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Fisheries And Marine Living Resources-Related Research In Malaysia: Current Research And Some Views On Priorities

The exploitation of marine living resources is of major economic importance to Malaysia. The long-term continued well being of fisheries stocks and marine living resources as well as the maintenance of the quality of the marine environment is the delicate foundation that underpins the sustainable development of the marine resource. Sustainable marine resources utilization are dependent on maintaining a high-quality marine environment and must be supported by a level of research, monitoring and assessment appropriate to meet existing needs and the increased pressure on the resources which will accompany a growing marine economic sector.

Future fisheries and marine living resources-related research should be directed towards four broad areas of national importance: (1) Develop a scientific basis for managing marine resources; (2) understanding the marine environment, (3) leveraging scientific understanding to bolster food production efforts, and; (4) understanding the nature of marine biodiversity and its application for human welfare. Technological innovation should be a key research strategic area aimed to develop advanced methodology and techniques particularly in marine aquaculture and fishing to achieve food production goals.

Key words: marine living resources, resource exploitation, fisheries and aquaculture research, marine environment, biological diversity.

Introduction

In the marine sector the exploitation of marine living resources is ranked second in economic importance to the petroleum and hydrocarbon industry in Malaysia. The fisheries sector's contribution is seen from the aspects of generation of employment opportunities, socio-economic development, animal protein supply, foreign exchange earnings as well as food security. The national fisheries production (including inland fisheries and freshwater aquaculture) for 1999 was some 1.5 metric tonnes worth more than RM 5 billion. The sector also directly employed almost 98,000 persons. The Third National Agriculture Policy (NAP3), which was formulated in 1999 has a stong focus on food production. It targets the marine fisheries and aquaculture sector to achieve a production value of some RM 8.5 billion by the year 2010. Of this, deep sea fisheries and aquaculture production were aimed to contribute the bulk of the increase. Of aquaculture, production is hoped to produce almost 6 times the present quantity of 180,000 tonnes.

Many challenges are faced in order to transform the fisheries sector in order to achieve the national targets (Mazlan, 2000). The present structure of the industry which is comprised of

majority of small-scale producers accounts for the comparative low productivity of the sector. It is estimated that this sector only attains 60% of the productivity achieved by the manufacturing sector. Because of the predominance of small-scale operators it makes it difficult to use modern technology on an industrial scale. Labour productivity ranges from 7.74 to 23.7 tonnes/person/year; this is low compared to countries such as Denmark and Iceland which achieve 230 and 250 tonnes/person/year respectively. There is therefore a need to adopt new fisheries production strategies to improve gross production as well as efficiency of the production units. This will involve devising new production methods as well as the adoption of modern effective technologies in both marine capture fisheries as well as aquaculture. A key challenge will be on how to utilize large-scale production technologies as more bigger operators are encouraged to operate in the industry. In addition, there is a necessity to explore and assess new fisheries and marine living resources for exploitation especially in the unexplored fishing grounds of the Malaysian Exclusive Economic Zone to supplement and expand fish production

The task facing those engaged in harvesting the living resources of the sea as well as utilising and maintaining the marine environment for food production is to discover practical ways in which a profitable Malaysian marine food industry can be sustainably developed for present and future generations. The delicate foundation that underpins the sustainable exploitation and development of the marine living resources will be the long-term continued well being of fisheries stocks and marine living resources as well as the maintenance of the good quality of the marine environment. In addition, aquaculture development in the country must be undertaken in an environmentally sustainable manner. Both fisheries stocks management and the maintenance of marine environmental quality upon which fisheries and marine living resources utilization industries as well as aquaculture depends on must be supported by a level of research, monitoring and assessment appropriate to meet existing needs as well as the increased pressure on the resource which will accompany a vibrant marine economic sector. Additionally, there is a burgeoning interest in maintaining natural resources (including marine living resources) to be utilized for only non-consumptive purposes, i.e., keeping them in their pristine state to be used as an amenity, for tourism and scientific research purposes.

A multidisciplinary methodology to marine sciences research is needed in order to meet the demands of better resource management and ecosystem-based approach to natural resources exploitation and utilization. In addition to the well-established fields of stocks assessment, fisheries and aquatic biology and ecology, there will be needs to utilise expertise in such areas as remote sensing, oceanographic instrumentation, molecular and genetic sciences, and physio-chemical oceanography.

Recent and Current Research

This section presents a brief overview of past and current research in fisheries and marine living resources-related research in Malaysia. This overview are by no means comprehensive as the author is not appraised nor privy of the many researches undertaken by the many institutions conducting marine science-related research. A special focus is given to research work undertaken by the Department of Fisheries, Malaysia and its related organizations. Research and development in fisheries resources, fishing and marine ecology as well as mariculture technology as undertaken by the Department of Fisheries, Malaysia are undertaken by the Fish-

eries Research Institute (FRI) and its four branch centers, namely the Marine Finfish Production and Research Center (MAFPREC), the National Prawn Fry Production and Research Center (NAPFRE), and the Brackish Water Aquaculture Research Center (BARC). Activities are also carried out in related centers at Likas Fisheries Research Center, the Fisheries Research Institute, Sarawak Branch. The main center for marine fisheries resources research and surveys are conducted at the Marine Fisheries Resources Development and Management Department (MFRDMD) which is the Fourth Department of the South-East Asian Fisheries Development Centre (SEAFDEC). Prominent academic institutions undertaking marine science and fisheries-related studies and research include the School of Biological Sciences and the Center for Marine and Coastal Studies at the Universiti Science Malaysia in Penang, UNIMAS in Sarawak, Universiti Malaysia Sabah principally at the Borneo Marine Research Unit, and University College Terengganu and the Department of Environmental Sciences at Universiti Putra Malaysia. Some similar researches are and were undertaken at the Department of Zoology and the Department of Chemistry at the Universiti Malaya.

For the convenience of this discussion marine-living resources research is divided into the following categories: marine life stocks assessment and population studies, animal biology, taxonomy and ecology, environment and ecosystem studies, capture fisheries production and related technology, aquaculture production and husbandry research, physical, chemical and biological oceanography, genetics and molecular biology, and bio-diversity research.

The Department of Fisheries is the prime organization undertaking marine life stock assessment and population studies primarily due to its legally mandated responsibility to manage marine capture fisheries. Current studies include fisheries stock assessment of deep sea marine resources through fishing surveys and marine hydro-acoustical and imaging means. Specific research includes studies on the population dynamics of marine prawns, mackerels and squids, and assessment of the kinds, abundance and distribution of fish eggs and larvae. Related studies and refinement of techniques include acoustic survey methodology and analysis, utilization of GIS/remote sensing and imaging techniques in the determination and forecasting of marine resources, fisheries stocks and resource production parameters. UPM at Kolej Universiti Terengganu has similar programs in conjunction with their marine fisheries stocks and turtles population assessment research projects.

Biodiversity research, taxonomic and population studies is the focus of many of institutions. Stocks assessment and biodiversity research, animal biology, taxonomy, and ecology and habitat and related studies including on coral reef populations and species, commercially important fish species, giant clam, corals, shrimps, sea snakes and crabs, plus favorite subjects such as whale sharks, turtles and aquatic mammals are on the research programs of UNIMAS, UMS, UPM and USM. In Sabah, UMS, together with 3 Danish universities, undertook a series of biodiversity studies and related research including studies on marine resources. Artificial reef studies including on stock biodiversity, succession and recruitment have been conducted by both UPM and the Department of Fisheries, Malaysia. The use of molecular genetics and DNA fingerprinting technique in the assessment of the population genetic structure or stock composition of some marine animals has been done in Malaysia although this research field is much at its infancy. These studied animals include *dugongs* (the Department of Fisheries, Malaysia), turtles (UPM) and clownfish (USM).

Understanding the brackishwater (including estuaries, coastal wetlands and mangroves) and marine environment and oceanographic parameters and processes, including the effects of pollution, fishing and other human activities on the environment and the living resources is part of the many research programs at UNIMAS, UPM, USM, UMS as well as the Department of Fisheries itself. Red tide research has been conducted at UNIMAS, UMS and UPM.

The Fisheries Department is prominent in the fields of aquaculture production and aquatic animal husbandry research. Researches include in the aquaculture of shrimps, mollusks and finfish. In culture technology, there have been past success in the research of tank culture, pond culture, mariculture as well as fish cage culture. Trials are underway for large oceanic fish cage culture as well as aquaculture systems that are more environmentally sustainable. In hatchery technology, the breeding and spawning of estuarine and coral groupers, snappers, marine prawns, several molluscs have been meet with several successes. These include the development and refinement the broodstock spawning, larval rearing and grow-out techniques. Some research success were achieved in sea cucumber, abalone and squid spawning and larval culture. Experiments in sea bass and tiger prawn broodstock improvement through genetic selection are current research projects. There are also some preliminary achievements in feed formulation and fish nutrition including the use at palm kernel as an ingredient at the Fisheries Research Institute. UMP (Institute of Bioscience) have comparable research programs in fish nutrition (formulation of *Penaeus monodon* diet using locally-available ingredients), culture systems (recirculated systems). At University College Terengganu, studies are done on broodstock, culture technology management and larval rearing of several marine fish and crustaceans.

For aquatic animal disease management, the Department of Fisheries has come up with a diagnostic kit for freshwater fish bacterial diseases and currently working on the marine fish equivalent as well as producing bacterial fish disease vaccines. A notable achievement by UPM is the development and commercialization of rapid PCR-based diagnostic kit for WBVS (White spot Bacculo-Virus Syndrome) disease. Other fish disease-related studies are on the assessment, inventory and survey of diseases and pathogens in the aquaculture industry.

Universiti Malaya at the Department of Chemistry conducts research activities on various pollutants in seawater; sediment and biota; distribution, fate and toxic effects of pesticides in marine ecosystems, and at the Department of Zoology whose main research areas involve mangrove benthos, mangrove fisheries, and pollution.

Universiti Kebangsaan Malaysia has comparatively less marine science-related research. The Faculty of Natural Resource Science however has been reported to have undertaken research in benthic communities and plankton.

Some thoughts on research priorities and thrust areas

It is important that marine research initiatives must be consistent with national and international thinking on the essential role of research, technology, development and innovation, both in supporting existing marine activities and employment and in underpinning future innovation and growth.

NAP3's emphasis is on increasing food production for food security as well as foreign exchange earnings, sustainable utilization of natural resources and the enhancement of productivity and efficiency of agriculture production inputs. Capture fisheries and fishing as well as aquaculture will much remain as the major component of the exploitation or utilization of marine-living resources. However non-consumptive interests such as the conservation of flora and fauna as *in-situ* biodiversity banks of natural resources and locus of research as well as use as aesthetic and recreation amenities and tourism attractions should be given greater emphasis. In addition, minimal consumptive uses especially for resource utilization for biotechnology development will also gain more importance.

Fisheries and marine living resources-related research should directed towards developing a scientific basis for managing marine resources, understanding the marine environment, and understanding the nature of marine biological resources, ecosystems and biodiversity and its application for human welfare. Technological innovation should be a key research strategic area aimed to develop advanced methodology and techniques particularly in marine aquaculture and fishing. There is also significant potential for Malaysia to develop niche high value products and services which will support and enable the development of the nation's marine resource. Thus, on a broad front, the thrust areas for marine living resources research should be guided by the following considerations.

Research should be directed towards achieving high–order improvements in production technologies and methods in capture fisheries and harvesting aquaculture consistent with the broad objective to increase fish production in the nation. This involve the wide-spread adoption of new production technologies with high and efficient outputs. For aquaculture development, R&D that will develop aquaculture in a sustainable way, including identifying new species for aquaculture, general biology and genetics, fish behaviour, reproduction growth and survival should be given emphasis. Research, aiming at improved knowledge of the biological and physiological issues of aquacultured stocks as well as of new species which allow a diversification of the aquaculture production, should also be promoted. Concomitant with the policy to encourage large-scale and commercial operators in the industry, R&D in technology that will improve production technologies and systems on the industrial scale, including fishing and farming methods, handling; processing; and transporting should be accorded matching emphasis.

The limitations in finfish seed production in local aquaculture has been reiterated many times (Ismail, 2000 and Tang, 2000). Although there are several successful aquaculture species and promising new developments in the breeding of high-value species (Sih, et. al. 2000), it remains that research should be done to explore alternative and new candidate species. Cutting-edge techniques including the use of molecular genetics should be employed.

There is increasing attention being paid to reduction in the use of fish meal in diets for aquaculture species. The use of moist and fresh diets are known to be more polluting and wasteful of higher-order natural resources inputs. The utilization of readily available local feed ingredients such as palm kernel should be explored further to reduce feed costs. Because of the increasingly scarcity and high-cost of resource-based feed formulation ingredients, there is a

need to research the potential of aquaculture species low in the food chain (such as sea cucumber) and aquatic plants (seaweed).

To address environmental and disease threats, applied research is needed to formulate approaches adapted to production systems. Although significant progress has been made in many aspects of disease control, it remains a complex field which will require constant research to formulate preventive measures, and to contain or eradicate pathological threats as they occur. The adoption of environmentally sustainable aquaculture production methods including semi- and closed recirculation systems and aquaculture of broodstock as opposed to exploiting from wild stocks are also very important areas of research.

Fisheries stocks and marine resources assessments and related studies such as aquatic animal biology and species information are imperative to provide a good scientific base in order to support management measures to ensure balanced sustainable exploitation of fisheries and marine-living resources, and also explore new stocks of fish for exploitation. These include R&D that will increase knowledge of wild fish resources for sustainable management, including: general biology and genetics; fish behaviour; stock definition; interaction between fish stocks; and resource assessment techniques. For fisheries management improvement, R&D should be focused on that will develop and evaluate sustainable fisheries management, including developing systematic approaches to environmentally sustainably development, developing sustainability indicators, assessing fishing effort and effort changes and regulating access to resources. The urgent need for further fisheries resiurces assessment in Malaysia is well-recognised (Chuan, *T.T., et. al.*, 1996). While significant work has been done on this field, many potential fishing areas, especially in the deep sea areas off Sabah's coast, are still poorly assessed in terms of quantity and quality as well as seasonalities of fisheries stocks.

Malaysia sits at one of the 12 globally-recognized megadiversity locations in the world. However information on the present state of marine biological diversity in Malaysia is severely lacking because no comprehensive survey of these resources has been conducted. "The lack of authoritative information on the present state of marine biological diversity in Malaysia could have serious future implications for biological diversity conservation" (Mohd Nizam, 1999).

The usual public perception of the importance of maintenance of biodiversity is limited to high-profile animal species which are those considered endangered, threatened or otherwise always in the public eye such as elephants, turtles and whales. But the preservation of genetic diversity is just as important for example in the continued well-being of wild life stocks, the maintenance of resource base for prospecting for biotechnology products and assurance of a genetically-robust broodstock bank for aquaculture (Bert, 1999).

Effective management and conservation of a fishery require a basic knowledge of a species population genetic (stock) structure. This information is vital in assessing the ranges and make-up of management units (are *Tulai* along the west coast of Sabah comprise of a single stock, or are several genetically distinct stocks present?), or to determine if unique genetic variation is restricted to specific regions (will a fishery collapse in one area if genetic variation is removed from a species?). Although some preliminary work has been done in this area

(Palaniappan, S.S. et. al. 2000, Ismail, A.K., pers. communication, DNA profiling of sea turtles by UPM) in Malaysia) unfortunately little is known about the population genetics of many coastal fishes and aquatic animals; practically none exists for open ocean (pelagic) fishes.

Recent advances in biotechnology have spawned exciting new techniques that can be applied to long-standing problems in fisheries science. Foremost among these are successful studies of the population genetic structure or stock composition of commercially and/or recreationally important fisheries. The successful use of RAPD (Random Amplified Polymorphic DNA fingerprinting technique in the assessment of genetic diversity in several fish such as tilapia, discus, striped bass and catfish has been reported in some countries (Siti Azizah and Abu Bakar, 2000). Locally, there are completed research projects which uses molecular techniques to determine the species and population relationship of marine fish (Palaniappan, S.S. et. al. 2000).

Environmental interactions in aquaculture arise from because aquaculture relies a lot on heavily on environmental "goods" (e.g. water, feed ingredients, seed etc) and "services" (e.g. coastal ecosystems for pond water discharge). Many aquaculture activities are highly sensitive to adverse environmental changes (e.g., water quality, seed quality), and can be seriously affected by aquatic pollution (see for example, Din, 1999 and Bartley, 1999). Improvements in scientific knowledge of the aquatic environment and ecosystems and the impacts of human activities, including aquaculture and fishing and the environment are essential. These knowledge are required to establish development strategies and plans, and management measures that are consistent with sustainable resources uses be it land and water or marine living and non-living resources.

Research institutions should also direct efforts into studies of environmental issues arising from, or associated with, priority developments in order to endow a firm scientific foundation for environmentally sustainable marine investments and developments. Further, a better understanding of the environmental impacts of industries (agriculture, tourism, fishing, mining and oil and gas) and development of options to ensure ecological sustainable development is imperative. As a parallel but equally important activity, efforts should be carried out to improve the quality of marine environmental monitoring, modelling and reporting in order to accurately identify and understand changes and trends in marine environmental quality and provide appropriate management advice.

Prominence should also be accorded to R&D that will maintain and improve ecosystems, including: protecting, restoring and enhancing habitat; reducing bycatch and impacts on other non-target flora and fauna; and enhancing wild fish resources. Further, strong emphasis on R&D that will increase knowledge for the protection of ecosystems, including: interrelationships between fish and their environments; impacts of fishing, aquaculture and other marine and land use; biodiversity; fish health; and impacts of exotic organisms.

The influence of environmental factors, both natural (oceanographic, climate, primary production) and man-made (excluding fisheries and aquaculture), on the key biological parameters (e.g. recruitment, distribution, natural mortality) of aquatic resources should be studied. Oceanographic research is important for proper exploitation and management of our fishery resources for fishery populations and their characteristics are closely related to the environmen-

tal conditions in which they are in. Scientific information on marine environment such as data and information on the physical oceanography (depth, air temperature, wind speed and direction, current, sea temperature, salinity and turbidity) chemical oceanography (dissolved oxygen, nutrients, trace metals) biological oceanography (plankton) represent an important foundation for fisheries resources management.

Specific to Sabah is the problem of toxic algal blooms (red tide) and paralytic shellfish poisoning which is an almost yearly occurrence. It follows that further studies on red tide such as the detection of toxins and the environmental factors which promote toxic algal blooms as well as calibration studies, including research on contamination and decontamination dynamics should be conducted. Endeavours should also be carried out to establish new methods of PSP toxin levels estimation in affected marine species which should complement the currently-used technique of mouse bioassay.

Biotechnology is a rapidly advancing field and is seen by many as one of the most promising enabling technologies for advancement in many fields of human welfare and betterment. Malaysia's flora and fauna constitutes a rich biodiversity and indeed located in a 'megadiversity' region of the world. Be that case maybe, marine biotechnology and indeed biotechnology as a whole is still a nascent field in Malaysia. There have not been many advances locally although reports from other countries show that marine bio resources hold many promises (see for example, National Science and Technology Council (USA), 1995 and Phang, S.M., *et. al*. 1994). Biotechnologically designed new feeds, hormones and disease control agents are already favourably impacting fish production. Marine organisms, from microalgae to fish, represent a unique repository of genetic biodiversity and biochemistry with potential for use in new pharmaceutical, agricultural and industrial applications. Chromosomal manipulation techniques and genetic adaptation (recombinant DNA) of aquacultured species hold many promises for improvements in production technology. It is important therefore to initiate a concerted research effort in the application of biotechnology in aquaculture production and marine bio resource utilization. The field of biotechnology is characterized by two important features: one, that biotechnology products and process are eminently patentable; and two, great rewards are attained by those first to market. It is vital that research in this field start as soon as possible especially in leveraging the abundance of local bio resources.

Research programs and projects including in marine sciences are fragmented due to research priorities of institutions undertaking these exploits. Research findings and scientific data still occurs in islands of information in these organizations although a lot of headway been achieve through planned collaborative work as well as utilization of established frameworks of information sharing. While it is understandable that there are considerations of intellectual property rights to patentable products and processes, useful scientific information acquired from public good researches should be made available or accessible to policy makers and organizations who are legally mandated and responsible for environment and natural resources management. It is only with the foundation of an extensive and comprehensive information base that law makers and implementers of policies can enact the best possible development and management measures for common-user resources.

The granting of research grants under the Ministry of Science and Technology's IRPA (Intensification of Research Priority Areas) program is influenced by its policy in that emphasis is in the use and adaptation of existing technologies and creating new technologies, products and processes, and their subsequent commercialization. In the field of marine living resources and environment sciences much of the research done in Malaysia is categorised under public good research which focus is on the acquisition of information and new knowledge to support industry development and management as opposed to the development of processes and products. Public good research at the moment ranks lower in priority in the IRPA program. Since the essentiality and importance of these types of research are undeniable, it is hoped that the Ministry of Science and Technology (MOSTE) will take a positive relook at such funding schemes in future. In addition, granting of IRPA grants, as set by MOSTE, are by competitive individual bidding. This fosters a climate in which research endeavors become more individualistic and piece meal. In the case of marine sciences which relies more on an integrated and multidisciplinary approach, such a situation favors a fragmented and discontinuous research initiative among participating institutions.

It is also proposed here that academic institutions and private sector research (including those funded through the IGS (Industry Research and Development Grant Scheme) and IRPA take the lead in the development of innovative products (including biotech and marine-based products) and services in instrumentation, remote sensing, information technologies and fishing and aquaculture technologies. It will be asking too much to look towards full government research institutions and centers for leadership and pioneering work in this field since they are saddled with many and heavy responsibilities that they are legally obligated to undertake. For example, the Department of Fisheries has the legal responsibility to manage the aquaculture industry as well as regulating fishing activities. In order to effectively do so this Department has to commit much of its research resources towards acquiring scientific knowledge and information to support this effort.

Conclusion

The exploitation of marine living resources is of major economic importance to Malaysia. Sustainable marine resources utilization must be supported by a level of research, monitoring and assessment appropriate to meet existing needs and the increased pressure on the resources which will accompany a growing marine economic sector. Fisheries and marine living resources-related research should directed towards developing a scientific basis for managing marine resources, understanding the marine environment, and understanding the nature of marine biological resources, ecosystems and biodiversity and its application for human welfare. Technological innovation should be a key research strategic area aimed to develop advanced methodology and techniques particularly in marine aquaculture and fishing. There is also significant potential for Malaysia to develop niche high value products and services which will support and enable the development of the nation's marine resource.

References

Bartley, D.M. 1999. "The Introduction of Exotic Species through Mariculture and Its Impact on the Marine Environment." Presented at the Conference on Mariculture and the Environment - Towards the New Millennium, 24-25 August, 1999. Kuala Lumpur. Maritime Institute of Malaysia.

Biusing, E.R. 1996. Status of the Coastal Fisheries Resources of Sabah, Malaysia. Pp. 31-80. In: Ti, T.C. et al. (eds). "Development and Management of Fisheries Resources in Malaysia." Institute for Development Studies, Sabah, 1996.

Biusing, E.R. and Jintoni, B. 2000 "Strategic Plan for Fisheries Research for Department of Fisheries Sabah 2001-2005." Department of Fisheries Sabah. (Unpublished) (Bahasa Malaysia)

Bert, T.M. 1999. "The Preservation of Genetic Diversity for Sustainable Aquaculture." Presented at the Conference on Mariculture and the Environment - Towards the New Millennium, 24-25 August, 1999. Kuala Lumpur. Maritime Institute of Malaysia.

Chuan, T.T., Othman, M., and Fung, S. 1996. eds. "Development and Management of Fisheries Resources in Malaysia." p.212. Institute for Development STudies (Sabah). Kota Kinabalu.

Din, D. 1999. "The Impact of Effluent Discharge from Mariculture Activities on the Coastal Environment." Presented at the Conference on Mariculture and the Environment - Towards the New Millennium, 24-25 August, 1999. Kuala Lumpur. Maritime Institute of Malaysia.

Ismail, A.K. 1999. "Development of Appropriate Technologies for the Mariculture Industry in Malaysia." Presented at the Conference on Mariculture and the Environment - Towards the New Millennium, 24-25 August, 1999. Kuala Lumpur. Maritime Institute of Malaysia.

Ismail, A.K. 1999. "Seed Technology and Breeding Research and Development Strategy." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 6-9 September, 1999. Pulau Pinang. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

Ismail, A.K. 1999. "Marine Ecosystem Research Strategy Towards Strengthening the Processing Industry and Development of a Sustainable Fisheries." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 6-9 September, 1999. Pulau Pinang. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

Ismail Taufid, M.Y. 1999. "Marine Fisheries Research and Development Strategy." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 6-9 September, 1999. Pulau Pinang. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

Ismail, A.K. 2000. "Fisheries Research Institute Research Program: Targets and Performance Indicators." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 5-8 September, 2000. Melaka. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

Ismail Taufid, M.Y. 2000. "TMFRDMD/SEAFDEC National Research Program: Targets and Performance Indicators." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 5-8 September, 2000. Melaka. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

Mohd Nizam, B. 1999 "Future Challenges In The Management Of The Marine Environment In Malaysia." Centre for Coastal Development, Marine Environment and Resources. Maritime Institute of Malaysia, Kuala Lumpur, Malaysia

Mohd. Mazlan, J. 2000. "Transformation of the Fisheries Sector: Directions and Strategies." Presented at the Annual Conference of Senior Fisheries Officers, Department of Fisheries, Malaysia. 5-8 September, 2000. Melaka. Department of Fisheries Malaysia. (Unpublished) (Bahasa Malaysia)

National Science and Technology Council. 1995. "Biotechnology for the 21st Century: New Horizons. Chapter 5 - Opportunities In Marine Biotechnology And Aquaculture." In A Report from the Biotechnology Research Subcommittee. Available http://www.nal.usda.gov/bic/bio21/aqua.html. (accessed 12 August 2001).

Palaniappan, S.S. *et. al*. 2000. "The Use of Molecular Techniques for Identification in Coral Reef Fish Genus *Amphiprion*." Presented at the International Conference on In-situ and Ex-situ Biodiversity Conservation in the New Millennium. 19-22 June, 2000. Kota Kinabalu. Sabah Museum and Yayasan Sabah/Innoprise Corporation Sdn. Bhd.

Phang, S.M., Lee, Y.K., Borowitzka, M.A., and Whitton, B.A., eds. 1994. "Algal Biotechnology in the Asia-Pacific Region." University of Malaya. Kuala Lumpur.

Phillips, M. 1999 "Management strategies in development of sustainable shrimp culture." Presented at the Workshop on Development of Sustainable Management Practices in Shrimp Farming. Bhubaneswar, India. 30th-31st July 1999. Ministry of Agriculture, India and the Department of Fisheries, State of Orissa, India.

Siti Azizah M.N. and Abu Bakar, T. 2000. "Comparisons of Species Identification Techniques Applied for Taxonomic and Systematic Studies." Presented at the International Conference on In-situ and Ex-situ Biodiversity Conservation in the New Millennium. 19-22 June, 2000. Kota Kinabalu. Sabah Museum and Yayasan Sabah/Innoprise Corporation Sdn. Bhd.

Sih, Y.S., *et. al.* 2000. "Improving Hatchery and Grow Out Technologies for Grouper Aquaculture in the Asia-Pacific Region." Presented at the Seminar and Workshop on Sustainable Marine Aquaculture Development In Sabah, Malaysia. Kota Kinabalu, Malaysia. 15-16 August, 2000. Institute for Development Studies (IDS) and Department of Fisheries, Sabah.

Tang, T.P. 2000. "Development Issues, Challenges and Future Direction of Marine Aquaculture Development in Sabah: A Private Sector's Perspective - Marine Cage Culture Farming." Presented at the Seminar and Workshop on Sustainable Marine Aquaculture Development In Sabah, Malaysia. Kota Kinabalu, Malaysia. 15-16 August, 2000. Institute for Development Studies (IDS) and Department of Fisheries, Sabah.