USE OF LENGTH-FREQUENCY AND CPUE DATA TO ESTIMATE GROWTH AND MORTALITY RATES AND TRENDS IN ABUNDANCE FOR *MACRODON ANCYLODON* (BANGAMARY) AND *NEMATOPALAEMON SCHMITTI* (WHITEBELLY SHRIMP) EXPLOITED BY THE CHINESE SEINE FISHERY IN GUYANA

by

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ABSTRACT

A study of the population dynamics of *Macrodon ancylodon* and *Nematopalaemon schmitti* is presented, based on the length frequency data for the period 1995/1996 (*Macrodon ancylodon* only) and catch per unit of effort (cpue) data for the period 1984-1986,1996 from the Chinese seine fishery of Guyana. Fishing mortality, yield per recruit and biomass per recruit analyses (*Macrodon ancylodon* only) and cpue as an index of abundance for both species are investigated.

1. INTRODUCTION

1.1 Gear Type

The Chinese seine fishery accounts for 27% (or 253 vessels) of the artisanal fleet of Guyana based on the 1994 Artisanal Frame Survey. The Chinese seine is a funnel-shaped net, 16m long and 4-6m wide at the mouth. The mesh size at the mouth of the net is 8cm and gradually decreases as it proceeds to the bag of the net where the mesh size is 1cm.

1.2 Fishing Strategy

The vessels work according to the tide and spend between 6-12 hours per day fishing. The net is attached to poles (pens) and set on mud banks, mainly in river mouths, where tidal currents sweep the fish and shrimp into the seine. This operation is heavily dependent upon the influence of the river currents. These poles (pens) are set at depths between 2-4 fathoms, at a distance of about one mile from the shore. Each vessel operates between two to ten seines. The crew size of these vessels ranges between 2-4.

The catch consists primarily of *Nematopalaemon schmitti*, *Xiphopenaeus kroyeri*, *Macrodon ancylodon* and *Nebris microps.* A large amount of juvenile fish is caught in the Chinese seine fishery and is discarded with a mortality of 100% or used to produce "fish meal".

1.3 Biology of the Species under Investigation

M. ancylodon and *N. schmitti* are the major species caught by the Chinese seine fishery. In fact, the Chinese seine is the only gear type in the Inshore Shrimp Fishery of Guyana which is used to capture the *N. schmitti* species.

According to Gutherez and Thompson (1977), December and February are the most intensive spawning months for *M. ancylodon*. This suggests two modes in the level of spawning activity from spring until summer in this region. *M. ancylodon* migrates to the spawning grounds and there appear to be more males than females in the spawning area during the spawning season. The estuarine and inshore zones appear to be principal nursery and rearing grounds for *M. ancylodon*, with the spawning grounds probably occurring further offshore. This is demonstrated by the large numbers of immature fish (*M. ancylodon*) caught by Chinese seine in the inshore and estuarine areas.

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According to Guttherez and Thompson (1977), estuaries function as the nursery grounds for the species. Juvenile and mature fish of the species are caught further offshore by shrimping vessels. *Xiphopenaeus kroyeri (*seabob*)* is the main prey of the species (Bianchi, 1992), and is closely associated with its distribution. *M. ancylodon* has been reported as one of the most abundant fishes off Guyana, representing 18% of the catch (Lowe-McConnel, 1966) and in 1988, it represented 17% of the catch in the nearshore stations (20m), indicating a stable community structure (Talbot, Benfield & Morton, 1996).

N. schmitti (whitebelly) is a cariadean shrimp which is distributed along the Brazil-Guianas shelf from Venezuela to northeastern Brazil (Holthuis, 1983; Cervigon *et al.*, 1993). Dragovich *et al*. (1980) found *N. schmitti* occurring predominantly over soft mud bottoms.

The abundance of *N. schmitti* along the coast of Guyana, as indicated by catches, peaks during March and April (Chackalall and Dragovich, 1980). However, it is unclear whether this reflects recruitment of juveniles to the fishery or changes in catchability related to water flow (outflow of freshwater from the rivers). The increase observed off Guyana in March-April also coincides with the onset of the rainy season, and the outflow of freshwater from the many rivers during this period is low.

2. DATA

2.1 Data Used for the Assessment of Length Frequency for *Macrodon ancylodon*

The data used for the assessment of *M. ancylodon* (bangamary) were monthly length frequency data (May 1995-November 1996), giving a total of 14 samples.

2.1.1 <u>Method of collection</u>

The sample was taken from unsorted landings and each fish was measured to the nearest centimetre (cm) below, from the tip of the snout to the longest caudal fin.

2.1.2 <u>Approaches Used for the Integration of the Data</u>

For the given vessels, if the total landings of *M. ancylodon* were not measured, the sample length frequency was extrapolated to estimate the total frequency. Each size class represented a 1cm interval. Since the monthly samples were found to be too small to clearly identify age group modes, the length frequencies were grouped into three (3) month samples. See Table 1 for the grouped length frequencies of *M. ancylodon*.

2.2 Data Used for the Assessment of cpue Trends in *M. ancylodon* and *N. schmitti*

Data used for the assessment of cpue trends in *M. ancylodon* and *N. schmitti* were monthly cpues (1984-1986 and 1996) for Regions 3 and 6 in Guyana (Shepherd *et al.,* this volume). An important old database was identified for the artisanal fishery and a review of the data forms showed that for regions 3 and 6, there were more entries in every month during the period 1984-1986 than for the other regions (2, 4 and 5). This inconsistency prevented the use of statistics generated from these other regions. Also during that period, the two species under observation were landed in large amounts in Regions 3 and 6. Region 3 accounts for more whitebelly shrimp than Region 6. For groundfish, Region 6 accounts for larger landings than Region 3. Region 3 spreads from the islands of Essequibo to West Demerara area and Region 6 is located from east Berbice to Corentyne.

2.2.1 <u>Method of collection</u>

The catch and effort data were collected via the Logbook System (census) during the period 1984-1986 and the Artisanal Data Collection Program (stratified random sampling approach) for the period 1996.

Table 1. The quarterly length frequencies used to estimate the growth parameters and total mortality, Z

Size Class (cm)	Jul/Aug 1995	Jan-Mar 1996	Apr-Jun 1996	Jul-Sep 1996
5	0	0	0	0
6	0	1	0	0
7	0	3	0	0
8	0	18	0	0
9	0	41	0	0
10	0	94	0	0
11	0	103	2	0
12	0	91	4	1
13	3	60	5	1
14	3	47	19	5
15	7	44	19	4
16	22	39	23	8
17	29	38	69	14
18	40	29	47	11
19	29	18	42	14
20	36	17	60	10
21	25	21	34	16
22	10	11	30	13
23	12	8	29	7
24	9	11	26	18
25	10	10	10	16
26	16	5	18	11
27	15	5	15	16
28	11	3	8	6
29	11	5	6	3
30	6	2	6	5
31	8	4	7	6
32	4	2	2	7
33	4	2	6	4
34	1	6	2	1
35	1	1	1	2
36	1	0	1	0
37	1	0	1	0
38	0	0	1	0
39	0	0	0	0
40	0	0	0	0
41	0	0	0	0
52	0	0	1	0

2.2.2. Approaches used for the integration of the data

Estimation of monthly catch per unit of effort for *M. ancylodon* and *N. schmitti* per region used the following procedures:

1. Select the given boat-type by month/year
2. Add all the catches for the given species for this boat-type.
3. Add the total number of nets for this boat-type.
4. Divide the catch by the total number of landings(total # of days)
5. The result of step 4 divided by the number(#) of nets used.
6. The CPUE for all vessels by month/region are totaled.
7. The result of step 5 divided by the total number(#) of boats with cpue values for the month.

3. METHODS

3.1 Methods Used in the Assessment of *M. ancylodon*

1. Due to the small sample size in each month, the length frequencies for each year were grouped into three (3) months intervals, giving a total of four quarterly samples (Table 1).

2. Preliminary identification of modal length and standard deviation of each of the normal distributions making up each polymodal length frequency distribution was done using the Bhattacharya method, using the FISAT software (Gayanilo *et al.*, 1995).The results were used as starting values in the NORMSEP routine, which was also run using FISAT.

3. The mean lengths and standard deviations obtained from the Bhattacharya method were used as starting values in the NORMSEP routine. However, it was found that NORMSEP sometimes generated unrealistic modes in this way. In these cases, the starting values were adjusted until the modes identified by NORMSEP were considered to be biologically realistic.

4. The modes identified were then used in the Linking of Means routine of FISAT in order to generate a Gulland and Holt plot of growth increments against initial length (Sparre and Venema, 1992). This generated estimates of K and L_∞.

5. Estimates of Z were obtained from the catch curve analysis using the software described by Ehrhardt and Legault (1996). This makes use of the relationship (Sparre and Venema, 1992):

$$\ln \frac{C_{L1,L2}}{\Delta t_{L1,L2}} = c - Z * t(\frac{L1, L2}{2})$$

where

$C_{L1,L2}$	=	the catch of fish between lengths *L*1 and *L*2
$\Delta t_{L1,L2}$	=	the time a fish will spend within the size group *L*1,*L*2 (yrs)
c	=	the intercept of the relationship between the terms on the left and right of the equation
Z	=	the instantaneous coefficient of total mortality (per year)
$t(\frac{L1, L2}{2})$	=	the average age of a fish in the length class *L*1 to *L*2 (yrs).

Within the programme, a straight line, of slope -Z, is fitted to a plot of $\ln \frac{C_{L1,L2}}{\Delta t_{L1,L2}}$ on $t(\frac{L1, L2}{2})$.

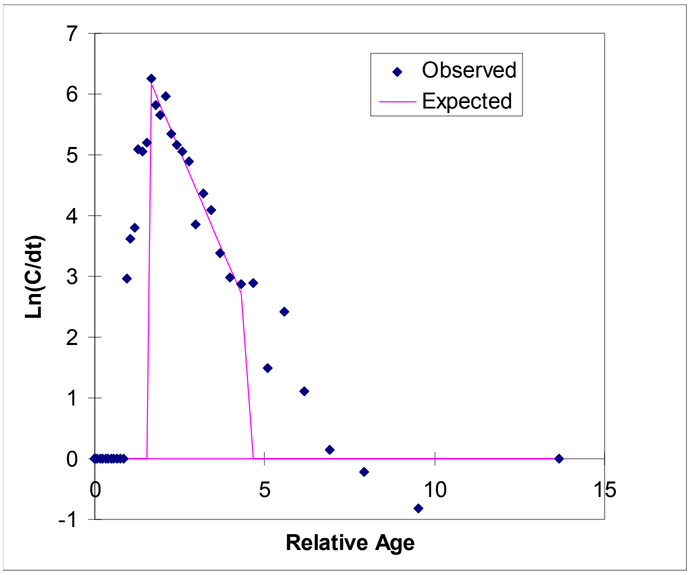

Figure 1. Example of linearised catch curve based on length composition data and the fitted straight line, using data from Table 1 for April to June 1996. (See text for details)

An example of such a plot, using the data from April to June 1996, is shown in Figure 1.

This was done for each quarterly length frequency sample listed in Table 1. Hence an assumption of equilibrium was made in the determination of the Z value. The inputs for this routine were the pooled quarterly length frequencies for the study period, along with the L_∞ and K values (38.3cm and 0.355 respectively) obtained from the literature, using values for Brazil. The L_∞ and K values estimated in step 4 were not used in these calculations since the K value obtained was unrealistically high.

6. Natural mortality, M, was obtained using the Pauly empirically-derived estimates as contained in FISAT, using the K and L_∞ values from the Brazil equation and a value of mean temperature of 27°C. FISAT does not include estimates of the confidence-intervals of the estimated M. However, sensitivity analyses of estimates of F and of yield-per-recruit (YPR) and biomass-per-recruit (BPR) results were undertaken on 0.75 and 1.25 of the estimated M.

7. The values of M and Z were used to estimate F at the time of sampling from the equation: Z = F+M.

8. The yield-per-recruit and biomass-per-recruit analyses were undertaken using a spreadsheet package based on the method of Beverton and Holt (Sparre and Venema, 1992) and using the estimated growth and mortality parameters described above. The YPR and BPR analyses were used to estimate single-species reference points for the stock under consideration. These were compared to the estimates of the current fishing mortality obtained by step 7. L_{rec} (size at first capture) was estimated as 100 mm by looking at the length frequency graphs for the various intervals for the period of the study.

3.2 Method Used to Estimate an Index of Abundance for *M. ancylodon* and *N. schmitti* from cpue

An analysis of variance was used to standardise monthly cpues of *N. schmitti* (whitebelly shrimp) and *M. ancylodon* (bangamary). In these analyses, the month and two regions were used as factors. The resulting standardised cpue series were simply plotted and the trends interpreted. For the detailed method used to estimate the cpue as an index of abundance for *M. ancylodon* and *N. schmitti* refer to the Methods section of the Shrimp and Groundfish Stock Assessment Workshop Report (FAO, 1997).

4. RESULTS

Table 2 gives the growth parameters for *M. ancylodon*, estimated using a Gulland and Holt Plot. As explained under methods, these values of L_∞ and K were not used in the length converted catch curve analysis, because of doubt about the validity of the estimated K.

Table 2: Estimated growth parameters

Parameter	Value
L_∞ (cm)	40.9
K/yr	0.95
r^2	-0.56

Table 3. Estimates of fishing mortalities (F) and total mortalities (Z) of *M. ancylodon* landed by the artisanal vessels operating in Guyana during the period Jul. 95-Sept. 96. Natural mortality (M) was estimated at 0.83. Values used for L_∞ and K were 38.3cm and 0.355 respectively

Period	F value	Z value	r^2
Jul/Aug 95	0.16	0.99	0.94
Jan/Mar 96	0.72	1.55	0.98
Apr/Jun 96	0.47	1.29	0.95
Jul/Sep 96	0.05	0.89	0.84

The results from Table 3 lead to the following estimates:

Average F = 0.35
Standard error of F = 0.15
Average Z = 1.18
Standard error of Z = 0.15

The above results provided the basis for the yield per recruit (YPR) and biomass-per-recruit (BPR) analyses. The biomass per recruit for *M. ancylodon* during July 1995- September 1996 was estimated using Equation 1 below:

$$B / R = \exp[-M * (T_c - T_r)] * W_\infty * \left(\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} - \frac{S^3}{Z+3K} \right\} \qquad \text{......... (1)}$$

where

S = $\exp[-K*(T_c-t_0)]$
B/R = mean biomass per recruit
M = instantaneous rate of natural mortality per year
T_c = age at first capture
T_r = age at recruitment to the fishing grounds
W_∞ = asymptotic body weight (obtained from asymptotic length L_∞ and the length weight relationship)

Z = F+M = total mortality rate (where F = instantaneous rate of fishing mortality per year)
K = von Bertalanffy growth parameter
t_0 = von Bertalanffy growth parameter

The yield per recruit was estimated as :

$$Y/R = F*B/R \tag{2}$$

The results for these analyses are presented in Figures 2 and 3 (yield per recruit) and Figure 4 (biomass per recruit).

5. DISCUSSION

5.1 Growth and Mortality Rate Estimates

From the results of the Gulland and Holt plot the following interpretation was made.

a. The estimated K value suggested that the species is fast growing. However, current knowledge does not support this, suggesting that the estimated value of K was incorrect. The results could have been influenced by the small sample size used for the analysis or by the fact that males and females of the species have different growth rates while the samples used were unsexed.

b. The estimated L_∞ value appeared reasonable in comparison to the value cited in the literature. It must be noted, however, that the assessment was done using only length measurements from the Chinese seine gear. Several others gear types exploit this species and the use of data from these types could give different results for the growth parameters.

From the results in Table 2, the estimates of F and Z obtained from each period varied considerably and, as a result, the standard errors of the means were high. This variability was probably due mainly to a combination of differences in the availability of fish of different sizes to the gear in the different seasons and relatively small sample sizes, leading to errors in the estimated relative abundance of the different size classes. The fact that samples of combined males and females were used would also have introduced errors into the estimates of Z. Both sexes of this species have different growth rates and the K value used was a value for both males and females, which could have influenced the results. The periods January-March 1996 and April-June 1996 showed higher estimated fishing mortalities than the other two periods. From the knowledge of the fishery it is known that during the months of January to May the catch of *N. schmitti* is high (hence fishing mortality would increase). Most Chinese seine operators are known to double their fishing effort during this peak season. In most Chinese seine operations the target species is *N. schmitti,* but fishing effort directed to capturing *N. schmitti* would also affect *M. ancylodon* since the Chinese seine is not a very selective type of gear.

5.2 Yield per Recruit and Biomass per Recruit

From the yield per recruit graph (Figure 2), the position of F_{max} depends on the age-at-first capture, which in turns depends on the mesh size used in the fishery. The Chinese seine is a less selective gear and tends also to take smaller fish.

For the given size at first capture of 100 mm, F_{max} was estimated at 0.8 (Figure 2). At F_{max} 0.8, the yield per recruit was estimated at 10.4 g. The mean value of F for 1995/96 estimated from the length converted catch curve analysis, was only 0.35, suggesting that the stock was being underexploited at that time, in terms of yield per recruit. However, as was stated earlier, the F value estimated from the

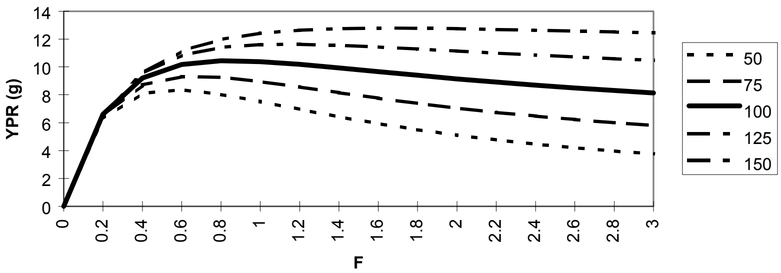

Figure 2. Estimated yield-per-recruit (YPR) for *M. ancylodon* for different lengths at first capture (shown in legend in mm) and different levels of F

length converted catch curve analysis may need to be refined using larger samples and obtaining length frequencies from other gear types exploiting the species under study, before any firm conclusions can be drawn on the actual state of the resources. Further studies should therefore be undertaken for this species.

The results are also very sensitive to the assumed value of M and the F_{max} varied from 0.6 for a value of M of 75% of the estimated value to 1.2 for a value of M of 125% of the estimated value. The true confidence limits of the estimated value of M is likely to be greater than this range, indicating the potential error in the estimate of F_{max}.

The results for the biomass per recruit curve indicated that in the absence of fishing, the equilibrium biomass per recruit would be 51.3 g (Figure 4). A suggested management threshold, representing a limit reference point, is 30% of unexploited spawner biomass (Mace and Sissenwine, 1993), which, if applied directly to the biomass per recruit, would mean that F should not be allowed to exceed approximately 0.65, in order to maintain biomass per recruit above approximately 15.4 g. At the estimated F for 1995/96 of 0.3, the biomass per recruit would be above 50% of the unexploited biomass per recruit, again suggesting that, if the estimates are accurate, the stock was being under-exploited during this period. However, it should be noted that the estimated F for the sample obtained from January to March 1996 was above 0.7.

Again these results would be influenced by the uncertainty arising from the small sample size, short duration of the time series and absence of information from other gear types, leading to substantial uncertainties in estimated parameter values such as M and K. Also the F value used was estimated from only one gear type and could be affected by selectivity factors. Further studies need to be done before any management action is considered based on per recruit analyses. In addition, the biomass per recruit calculations should be repeated but using spawner biomass per recruit as this will give a better estimate of the spawner potential, and hence likely average recruitment, than having the total biomass per recruit.

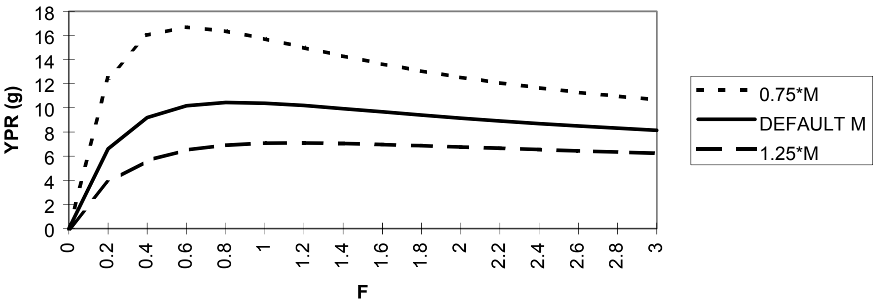

Figure 3. Estimated yield per recruit (YPR) for *M. ancylodon* for length at first capture of 100mm and for different values of M and F, where the default M in the example shown was 0.83

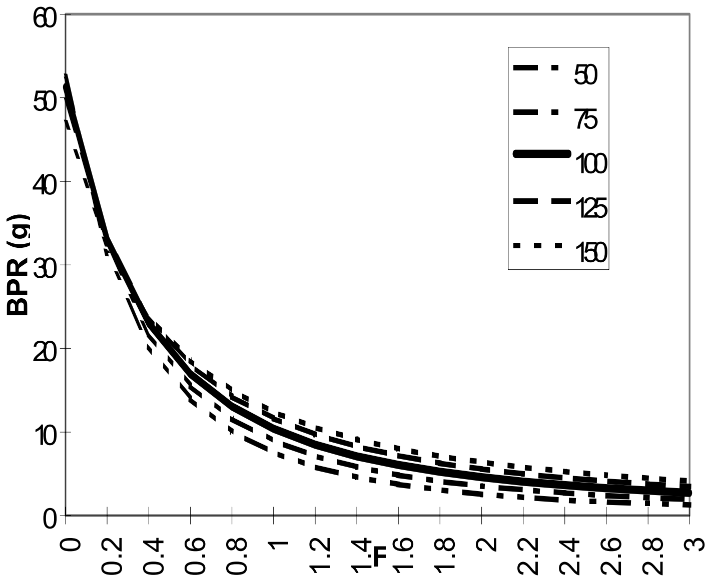

Figure 4. Estimated biomass-per-recruit (BPR) for *M. ancylodon* for different lengths at first capture (shown in legend in mm) and different levels of F

5.3 Cpue as an Index of Abundance

The catch per seine per trip indicated that the abundance of *N. schmitti* (whitebelly shrimp) was relatively high during the period 1984-1986 whilst the abundance of *M. ancylodon* (bangamary) was comparatively low. However, by 1996, the converse had happened, i.e. *N. schmitti* abundance, as indicated by cpue, had decreased while *M. ancylodon's* had increased. However, this trend may not have been reflecting the abundance of the two stocks, but may have been due to fishermen responding to market issues. BEV Processor which is a local processing plant, started its operation in 1985 and used to purchase *N. schmitti* from the Chinese seine fishermen since the industrial trawlers at that time were not fishing for *X. kroyeri (*seabob*)*. During the late 1980s, the trawlers began landing *X. kroyeri* and BEV Processor stopped purchasing *N. schmitti* from the Chinese seine fishermen which could have led to them targeting on fish species instead.

Preservation techniques also contributed to the decline in purchasing the shrimp. In 1993 BEV Processor started issuing the Chinese seine fishermen with ice-boxes so that they would land large quantities of *M. ancylodon*. Thus the fishermen converted to catching *M. ancylodon* since there was a market for their catch. Fishermen are able to determine, by fixing their seine location during fishing, whether they capture more *M. ancylodon* than *N. schmitti.* This probably accounts for the trends in the cpue for *N. schmitti* and *M. ancylodon*.

In March 1984, there was a high abundance of whitebelly shrimp compared to other months, as indicated by the cpue. However this began to decline in July-August. For the same period in 1985 and 1986 there were similar peaks, possibly reflecting a seasonal availability. In 1996, there were some increases but not as significant as in former years.

Similarly for *M. ancylodon*, periods of high abundance as suggested by cpue were approximately May-September for 1984, 1985, 1986. The finfish catch is better during and for a short while after the heavy rainy season (May-July). This is probably due to the large amount of freshwater outflow from the many rivers. Results from surveys by *M.V. Calamar* and *Cape St.Mary* show that during the heavy rainy season (May-July) when the freshwater outflow from the rivers is the greatest, there is an inshore movement of the marketable fish (*M. ancylodon* included) into estuaries, and during periods of low river run off there is a general dispersal into deeper waters. During these high flow periods the Chinese seine operators catch more fish and less shrimp compared to the period January to May. For 1996, there seemed to be two peaks (May/September and October/November) with the later peak being smaller.

6. CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Further studies, notably of the fishery itself, will have to be conducted before these findings can be translated into management actions.

6.1 Recommendations for Future Work

a) Field Sampling commenced in May 1995 which meant that the analyses described in this report were based on less than two years data. Considering the importance of the fishery, data collection and analysis should proceed for at least another three to four years.

b) The study as reported here deals only with the Chinese seine fishery. Bearing in mind the likely inter-relationship with the gillnet nylon, pin seine and industrial trawl fisheries which capture the same species, except at different length ranges, it would be highly desirable when possible to undertake an analysis based on combining the data sets for these fisheries.

c) In the present study, the estimates of growth and mortality parameters are provisional and further work is needed. This should include an expanded sampling of the landings to obtain more comprehensive data sets concerning sex and length and weight composition. Particular attention must be given to refining the estimates of fishing mortality.

d) A stock assessment for the combined inshore artisanal and offshore industrial trawl fisheries should be undertaken. This is justified both in the context of establishing the overall need for the resource to be managed, and the extent of the inter-dependence between the fisheries. It seems clear that the offshore fishery will be dependent on quantities of younger *M. ancylodon* surviving the inshore artisanal fishery and migrating offshore, although the extent of the dependence is not known.

e) An in-depth study should be conducted on the trends in landing for *M. ancylodon* and *N. schmitti* in the future.

7. ACKNOWLEDGMENTS

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