of co-management might add up in Africa, nine case studies were selected, representing a range of both inland and marine co-management systems.

Benin: Lake Nokoue (Atti-Mama 1997)

The fishing site covers an area of about 12 000 ha, with a fishing population of 13 500. Many types of fishing gears are employed to catch a wide variety of fish species. Access to the resource is communal with poor compliance with regulations from the users. Lack of fishery data, high fishing pressure, and poor enforcement are the main management problems. The Department of Fisheries and the Center for Regional Rural Development administer fishery regulations with the local administration (Sous Prefet). The formation of fishery committees with the local fishermen, in consultation with the formal institutions, strengthened resource use and management. One of the paramount benefits of co-management in lake Nokoue was the sensitization program, aimed at training and education of fishers in the principles of fishery management. This has yielded better compliance with fishery regulations, and improved sustainability of the fishery.

Cote d'Ivoire: Aby Lagoon Complex (Kponhassia and Konan 1997)

This is a multi-species and multi-gear coastal fishery with a population of approximately 3 000 fishers. The Lagoon complex extends over an area of 424 km^2, which is a common property with territorial rights limiting access to certain areas. Fishing boats are 8 to 12m long but poorly mechanized. This is a low value fishery, targeting species with a variable market, but generally low market value. Conflicts over access rights are common. High fishing pressure and lack of reliable stock assessment are other key problems. The Directorate of Fisheries in partnership with the local administration (Government appointed Sous Prefet) has tried to regulate the high fishing pressure on the resource. A co-management structure, the Consultative Fishery Surveillance Committee, has been empowered to regulate and enforce government policies. Education and sensitization programs for greater user participation have been organized and have led to improved compliance and resource conservation.

The Gambia: Central River Division (Njie and Mikkola 2002)

This is a multi-gear and multi-species riverine fishery on the Gambia River used by 314 poorly mechanized fishers. There is a high influx of migrant and foreign fishermen with indiscriminate gear use and consequent environmental degradation. Human and technical constraints are evident, with inaccessibility of landing sites being a key management problem. The Department of Fisheries in consultation with the local traditional authority (village head and council of elders) and local Community Fisheries Management Committees devised a number of co-management approaches to common problems, which include the lack of fishery data, poor implementation of Government policies, weak enforcement of rules, and conflicts among resource users. Since the advent of co-management, there is greater user participation and better enforcement. Participatory control and surveillance has improved resource conservation as have the implementation of new seasonal and area closures.

Malawi: Lake Malombe (Donda 1996)

This is a multi-gear and multi-species fishery, with an area of about 390 km^2 and with a fishing population of about 2 300 and open access rights with low mechanization within the industry. Input cost is rather high, with a variable market structure, and poor technical facilities for fish processing and transportation of fish products. Management challenges include unregulated access, limited control and monitoring by the regulatory authority and over exploitation. The Department of Fisheries administers fishery regulations and has, in consultation with the local village authority and fisher associations, developed a co-management approach. Entry and gear restrictions have now been implemented, along with seasonal closures. Co-management has generally led to better compliance from resource users and greater participation.

Mozambique: Angoche District in Nampula Province (Lopes et al. 1997)

This is a multi-gear and multi-species coastal marine fishery with a surface area of 3 600 km^2 and a fishing population about 200 000. Although the fishery is poorly mechanized, the open access and common property nature of the resource makes it highly susceptible to over-exploitation. Moreover, the lack of alternate job activities within the community has been steadily increasing the number of fishers and conflict among them is increasing. Poor processing and other marketing infrastructure limit the profitability of the fishery. From the point of view of management, stock assessment, regulation of effort and over-exploitation are key problems. The Marine Fisheries Administration, the Ministry of Finance and the Fisheries Secretariat undertake fishery management and regulation. This top-down structure has been strengthened through consultation with traditional local authorities and a council of Chiefs together with communal associations (Guias de Pesca) to co-manage the fishery. Consultative committees from both formal and informal institutions have been formed to address common fisheries problems and to manage the fishery resource in terms of regulation and encouraging compliance by users.

Nigeria: Lake Chad (Nieland 2000)

This is a mono-gear (basket) fishery with entry restrictions. Consequently, the fishery yields high catches and profits per unit area. However, high fishing pressure, poor fishery data, unclear property rights, and environmental degradation are increasingly common problems. The Department of Fisheries, together with traditional authorities have formed a Monitoring Unit that seeks to ensure compliance with management measures aimed at guaranteeing sustainability. User participation has increased, but capacity building and better legal structures are still required.

South Africa: Arniston (Hutton and Lamberth 1997)

This is another multi-gear, multi-species coastal marine fishery with a moderate level of boat mechanization. The biggest issue here is racial segregation and the absence of harbors. Conflicts are common, with illegitimate rules and fishery regulations left over from the Apartheid era. A Sea Fisheries Committee oversees fishery management and regulations under the Ministry of Environmental Affairs and Tourism. One of the greatest challenges is competition between industrial and artisanal fisheries, leading to high fishing pressure and problems with control and monitoring. However, consultations within the local fisher's forum, and amongst the local Communal Trust and the Sea Fisheries Committee have yielded fruits in a joint co-management approach. One of the most important outcomes of this has been the formation of co-operatives and communal organizations with a high degree of participation and legitimacy, which has been able to enforce fishery regulations and the increase the sustainability of resource use.

Zambia: Lake Kariba (Sen et al. 1997)

Lake Kariba is one of the largest man-made lakes in the world with 5 500 km^2 surface area, 300 km long and 40 km at its widest point. It is a multi-gear and multi-species fishery with open access, although preference is given to certain ethnic groups like Valley Tonga people. The fishermen often have conflict with other non-fishing resource users like Safari operators and illegal cross-border traders. This, coupled with a variable market structure, post harvest spoilage and poor returns, make risky the high investment costs. Multiple and destructive fishing gears like explosives, chemicals, poisons, jigging and illegal size nets have the potential to overexploit the resource. The lack of reliable catch and effort data thwarts management initiatives. The Department of Fisheries regulatory structure has been enhanced with local traditional institutions and committees in a joint participatory and consultative approach that has reduced conflict. In addition, more consultation and participation on the part of the resource users has led to better compliance with regulations.

Zimbabwe: Lake Kariba (Sen et al. 1997)

As is the case for the Zambian part of the lake, the Zimbabwe fishery on Lake Kariba is a multi-user resource, with the fishermen competing with other users for access. The fishing population is about 1 240 with a form of government regulated access, but conflicts are common with other stakeholders. The fishery is poorly mechanized, with low economic returns, large post harvest spoilage and fixed market prices. One company is the largest single buyer and, therefore, practically determines the price of fresh fish. The company often provides fishers with nets and some foodstuff on credit. Repayments are usually made with fish. Fishing is generally regarded as risky due to the presence of game scouts, crocodiles and hippos. The use of destructive fishing gear and a high fishing effort is unsustainable. This is compounded by unreliable fishery data. The Department of Fisheries, Parks and Wildlife, in consultation with the Lake Kariba Fisheries Research Institute, is responsible for administering fishery regulations. Together with traditional local authority and fishery development committees, a new co-management approach has led to the formation of exclusive fishing zones and closures and has gone a long way in resource conservation. There is now greater user participation, with trust and cooperation between the resource users and the fishery officers, which has lead to legitimacy and compliance with fishery regulations.

Analysis of Case Studies

The case studies represent typical African fisheries in that they are generally multi-species and use a range of gear types. Motorized boats are rare. Tenure is mostly common property and open access, with consequent conflicts between traditional and new users displaced by poverty into fishing. Resource over-exploitation, lack of respect for management decisions and environmental degradation are other common problems.

From these cases, several common denominators that have engendered successful outcomes can be identified. These should be considered as key elements that any effort at sustainable co-management of African fisheries needs to consider:

- Participation: The legitimization of laws and the harmonization of traditional and colonial enforcement systems through active participation by all resource users.
- Management: The provision of adequate financial, technical and intellectual resources to make, explain and enforce regulations.
- Transparency: An honest willingness on the part of governments to relinquish exclusive control of natural resources and the establishment of trust and confidence among the various partners.

Participation

A key aspect of successful management involves the delegation of managerial responsibility to traditional fishery institutions with active participation by fishers. This process has variously led to the formation of consultative committees, sensitization programs on resource sustainability, control and surveillance systems and conflict resolution entities. In many cases, this emphasis on user involvement has necessitated education and other capacity building initiatives so as to enhance effective participation and consultation.

Traditional property rights, customary laws and agreements in African fisheries dictate access, ownership, seasonality or fishing hours, permitted gear types and penalties for breaking the rules. Such customary tenure systems work best where ownership is limited and clearly defined. Within offshore or open-access fisheries, migratory (non-indigenous) fishers often make local laws difficult to enforce.

The establishment of local informal organizations within fishing communities goes a long way to institutionalize local participation. These organizations, associations or co-operatives tend to build up a sense of solidarity and trust. For successful co-management, such local institutions should be strengthened where they exist, and new ones created where they are non-existent. These social structures are essential in communal integration, consensus decision making and as a body to which management responsibility can be delegated.

Management

The size of the resource and the number of fishers or other resource users is a critical component of success. Among the cases reviewed, success tends to be easier to achieve in inland fisheries and small waterbodies. In effect, the smaller the water body, the more likely that co-management will work. A major part of this success is the ability to capture sufficient biological data to enable the formulation of efficacious management strategies.

Fishing communities are composed of households and family units with complicated kinship relationships being a crucial factor in access to resources. In small homogenous communities, cohesion and effective communication can help build consensus. Heterogeneous communities need to respect different ethnic, religious and social values so as to foster harmony. Fishery managers should take into consideration overlapping communities with reference to priorities and resource use. States can help to enforce communal property rights by facilitating co-operation within and among communities.

Poor allocation of financial resources causes lack of compliance and poor user participation in management. The increased sense of ownership within fishing communities makes monitoring easier as the resource is seen as a personal property thereby increasing on compliance and sustainability. However, government cannot pass on to communities all the responsibility for data collection, analysis, formulation of regulations and enforcement without also providing some funds to support their work.

Relevant skills in fisheries biology and ecology, fish processing, marketing and other business skills are essential for successful management. Training of local institutions and users in conflict resolution, consensus building and resource use are also helpful.

Transparency

Successful collaboration between the state and local resource users requires trust, credibility and reliability. Central government must be flexible, both with respect to occasional lapses on the part of communities and in the development of creative means of enforcement that take local cultural values into consideration.

Co-management requires incentives for users to participate effectively. Such incentives can be social, economic or communal. Community development quotas can be instrumental, particularly within societies where communities lose benefits to other stakeholders.

The role of the government in establishing conditions for co-management is crucial, particularly in the creation of legitimacy and accountability for institutional arrangements and the delineation of power sharing and decision-making.

Institutions should be respected, with stakeholders having the confidence to trust their opinions. It is important that local institutions be empowered and enlightened as to their function, rights and responsibilities, membership and organizational arrangements. Good local leadership, which has the respect and trust of the locals, and is able to create consensus around key decisions, can play an important role.

Conclusion

There is no single model or formula for the successful implementation of fisheries co-management. It depends to a large extent on the extent to which limiting factors can be overcome and the willingness of institutions to harmonize their activities. Local users, through education and empowerment, can act responsibly in resource use. However, sustained funding and the willingness to co-operate and participate in power sharing, despite discords or other limiting factors, are crucial to success.

Before undertaking a co-management initiative, there is a need to carefully examine the feasibility of various approaches as different African states may respond quite differently to such arrangements. Exactly how the sharing of rights and responsibilities can be negotiated will vary from place to place.

Future research should target institutional arrangements at the government and local levels, capacity building of the local resource users, the development of trust and confidence between the actors, and determine rights and rules to govern users. Questions that future research could target are:

- How long can the traditional beliefs, rules and authorities work in the modern society?
- Has foreign aid altered fisher's perception of their role in management, thereby making it more difficult to implement co-management programs?
- Would co-management still work under current conditions of high population densities and transient fishing communities?

Answering these questions would go a long way towards setting the stage for co-management approaches.

Acknowledgements

The authors would like to thank Ms Jean Collins, FAO Fishery Librarian, for introducing us to Aquatic Science and Fishery Abstracts. In Africa, free photocopies of ASFA articles can be obtained through the South African Institute of Aquatic Biodiversity (SAIAB) at Rhodes University in Grahamstown.

References

Atti-Mama, C. 1997. Trends in the management of continental fisheries in Benin: The case of Lake Nokoue. Paper presented in a regional workshop on fisheries co-management research in Mangochi, Malaŵi, 1997:1-20.

Baland, J.M. and J.M. Platteau. 1996. Halting degradation of natural resources; is there a role for rural communities? FAO and Claredon Press, Oxford, UK.

Berkes, F., P. George and R.J. Preston. 1991. Co-management. alternatives 18(2):12-18.

Borrini-Feyerabend, G. 1996. Collaborative management of protected areas: tailoring the approach to context. International Conservation Union, Gland, Switzerland.

Davies, A. and S. Jentoft. 2001. The challenge and promise of indigenous peoples fishing rights-from dependency to agency. Marine Policy 25:223-237.

Donda, S.J. 1996. The management of artisanal fisheries in Lake Malombe and Upper Shire River. Paper presented at the Participatory Fisheries Management Programme (PFMP) progress review meeting in Mangochi, Malawi 1996, 10 p.

Hanna, S. 1995. Efficiencies of user participation in natural resource management, p.59-67. ***In*** S. Hanna and M. Munasinghe. Property Rights and the Environment: Social and Ecological Issues. Biejer Int. Inc., Washington, D.C., US.

Hara, M. 1999. Fisheries co-management: a review of theoretical bases and assumptions. Southern African Perspectives 77:1-32. University of the Western Cape, Belville, South Africa.

Hara, M., S. Donda and F.J. Njaya. 2002. Lessons from Malaŵi's experience with fisheries co-management initiatives, p. 31-48. ***In*** K. Gehep and M.T. Sarch. (eds.) 2002 Africa's Inland Fisheries – The Management Challenge. Fountain, Kampala, Uganda.

Horemans, B., and A.M. Jallow. 2000. Present state and perspectives of marine fisheries resource co-management in West Africa. Programme for the Integrated Development of Artisanal Fisheries in West Africa (IDAF). WP/W4, 29 p. Cotonou, Benin.

Hutton, T. and S.J. Lamberth. 1997. Opportunities for Co-Management: the Application of a Research Framework to Case Study from South Africa. Paper presented in a regional workshop on fisheries co-management research in Mangochi, Malaŵi, 1997.

Jentoft, S. 1989. Fisheries co-management: delegating government responsibility to fishermen's organizations. Marine Policy 13(2):137-154.

Jentoft, S. and B. McCay. 1995. User participation in fisheries management: lessons drawn from international experience. Marine Policy 19(3):227-246.

Kponhassia, G. and A. Konan. 1997. The traditional management of artisanal fisheries in Côte d'Ivôire: The case of Aby Lagoon. Paper presented in a regional workshop on fisheries co-management research in Mangochi, Malaŵi, 1997.

Kuperan, K., N. Mustapha, and R. Pomeroy. 1998. Transaction cost and fisheries co-management. Marine Resource Economics 13:103-114.

Lopes, S., E. Poiose, J. Wilson, J.L. Kromer, L. Manuel Cululo and R. Pinto Ascensao. 1997. From no management towards co-management? A case study on artisanal fisheries in Angoche district, Nampula Province, Mozambique. Paper presented in a regional workshop on fisheries co-management research in Mangochi, Malaŵi, 1997.

McCay, B.J. and S. Jentoft. 1996. From the bottom up: participatory issues in fisheries management. Society and Natural Resources 9:237-250.

McGoodwin, J.R. 2001. Understanding the culture of fishing communities: a key to fisheries management and food security. FAO Fisheries Technical Paper 401:1-287. FAO, Rome, Italy.

Munro, G. 1987. The management of fishery resources under extended jurisdiction. Marine Resources Economics 3:271-296.

Munro, G. 2002. Cooperative versus non cooperative fisheries management arrangement. Paper presented in the workshop on the management of shared small pelagic fishery resources off North West Africa, Banjul, The Gambia, 2002.

Nieland, A. 2000. Traditional management systems and poverty alleviation in Nigeria. Paper presented in seminar on livelihoods and inland fisheries management in the Sahelian zone, Quagadougou, Burkina Faso, 2000.

Njie, M., and H. Mikkola. 2002. Management and development of the Gambian River fisheries: a case for the co-management in inland fisheries resources, p.228-239. ***In*** K. Gehep and M-T. Sarch. (eds.) Africa's Inland Fisheries - The Management Challenge. Fountain, Kampala, Uganda.

Pomeroy, R.S. and M. Williams. 1994. Fisheries co-management and small scale fisheries: a policy brief. ICLARM, Manila, Philippines.

Raakjaer Nielsen, J., S. Sen , S. Sverdrup-Jensen and R.S. Pomeroy. 1996. Analysis of fisheries co-management arrangements: a research framework. ICLARM and IFM Fisheries Co-management Research Project working paper 1. Manila, Philippines.

Schreiber, D.K. 2001. Co-management without involvement: the plight of fishery communities. Fish and Fisheries 2:376-384.

Sen, S., P. Hachongela, J. Jackson, I. Malasha, W. Murirtirwa and K. Nyikahadzoi. 1997. An analysis of emerging co-management arrangements the Zambian and Zimbabwean inshore fisheries of Lake Kariba: a case study applying a research framework developed by the Institute for Fisheries Management and Coastal Community Development (IFM) and the International Centre for Living Aquatic Resources Management (ICLARM). Paper presented in a regional workshop on fisheries co-management research in Mangochi, Malaŵi, 1997.

Sen, S. and J. Raakjaer Nielsen. 1996. Fisheries co-management: a comparative analysis. Marine Policy 20(5):405-418.

West, P.C. and S.R. Brechin. (eds.) 1991Resident peoples and national parks. University of Arizona Press, Tucson, US.

A. S. Khan is a United Nations Volunteer (UNV) with the UNDP/Gambia Government Youth and Environment Project, Banjul, The Gambia. **R. Brummett** is from WorldFish-Cameroon. **H. Mikkola** is the corresponding author. Address - Institute of Applied Biotechnology, University of Kuopio, P.O.Box 1627, FIN-70211 Kuopio, Finland. Email: heimomikkola@yahoo.co.uk

High level of hybridisation in three species of Indian major carps

V. Simonsen, M.M. Hansen, Md. R.I. Sarder and Md. S. Alam

Abstract

Thirty individuals of each species of Indian major carps, i.e., *Catla catla*, *Cirrhinus cirrhosus* (*C. mrigala*) and *Labeo rohita*, obtained from a nursery near Mymensingh, Bangladesh were analysed by means of allozyme electrophoresis. Twenty-one loci were studied. Several loci revealed significant deviation from Hardy-Weinberg expectations caused by deficiency of heterozygotes, indicating Wahlund effects due to problems with species identification. Moreover, bimodal distributions of individual heterozygosity within the three putative species indicated hybridisation. This was confirmed using analysis of individual admixture proportions, as individuals misidentified to species and hybrids between species were observed. Furthermore, factorial correspondence analysis to visualize genetic relationships among individuals revealed three distinct groups containing misclassified individuals, along with some intermediate individuals interpreted as hybrids. Ten per cent of all *C. catla* and *L. rohita* had been erroneously identified to species, and 40 per cent of all presumptive *C. catla* were hybrids between *C. catla* x *C. cirrhosus* and *C. catla* x *L. rohita*. In the case of *C. cirrhosus*, 37 per cent of the samples were *C. cirrhosus* x *L. rohita* hybrids. Thirty per cent of all presumptive *L. rohita* turned out to be hybrids between *L. rohita* x *C. catla* and *L. rohita* x *C. cirrhosus*. The high incidence of hybrids in *C. catla* might be responsible for slower growth of the fish in aquaculture.

Introduction

Three years ago, the Danish aid-organisation (DANIDA) gave support to a study for detecting genetic erosion using allozyme and microsatellite analysis on three species of Indian major carps, *Catla catla*, *Cirrhinus cirrhosus (C. mrigala)* and *Labeo rohita*.

The study was the result of increasing concern over a declining growth performance of the three Indian major carps in aquaculture. A former study by Eknath and Doyle (1990) suggested that aquaculture rearing practices might lead to a high level of inbreeding. However, a 10 per cent incidence of hybrids was found in a pond based on analysis of DNA markers (Padhi and Mandal 1997).

The aim of this study was to analyse broodstocks using allozymes, microsatellites and mitochondrial DNA (mtDNA) in order to detect genetic erosion and later to compare the results

Table 1. List of enzymes used, their abbreviations, E.C. number, the tissue and buffer used for the enzyme and the number of loci revealed.

Enzyme	Abbreviation	E.C. No.	Tissue	Buffer	No. of loci
Aspartate aminotransferase	AAT	2.6.1.1	Muscle	B[2]	2
Adenosine deaminase	ADA	3.5.4.4	Eye	A[1]	1
Adenylate kinase	AK	2.7.4.3	Muscle	B	1
Creatine kinase	CK	2.7.3.2	Muscle	B	1
Esterase	EST	3.1.1...	Eye	B	2
Glucose-6-phosphate isomerase	GPI	5.3.1.9	Muscle	A	2
Glycerol-3-phosphate dehydrogenase	G-3-PDH	1.1.1.8	Muscle	A	1
Iso citrate dehydrogenase	IDH	1.1.1.42	Eye	B	2
Lactate dehydrogenase	LDH	1.1.1.27	Eye	B	2
Malate dehydrogenase	MDH	1.1.1.37	Eye	B	2
Mannose-6-phosphate isomerase	MPI	5.3.1.8	Eye	B	1
Peptidase (leucyl-glycyl-glycin)	PEP(LGG)	3.4.11 or 13	Muscle	C[3]	1
Peptidase (valyl-leucine)	PEP(VL)	3.4.11 or 13	Muscle	C	1
Phosphogluconate dehydrogenase	PGDH	1.1.1.44	Eye	A	1
Phosphoglucomutase	PGM	5.4.2.2	Muscle	B	1
Purine nucleoside phosphorylase	PNP	2.4.2.1	Eye	B	1

[1] Buffer A Clayton and Tretiak (1972)
[2] Buffer B Ayala et al. (1972)
[3] Buffer C Ridgway et al. (1970)

Table 2. Allelic frequencies of 21 loci analysed in three nursery samples of carps. N is the number of individuals scored.

Locus	Allele	*C. catla*	*C. cirrhosus*	*L. rohita*
AAT-1	1	0.97	0.18	0.80
	3	0.03	0.82	0.20
	N	30	30	30
ADA	4	0.35	0.40	0.77
	5		0.60	0.18
	6	0.65		0.05
	N	30	30	30
AK	1	1.00	1.00	1.00
	N	30	30	30
CK	2	0.97	0.18	0.75
	3	0.03	0.75	0.25
	4		0.07	
	N	30	30	30
EST-1	2		0.50	0.18
	3	1.00	0.50	0.82
	N	30	30	30
EST-2	2	0.63		0.05
	3		0.82	0.18
	4	0.37	0.18	0.77
	N	30	30	30
GPI-1	1	0.97	0.18	0.80
	2		0.23	0.07
	3	0.03	0.58	0.13
	N	30	30	30
GPI-2	2	0.97	0.18	0.80
	4	0.03	0.82	0.20
	N	30	30	30
GPD	2	0.98	0.80	1.00
	3	0.02	0.20	
	N	30	30	30
IDH-1	1	0.15	0.87	0.52
	2	0.85	0.13	0.48
	N	30	30	30
IDH-2	1	1.00	1.00	1.00
	N	30	30	30
LDH-1	1	1.00	1.00	1.00
	N	30	30	30
LDH-2	1	1.00	1.00	1.00
	N	30	30	30
MDH-1	1	1.00	1.00	1.00
	N	30	30	30
MDH-2	1	1.00	1.00	1.00
	N	30	30	30
MPI	1	0.97	0.18	0.82
	3	0.03	0.80	0.18
	5		0.02	
	N	30	30	30
PEP(LGG)	2	0.12	0.02	0.32
	3	0.87	0.17	0.50
	4	0.02	0.72	0.18
	5		0.10	
	N	30	30	30
PEP(VL)	2	1.00	0.95	0.93
	3		0.05	0.07
	N	30	30	30
PGM	1	0.68	0.82	0.38
	2	0.02		0.03
	3	0.27	0.18	0.58
	4	0.03		
	N	30	30	30
PGD	1	0.63		0.05
	2		0.82	0.20
	3	0.37	0.18	0.75
	N	30	30	30
PNP	1	0.70		0.03
	2		0.75	0.17
	3	0.30	0.25	0.75
	4			0.05
	N	30	30	24

to wild samples from rivers. As it was not possible to get samples from broodstocks, the study was based on the analyses of fingerlings from nurseries. This paper presents the results of the analysis by allozyme electrophoresis of sample fingerlings of the three species of Indian major carps.

Materials and Methods

Thirty individuals of each species (fingerling size, 4 to 8 cm) were obtained from a local middleman. The fish were brought live to the laboratory at Bangladesh Agricultural University and morphologically identified to species with help of the suppliers and the staff at the university. A muscle sample was removed from each fish and stored in absolute ethanol. The rest of the fish was put into a small plastic-bag and, together with the muscle sample, placed in a freezer at – 20°C. The samples were brought to the National Environmental Research Institute (DMU), Silkeborg, Denmark for analyses of allozymes and to the Danish Institute for Fisheries Research (DFU), Silkeborg, Denmark for analyses of microsatellites and mtDNA.

Sixteen enzymes could be reliably scored, representing 21 loci (Table 1). The buffers used were listed in Table 1 and the staining procedures used were similar to the ones described by Machenko (1994).

The data was analysed using the software G-stat (Siegismund 1995), a general software for population genetic analyses, and Structure (Pritchard et al. 2000). Structure is a novel approach for assigning individuals to populations and, in the present case, to species. In addition to assignment tests, it also allows for estimating individual admixture proportions, i.e., the proportion of an individual's genome derived from one or the other population or species. Finally, factorial correspondence analysis was used to analyse the genetic relationships among individuals. This analysis was conducted using the software Genetix 4.0 (Belkhir 1998).

Results and Discussion

Allelic frequencies are listed in Table 2 and various measures of genetic variation are presented in Table 3. Tests for fit to Hardy-Weinberg expectations were performed for 14 loci from *C. catla* and no significant deviations were found. However, 1 of 15 polymorphic loci in *C. cirrhosus* and 6 of 14 polymorphic loci in *L. rohita* showed significant deviations after Bonferroni correction (Rice 1989). The significant deviations were all due to lack of heterozygotes. Depicting the individual heterozygosity, a bimodal distribution was seen for *C. cirrhosus* and lesser pronounced for *L. rohita* (Fig. 1, upper part). An example of a theoretical distribution was shown in

Table 3. Genetic variation in three samples of Indian carps. A locus is defined as polymorphic if the allelic frequency of the most common allele is 0.99 or less (P_{99}).

Sample	Number of loci (n)	Average number of individuals scored (N)	Fraction of polymorphic loci (P_{99})	Average number of alleles (A)	Average observed heterozygosity (H_o)	Average expected heterozygosity (H_e)
C. catla	21	30.00 ± 0.00	0.67	1.81 ± 0.75	0.11 ± 0.12	0.15 ± 0.19
C. cirrhosus	21	30.00 ± 0.00	0.71	1.95 ± 0.81	0.26 ± 0.22	0.25 ± 0.19
L. rohita	21	30.00 ± 0.00	0.67	2.05 ± 0.92	0.15 ± 0.14	0.26 ± 0.21

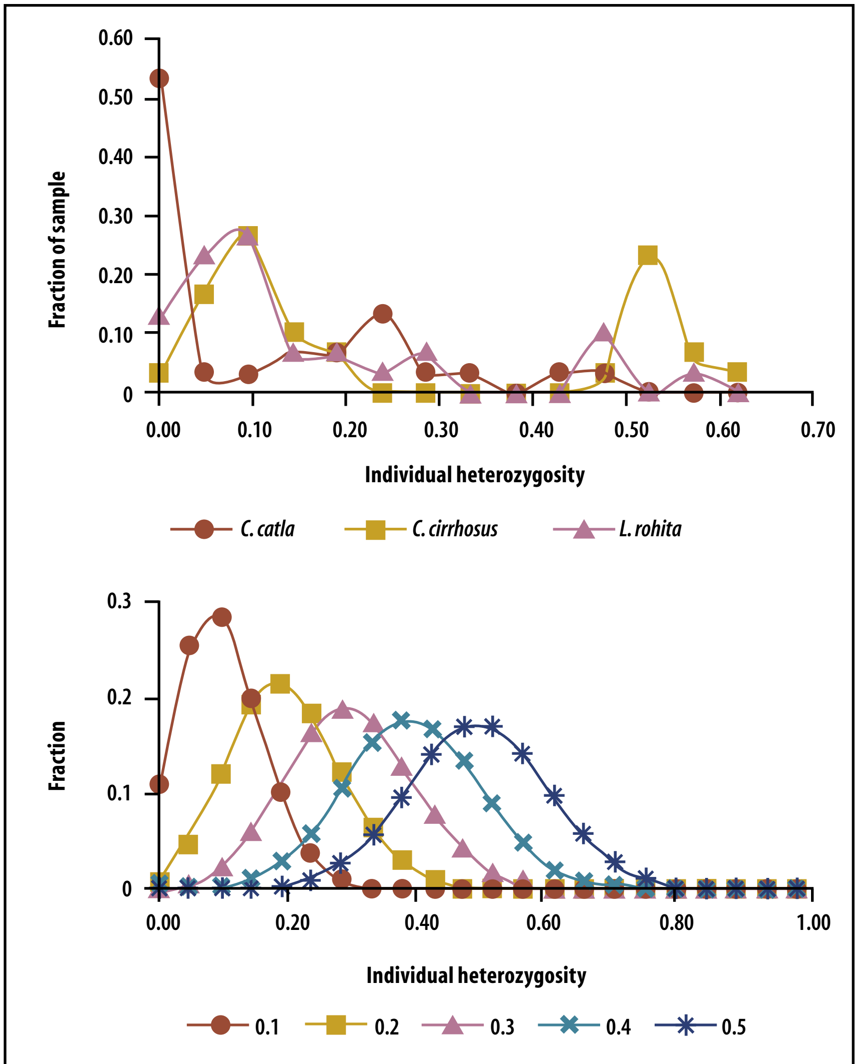


Fig. 1. Distribution of individual heterozygosity for 21 loci in three samples of Indian major carps (upper part) and the hypothetical distribution of individual heterozygosity (lower part), assuming identical frequency of heterozygotes for all loci.

Fig. 1 (lower part). The excess of heterozygotes in the *C. cirrhosus* sample might be due to hybrids between species. The deficiency of heterozygotes in the *L. rohita* sample might be caused by two reproductively separated populations or species (i.e., other species incorrectly identified as *L. rohita*).

The results of the analysis of individual admixture proportions using the software Structure are shown in Fig. 2. It is apparent that the *C. catla* sample contained three fish that were clearly "pure" *L. rohita*, despite having been classified as *C. catla* based on morphological characteristics. Two fish appeared to be *L. rohita* x *C. cirrhosus* hybrids, and 10 fish were hybrids between *C. catla* and *L. rohita*. In the sample of presumptive *C. cirrhosus*, 11 fish were hybrids between *C. cirrhosus* and *L. rohita*. This high incidence of hybrids might explain the high number of allozymes with excess of heterozygotes, as mentioned above. In the *L. rohita* sample, three individuals were most likely *C. cirrhosus*, which might have caused the observed deficiency of heterozygotes, but it was not compensated by the three *C. catla* x *L. rohita* hybrids and four *C. cirrhosus* x *L. rohita* hybrids.

The visualization of genetic relationships among individuals using factorial correspondence analysis (Fig. 3) confirmed the analyses of individual admixture proportions. Three groups of "pure" individuals of the species were identified, along with some individuals that had been misclassified to species. Additionally, several individuals exhibited an intermediate position relative to the parental species and are presumably hybrids, again corresponding to the results of the individual admixture proportion analyses.

The conclusion of this study is that all the three species can interbreed, as mentioned in the review by Das et al. (1996). However, in addition to F_1 hybrids, F_2 or backcrosses were probably also found in the nursery sample (see fish No. HC14, HC25, HR28 and HR26 in Fig. 2). The presence of *L. rohita* in the *C. catla* sample and *C. cirrhosus* in the *L. rohita* sample further illustrated the difficulties in species identification based exclusively on morphological characteristics at the fingerling stage.

These results point to the possibility of hybridisation being at least partly responsible for the decreased growth performance of these species in aquaculture. Thus, Gopal et al. (1989) report slower growth of *C. catla* x *C. cirrhosus* hybrids compared to the parental species, *C. catla*. Therefore, it has to be emphasised that broodstock fish have to be pure species to avoid further genetic erosion of the three species, *C. catla*, *C. cirrhosus* and *L. rohita*.

References

Ayala, F.J., J.R. Powell, M.L. Tracey, C.A. Mourro and S. Perez-Salas. 1972. Enzyme viability in *Drosophila willistoni* group. IV. Genic variation in natural populations of *Drosophila willistoni*. Genetics 70:113-139.

Belkhir, K. 1998. GENETIX, logiciel sous WindowsTM pour la génétique des populations. Laboratoire Génome et Populations, CNRS UPR 9060,

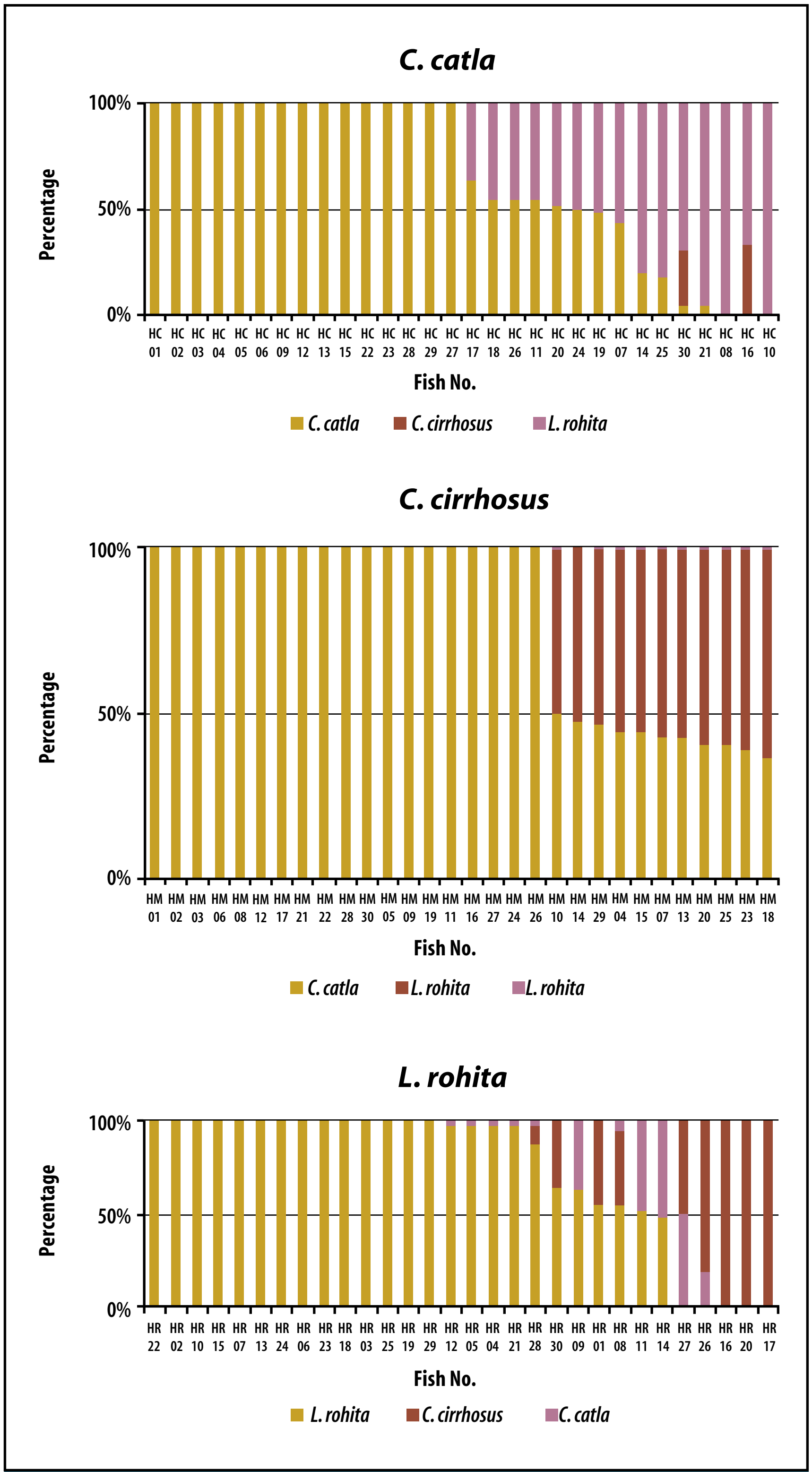


Fig. 2. Results of analyses of individual admixture proportions using Structure (Pritchard et al. 2000). The figure shows the proportion of the genome of each individual in the three samples of putative *C. catla*, *C. cirrhosus* and *L. rohita*, estimated to be derived from any of the three species.

Université de Montpellier II, Montpellier (France).

Clayton, J.W. and D.N. Tretiak. 1972. Amine-citrate buffers for pH control in starch gel electrophoresis. Journal of the Fisheries Research Board of Canada 19: 1169-1172.

Das, P., A. Mishraand and S.K. Srivastava. 1996. Status on research in applied carp genetics and breeding in India. Journal of Aquaculture in the Tropics 11:307-317.

Eknath, A.E. and R.W. Doyle. 1990. Effective population size and rate of inbreeding in aquaculture of Indian major carps. Aquaculture 85:293-305.

Gopal, C.K., T.J. Varghese and P. Keshavanath. 1989. Morphological features of catla-mrigal and mrigal-catla hybrids and their comparison with the parental species, p.183-191. ***In*** P. Das and V.G. Jhingran (eds.) Fish genetics in India, Today & Tomorrow's Printers and Publishers, New Delhi.

Manchenko, G.P. 1994. Handbook of detection of enzymes on electrophoretic gels. CRC Press, Boca Raton, USA, 341 p.

Padhi, B.K. and R.K. Mandal. 1997. Inadvertent hybridization in a carp hatchery as detected by nuclear DNA RFLP. Journal of Fish Biology 50: 906-909.

Pritchard, J.K., M. Stephens and P. Donnelly. 2000. Inference of population structure from multilocus genotype data. Genetics 155:945-959.

Rice, W.R. 1989. Analysing tables of statistical tests. Evolution 43:223-225

Ridgway, G.J, S.W. Sherburne and R.D. Lewis. 1970. Polymorphism in the esterases of Atlantic herrings. Transactions of the American Fisheries Society 99:147-151.

Siegismund, H.R. 1995. G-stat, version 3.1, genetical statistical programs for the analysis of population data. Department of Plant Ecology, Botanical Institute, Oester Farimagsgade 2D, DK-1353 Copenhagen K, Denmark.

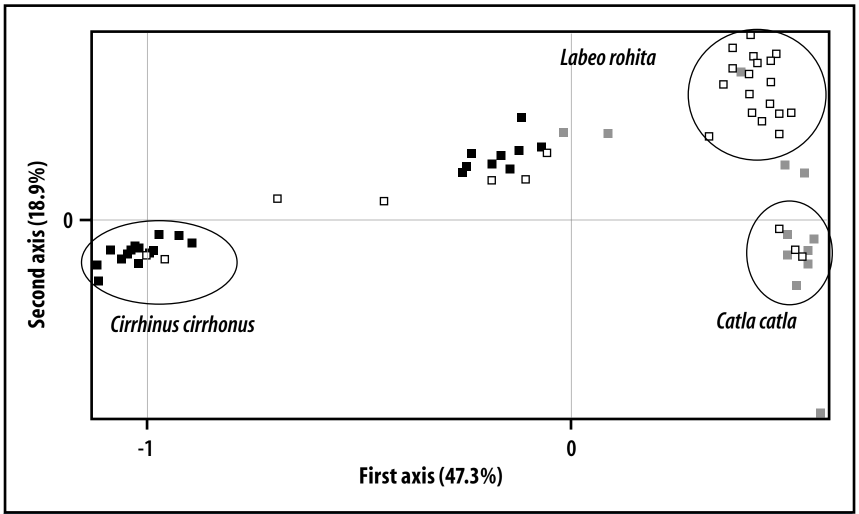


Fig. 3. Factorial correspondence analysis plot showing the genetic relationships among individuals from the three putative species. Black squares denote individuals visually identified as *C. cirrhosus*, white squares denote *L. rohita*, and grey squares denote *C. catla*. Some individuals exhibit identical genotypes, therefore the number of squares does not add up to the total sample size (90). The approximate locations of "pure" individuals of the three species are indicated by circles.

V. Simonsen is from the National Environmental Research Institute, Vejlsoevej 25, P.O. Box 314, DK-8600 Silkeborg, Denmark. **M.M. Hansen** is from the Department of Inland Fisheries, Danish Institute for Fisheries Research, Vejlsoevej 39, DK-8600 Silkeborg, Denmark.
Md. R.I. Sarder and **Md. S. Alam** are from the Department of Fisheries Biology and Genetics, Bangladesh Agricultural University, Mymensingh-2022, Bangladesh
Corresponding author: V. Simonsen, National Environmental Research Institute, Vejlsoevej 25, P.O. Box 314, DK-8600 Silkeborg, Denmark, phone +45 8920 1400, fax +45 8920 1413. Email: vs@dmu.dk

Winner of the *NAGA* Award 2002-03

NAGA AWARD

Dr K.V. Jayachandran is the winner of the *NAGA* Award 2002-2003 with the winning entry titled **Palaemonid Prawns: Biodiversity, Taxonomy, Biology and Management**.

Congratulations!

We wish to thank all the nominators and nominees who participated in the 2002-2003 *NAGA* Award Competition.

Jayachandran, K.V. 2001. Palaemonid prawns: biodiversity, taxonomy, biology and management. Science Publishers, Inc., Enfield, NH, USA.

This book is a monumental work on the subject. It is an excellent compilation of information on the systemic, biology and culture aspects of a number of species of palaemonid prawns. The book will be of great value to scientists, aquaculturists and students.

FishBase 2004 Published!

The 2004 Edition of FishBase, the world's premier global information system on fishes, has been published by the WorldFish Center in DVD format, and the CD-ROM Version will be published soon. FishBase 2004 represents significant new information compared to FishBase 2000:

Coverage	FishBase 2000	FishBase 2004
Species	25 100	28 500
Synonyms	71 000	79 600
Fish common names	107 900	188 300
Images	26 200	36 100
References	20 800	33 100
Geo-referenced records	630 000	1 803 000
Collaborators	561	1 080

FishBase 2004 has been published by the WorldFish Center for the FishBase Consortium (WorldFish Center, Food and Agriculture Organization of the United Nations, Leibniz Institute of Marine Sciences at Kiel University IFM-GEOMAR, University of British Columbia - Fisheries Centre, Muséum National d'Histoire Naturelle, Swedish Museum of Natural History, Musée Royal de l'Afrique Centrale). FishBase is also available and updated monthly on the web as a global public good at http://www.fishbase.org. Inquiries and orders can be directed to the FishBase Project at the WorldFish Center Philippine Office, MCPO Box 2631, 0718 Makati City, Philippines, or Email: fishbase@cgiar.org

WorldFish Center announces 2004 change at the helm

Dr Stephen Hall has been named the incoming Director General of the WorldFish Center. He will succeed Dr Meryl Williams when she completes her 10-year appointment in early 2004.

Dr Hall, educated in Wales and Scotland, is an eminent fisheries scientist and research leader. His recent positions include Professor of Marine Biology at Flinders University and Director of the Australian Institute of Marine Science (AIMS). His many achievements and publications include a recent major work on the effects of fishing on marine ecosystems that has already become an essential text in this field.

Professor Robert Kearney, Chair of the Board of Trustees of WorldFish, noted that "the quality and breadth of experience of science leaders interested in the position of Director General of the WorldFish Center was outstanding, confirming the international recognition of the Center and its work. The Board is delighted to announce that Dr Hall will take up the position in February 2004. He will continue the Center's focus on fisheries research of the highest quality directed to the eradication of poverty, improvement of people's nutrition in developing countries and reduction of pressure on the environment."

Dr Hall stated "I am delighted to be given the opportunity to take up such a key position in world fisheries as Director General of the WorldFish Center. I look forward with great enthusiasm to leading the WorldFish Center in delivering fisheries benefits to developing countries."

The WorldFish Center is headquartered in Penang, Malaysia, and operates from 11 sites and works in 25 countries in Asia, Africa, the Pacific and Caribbean. It has generated acclaim throughout the world for its work on capture fisheries and aquaculture in developing countries.

WorldFish is the only fisheries and aquaculture Center in the Consultative Group on International Agricultural Research (CGIAR), a System of 62 donor member countries, multilateral agencies and foundations that support 16 research Centers. The other Centers focus on crops, livestock, trees, water, and policy research.

Catalogue of Life 2004 Now Available on CD-ROM!

The WorldFish Center has produced the fourth release of the Catalogue of Life: Year 2004 Annual Checklist: Indexing the World's Known Species in CD-ROM format. The checklist acts as a stable taxonomic reference and contains a searchable database with information on animals, plants, fungi and microorganisms from 23 contributing taxonomic databases. The 2004 edition features two new databases: Orthoptera Species File and Computer-Aided Identification of Phlebotomine Sandflies (CIPA). Additional common names have also been included from Catalogue of Life. The Year 2004 Annual Checklist covers significantly more new information compared to the Year 2003 Annual Checklist:

Coverage	Year 2003 annual checklist	Year 2004 annual checklist
Species	272 101	323 680
Infraspecies	32 609	37 669
Synonyms	181 774	222 120
Common names	217 589	242 381
Hierarchies	5 411	6 024
Distribution	92 517	129 258
References	87 409	119 433
Contributing databases	20	23
Collaborators	204	232

The Catalogue of Life program is a partnership of Species 2000 and Integrated Taxonomic Information System (ITIS). It will be a baseline species list for use in inventorying projects and as a comprehensive worldwide catalogue for checking the status, classification and names of species. This is a work in progress and does not yet cover all of the world's species. The 2004 Annual Checklist is also available online at http://www.fishbase.org.ph/sp2004/search.php. The WorldFish Center, as a partnership activity with the Species 2000 Secretariat, ITIS and other contributors, compiles and produces the checklist on an annual basis. Inquiries about the CD-ROM, its databases or Species 2000 should be directed to the Species 2000 Secretariat, School of Plant Sciences, The University of Reading, Reading RG6 6AS, UK, or email: sp2000@sp2000.org.

ReefBase: International Workshop on Coral Reef Monitoring Data

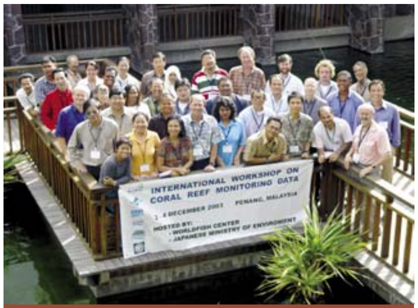
Coral reef monitoring programs around the world generate volumes of important data on coral reef parameters, but standardized and easily accessible information from these programs is often lacking. Linking information from reef-monitoring programs in a coordinated framework will collectively generate key indicators and statistics for national, regional and global assessments of the status of coral reefs. Such collaboration will provide a quantitative basis for future coral reef status reports as well as the much needed, tools for promoting informed management of coral reef resources.

This objective is becoming a reality - an International Workshop on Coral Reef Monitoring Data was held on December 2-4 2003, at WorldFish Center's headquarters in Penang, Malaysia. The Workshop was organized by Japan's Ministry of Environment, the Global Coral Reef Monitoring Network (GCRMN), the International Coral Reef Action Network (ICRAN) and the WorldFish Center, with subsequent funding from the World Bank. The Workshop brought together some 40 representatives from major reef monitoring programs around the world, with emphasis on the Southeast Asian region. The goal of the Workshop was to explore ways for improved collaboration between monitoring programs.

The Workshop focused on how the output from the various reef monitoring programs could be used to: (1) support the Global Coral Reef Monitoring Network (GCRMN) and its central database ReefBase, to generate essential statistics, indicators, and status reports at the national, regional, and global levels; and (2) create a public knowledge-base on the status of coral reefs globally to support sustainable management and conservation of coral reefs.

The specific objectives of the Workshop were to generate:

- Greater awareness of existing monitoring programs and their databases.
- Ideas on how to develop common summary databases and data presentations for reporting on the status of coral reefs.
- Ideas on how to share data more effectively and the tools needed to do this.
- Agreement on the need to collaborate (formally and/or informally) in developing database systems and tools.
- A network of database systems (i.e., a Reef Monitoring Data Consortium).
- A comprehensive list of all major coral reef database systems and input/analysis tools.
- An outline for a standard format for national reef status reports.
- A draft list of common variables and measurement units for summary reporting and comparisons (including core and optional elements).
- A draft list of common data structures (tables, fields) to hold this summary data.
- A list of user needs for countries and organizations wishing to



Participants of the International Workshop on Coral Reef Monitoring Data.

develop better capacity for managing monitoring data, and the possible providers of such expertise.

- A list of potential collaborative projects that could be developed for submission to funding bodies.
- A timetable for producing outputs for the 10th International Coral Reef Symposium in Japan (July 2004).

The first day of the Workshop was spent on 19 presentations from participating monitoring programs and related organizations. During days two and three, the participants used breakout groups to discuss Reef Monitoring Data Reporting Formats and Standards and Reef Monitoring Data Coordination and Collaboration.

Workshop Conclusions and Recommendations

- A number of excellent databases on coral reef monitoring were demonstrated at the Workshop. It was recognized that these should form the basis for the development of a standardized data entry and analysis package that could be disseminated for national, regional and global use to countries and regions that lack adequate data management systems. This data entry and analysis package should be designed to link directly to ReefBase, the global database on the location, status, threats, and management of coral reefs.

- Representatives recommended that ReefBase initiate the process to develop a data entry and analysis system that could be offered to all countries and regions to assist in data management and report writing. Representatives of institutions from Australia, France, Japan and USA (NOAA), as well as ReefBase and the GCRMN, offered to assist in the development of the system through the provision of support and/or funds. Specific steps recommended were:
  - o Data managers who participated in the Workshop review the existing packages (e.g., CoReMo from Southwest Indian Ocean) to determine their suitability and limitations for use as a country and regional data management system.
  - o A Workshop to be held in early 2004, possibly at the WorldFish Center, to scope the process of developing a data entry and analysis package that could be offered to countries and regions of the GCRMN.
  - o The Workshop should include representatives from Australia, USA and Japan, ReefBase, the Southwest Indian Ocean GCRMN Node (France), and other organizations with a direct interest and capability in assisting in this process.
  - o The Workshop should develop a timetable to produce a data entry and analysis package and determine the content and component priorities. This will include requirements for software, hardware and specific roles of participants in the production of the package.

- The meeting recommended the production of English, French, Japanese, Spanish and Bahasa versions of the data entry and analysis package. The core component of the database (data entry and analysis) should be provided as soon as possible, with more refined versions (e.g., GIS capacity, report writing facility) added as incremental improvements.

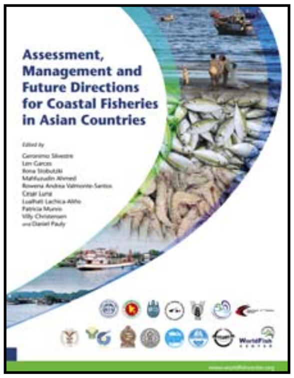
- Key supporting organizations and donor countries were requested to assist in production of the package to assist coral reef countries to manage monitoring data in an efficient and effective manner and to produce improved reports on the status of coral reefs. Funds will be needed for: travel and Workshops; employment of an expert programmer; training national and regional database managers in the use of the database; and distribution and publicity of the package.

- The Workshop participants agreed that implementation of these recommendations could result in an unprecedented knowledge base that will make a major contribution to the informed management of coral reef resources around the world.

Workshop Report and CD-ROM

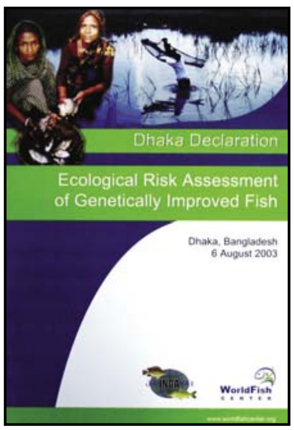
The Workshop Final Report presents the initial outcomes and recommendations from the workshop, and calls for the establishment of a formal Reef Monitoring Data Consortium. This Consortium will provide guidance and coordination for coral reef monitoring programs and partners, and initiate the development of standardized database templates, data analysis tools, and reporting formats that could: (a) benefit participating monitoring programs; (b) provide a better translation of reef monitoring results into information relevant to natural resource managers; (c) substantially improve and simplify the compilation of GCRMN Coral Reef Status Reports; and (d) allow for sharing of reef monitoring data at various geographic levels.

A CD-ROM of the Workshop is currently in print, containing the Workshop Final Report, all relevant materials related to the Workshop, and extensive information on coral reef monitoring activities around the world. For further information, please visit the ReefBase website (http://www.reefbase.org).



Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries

The fisheries sector in Asia is important for food security, livelihoods and foreign exchange earnings. However, as in many other parts of the world, there are signs that capture fisheries are fully exploited or over fished. Management of fisheries in the region is often hampered by the lack of information on the status of fisheries in terms of biological, social, economic, policy and governance aspects. This regional project documents an alarming decline of coastal fishery resources, based on historical research surveys in South and Southeast Asia. Socioeconomic analyses and policy reviews highlight the importance of the fisheries sector as well as the challenges facing it. Potential interventions to improve fisheries management are outlined and defined in terms of environmental, socioeconomic and institutional objectives.

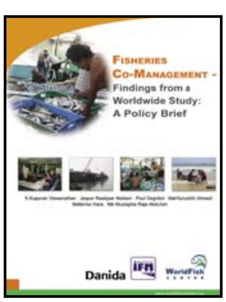


Dhaka Declaration: Ecological Risk Assessment of Genetically Improved Fish

Fish is the major source of animal protein and contributes to livelihoods and food security of millions in most developing countries. Fish production from natural resources has been declining and nations are looking to aquaculture to bridge the gap between supply and demand for fish. Studies undertaken in recent years on 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.

The improved strains of fish have generated significant economic and social benefits. However, if not properly managed, their escape into the natural environment could pose risks for aquatic ecological integrity and biodiversity. Hence, prior to disseminating improved strains of fish, it is imperative that protocols and policies governing dissemination 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.

Fifty-four participants held an Expert Consultation on Ecological Risk Assessment of Genetically Improved Fish during 4-6 August 2003 in Dhaka, Bangladesh, under the auspices of the International Network on Genetics in Aquaculture (INGA). The participants included aquaculturists, geneticists, ecologists, biodiversity specialists, researchers, administrators and development workers from 20 countries representing national/research institutions in Africa, Asia and the Pacific, non-government organizations and regional/international organizations (e.g., Food and Agriculture Organization – FAO, The World Conservation Union – IUCN, Southeast Asian Fisheries Development Center – SEAFDEC, Secretariat for the Pacific Community – SPC, Network of Aquaculture Centers in Asia-Pacific – NACA, Asian Institute of Technology – AIT, and the WorldFish Center). They discussed the benefits and potential risks of improved fish strains, and initiated development of guidelines for the environmentally safe dissemination of improved fish strains and a framework for risk assessment.

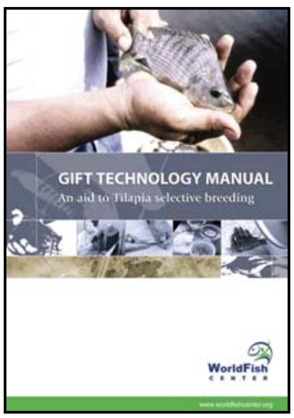


Fisheries Co-Management Policy Brief: Findings from a Worldwide Study

Fisheries in developing countries are under intense pressure from increasing human populations, overexploitation of dwindling and degraded aquatic resources, and conflicts over access to them. A new governance approach is required to address the challenges facing rural fishing communities. One promising approach explained in this policy brief is co-management – sharing responsibility among the government, fishing communities and other stakeholders.

Ecolabelling and Fisheries Management

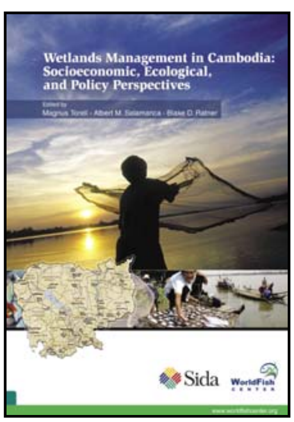
Many industrial and small-scale fisheries around the world are declining because of over-fishing and environmentally damaging fishing practices. Despite evidence of the decline, finding incentives to induce better fisheries management is proving problematic. One reason for this is that fish and seafood products remain highly profitable commodities, extensively traded in international markets. It has been suggested that ecolabelling fish and seafood products that have been harvested appropriately will increase consumer awareness of the issues and provide market incentives for better fisheries management. This study examines the pros and cons for those developing countries considering the introduction of ecolabelling. The appropriate balance between ecolabelling and other systems aimed at increasing the sustainability of fisheries management (such as co-management, property rights and ecosystem approaches) is also discussed.



GIFT Technology Manual: An aid to Tilapia selective breeding

This Manual is intended to be an aid in the transfer of the selective breeding technology developed by the WorldFish Center and its partners. It is based on the experience and material accumulated during the Genetic Improvement of Farmed Tilapia (GIFT) project (1988 to 1997). In its development, particular attention has been paid to the description of key husbandry operations in a sequential manner, using illustrations and photographs. However, there will be instances in which some adjustment of the GIFT technology are required to suit local conditions.

The manual constitutes an integral part of the UNDP/Technical Cooperation among Developing Countries (TCDC) financed project titled Transfer of Selective Breeding (GIFT) Technology for Aquaculture Improvement from the Philippines to Sub-Saharan Africa and Egypt.



Wetlands Management in Cambodia: Socioeconomic, Ecological, and Policy Perspectives

Wetlands in Cambodia are a lifeline of the rural economy – essential to the livelihoods of millions of Cambodians, the food security for the most vulnerable members of society, and the prospects for national development. Making progress towards the sustainable management of wetlands demands a systemic, holistic perspective, precisely because wetlands defy boundaries. By presenting in one volume the perspectives on a number of key facets of the overall challenge of wetlands management in Cambodia, this collection of papers aims to broaden the platform for dialogue and debate about the importance of wetlands, trends affecting their health and productivity, and priority actions in response.

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 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@cgiar.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 of 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@cgiar.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 illustrations.

- **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.