SPECIAL REPORT

CHANGES IN *NEOTRICULA β–APERTA* POPULATION DENSITY FOLLOWING CONSTRUCTION OF THE PAK MUN DAM IN NORTHEAST THAILAND, WITH IMPLICATIONS FOR THE TRANSMISSION OF SCHISTOSOMIASIS

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There is concern that water resource development in the Lower Mekong Basin could lead to an outbreak of schistosomiasis in Northeast Thailand and other areas that are not known to be affected by this disease at present (Attwood, 1994, 1995). Endemic transmission of human schistosomiasis mekongi, causative agent *Schistosoma mekongi* (Trematoda: Schistosomatidae), has been reported at Khong Town on the Mekong river in southern Laos (Sornmani *et al*, 1971); the disease is probably also common along the river in Cambodia and Vietnam (Iijima and Garcia, 1967; Schneider, 1976) but has yet to be reported from Northeast Thailand or central Laos. A number of developed nations have expressed an interest in development of the Lower Mekong and 11 major dams are planned along the river system (EGAT, 1994). One dam, that at Pak Mun on the Mun river 6 km from its confluence with the river Mekong at Khong Chiam, Ubon Ratchathani Province, Northeast Thailand (15° 18' 45" N; 105° 25' 30" E), has already been completed. This paper presents the results of initial population density surveys for schistosomiasis vector snails at Pak Mun. These data suggest that operation of the dam has had no immediate deleterious effect on snail populations and there may, in fact, have been increases in population density since impoundment.

The epilithic snail *Neotricula β-aperta* (Gastropoda: Pomatiopsidae) is found in the Mun river at Pak Mun. Although the natural intermediate host of *S. mekongi* is *N. γ-aperta*, laboratory studies indicated that the β-race is potentially a more efficient transmitter of the disease by a factor of some two and a half (Sornmani, 1976; Upatham *et al*, 1980). Consequently the Pak Mun project, which could lead to the introduction of schistosomiasis mekongi to *N. β-aperta* habitats in the Mun river, has serious public health implications. The main effect of the dam is likely to be year round deeper water in *N. β-aperta* habitats with severe flooding in July to October. The stream flow of the Mun river (like the Mekong) shows marked seasonal variations, with a low water period in March to May and a high water period in July to October. The dam may also attenuate this natural flood-cycle, which appears to limit *N. β-aperta* populations at present (Attwood, 1995), and so an increase in local *N. β-aperta* population density may be expected at Pak Mun.

Field work was carried out along the Mun river at Kaeng Kao, a series of rock outcrops (islands) opposite Ban Hin Laht, Ubon Ratchathani Province, Northeast Thailand (16° 2' 30" N; 105° 18' 30" E). Kaeng Kao lies approximately 27 km upstream of the Pak Mun dam. The islands at Kaeng Kao divided the overall 950 m breadth of the river to form a 190 m channel with the north (strictly northeast) bank of the river. The islands generate a series of small pools, backwaters and rapids during the low water period which provide ideal habitats for *N. β-aperta*. *N. β-aperta* is semelparous, with a maximum longevity of 12 to 15 months, and is found in large numbers on stones in the river during the low water period.

The present survey involved the collection of data from both before and after completion of the dam. β-snail population surveys were performed on 19/04/91, 18/04/92 and 07/04/95, *ie* during the low water period, it was not possible to visit the river on the same day each year. Construction of the Pak Mun dam began in June 1990, however, significant perturbation of the river flow did not occur until October 1993. The dam was completed in November 1994; thus the 1991 and 1992 surveys were performed prior to interruption of the flow, whilst the 1995 survey took place some 1.5 years after the damming of the river. All surveys were performed between 10 : 15 am and 12 : 30 pm. The severity of the annual spate made the collection of seasonal data impractical. Consequently data collection was restricted to the low water period, during which snail population growth occurred and any impact of the dam would be most significant.

Five different sample sites were identified at Kaeng Kao; these were selected using a series of random number coordinates relative to the North bank of the river. The approximate spatial interrelationships of the sites were as follows: site 1 lay in relatively shallow water only 18 m from the North bank; site 2 was situated 35 m from the North bank (17 m from site 1); site 3 lay in deeper, faster flowing water in the middle of the channel, 70 m from the North bank and 10 m downstream of sites 1 and 2; site 4 was located 105 m from the North bank (35 m from site 3) again near the middle of the channel; site 5 lay 185 m from the North bank and 20 m down stream of site 1. Site 5 was located approximately 5 m from the northern limit of the Kaeng Kao outcrops and, therefore, close to the bushes and marginal pockets there. The five sites thus formed a transect across the channel at Kaeng Kao.

As *N. aperta* is generally epilithic, estimates of population density were made on the basis of counts of snail numbers on individual stones collected from the river. At each sample site all stones encountered, within the size range 113 - 1,922 cm^2 (maximum surface area), were recovered as the collector moved upstream in a straight line. A total searching time of 15 minutes was permitted at each site, thus enabling 5-10 stones to be collected. This procedure allowed the examination of approximately 0.5 m^2 of substratum at each site. The collecting sites were rather remote and inaccessible; these factors greatly reduced the number of samples taken.

Stones found to harbor *N. β-aperta* were placed individually in trays *in situ* (still held beneath the water). The trays were then carried carefully to the boat. The epilithic fouling material containing snails was removed and the snails allowed to attach to the sides of the trays. In a process akin to "panning" for gold ore, the water was poured from the trays along with the suspended epilithic material. Fresh river water was then added to the trays and the numbers of *N. β-aperta* counted. The stones were measured so that their surface area could be estimated. The numbers and dimensions of stones bearing no *N. β-aperta* were also recorded so that the mean density over the sample area might be estimated. The β-snails collected during April 1995 were mostly juveniles (mean shell length ± SD = 2.9 ± 0.1 mm, n = 15).

A number of physiochemical measurements were made at Kaeng Kao (Table 1). River flow velocity at 1 m depth (0.5 m on 18/04/92) was estimated (to ± 5 cm s^{-1}) using a Geopacks MFP51 MJP flow meter. Dissolved oxygen concentrations were measured, for near bed water samples, using a Hasch portable water test kit.

Data collected during the surveys were used to express β-snail population density in two different ways. First, the "on-stone" snail density was estimated using the number of snails per stone (expressed as density m^{-2}) as a sampling count (Table

Table 1

Physiochemical data for *Neotricula β-aperta* habitats sampled at 3 sites along the Mun river at Kaeng Kao, Thailand. Sample site numbers correspond to those used in the text. All measurements were taken between 10.15 and 12.30. Replicated measurements are reported as mean ± SD, with the sample size in parentheses. Data are reported to no more than 3 significant figures.

Sample date (site No.)	Habitat depth (cm)	Flow velocity (cm s^{-1})	Dissolved O_2 (mg l^{-1})
18/04/92 (1)	55 ± 16 (5)	40 ± 5 (5)	-
07/04/95 (1)	127	25 ± 10 (6)	7
07/04/95 (3)	172	40 ± 10 (7)	5
07/04/95 (5)	144	35 ± 5 (5)	8

2). Second, a rough estimate of the overall population density (or snail density across the river bed) was made using the number of *N. β-aperta* per m^2 of sampled substratum, denoted here as D (Table 2); this equalled N/A, where N = the total number of snails collected and A = the total area of all stones collected (including those bearing no *N. β-aperta*).

For a statistical analysis, the Mann-Whitney U-test (Dawkins, 1975) was used to compare pairs of samples, whilst the Kruskal-Wallis one-way ANOVA was used to compare larger groups of samples (Daniel, 1978). All ANOVA tests referred to below were based upon the Kruskal-Wallis ANOVA.

Table 1 presents physiochemical data for the three main sample sites of the 1995 survey, and for sample site 1 of the 1991 and 1992 surveys at Kaeng Kao. These data show some between site variation with respect to habitat depth, flow velocity and dissolved oxygen concentration. An ANOVA comparing flow rates at sites 1, 3 and 5 (1995) was not significant ($T = 5.67$, $p = 0.06$, $DF = 2$). Similarly, there was little between site difference (during 1995) in terms of collection depth. Although changes in dissolved oxygen concentration were expected around the dam (Alam and Udayasan, 1991), no such changes were evident from the samples taken during the present study.

A Mann-Whitney U-test comparing water flow velocity data (Table 1) at site 1 during the 1992 and 1995 surveys was significant ($U = -2.5$, $p < 0.01$, $n_1 = 5$, $n_2 = 6$); this suggested a marked decrease in flow velocity at site 1 between 1992 and 1995. A second U-test compared collection depth data (Table 1) for 1995 (data for sites 1, 3 and 5 pooled) with those for 1992 (Data for site 1 only). Again the test was significant ($U = -3$, $p < 0.05$, $n_1 = 3$, $n_2 = 5$), suggesting that the depth at the sample sites had increased between 1992 and 1995; this suggestion should, however, be taken with caution as several sites from the 1995 survey were compared with a single site for 1992. The increase in habitat depth might also be attributed to year to year variations in river discharge.

Table 2 presents summary data for all the *N. β-aperta* population surveys at Kaeng Kao. ANOVA comparing on-stone β-snail densities between all five sample sites in 1995 failed to reveal any significant differences ($T = 2.17$, $p > 0.05$, $DF = 4$); thus suggesting a relatively well dispersed population density distribution across the boat passage at Kaeng Kao. In contrast, an ANOVA comparing on-stone snail densities at site 1 for the 1991, 1992 and 1995 surveys was significant ($T = 6.55$, $p < 0.05$,

Table 2

Population density for *Neotricula β-aperta* at 5 sites along the Mun river at Kaeng Kao, Thailand. The on-stone β-snail density, as number of snails found on each stone/ stone area (m^2), is reported to 4 significant figures as mean ± SD, with the sample size (No. of stones) in parentheses. D = the number of β-snail per m^2 of sampled substratum (total No. of snails collected/total surface area of all stones examined). SN+/SN - = the proportion of all stones collected which were found to bear *N. β-aperta*. N = total no. of β-snails collected on each date.

Site (sample date)	On-stone density (m^{-2})	D (m^{-2})	SN+/SN-	N
1 (19/04/91)	363.8 ± 796.3 (8)	299.6	3/8	72
1 (18/04/92)	1,297 ± 1,528 (7)	1,478	5/7	1,015
1 (07/04/95)	2,535 ± 2,516 (10)	2,108	9/10	1,442
2 (19/04/91)	193.9 ± 349.8 (6)	281.3	3/6	60
2 (07/04/95)	3,498 ± 2,833 (5)	2,112	3/5	776
3 (07/04/95)	3,380 ± 2,899 (6)	2,409	6/6	938
4 (07/04/95)	3,232 ± 1,744 (5)	2,841	5/5	911
5 (07/04/95)	2,067 ± 2,059 (5)	1,661	5/5	507
1-5 (07/04/95)	2,891 ± 2,372 (31)	2,235	-	4,574

DF = 2). Accordingly, a series of Mann-Whitney U-tests was used in a pair-wise comparison of the data for each year. Neither the 1991 and 1992 data sets nor the 1992 and 1995 data sets were found to differ significantly in terms of on-stone snail density ($p = 0.16$ and 0.28 respectively). How-ever, on-stone snail densities at site 1 in 1995 were found to be significantly greater than those at the same site in 1991 ($U = 12.5$, $p < 0.05$, $n_1 = 8$, $n_2 = 10$). Similarly, on-stone β-snail densities at site 2 in 1995 significantly exceeded those at the same site in 1991 ($U = -0.5$, $p < 0.05$, $n_1 = 5$, $n_2 = 6$).

Estimates of D (Table 2) for surveys conducted prior to completion of the dam (*ie* data for 1991, sites 1 and 2, and 1992 site 1) were compared with those made during the 1995 survey (sites 1-5). Values of D were significantly greater for the 1995 survey than for the earlier surveys ($U = 0.0$, $p < 0.05$, $n_1 = 3$, $n_2 = 5$); although the small sample sizes should be borne in mind. A X^2 -test (with Yates' correction, see Daniel, 1978) comparing SN+/SN-stone ratios (Table 2) between the 1991 and 1995 surveys was significant ($X^2 = 11.14$, $p < 0.005$); however, that comparing 1992 with 1995 was not significant ($X^2 = 2.74$, $p > 0.05$). Between site comparisons of on-stone snail density for the 1995 survey failed to reveal significant differences, however, the standard deviation on the mean on-stone density suggested an aggregated snail distribution.

The effects of any perturbation of flow, caused by the dam, on *N.* β-*aperta* have been difficult to predict. It has been suggested (Attwood, 1995) that β-snail population growth might be expected at Pak Mun, as impoundment essentially accentuates and prolongs low water conditions during which the snails normally feed and mature, and the present results appear to support this prediction. The over six-fold increase in (on-stone) density between 1991 and 1995 was statistically significant as were the post-impoundment increases in D. β-snails also appeared to colonise a greater proportion of the available substrata in 1995 than in 1991 (X^2-tests above). These observations suggest that there has been no decrease in β-snail populations since completion of the dam and there may, in fact, have been an increase in density. However, further data are required to substantiate these results as the data sets were not large. In addition, the existence of a natural population cycle (intrinsic or otherwise) may explain the increases in density without invoking an external factor such as the dam project. Natural population cycles would only become apparent by following the β-snail population density over several years (May, 1975).

On the basis of the present results the possibility that hydrological changes, favorable to schistosomiasis transmission, have taken place at Pak Mun cannot be ruled out. In view of this observation, further surveys are required to verify these findings and discount the possible effects of climate, natural cycles in the snail population and sampling error. Even if they are a genuine effect of the dam, the population density increases may be short lived; the changes in river depth and flow may ultimately favor the proliferation of competitor species of *N. aperta*, or the establishment of an unfavorable epilithic (aufwuchs) community. Nevertheless in view of the results presented here, and pending further studies, *there is a case for a possible slowing of the pace of water resource development in the Lower Mekong.*

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