

# Managing 'Sinarapan' *Mistichthys luzonensis* Smith in Lake Buhi, Camarines Sur: Insights from Its Biology and Population Dynamics

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## Abstract

The population dynamics and related aspects of the biology of 'sinarapan' *Mistichthys luzonensis* Smith, the world's smallest commercial fish, are used as basis in formulating management strategies for this goby in Lake Buhi, Camarines Sur. Mesh size limit (4.1mm) and catch limit, estimated through length-based analytic fishery methods, are proposed. Yield-per-recruit analysis using length-frequency data for 11 months provided the quantitative indices used in estimating fishing limits. Closed season for 'sinarapan' was established from temporal pattern of recruitment and the reproductive biology of the species. Much of the data on 'sinarapan' came from studies in Lake Manapao. To improve the recruitment success of 'sinarapan', a habitat enhancement scheme in Lake Buhi is hereby recommended.

## Introduction

Knowledge of the biology and vital population parameters of a finfish resource is essential to its rational management. Such data become especially needed if the fishery has taken disadvantageous complexities. The sad case of 'sinarapan' *Mistichthys luzonensis* Smith in Lakes Buhi and Bato is a vivid example. The fish was amazingly abundant in both lakes in the 1930's to the 1960's but almost disappeared in 1979 to the present. The exact mechanism of its disappearance is not known, but the depletion of the stocks is mainly due to the motorization of the 'sakag', a collapsible Y-shaped push-net which overfished both lakes and destroyed the breeding, feeding and refuge areas of 'sinarapan'. Today, only one natural freshwater body has a viable stock of 'sinarapan'. This is Lake Manapao (13° 26' N, 123° 29' E, 122 m above sea level, 3.75 ha and 7.6 m mean water depth), a tarn or mountain lakelet in San Ramon, a hinter barangay of Buhi, Camarines Sur. Lake Manapao was probably formed during the eruption of Mt. Asog (now Mt. Iriga) in 1641. Despite being declared a sanctuary for 'sinarapan' by a Buhi municipal resolution in 1982, Manapao is still being fished of 'sinarapan'. Tilapia, common carp, mudfish and catfish, coexisting with 'sinarapan', are caught in Manapao. A sergistid shrimp can also be found. Recently, tilapia fish cages in Lake Manapao were removed as a response to the alarming mortality of the 'sinarapan'.

## Population Dynamics of 'Sinarapan'

Key morphometric features of 'sinarapan' are shown in Table 1. The greatest standard length of 23.5 mm from Lake Manapao (Soliman 1994) was longer than that recorded for the goby by Herre (1927; 14.0 mm) or Te Winkel (1935; 14.5 mm). By contrast, the maximum standard length of the fish recorded by Gindelberger (1981; 24 mm) was close to that from Lake Manapao, but greater than that in the two earlier studies on 'sinarapan' in Lake Buhi. This could reflect the fact that Gindelberger's samples were taken when 'sinarapan' stocks had diminished greatly, which may have led to the concomitant increases in food availability and hence increases in size attained.

**Table 1. Key morphometric and related features of 'sinarapan'**  
(Items 1-13 from Soliman 1994 and 14-15 from Sergio 1995)

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1. Morphometric relationship of total length (TL) to live weight (LW, g)  
 $TL = 1.947 \times 10^{-6} * LW^{3.499}$
  2. Allometric growth indicated by  $b (=3.499) \neq 3$ .
  3. Regression analysis:
    - a) total length to standard length (SL, mm)  
 $TL = 1.1252 + 1.0011 * SL$
    - b) number of eggs per gram female (NE) to total length  
 $NE = 3.9858 * TL^{0.282}$
  4. Maximum observed TL = 25.0 mm
  5. Smallest observed TL = 5 mm
  6. Asymptotic total length ( $L_{\infty}$ ) = 24.6 mm
  7. Low exploitation rate (E) = 0.328/yr
  8. High natural mortality (M) = 6.201/ yr
  9. High growth constant (K) = 2.25/yr
  10. High total instantaneous mortality (Z) = 9.234/yr
  11. Moderate fishing mortality (F) = 3.033/yr.
  12. Early maturity of 3 months and 5 days
  13. Short longevity ( $t_{max}$ ) = 2.45 years
  14. High relative monthly fecundity = 2,640 eggs per gram female with spawning peaks in May and October
  15. Sex ratio of 1:1 mature male or female fish
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Sergio (1995) studied the sex ratio, relative fecundity and diet composition of 'sinarapan' in Lake Manapao. From extensive samples, he found a 1:1 male to female ratio for most months (August-January) except in July (3:1) and October (2:1). Data over an 8-month period showed a mean of 2640 eggs per gram female with a range of 1937 - 3204 eggs. Diet is 92% zooplankton and 8% phytoplankton and undetermined digested items. Bulk of food in the gut is generally low with a mean of 0.3% of body weight. Maximum level observed from few samples reach 10% of body weight. Feeding has been shown to have a single peak occurring about midnight and minimum at noontime.

Recently, Esplana (1996) estimated the total instantaneous mortality coefficient (Z) of 'sinarapan' in Lake Manapao to be 860/yr, equivalent to mortality rate of more than 90%/year. This is a very high mortality which researchers at Bicol University Tabaco Campus (BUTC) found to be due to the fish cages stocked with tilapia installed in the sanctuary. The municipal council of Buhi acted on this by ordering removal of the cages from the lake. Catch curve analysis was used to

compute the mortality coefficient based from more than 1000 'sinarapan' individuals collected from May to August 1996. Catch curve analysis regresses the relative age with the transformed frequency of fish by length class. The points chosen for the regression analysis are those which represent fully-recruited and fully-selected individuals. These points, included in the left ascending part of the catch curve, were used to generate a resultant curve based on the method of Pauly (1984 and 1983) where its slope, multiplied by -1, is the mortality coefficient.

Parameters of the Von Bertalanffy Growth Formula (VBGF) estimated for 'sinarapan' were as follows: asymptotic length ( $L_{\infty}$ ) = 24.6 mm and growth constant ( $K$ ) = 2.25/yr (Soliman 1994). The high growth constant is typical of most short-lived tropical fish (Pauly 1978). The  $L_{\infty}$  matched closely with the greatest total length (25 mm) achieved by the fish in Lake Manapao.

Initial estimates of  $L_{\infty}$  and  $Z/K$  were obtained using the modified Wetherall method (Wetherall 1986; Pauly 1986). This is a routine in ELEFAN II (Electronic Length Frequency Analysis II, see Gayanilo *et al.* 1988). Assuming an approximately 1.5 years longevity of 'sinarapan' ( $t_{\max}$ ) and  $t_0 = 0$ ,  $K$  was tentatively estimated through Taylor's (1958) approximation cited in Pauly (1980).

Better estimates of  $L_{\infty}$  and  $K$ , fitted to the non-seasonalized VBGF, were obtained using ELEFAN I routines. Restructuring of length-frequency data and subsequent fitting of growth curves by ELEFAN I were done. Two growth curves (one for the primary cohort and another for the secondary cohort) were identified and traced. Details of the growth curve-fitting procedures are given in Gayanilo *et al.* (1988).

The  $Z$  was estimated through length-converted catch curve analysis and from mean length in the catch. Pauly's method was used to estimate  $M$ . Subtraction of  $M$  from  $Z$  yielded  $F$ . Exploitation rate ( $E$ ) was estimated as  $F/Z$ .

The recruitment pattern in relative times was drawn from the apparent monthly recruitment expressed in percent of annual recruitment. A recruitment pattern over real times was also generated using a  $t_0 = -0.01$ .

The estimation of  $Y'/R$  and  $B'/R$  was done using the model of Beverton and Holt (1957) as modified by Pauly and Soriano (1986) to account for wide selection exhibited by the investigated species.

Two versions of VPA were used namely: the functional equivalent of Length Cohort Analysis (Pauly 1984) by Jones (1981), the length-structured VPA (Pope 1972), also termed as VPA II and III, respectively, in the Compleat ELEFAN.

## Management Implications of Population Parameters

The parameters of growth and mortality, indices of yield-per-recruit, and virtual population have been estimated, based on 11 months (April 1988 - May 1989) of size frequency and catch data, by using the routines of Compleat ELEFAN (see Pauly 1986, Gayanilo *et al.* 1988). Following the methods given in Jones (1981) and Pauly (1983) the foregoing parameters, complemented by other metric characteristics of 'sinarapan', were used to estimate an optimum mesh size of push-net for sustainable harvest of the fish. A mesh size of 4.1 mm appears necessary for the protection of the

Manapao stock. This is considerably greater than the very fine-meshed nets used by fishers in the past in Lake Buhi. The use of a mesh limit of 4.1 mm should be enforced in both lakes even when collection is allowed for educational purpose, except for a research activity that requires data for the size structure of the stock. In the virtual population analyses of the Manapao stock, projections on the outcome of increasing  $E$  (hence  $F$ ) from the present level are given elsewhere (Soliman 1989 and 1991). The bulk of the catch is composed of small individuals (4-7 mm) which make up a major portion of the population. Implementing the mesh size limit will meet this requirement and prevent overfishing.

The analysis of yield-per-recruit revealed that increasing  $E$  (hence,  $F$ ) from the current level ( $E=0.337$ ) to its biologically maximum allowable level ( $E_{\max}$ ) can result to a corresponding increase of  $Y'/R$  by about 15 percent.  $Y'/R$  at  $E_{0.1}$  ( $E$  level at which beyond this point there is no significant increase in  $Y'/R$ ) is higher than  $Y'/R$  at current  $E$ .  $B'/R$  at current  $E$  is greater than  $B'/R$  at  $E_{\max}$ . Current  $E$  is between the exploitation rates of  $E_{0.1}$  and  $E_{0.5}$  ( $E$  level at which  $F$  is 50% of  $Z$ ). These are desirable considerations to maximize yield from an open fishery but it is not in the case of the Lake Manapao sanctuary. The models which derived these indices can also be useful to evaluate the effects of varying  $F$  (hence,  $E$ ) and/or  $L_c$  (the parameter roughly equivalent to the size at first capture) to  $M$  using empirical data which are absent to date. The matter of biological interaction (i.e., predation by tilapia, mudfish and shrimp) which is ignored in the length-based models used equally needs careful study.

The recruitment pattern of 'sinarapan' in Lake Manapao appears bimodal with peaks in July and November when heavy rainfall occurs. This is consistent with the observations of fishermen in Lake Buhi on the abundance of 'sinarapan' during the rainy months of July and December (Gindelberger 1981). Most (70%) of female 'sinarapan' in Lake Manapao which gather underneath water hyacinth *Eichhornia crassipes* about this time are gravid; those collected during the same period in areas lacking vegetation comprise approximately 20% gravid females. Egg count 1-2 months before these peaks (i.e., May and October) was high (Sergio 1995). The preponderance of gravid 'sinarapan' was also observed in Lake Buhi during these months (Gindelberger 1981). To protect the stocks in the sanctuaries of both lakes, collection of 'sinarapan' should be prohibited from June to August and in October and November. Even when allowed during other months, collection of fish from underneath floating macrophytes and other vegetation should be prohibited.

## Legal Bases of the Present Management Activities

The catching of 'sinarapan' in Lake Buhi is prohibited by virtue of Fishery Administrative Order No. 127, Series 1980. The issuance of this order was intended to save the species from near-total loss. However, two major aspects were lacking for the order to effectively achieve its main objective. First the timing of the order should have been made 2-3 years earlier when catches were not seriously dwindling. Second, the order should have included aspects to rationally manage and conserve the species through ecological enhancement activities. To complement efforts in protecting the endangered species, the Buhi municipal council passed Resolution No. 80-022, Series 1981 declaring Lakes Katugday (2.66 ha) and Manapao as 'sinarapan' sanctuaries. Buhi Municipal Ordinance No. 3, Series 1981 which banned the fishing of the small goby in the lakelets was passed shortly thereafter. Katugday, located about a kilometer northeast of Manapao, was disastrously

depleted of the fish six years later (Soliman 1989). This near-total loss of the stock had been reported by the residents near the lakelet to be due to the chemical pesticide applied by a villager who wanted an easy catch of the tilapia and common carp. Repeated sampling in the site by the authors confirmed the virtual absence of 'sinarapan'.

The laws enacted for the minute goby delve on the regulatory aspect of resource protection. While this aspect in the three laws is urgent then to prevent an impending stock collapse, adequate provisions should be made for managing the resource to maintain and enhance the integrity and biodiversity of its ecosystem. Such schemes include habitat enhancement, repopulation strategies, community networking and education/information projects. Specifically, the proposals of BUTC to Buhi Municipal Council for the management of Lake Manapao sanctuary are as follows:

- All forms of aquaculture in the Lake Manapao have to be banned
- Introduction of any fish is prohibited
- Watershed enhancement activities should be conducted
- Regulation of non-fishery uses of the lakelet
- Regulation of selective fishing in the lakelet
- Regular maintenance of vegetation
- Prohibition of human settlements in the lake periphery
- Employment of a regular sanctuary manager
- Fund allocation for sanctuary management
- Regulation of 'sinarapan' collection for educational purpose
- Creation of a sanctuary management body

In Lake Buhi, a sanctuary (c. 15 ha) for 'sinarapan' was declared by the municipal government. The sanctuary was established off the barrios San Buena and Sta. Cruz to provide breeding and refuge area for the threatened goby. San Buena, the most populated in Buhi, is where agricultural crops such as turnips, peanuts, corn, sweet potato, water melon and other cash crops are being produced. The sanctuary has become shallow due to siltation from the denuded watershed area. Aypa *et al.* (1995) also recommended the transfer of the fish sanctuary to another area because of increasing human settlements in the bordering barrios. With this present state, the sanctuary has to be relocated in the lake's northern portion bordering Tambo and Ibayugan. The new sanctuary has to be larger (c. 75-150 ha) and better managed.

## Habitat Enhancement Scheme

Activities for enhancement of 'sinarapan' habitat in Lake Buhi should include:

- *Demarcation of the sanctuary.* Buoys to physically define the boundaries of the 'sinarapan' sanctuary should be installed. Netting to fence off the sanctuary can be used to prevent unwanted entry. Information on the established sanctuary should be widely disseminated.
- *Provision of breeding, feeding and refuge areas for 'sinarapan'.* 'Sinarapan' do not guard their eggs so nursery and breeding areas in the sanctuary have to be adequately secured and free from predators. Provision of managed aquatic vegetation in the nursery zone will be helpful. 'Sinarapan' eggs are planktonic and attach to roots of vegetation.
- *Enhancement of zooplankton growth through maintained organic loading.* Organic materials can be used to enhance growth of zooplankton, rotifers and cladocerans which are the natural

food of 'sinarapan'. Organic matter in sacks may be piled in the sanctuary in points which will facilitate maximum dispersion to other areas.

- *Transplantation of useful vegetation.* Aquatic plants (e.g., eelgrass, water hyacinth, water lily) should be introduced into the sanctuary to provide feeding area, substrate for egg attachment, and shade.
- *Maintainance and protection of watershed areas bordering the sanctuary.* Reforestation and watershed management should be a priority. This would minimize shallowing of the sanctuary through siltation. In general, tree-planting program should be undertaken around the lake.

## Challenges and Constraints for Management

Successful management of 'sinarapan' in Lake Buhi will need inputs from both biology and the social dimension of resource management. Effective management of 'sinarapan' in Manapao partly spells success for 'sinarapan' management in Lake Buhi. With the almost total disappearance of the Katugday stock in 1988\*, Lake Manapao is the only viable source of 'sinarapan'. Collection activities, if allowed, must be strictly in line with scientific or conservation goals. This is a reality that concerned authorities, specifically the Department of Agriculture and the Bureau of Fisheries and Aquatic Resources, must be propelled to action. Presently, the local government of Buhi has employed a regular overseer on the basis of proximity of the overseer's residence to the sanctuary. Obviously, this cannot be an effective mechanism to manage Lake Manapao towards desirable and long-term ends. A watcher may wield the force of law and enforce it, but he must also be equipped with the technical background on management of the sanctuary.

Preparations by the Buhi Municipal Council in collaboration with BUTC to gather, through the barangay council, the 15-20 families residing near the lakelet for a forum on the dire need to maintain Manapao and preserve 'sinarapan' are underway\*. A vital information to disseminate in the forum is the current status of 'sinarapan' as an endangered species using an objective and explicit criteria based on the 1994 International Union for the Conservation of Nature (IUCN, Gland, Switzerland) Red List Categories as follows:

- An observed, estimated, inferred, or suspected reduction of at least 50% over the last 10 years based on direct observation, index of abundance appropriate for the taxon, decline in area of occupancy, extent of occurrence, and/or quality of habitat, actual or potential levels of exploitation, and effects of introduced taxa.
- A reduction of at least 50%, projected or suspected to be met within the next ten years based on an index of abundance appropriate for the taxon.

Coupled with continuing education and information dissemination to the community, these activities will strengthen and widen the network of protection for the sanctuary. Positive results may not be immediately apparent but it is through this process that a clearer perspective of the problem involving socio-economics of the people and the need for conservation for future benefits can be attained.

Sustainability as an operational concept is holistic and considers the total ecosystem and its components as beneficiaries. The sustainability of aquaculture in a natural water body should be

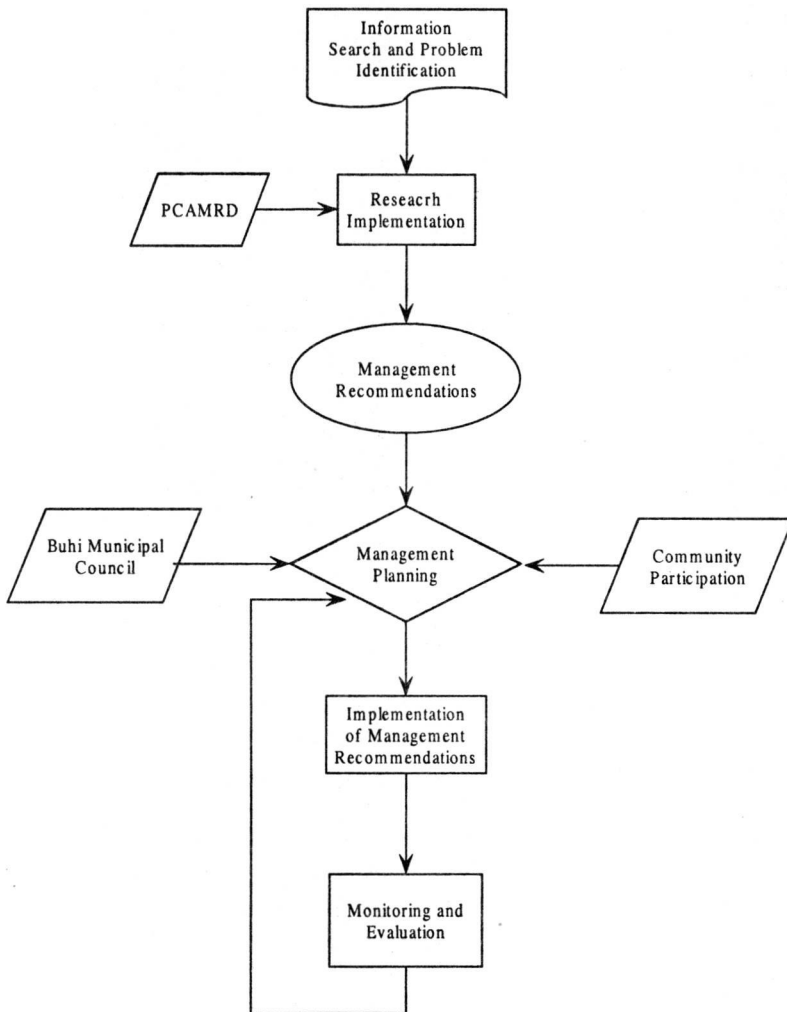
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\* While this paper was in press, two vital achievements of the Sinarapan Conservation Project were attained. Successful 'sinarapan' repopulation was made in Lake Katugday (Soliman *et al.* 2000). In May 1998, the First Symposium on Sinarapan Biology and Management was held in Buhi.

based on the environment's natural biotic potential or carrying capacity. Exceeding such capacity destroys or adversely alters the diversity of life in the habitat. Cage/pen culture in the lake is showing symptoms of a possibly ruined sustainability -slow fish growth, longer rearing period and occurrence of diseases. While it took 4-6 months to grow tilapia 5-7 years ago, the rearing period now is 10-14 months. There had also been cases when tilapia stock in cages suffered heavy loses due to sulfur poisoning and mortality caused by fish diseases. Fish farmers today have to provide artificial feed so that the stocks grow to marketable size. These are signs that the lake may have exceeded its natural carrying capacity due to the high stocking density in cages and pens.

Presently, about 6,000 units of tilapia fish cages (general dimension of 16 m x 5 m x 2.5 m) stocked with 3000 fingerlings per cage are operated in Lake Buhi (E. Bon, pers. comm.). The natural population of tilapia and other potential predators of 'sinarapan' have been harvested from the lake at 14.8 t/yr (Aypa *et al.* 1995). On scientific grounds, the matter of 'sinarapan' management in Lake Buhi will eventually be a choice between 'sinarapan' or tilapia fish cage industry. Success of the repopulation program for the lake will depend on the way this issue is resolved or remedied. It was documented in Lake Manapao that the tilapias, mudfish, catfish, sergistid shrimps, and common carp can coexist without causing serious population failure upon 'sinarapan' (Soliman 1994). This was under a condition of ecological balance among the different species. With the stocking of tilapia in the cages and their subsequent recruits, the equilibrium has been altered in favor of the predators (Soliman and Sergio 1997). Studies indicate that Nile tilapia prey upon 'sinarapan' (Aypa *et al.* 1995 and Gindelberger 1981).

There is a need for regular, close monitoring of Lake Buhi especially the new sanctuary. Research to aid management and legislation should be conducted in collaboration with concerned agencies. Some of the technical issues are being addressed (e.g., predatory-prey relationships, closing of the life cycle of 'sinarapan' under laboratory conditions, assessment of other lakes where the fish exists) in on-going studies by BUTC. The new sanctuary should be properly demarcated with buoys. Field monitoring to assess the status of the sanctuary should be conducted by field personnel of the municipal government. Vital aspects to monitor are water quality, status of key species of fauna and flora in the habitat, and condition of bottom. Technical assistance from research institutions may be requested. The framework for 'sinarapan' sanctuary management being adopted for Manapao in the research project at BUTC is shown in Fig. 1. This may well be adopted for Lake Buhi because protection and management of the endangered species can inevitably take the larger perspective of 'sinarapan' conservation in general. Finally, managing the goby in Buhi may ultimately take a larger role in the proposed management schemes for the lake as a whole.



**Fig. 1. Framework of Sinarapan Sanctuary Management Planning**



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