77

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The Development of *Macrobrachium Rosenbergii* Nursery Procedures by Modifying Post Larval Size Distribution

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B. TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	1
OBJECTIVES OF THE RESEARCH	2
BODY OF THE REPORT	3
1. Introduction	3
2. Factors influencing growth in juvenile populations	5
2.1 Characterization of changes in the weight distribution of juvenile populations with time	6
2.2 The effect of initial stocking density on growth of postlarvae	8
2.3 The effect of interactions among individuals on the development of size variation	10
2.4 The effect of selective removal of jumpers on growth of the remaining population	16
2.5 The effect of size ranking on growth rate of juveniles	18
2.6 Summary	22
3. Growth potential of nursed juveniles	24
3.1 The effect of initial size of juveniles stocked on subsequent growth: selective stocking I	24
3.2 The effect of initial size of juveniles stocked on subsequent growth: selective stocking II	25
3.3 The effect of juveniles' age on growth potential	26
4. Establishment of commercial nurseries	28
4.1 Effects of temperature on nursed populations	28
4.2 Commercial nurseries operated in Israel	29
5. References	31
6. Tables	41
7. Figures	49
DESCRIPTION OF THE COOPERATION	62
BENEFIT TO AGRICULTURE	63

C. ABSTRACT

The tropical freshwater prawn Macrobrachium rosenbergii is becoming a significant crop organism in fresh water aquaculture in the temperate zone of Israel and the USA. A key factor to the success of its cultivation is the nursery phase during which post larvae (PL) are being accumulated from the hatchery and maintained until springtime, when they are released into production ponds.

The present study dealt with the relationship between various growth characteristics and environmental factors, aiming at the optimization of nursery facilities with respect to intensification and the improvement of juvenile growth potential after their release into growout ponds.

The main findings of the research are:

1. Individual growth rate is highly dependent on social environment (i.e. size ranking within the group) and less on genetic variation.
2. Density is inversely related to growth rate.
3. PL react stronger to density per surface area than to density per volume, therefore, intensification of a nursing facility can be achieved by the introduction of suitable substrates.
4. Optimal temperature with respect to growth rate is in the range of 27-29°C. However, in high densities, it is recommended to slow growth rate and the degree of size variation in order to prevent cannibalism and improve survival. We have proven that keeping PL in lower temperatures (20-23°C) does not interfere with future growth rate of juveniles once conditions are improved.
5. Space selective harvest of jumpers during nursery may improve overall survival, size homogeneity, and final average weight of nursed juveniles.

Based on the above, a few commercial nurseries have been established and are currently being improved. Large amounts of PL are being accumulated and nursed during 2-3 winter months, yielding juvenile populations characterized by improved growth performance to be stocked into the production ponds in springtime.

D. OBJECTIVES OF THE RESEARCH

The main purpose of the research was to investigate growth performance at early post larval (PL) development in order to establish adequate nursery procedures and to ensure accumulation of high quality juveniles to be stocked in production ponds.

The specific objectives of the research were:

1. Studying the nature of size distribution development in PL populations and the various factors influencing post larval growth.
2. Examination of growth potential of juveniles nursed under various nursing conditions.
3. The establishment of commercial nurseries

E. BODY OF THE REPORT

1. Introduction

Macrobrachium rosenbergii (Decapoda, Penaeidae) is the largest of the freshwater prawns (Rhimachar 1965), with a geographical distribution that covers most tropical and sub-tropical areas of the Indo-Pacific region including the continental margins of south-east Asia, Australia, India, and most of the Indonesian archipelagos, notably Malaysia (Holthuis 1950).

Although this species requires brackish waters for spawning and larval development (Fujimura & Okamoto 1970), the post larval stages have a low tolerance for salinity. Thus, in nature, M. rosenbergii larval development occurs in the estuaries, reflecting an obligatory requirement for a salinity of 12-14 ppt, while mature adults inhabit freshwaters such as lakes, reservoirs, paddy fields and inland streams. The distance between the two habitats may be as much as 500 km (Bardach et al. 1972). The life cycle is established by the downstream migration of sexually matured berried females and the return upstream of post larval populations (Raman 1967; Natividad 1980). One may view the river environment as a third, separate habitat, serving as a connection path between the two main biotops.

The simulation of M. rosenbergii life cycle in aquaculture includes three main phases (Figure 1): (a) Hatchery - where berried females release newly hatched larvae (2 mm) and larvae development continues through to metamorphosis into the post larval stage (1 cm), (b) Nursery - where newly metamorphosed post larvae are raised to the juvenile stage (3-4 cm), and (c) Growout - where juveniles are raised in earthen ponds to market size (10-15 cm) (Ra'anan & Cohen 1982).

The originally tropical freshwater prawn requires a temperature of 25-30° for optimal growth and development (Raman 1967). The temperature in Israel and in the Southern U.S.A. drops below that which is lethal for these organisms during the six month period of November to May. On the other hand, the six month summer season is not long enough for the development of economic yields of prawns when the entire production cycle, hatchery included, is carried out within this interval. Thus, economic feasibility dictates the extension of the growth period into the winter in this and other temperate zones areas. Larval development in the hatchery lasts for about one month. Since growout performance is markedly improved when nursed juveniles rather than post larvae are stocked in production pods (Smith & Sandifer 1980, Willis & Berrigan 1977, Ra'anan & Cohen 1982), the introduction of a nursery phase, in which post larvae are accumulated and stored, has been recognized to be significantly beneficial.

The major economic constraint on the winter activities of the hatchery and the nursery is the need to conduct operations under cover and to apply and preserve heat in order to maintain suitable water temperatures. On the other hand, the flushing and exchange of the growth medium necessitates high production efficiency in order to justify the cost.

Economic efficiency in the nursery stage is strongly dependent on the stocking density of the post larvae (PL). Density may be increased as long as it allows for growth in body weight and ensures high survival probabilities of the nursed juveniles, without exerting a negative effect on the juveniles' growth potential upon their release into the growout ponds.

In the present study, we have concentrated on problems associated with post larval growth performance during the nursery stage.

The research was carried out on two parallel levels: laboratory experiments conducted in aquaria and tanks of various sizes, dealing mainly with problems associated with factors influencing growth in post larval populations; and field experiments conducted in ponds where the growth potential of the nursed juveniles was examined.

In addition, we have up-scaled our nursery facilities to commercial operations while applying our recommendations to improve nursery management procedures.

2. Factors influencing growth in juvenile populations

Since the main objective of the present study was to establish nursery procedures, it was extremely important to examine in detail the factors which influence growth and development during this early stage.

The following is a series of experiments designed to elaborate on these aspects.

2.1 Characterization of changes in the weight distribution of juvenile populations with time

The weights of newly metamorphosed post larvae average $9 \times 10^{-3} \pm 2.4 \times 10^{-3}$ g, $N = 400$. With time, the distribution changes gradually, as variance and skewness increase (Sandifer & Smith 1975, Malecha et al. 1977). A "leading tail" is formed representing individuals which are larger than the bulk of the population. Fast growing individuals, henceforth termed "jumpers", can grow as much as fifteen times larger than the population mode within a period of 60 days from metamorphosis (Willis & Berrigan 1977, Ra'anan & Cohen 1983).

Heterogeneous growth in aquatic species has been associated with (a) intrinsic factors, such as genetic differences, hatching order, or age at metamorphosis (Newkirk et al. 1977, Sandifer & Smith 1979), (b) environmental factors, giving rise to competition for limited resources such as space and food (Magnuson 1962), and (c) social factors, such as position within the size hierarchy (Brown 1946), social status, and territoriality (Symons 1972).

Growth of body weight can be described (Brown 1946, Ricker 1958, Wilbur & Collins 1973) by the exponential function,

$$W_T = W_t e^{R(T-t)}$$

in which W_T and W_t represent body weights at times T and t ($T > t$), respectively, e is the base of the natural logarithm, and R is the exponential relative growth rate. Ostensibly then, a population of individuals growing at a uniform exponential R value would have an expanded variance in size distribution at maturity as a result of differing initial weights at metamorphosis. Alternatively, a leading-

tail of individuals which are much larger than the bulk of the population may be a result of a significantly higher R value possessed by these, the jumpers, as compared to the R of the remaining population. In order to distinguish between the two possibilities, weights were transformed on a natural logarithm base ($\ln W$), and the changes of the $\ln$ -transformed weight distribution with time was examined. An increase in the variance of the logarithmic function would indicate variability of the growth rates among individuals within the population.

Frequency histograms of body weights of juveniles stocked at a density of 0.5/liter, at three time points after metamorphosis are given in Figure 2, and shown as their $\ln$ -transforms in Figure 3. The change in the $\ln$ -transformed weight distribution curve with time (Figure 3) showed an increase in both skewness and percent coefficient of variation, indicating that the jumpers' leading tail in the linear size distribution (Figure 2) results from specific variations in the relative growth rates of individuals within the population. It is the jumpers, which may or may not be the largest animals at the time of metamorphosis, which are characterized by relatively enhanced growth rates.

Larvae from a single brood may transform into the post-larval stage in 3-7 days (Ra'anan & Cohen 1982). Sandifer & Smith (1979) reported that early metamorphosis confers no growth or development advantage, nor late metamorphosis any disadvantage, in M. rosenbergii post larval populations. The initial stimulus for the enhanced relative growth rate exhibited by the jumpers is not yet clear. However, once a size hierarchy is formed (within two weeks after metamorphosis), larger post larvae will

will continue to grow at an accelerated rate (Ra'anan & Cohen 1983). Similar phenomena have previously been observed and were termed "heterogeneous individual growth" (Nakamura & Kasahara 1955) wherein the individuals in a given population show a higher relative growth rate than the smaller individuals, a tendency that generates an increasing asymmetry in the size distribution curve with time. The possible role of competition for limited resources, such as space and food, as the basis for this phenomenon in the case of M. rosenbergii post larvae can be evaluated by examining the effect of population density on the dynamics of the size distribution curve.

2.2 The effect of initial stocking density on growth of post larvae

Newly metamorphosed post larvae (PL) swim freely in the water column and gradually shift their behavior until they come to settle on the available benthic surface (Ling & Merican 1961). We therefore examined the effect of population density on post larval growth by modifying stocking densities per volum as well as on a surface area basis. PL from a single brood, averaging 0.009g, were stocked in four replicates each at 1/liter, 5/liter, and 10/liter. At each density, two of the four replicates included identical amounts of added submerged substrates. Haphazard samples of at least 100 PL were individually weighed weekly, during a period of 60 days. In the relative frequency histograms of body weights of juveniles sampled at selected times after the start of the experiment (Figure 4), it can be seen that each of the final curves obtained under the higher densities corresponds to an intermediate stage of the size distribution curves at the various time intervals for the lowest

density. This suggests that the same process of size differentiation occurred at all densities examined, but at different rates. Increased stocking densities affected the dynamics of the size distribution of a juvenile population in several ways. Average growth rate and degree of size variation decreased as density increased, and, significantly, skewness of the distribution also decreased with increasing density.

Wilbur & Collins (1973) describe similar effects of stocking density on the development of size variation in larval Rana sylvatica reared under various initial densities. Median body size and percent coefficient of variation were both inversely related to the initial stocking density. However, when they examined the effect of stocking density on skewness, they found that skewness increased as a function of increasing density, a result that was interpreted as evidence for competition. Initial small differences between individuals are magnified during the course of competition, suppressing the growth of smaller individuals while increasing the relative growth advantage of larger ones. Similar phenomena were described by Wohlfarth (1977) in a review of the "shooting phenomenon" apparent in various types of fish such as the common carp, sunfish hybrids, and catfish. In all cases, the increased asymmetry was more pronounced under restricting growth conditions, whereas, under improved conditions it gradually disappeared. This, too, was interpreted as an effect of competition.

In contrast to the preceding studies, skewness in M. rosenbergii experimental populations is *inversely* related to density. In other words the positive asymmetry becomes more pronounced in less competitive situations. The possibility of competition for food in the present

study was obviated to the extent that all tanks were fed with excess live Daphnia which remained alive and suspended in the entire body of water throughout the whole experiment. These findings suggest that the appearance of jumpers is not primarily a result of competition, if at all, but of factors intrinsically associated with population development.

The next step was to evaluate the relative contributions of genetic and social factors to the wide variations in growth rates of M. rosenbergii juveniles.

2.3 The effect of interactions among individuals on the development of size variation

We have seen, then, that unlike the situation in other aquatic organisms, the advent of M. rosenbergii jumpers becomes *more* pronounced when the competition for space and food is reduced. Apart from competition, heterogeneous growth in aquatic species has been associated with intrinsic factors (Newkirk et al. 1977) and social factors (Brown 1946, Symons 1972). With regard to M. rosenbergii, Sandifer & Smith (1975) suggested that the observed wide variation in growth rates may be caused primarily by genetic rather than environmental factors. On the other hand, Malecha et al. (1977) felt that size variance was due more to social interactions than to the segregation and independent assortment of genes controlling growth.

One way to differentiate between the relative contribution of genetic and social factors to the observed heterogeneous growth is to compare the change in the logarithmic variance of weight with time in post larval populations reared communally to the corresponding change in those raised individually. An increase in variance of the ln-transformed

weight would indicate the heterogeneity of the individuals' relative growth rates. If intrinsic factors are directly responsible for the variation in growth rates, one would expect the logarithmic variance to increase in a similar manner in both the individual and the communal rearing systems. However, if interactions among individuals, whether through direct physical contact or mediated by the communal growth medium, are responsible for the observed growth heterogeneity, the logarithmic variance in weight should differ between the two culture regimes, since that of juveniles reared individually should tend to remain constant with time.

In order to examine these questions, newly metamorphosed post larvae were divided into two groups. One group was reared in individual aquaria without water connections, while the other group was reared in a communal aquarium. Stocking densities per volume and per surface area were equivalent in both groups. All prawns were individually weighed once a week during a period of 63 days. Data were analyzed on two levels. First we estimated the changes occurring in the variance of the $\ln$ -transformed weights in order to assess the degree of growth variation in both the individually and communally reared juveniles. Next we calculated the individual relative growth rates, R , for all the juveniles in both populations. Comparative estimates of the R value distributions of communally and individually reared juveniles would permit a direct evaluation of the respective growth heterogeneities.

2.3.1 The development of size variation

The frequency histograms of body weights for the individually reared post larvae (Figure 5) and their statistical analyses (Table 1)

approximated a lognormal distribution. While the average weight increased with time, the logarithmic variance remained relatively constant throughout the experiment. Under communal growth conditions, however, both the average weight and the logarithmic variance continued to increase with time, and the initial lognormal distribution became positively skewed. The degree of skewness increased until the fifth week and then decreased slightly. The rate of the average weight increase in both groups was similar until the sixth week (Figure 6). Afterward, weight increase in the communally reared population exceeded that of the experimental group. A comparison of the growth of the largest 10%, smallest 10%, and the median body weight individuals of both populations (Table 2), shows that the highest average growth rate is attained by the largest communally reared juveniles. Growth of the smallest communally grown animals began to lag about four weeks after metamorphosis, while the median individuals in both populations grew at similar rates. Clearly, growth heterogeneity in juvenile populations, as evaluated by the increased variance of the ln-transformed weight distributions with time, is much higher for communally reared juveniles than for those reared as individuals.

Communally raised carps also had larger size variance than those reared individually (Yamagishi 1962). The isolated carp, however, grew at rates similar to those exhibited by the fastest growing individuals under communal growth conditions. This result was explained by the absence of the competition which had apparently inhibited growth of the smaller group-reared fish. In contrast, the excess in average weight of the communally reared M. rosenbergii juveniles relative to

that of the individually grown animals (figure 6) indicate that the jumpers' superior growth rate results from the presence of some stimulus which is lacking under conditions of individual isolation. This is supported by the observation that the 10% largest individuals in the communal growth group reached an average weight of 1.19g while the 10% largest isolated individuals reached an average weight of only 0.57g during the same interval (Table 2). Lee & Fielder (1983) reported the identical phenomenon in the prawn M. australiense, "Under laboratory conditions, group held juveniles produce more biomass than equivalent numbers of individually held prawns kept for the same time. However, the individually held prawns had a more uniform growth as shown by smaller standard errors in their mean sizes..." without reference to the social stimulation of growth that is the basis of the distribution patterns they observed. Growth stimulation was also described by Uematsu (1971a,b) in the guppy Poecilia reticulata Peters where the social facilitation of growth observed in the communal rearing system was associated with changes in feeding behavior and rates of respiration. In the Himedaka (Oryzias latipes), social facilitation of growth, exerted by a companion, was recognized and termed "the presence recognition effect" (Uematsu & Takamor 1976).

Sastry & French (1977) and Aiken & Waddy (1977) found a strong correlation between the size of the container and the growth rate of the housed subject (Homarus americanus). Van Olst & Calberg (1979) estimated that in order to avoid reduction in growth rate, the area of the container must be approximately the square of three times the body length of the lobster, or $(3BL)^2$. The maximum body length we observed

associated with the growth suppression of "laggards" within the population. Neither jumpers nor laggards were evident under individual growth conditions. These data support the notion that social rather than genetic factors control size variation in M. rosenbergii juvenile populations.

4.3.2 The distribution of relative growth rates

So far we found that the logarithmic variance of body weights of juveniles reared in groups increased with time, while that of individually housed prawns remained constant. This suggests that some interactions among juveniles are responsible for the observed wide size variation.

We then calculated individual relative growth rates in both systems in order to measure directly the variation of R values in each case, as well as to learn about the changes of R value with time in isolated versus communally grown prawns. In the communal culture we noticed that several marked individuals maintained their relative size ranking, on which basis we inferred that such a stability is fairly general. Variance of 1.12 and 0.72 of communally and individually reared populations, respectively, two weeks after metamorphosis, decreased to 0.34 and 0.23, respectively, by the seventh week. The R distribution of the communal population was wider, and was positively skewed at the initial growth period as compared with a narrower, more normal distribution attained by the individually reared juveniles (Figure 7). Respective R values were plotted against initial body weights of juvenile prawns reared communally between 14 to 21 and 56 to 63 days after metamorphosis (Figure 8). Dividing the population into deciles in order of increasing

weight, we found that R was positively correlated with the initial body weight in both periods, and that this correlation was more pronounced during the first interval, when animals were smaller.

R ordinarily decreases with age and size (Brown 1946, Yamagishi 1962), and, indeed, the growth rate of all the individuals in this experiment decreased with time as their weight increased, under both culture conditions applied. The R value variance at the initial growth period was more pronounced for the communally than for the individually reared populations, but with time, it, too, decreased.

Koyama & Kira (1956) proposed four types of size frequency distributions which were obtained mathematically, assuming an exponential growth by individual plants in a population. They refer to the condition in which initial weight (W_0) and R have normal distributions, and in which R is positively correlated with size, as the N-N correspondent type. Just such a positive correlation was obtained between initial body weight and relative growth rates of our juveniles throughout the eight week period after metamorphosis. The marked increase in the positive asymmetry of the juvenile weight distribution observed under communal growth conditions can be attributed to the high growth rate shown by the larger juveniles, and especially the largest juveniles. Yamagishi (1962), examining frequency distribution of larval length during the post-embryonic growth of three marine fishes, found an opposite kind of N-N correspondent type distribution in which it was the slow growth of the smallest individuals which skewed the length distribution negatively. Brown (1946) had reported that individual relative growth rates in trout fry were usually higher for larger

individuals. Thus, the order of descending weight was also an order of decreasing relative growth rate for the group. The correlation of R values with the individual's position in its population's size ranking may be fairly general phenomenon.

The next step in our study was to investigate the nature of the relationship between the relative growth rate and size ranking in M. rosenbergii juvenile populations.

2.4 The effect of selective removal of jumpers on growth of the remaining population

In sections 2.2 and 2.3 we showed how skewed size distributions of post larval populations developed with time, suggesting that the presence of jumpers brings about a suppression of growth in the remaining population. In order to validate this view, we investigated the effect of selective removal of the first occurring jumpers on subsequent growth of the remaining population.

Newly metamorphosed PL were divided into three groups with two replicates each. In each of the three replicate groups, jumpers, defined heuristically by the shape of the logarithmic weight distribution curve, in this instance about 15% of the population, were harvested selectively, at 30, 60, and 90 days post-metamorphosis, for groups I, II, and III, respectively (Figure 9).

Soon after any removal of jumpers, a rapid increase in average weight of the remaining prawns was observed, especially obvious when compared to the normal average growth of the unharvested control population (Figure 10). For example, following the first selective

harvest, 30 days after metamorphosis, the average weight of the residual animals was 0.042g, as compared to 0.064g in the unharvested population. Thirty days later, the average weight of the selectively harvested population increased to 0.123g, $R=3.58$, while the average weight in the control unharvested population increased to 0.111g, $R=1.83$. This is remarkable because the growth rate of the control population is expected to be positively biased by the rapid growth of the original jumpers which were not removed. The phenomenon was not time dependent. A similar pattern was found when jumpers were removed 60 and 90 days after metamorphosis. The gradual increase of both the standard deviation and the skewness of the size distribution curve after the selective removal of jumpers gives expression to the gradual regeneration of the positively skewed distribution curve as new jumpers emerge.

Selective removal of large individuals, or size grading, is routinely practiced in fish hatcheries on the assumption that small fish will grow better when larger contemporaries are removed, probably because of the diminution of competition and the disruption of the social hierarchy. Gunnes (1976) examined the effect of the stage of development of salmon fry at the time of selective harvest of larger fry on subsequent growth performance. The best mean growth occurred when the fish were graded at 6 months, before the weight distribution had departed from normal, that is, before a social hierarchy had developed. Although we, too, observed increased growth rates of small individuals after the removal of large ones, the compensatory growth of M. rosenbergii juveniles occurred continuously throughout the juvenile period. The regeneration of the jumpers' leading-tail indicates that non-jumpers are actually manifesting

heterogeneous individual growth after the removal of jumpers, and new jumpers consequently evolve. This again indicates that non-jumpers retain an inherent capacity for compensatory growth, and that their growth rate does not depend individually on genetic factors, a result which is consistent with the view expressed by Malecha et al. (1981).

2.5 The effect of size ranking on growth rate of juveniles

Interactions among individuals play a major role, as we have seen, in generating the wide size variation that is apparent in juvenile populations. We demonstrated that juveniles in a group can be affected in different ways. Their growth is either stimulated or inhibited as a function of social position, defined by rank within the group's size hierarchy. A strong association between relative size and social rank was also reported by Bovbjerg(1953) in a study of the dominance order in the crayfish Orconectes virilis, in which he reported that size is an important factor in determining the dominance order, wherein individuals can loose or regain their dominance according to their relative size within the group.

By shifting the group associations of M. rosenbergii juveniles to reposition their rank by weight, we asked whether the growth characteristics of individual prawns would be retained or adjusted to accord with the imposed changes in social position.

2.5.1 Size ranking and the individual's growth rate

In a given population, prawns of different social positions may vary in age as well as in body weight. We have generally used an animal's weight as the criterion determining its size ranking, our key to

categorizing its social position. Now, we should like to differentiate between the effect of the prawn's absolute-weight-dependent growth characteristics and those aspects which are influenced by its own weight relative to that of other prawns in its immediate group. In order to clarify the direct association between size ranking and growth performance, we established a situation in which juveniles of the same age and size were placed in several defined social situations and then we measured the effects on their subsequent growth.

PL from a single brood were stocked at a density of 3/liter in a 120 liter aquarium equipped with a built-in biofilter. Ninety days after metamorphosis, all juveniles were collected and individually weighed. At this stage, selected juveniles (SJ) were obtained from a narrow weight range ($0.33\text{g} < \text{SJ} < 0.35\text{g}$) at the middle of the wide size distribution of the whole population.

Each SJ, marked by clipping off the right tip of its telson fin, was restocked together with four other individuals taken from the same population. In each of four categories of social position, six replicates were established in which the SJ was: (a) Largest - SJ plus four prawns $< 0.25\text{g}$ ($\text{SJ} > 4$), (b) Medium - SJ with two $< 0.25\text{g}$ and two $> 0.50\text{g}$ individuals ($2 > \text{SJ} > 2$), (c) Equal - SJ and four others of 0.33g to 0.35g ($\text{SJ} = 4$), and (d) Smallest - SJ and four prawns $> 0.50\text{g}$ ($4 > \text{SJ}$). In order to minimize the competition for food, juveniles were fed daily with an excess of live Daphnia and ground fresh fish. The selected juveniles were weighed individually for four weeks. R values were calculated accordingly.

The observed growth rates were directly related to the individual's size ranking (Figure 11). Juveniles in the presence of smaller individuals

increased in weight at a faster rate than those stocked together with larger individuals, and those stocked in the Medium position ($2 > SJ > 2$) grew at a faster rate than those stocked in the Equal position ($SJ=4$). The mean relative growth rate over four weeks was significantly higher for juveniles in the Largest position, 2.22 ± 0.53 , as compared to the Medium position, 1.23 ± 0.22 , or the Smallest position, 0.51 ± 0.06 . The relative growth rate of juveniles in the Equal position, 0.76 ± 0.26 , was slightly higher than that of the juveniles in the smallest position, although not statistically different at the level of $\alpha=0.05$. It is evident that exposure of juveniles to a change of position within the size hierarchy resulted in strong immediate effects on their growth performance as individual's relative growth rate adjusted in relation to the sizes of the other individuals present. Since all the selected juveniles were originally obtained from the same population, had the same size and therefore the same R , as well as the same age, the observed differences in their growth rates can only be associated with the experimentally imposed change in their size ranking.

2.5.2 Lasting effect of size ranking on growth

Having found that juveniles of *identical* original social position underwent drastic growth rate modifications upon transfer to alternative positions of size rank, we wanted to know whether animals of equal size and age, occupying *different* positions within their particular populations would retain their growth characteristics after being separated from their original populations.

Drawing on our previous observation, Section 2.2, that average weight in the population is strongly affected by the population stocking density,

we raised two groups of single age post larvae under different stocking densities, 10/liter and 1/liter. We obtained two populations (Figure 12), in which jumpers from a high-density group (I) were equal in size to the non-jumpers from the low-density group (II). At this stage, jumpers, marked by clipped right telson fins, from Group I, and non-jumpers from Group II, all weighing between 0.12g and 0.22g, were withdrawn and restocked in two replicates each, in three different combinations: (a) jumpers alone, (b) non-jumpers alone, and (c) mixed population of 50% jumpers and 50% non-jumpers. Stocking density in 120 liter tanks, was uniformly set to 0.5 juveniles per liter, and every animal was weighed individually once a week for an additional growth period of 70 days.

The effect of social milieu on individual growth performance is clearly revealed by comparing the weights achieved by jumpers and non-jumpers stocked separately and in the mixed population. While jumpers alone attained an average weight of 1.075g, $R=2.64$, in the mixed population they rose to an average weight of 1.275g, $R=2.85$. Non-jumpers alone had an average weight of 0.655g, $R=1.99$, but in the presence of jumpers had an average weight no greater than 0.475g, $R=1.84$. R values for both classes were statistically different at the level of $\alpha=0.05$. In short, jumpers had augmented growth in the presence of non-jumpers, while the non-jumpers' growth was retarded in the mixed social setting (Figure 13).

The observation that jumpers had a higher growth rate than non-jumpers of similar size and age when all were stocked together indicated that the effect of social rank on growth is retained, even after size differences were neutralized. Moreover, the differential growth rates of jumpers and non-jumpers in pure and mixed groups correspond directly to the growth

stimulation of jumpers and the growth suppression of non-jumpers previously observed under communal growth conditions (Section 2.3).

The last two experiments indicate that social position and the growth characteristics accompanying it are not a function of the animal's absolute size or age alone. Breaking the associations of jumpers and non-jumpers away from their original populations revealed that social positions are more than merely differences in size ranking within a population. A juvenile social position and associated relative growth rate are based, therefore, on environmental, apparently social, stimuli, and on factors intrinsic to the individual which were presumably acquired during early post larval development when the initial size hierarchy evolved.

2.6 Summary

The changes which occur in the population size distribution, starting from newly metamorphosed post larvae through the juvenile stages can be summarized in the following points:

1. Newly metamorphosed post-larvae have a log-normal size distribution which becomes positively skewed with time.
2. Individuals within the size distribution's leading-tail, jumpers, exhibit a higher growth rate than the bulk of the population.
3. The advent of the leading tail is enhanced under low initial stocking densities. This suggests that the appearance of jumpers is not primarily a result of competition.

4. Interactions among individuals, present in the case of communal growth, play a major role in the development of the size distribution observed in juvenile populations. Two consequent processes were observed: (a) social stimulation, resulting in the enhanced growth rate of jumpers, and (b) growth suppression, resulted in a lag of growth, as evidenced by the later emergence, in the presence of jumpers, of slow growing individuals, laggard. Neither the jumpers nor laggards were apparent under solitary growth conditions, proving the lack of genetic predetermination of an individual's growth rate.
5. Following the selective removal of jumpers, smaller juveniles increased their growth rate, some acquired jumper's attributes, and, eventually, the jumpers' leading-tail regenerated in the size distribution curve.
6. The exposure of juveniles to various social conditions resulted in strong immediate effects on their growth performance. It is suggested that the relative growth rate of juveniles is correlated with, and readjusted to changes in, the prawn's relative social position within the population.
7. Juveniles of equal size and age, but differing in their social position within their particular populations, retained their original position and associated growth characteristics when separated from their native populations.

Note: The above described chapter of the BARD research was conducted within the framework of a Ph. D. thesis, under the supervision of Dr. Dan Cohen, submitted by Dr. Zivi Ra'anan to the Senate of the Hebrew University.

3. Growth potential of nursed juveniles

3.1 The effect of initial size of juveniles stocked on subsequent growth: selective stocking I.*

The effects of initial size were examined in two studies begun under another project and completed here. These experiments compared the growth of different sized postlarvae of the same age. Postlarval prawns from a single hatchery run were reared communally in 2,000 l fiberglass or 4,000 l concrete tanks until a reasonably broad size distribution was established. These populations were then divided into four treatment groups which were reared in replicate tanks. The four treatments were: A - slow growers (from the smallest 1/3 of the size distribution); B - average growers (from the middle 1/3 of the distribution); C - fast growers (from the larger 1/3 of the size distribution); and D - mixed (control) group consisting of 1/3 A, 1/3 B, and 1/3 C. Stocking data for these two studies are given in Table 3. The animals were sampled and survival determined at 4-7 week intervals for up to 156 days.

Examination of the growth curves (Fig. 14, A,B) indicates that the various treatment groups grew at similar rates. However, the initial differences in size were maintained throughout the studies, that is, the initially larger prawns produced larger animals at the end of the experiments while the mean size of the slow growers remained smaller. The average growers and mixed (control) group maintained similar positions intermediate between the fast and slow growers. Thus, removal of the larger, faster growing post-larvae did not result in any compensatory growth among the smaller prawns. However, the data suggest that the culling out of smaller juveniles prior to stocking grow-out systems might improve production.

* This experiment was conducted in the USA

3.2 The effect of initial size of juveniles stocked on subsequent growth: selective stocking II *

In order to evaluate the effect of selective stocking of separated size classes on final yields, two sets of ponds were investigated: group A were stocked with selected large juveniles and group B with a whole mixed juvenile population. A comparison of growth and survival between the two groups is presented in Table 4. The advantages of ponds stocked with large juveniles over those stocked with a mixed population are: (a) The average weight of prawns harvested after 125 growout days was 46.9 g and 40.0 g for group A and B respectively. (b) The total yield was $1366.6 \text{ kg}\cdot\text{ha}^{-1}$ for groups A and B respectively and the biomass increased 5-fold and 4.5-fold. (c) While 61% of the total yield was above the large market size ($>40 \text{ g}$) and only 10% remained below market size ($>25 \text{ g}$) in group A, only 48% of the total yield reached the large market size and 16% remained below market size in group B. (d) Food conversion ratios were 1.04 and 1.37 for groups A and B respectively, indicating a better utilization of added feed when large juveniles were stocked.

Survival rates in the growout phase of the large juvenile populations were above 80% in all cases apart from Pond number 24. This showed exceptionally poor yield and survival rate, probably due to an extremely high seepage rate forcing a fast water inflow, resulting in clear water with low natural productivity. Moreover, the penetration of several Tilapia specimens resulted in wild spawning and the accumulation of about $400 \text{ kg}\cdot\text{ha}^{-1}$ Tilapia fingerlings.

In general, we can conclude that selective stocking improves marketable yields. We predict that the relative contribution of this strategy will

* This experiment was carried out in Israel.

become more apparent when the overall management procedures of prawn monoculture systems are improved.

The small juvenile subpopulation was introduced at an average low stocking density of $5400 \cdot \text{ha}^{-1}$ into intensive common carp production ponds, stocked at a density of $4000 \cdot \text{ha}^{-1}$. The fish were fed through a demand feeder and no supplementary feed was added for the prawns.

Yields of prawns and fish in this system are summarized in Table 5. The selected subpopulation of small juveniles introduced at an average weight of 5.0g reached an average weight of 53.6 g in the 125 days' growout period. These prawns, which would almost certainly have remained below market size had they been stocked in a prawn monoculture system, all reached the large market size with a survival rate of 86.2%. The total prawn biomass increased 9-fold, yielding $2495 \text{ kg} \cdot \text{ha}^{-1}$ of large prawns.

Fish production was not affected by the introduction of prawns. Fish averaging 233 g, stocked at a density of $4000 \cdot \text{ha}^{-1}$, reached an average weight of 880 g, thus demonstrating a gain of $5.2 \text{ g} \cdot \text{day}^{-1}$. A total yield of $3534 \text{ kg} \cdot \text{ha}^{-1}$ with a 100% survival was obtained in 125 growout days.

3.3 The effect of juveniles' age on growth potential

In this experiment we had examined the effect of age on the growth potential of similar sized juvenile prawns reared in nursery systems. The growth, survival, and sex ratios of two age groups of prawns were compared in triplicate 600 l nursery tanks. One group of animals (A) was approximately 180 days postmetamorphosis and the other (B) approximately 90 days postmetamorphosis at the start of the experiment. Both groups of prawns were reared in the same laboratory systems prior to initiation of the study. An attempt was made to obtain animals of roughly the same

mean size from both age populations. To accomplish this, the small prawns were chosen from group A to represent "old", supposedly stunted animals, while the larger, more rapidly growing animals were selected from group B. Unfortunately, the mean sizes of these two groups were somewhat different (1.3 vs. 2.2 g) at the beginning of the study. The experiment was conducted for 84 days, with survival, growth and other data obtained at 4-week intervals.

Growth and survival curves are shown in Fig. 15. Analysis of covariance indicates that there is a significant difference between the two growth curves, with the younger, larger animals growing more rapidly than the older, smaller ones. However, part of this difference is undoubtedly accounted for by the differences in survival and initial mean size. Data on claw loss indicated that there was more aggressive behavior among the younger, more rapidly growing prawns, and this was reflected in the decreased survival rate in this group. While the older, stunted prawns did grow more slowly than the younger animals, the growth and survival performance of the older animals was still acceptable. This indicates that long-term, high density rearing in nursery systems does not result in a pronounced, permanent stunting effect.

Prawns from other large nursery tanks maintained in the laboratory were stocked in private grow-out ponds at the beginning of the growing season. Because of the nature of these ponds, direct comparison of growth/production results is not possible. Nevertheless, the recent harvest indicates that the older, supposedly stunted prawns perform well in pond culture. Thus, it appears that there is a potential for long-term "warehousing" of prawns in nursery systems without a major negative effect on growth potential.

4. Establishment of Commercial Nurseries

4.1 Effects of temperature on nursed populations

This study had two major purposes:

(1) to determine if a slight reduction in temperature from the optimal range ($28-30^{\circ}\text{C}$) would yield improved survival and/or a decrease in size variation; and (2) to determine if postlarvae could be held ("warehoused") at low temperatures for extended periods without permanently stunting the animals.

The experiment was set up using nine 80 l aquaria maintained in temperature baths. Three replicate aquaria at each of the three temperature ranges (control: $28-30^{\circ}\text{C}$, $23-25^{\circ}\text{C}$, and $18-20^{\circ}\text{C}$) were stocked with postlarvae (mean weight 0.18 g) from a single hatchery production cycle. Each aquarium was stocked with 100 prawns (density of $444/\text{m}^2$) at 28°C , and temperature in the treatment tanks were slowly lowered to the desired range. Water quality was sampled daily until it was determined that there were little or no differences among treatments. At this time, water quality observations were reduced to once per week. Water temperatures were recorded daily. Survival and growth of the prawns were determined at two-week intervals. At the end of six weeks, the animals were sampled and then restocked at the highest uniform density possible with existing survivors (i.e., 34 prawns/aquarium or $151/\text{M}^2$). Water temperatures in the treatment tanks were then increased $1^{\circ}\text{C}/\text{day}$ until all treatments stabilized at $28-30^{\circ}\text{C}$. The prawns were allowed to grow for an additional four weeks to evaluate the response of the cold-stunted animals to optimal growth temperatures.

Survival was best in the moderate temperature ($23-25^{\circ}\text{C}$) treatment and poorest in the low temperature groups (Table 6). Growth in the low temperature

groups (Table 6). Growth in the low temperature group was less than half that at the higher temperatures, and size variation was also markedly reduced (Table 6). However, upon increasing the temperatures to the optimal range (28-30°C), the prawns which had been held at 18-20°C for eight weeks exhibited by far the most rapid growth rate, catching up with those animals in the high (optimal) temperature treatment within six weeks. This rapid compensatory growth was accompanied by a wide variation (see Variance column on Table 6) and the highest survival. These results clearly indicate that long-term exposure to relatively low temperatures does not permanently stunt prawns (Fig. 16). Considering both growth and survival data, our results suggest that slightly higher low temperatures, perhaps 20-22°C, would provide good conditions for "warehousing" postlarvae until needed. Such animals could then be rapidly grown to suitable sizes stocking in seasonal growout ponds.

4.2 Commercial nurseries operated in Israel

Based on many of the findings reported above, commercial nursery facilities in Israel have been developed and largely improved. For example, during the course of this study, we found that in early post larval stages stocking density per unit of surface area was more significant than density per unit volume. The introduction of submerged substrates into the nursing facilities, for example, increased the carrying capacity of the system by 10 fold. It was a common belief, initially, that a density of 1 PL/liter is the maximum capacity of a commercial nursery. Today, some nurseries in Israel practice stocking densities of up to 10 PL/liter while still maintaining high survival rates and high growth potential (Ra'anani &

Cohen 1982). Usable substrates are as variable as plastic egg trays, fruit crates and palm leaves. The common denominator is that about 60-70% of the water body should contain substrates, and that these should be characterized by complexed surfaces in order to multiply hiding places for small and newly molted animals.

In general, commercial nurseries may be quite variable with respect to total volume, source of energy for temperature maintenance, water exchange rate etc. (for more details see Table 7).

Production of nursed juveniles during the winter of '83-'84 (Table 8) demonstrates a significant improvement in nursery procedures.

5. References

- Aiken, D.E., & Waddy, S.L., 1977. Effect of space and density on growth of large juvenile lobster. Environment Canada, Applied Physiology Research, Report No. 13, 17 pp.
- Allee, W.C., & Douglass, M.B., 1945. A dominance order in the hermit crab Pagurus longicarpus Say. Ecology, 26:411-412.
- Anderson, W.R., & Ford, R.F., 1976. Early development, growth and survival of the yellow crab Cancer anthonyi Rathbun (Decapoda, Brachyura) in the laboratory. Aquaculture, 7:267-279.
- Bardach, J.E., Ryther, J.H., & McDarney, W.O., 1972. Freshwater shrimp culture. In: Aquaculture: the farming and husbandry of freshwater and marine organisms. J. Wiley & Sons Inc., New York, pp:619-632.
- Barnes, R.D., 1965. Invertebrate Zoology. W.B. Saunders Co., Phil.
- Bhimchar, B.S., 1965. Life history and behavior of Indian prawns. Fishery Technology, 2:1-11.
- Borowsky, R.L., 1969. Ecological and social factors influencing the polymorphic pigmentation systems of Xiphophorus variatus. Ph.D. Thesis, Yale Univ. 123 pp.
- _____ 1973a. Relative size and development of fin coloration in Xiphophorus variatus. Physiol. Zool. 46:22-28.
- _____ 1973b. Social control of adult size in males of Xiphophorus variatus. Nature, 245:332-335.
- Bovbjerg, R.V., 1953. Dominance order in the crayfish Orconectes virilis (Hagen). Physiol. Zool., 26:173-178.

- Breteler Klein, W.C.M., 1975. Growth and molting of juvenile shore crabs, Carcinus maenas, in a natural population. *Neth. J. Sea Res.*, 9:86-89.
- Brody, T., Cohen, D., Barnes, A., & Spector, A., 1980. Yield characters of Macrobrachium rosenbergii in monoculture. *Aquaculture*, 21:375-385.
- Brown, E.M., 1946. The growth of brown trout (Salmo trutta Linn.): I. Factors influencing the growth of trout fry. *J. Exp. Biol.*, 22:118-129.
- Charniaux-Cotton, H., 1961. Sex determination. *In*: The physiology of crustacea, Vol. I. Waterman, T.H., ed., Academic Press, New York and London. pp:411-441.
- Cobb, J.S., & Tamm, G.R., 1974. Social conditions increase intermolt in juvenile lobsters Homarus americanus. *J. Fish. Res. Bd. Canada*, 32:1941-1943.
- Cohen, D., Brody, T., & Sandifer, P.A., 1980. The development of Macrobrachium rosenbergii nursery procedures by modifying post larval size distribution: The effect of size distribution and age on growth potential and final yields in growout ponds. Research proposal submitted to BARD, Proposal #I-190-80, 63 pp.
- Cohen, D., Ra'anan, Z., & Brody, T., 1982. Population profile development and morphotypic differentiation in the giant freshwater prawn Macrobrachium rosenbergii (de Man). *Proc. World Maricult. Soc.*, 1982: in press
- Cohen, D., Ra'anan, Z., & Barnes, A., 1983. The production of the freshwater prawn Macrobrachium rosenbergii in Israel: I. Integration into fish polyculture systems. *Aquaculture*, 31:67-76.
- Cohen, D., & Ra'anan, Z., 1983. The production of the freshwater prawn Macrobrachium rosenbergii in Israel: III. Density effect of all-male Tilapia hybrids on prawn yield characters in polyculture. *Aquaculture*, 34: in press.

- Constantz, G.D., 1975. Behavioral ecology of mating in the male Gila topminnow Poeciliopsis occidentalis (Cyprinodontiformes; Poeciliidae). Ecology, 56:966-973.
- Croock, J.H., 1970. Social organization and the environment: Aspects of contemporary social ethology. Animal Behavior, 18:197-209.
- Douglis, M.B., 1946. Some evidence of dominance-subordinance relationship among lobsters. Anat. Rec., 96:553(Abstract).
- Dunham, J.P., 1972. Some effects of group housing upon the aggressive behavior of the lobster Homarus americanus. J. Fish Res. Bd. Canada, 29(5):598-601.
- Fujimura, T., & Okamoto, H., 1970. Notes on progress made in developing a mass culturing technique for Macrobrachium rosenbergii in Hawaii. Indo-Pacific Fish Counc. Proc., 14th session, Bangkok, Thailand. Symposium 53, 17 pp
- Giant Prawn Conference, 1980. Bangkok, Thailand. International Foundation for Science 'IFS' Sibyllegatan 47, S-11442, Stockholm, Sweden.
- Gunnes, K., 1976. Effect of size grading young Atlantic salmon (Salmo salar) on susequent growth. Aquaculture, 9:381-386.
- Hanson, J.A., & Goodwin, H.L., 1977. Shrimp and prawn farming in the Western Hemisphere. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania, 439 pp.
- Harpaz, S., 1980. Studies on the feeding behavior of the freshwater prawn Macrobrachium rosenbergii (de Man). M.Sc. Thesis, submitted to the Life Science Institute, the Hebrew University of Jerusalem, Israel.

- Hartnoll, R.G., 1977. The effect of salinity and temperature on the post larval growth of the crab Rhithropanopeus harrisii. Physiology and biology of marine organisms. Proc. 12th Europ. Sym. on Marine Biol., Stirling, Scotland, Sept. 1977:349-358.
- Hartnoll, R.G., & Dalley, R., 1981. The control of size variation within instars of a crustacean. J. Exp. Mar. Biol. Ecol., 53:235-239.
- Hedgecock, D., & Nelson, K., 1980. Components of growth rate variation among laboratory cultured lobsters (Homarus). Proc. World Maricult. Soc., 11:125-137.
- Holthuis, L.B., 1950. The decapoda of the Siboga Expedition Part X. The Palaemonidae collected by the Siboga and Snellius expeditions with remarks on other species: I. Subfamily Palaemonidae. Siboga Expedition Monogram, 39a(9):1.268.
- Koyama, h., & Kira, T., 1956. Intraspecific competition among higher plants: VIII. Frequency distribution of individual plant weight as affected by the interactions between plants. J. Inst. Polytech. Osaka City University, Ser. D., 7:73-94.
- Krumholtz, L., 1963. Relationship between fertility, sex ratio, and exposure to predation in populations of the mosquitofish Gambusia manni, Hobbs at Bimini. Bahamas, Int. Rev. Ges. Hydrobiol., 48:201-256.
- Kurata, H., 1962. Studies on the age and growth of Crustacea, Bull. Hakkaido Fish. Res. Lab., 24:1-115.
- Law, R., 1979. The cost of reproduction in annual meadow grass. Am. Nat., 113(1):3-16.

- Ling, S.W., & Costello, T.J., 1976. Review of culture of freshwater prawns. FAO Technical Conf. on Aquacult., Kyoto, Japan, 1976. Ref. paper #29, 12 pp.
- Ling, S.W., & Merican, A.B.O., 1961. Notes on the life and habitats of the adult and larval stages of Macrobrachium rosenbergii (de Man). Proc. Indo-Pacific Fish Council, 9th Session, Section II, pp:55-61.
- Lowe, M.E., 1956. Dominance-subordinance relationships in the crawfish Cambarellus shufeldtii. Tulane Studies in Zool., 4(5):139-170.
- Mackay, D.A., 1929. Larval and post larval lobsters. Amer. Nat., 63:160-170.
- Mackay, D.C.G., & Weymouth, F.W., 1935. The growth of the Pacific edible crab Cancer magister Dana. J. Biol. Bd. Canada, 1:191-212.
- Magnuson, J.J., 1962. An analysis of aggressive behavior, growth and competition for food and space in the medaka (Oryzias latipes, Pisces, Cyprinodontidae). Canadian J. Zool., 40:313-363.
- Malecha, S.R., 1977. Genetics and selective breeding. In: Shrimp and prawn farming in the Western Hemisphere. Goodwin and Hanson eds. Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pennsylvania, Chapter XIV.
- Malecha, S.R., Kitaji, G., & Muraoka, A., 1977. Studies of size variability in Macrobrachium rosenbergii (de Man). I. The influence of stocking density and initial size on growth in tank reared juveniles. Proc. World Maricult. Soc. 8:Abstract # 53.
- Malecha, S.R., Masuno, S., Bigger, D., Brand, T., Weber, G., & Leuitt, A., 1982. Genetic and environmental sources of growth pattern variation in cultured freshwater prawn, Macrobrachium rosenbergii. Proc. World Maricult. Soc., 12:in press.

- Maruakawa, H., 1933. Biological and fishery research on Japanese king crab Paralithodes comtschtica. J.Imp. Exp. St. Tokyo, 4:1-152 (in Japanese with English summary).
- Mauchline, J., 1977. Growth in shrimps, crabs and lobsters - an assessment. J. Cons. Perm. Int. Explor. Mer., 37:162-169.
- Maynard Smith, J., 1978. The evolution of behavior. Scientific American, 239:137-145.
- Mayr, E., 1977. Concepts in the study of animal behavior. In: Reproductive behavior and evolution. Rosenblatt, J.S., and Komisaruk, B.R., eds, Plenum Press, 227 W17 St., New York, N.Y. 10011. pp:1-16.
- Mertz, D.B., 1971. The mathematical demography of California condor population. Am. Nat., 105:437.
- Nakamura, N., & Kasahara, S., 1957. A study of the phenomenon of the Tobi-Koi or shoot carp. III. On the results of culturing the modal group and growth of carp fry reared individually. Ibid, 22:674-678 (in Japanese with English summary).
- Natividad, J.M., 1980. Hydrobiological characteristics of some Philippine river systems which are natural habitats of Macrobrachium species. Giant Prawn Conf. 1980. Bangkok, Thailand.
- Nelson, K., Hedgecock, D., Borgeson, W., Johnson, E., Dagget, R., & Aronstein, D., 1980. Density-dependent growth inhibition in lobsters, Homarus, Decapoda. Biol. Bull., 159:167-176.
- Newkirk, G.F., Haley, L.E., Waugh, D.L., & Doyle, R., 1977. Genetics of larvae and spat growth rates in the oyster Crassostrea virginica. Mar. Biol., 41:49-52.

- Nie, N.H., Hull, C.H., Jenkins, J.S., & Steinbrenner, K., 1971. SPSS, ANOVA, ONEWAY-RANGES, LSD-test. In: SPSS 2nd Edition, MacGraw-Hill Book Company. Bowmen, K.J., & Cahill, M., eds. pp:425-430.
- Peebles, J.B., 1979. Molting movement and dispersion in the freshwater prawn Macrobrachium rosenbergii (de Man). J. Fish Res. Bd. Canada, 36:1080-1088.
- _____ 1980. Competition and habitat partitioning by the giant freshwater prawn Macrobrachium rosenbergii (de man) (Decapoda, Palamonidae). Crustaceana, 38(1):49-54.
- Ra'anan, Z., 1982. The effect of size ranking on the molting cycle of juvenile stages of the frshwater prawn Macrobrachium rosenbergii (de Man) when reared individually and in pairs. Crustaceana, in press.
- Ra'anan, Z., & Cohen, D., 1982. Production of the freshwater prawn Macrobrachium rosenbergii in Israel: Winter activiries 1980/1981. Bamidgeh, 34(2):47-58.
- _____ 1983. The production of the freshwater prawn Macrobrachium rosenbergii in Israel: II. Selective stocking of size subpopulations. Aquaculture, 31:369-379.
- Raman, K., 1967. Observation on the fishery and biology of the giant freshwater prawn Macrobrachium rosenbergii (de Man). Proc. Symposium on Crustacea, Marine Biology Association, India, Part II:649-669.
- Ricker, W.E., 1958. Handbook for computations for biological statistics of populations. Bull. Fish. Res. Bd. Canada, No. 119, 300 pp.
- Rose, S.M., 1958. Failure of survival of slowly growing members of a population. Science, 129:1026.

- Sandifer, P.A., & Smith, T.I.J., 1975. Effect of population density on growth and survival of Macrobrachium rosenbergii reared in recirculating water management system. Proc. World Maricult. Soc., 6:43-53.
-
1978. Preliminary observations on a short-claw growth form of the Malaysian prawn, Macrobrachium rosenbergii (de Man). Proc. of the National Shellfisheries Assoc. pp. 123.
-
1979. Possible significance of variation in the larval development of the palaemonid shrimp. J. Exp. Mar. Biol. Ecol., 39:55-64.
- Sastry, A.N., & French, D.P., 1977. Growth of the American lobster, Homarus americanus Milne-Edwards, under controlled conditions. Commonwealth Scientific and Industrial Research Organization, Division of Fisheries and Oceanography, Australia, Circular No. 7 (Abstract).
- Sato, S., 1958. Studies on larval development and fishery biology of king-crab Paralithodes camtschatica. Bull. Hokkaido Reg. Fish. Res. Lab., 17:1-102. (in Japanese with English summary).
- Schone, H., 1961. Complex behavior. In: The physiology of crustacea, Vol. 2. Waterman T.H. ed., Academic Press New York and London. Chapter 13:465-520.
- Scott, D.B.C., & Currie, C.E., 1980. Social hierarchy in relation to adrenocortical activity in Xiphophorus helleri Heckel. J. Fish Biol., 16:265-277.
- Smith, T.I.J., Sandifer, P.A., & Smith, M.H., 1978. Population structure of Malaysian prawns, Macrobrachium rosenbergii (de Man), reared in earthen ponds in South Carolina 1974-1976. Proc. World Maricult. Soc., 9:21-38.

- Smith, T.I.J., Sandifer, P.A., & Manzi, J.J., 1979. Epibionts of pond reared adult Macrobrachium rosenbergii (de Man) in South Carolina. Aquaculture, 16:299-308.
- Sohn, J.J., 1977a. Socially induced inhibition of genetically determined maturation in the platyfish Xiphophorus maculatus. Science, 195:199-201.
- _____ 1977b. The consequences of predation and competition upon the demography of Gambusia manni (Pisces: Poeciliidae). Copeia, 1977(2):244-227.
- Stern, S., 1979. Introduction of Macrobrachium rosenbergii culture to the brackish water of the Arava: The development of the osmoregulation apparatus. 7th Report of the H. Steinitz Marine Biology Laboratory - Elat. The Hebrew University of Jerusalem, p. 57 (Abstract).
- Symons, P.E.K., 1972. Behavioral adjustments of population density to available food by juvenile Atlantic salmon. J. Anim. Ecol., 40:569-587.
- Templeman, W., 1936. Local differences in the life history of the lobster (Homarus americanus) on the coast of the Maritime Provinces of Canada. J. Biol. Bd. Canada, 2:41-88.
- Travis, D.F., 1954. The molting cycle of the spiny lobster, Panulirus argus Lateceille. I. Molting and growth in laboratory maintained individuals. Biol. Bull., 107:433-450.
- Uematsu, T., 1971a. Social facilitation in feeding behavior of the guppy. I. Preliminary experiments. Jap. J. Ecol., 21:48-51. (in Japanese with English summary).
- _____ 1971b. Social facilitation in feeding behavior of the guppy. II. Influences of the social facilitation upon their activity,

- respiration and growth. Jap. J. Ecol., 21:69-103. (in Japanese with English summary).
- Uematsu, T., & Takamori, J., 1976. Social facilitation in feeding behavior of the himedaka, Orizias latipes. I. Continuous observations during a short period. Jap. J. Ecol., 26:71-83. (in Japanese with English summary).
- Van Olst, J.C., & Calberg, J.M., 1979. The effect of container size and transparency on growth and survival of lobsters culured individually. Proc. World Maricult. Soc., 8:251-264.
- Wallace, J.D., 1980. Female mimicry in male bluegill sunfish - a genetic polymorphism? Nature, 284(5756):546-548.
- Wilbur, H.M., & Collins, J.P., 1973. Ecological aspects of amphibian metamorphosis. Science, 182:1305-1314.
- Willis, S.A., & Berrigan, M.E., 1977. Effect of stocking size and density on growth and survival of Macrobrachium rosenbergii (de Man) in ponds. Proc. World Maricult. Soc., 8:251-264.
- Wilson, O.E., 1975. Sex and society. In: Sociobiology - The New Synthesis. The Belknap Press of Harvard University Press, Cambridge, Massachusetts 1975. pp 314-335.
- Wohlfarth, G. W., 1977. Shoot carp. Bamidgeh, 29(2):35-39.
- Yamagishi, H., 1962. Growth relation in some experimental populations of rainbow trout fry, Salmo gaiderni Richardson, with special reference to social relations among individuals. Jap. J. Ecol., 12:43-53. (in Japanese with English summary).

TABLE 1 : The effect of three stocking densities, with and without the addition of substrates, on population size distribution 60 days after metamorphosis*

Group No.	No. of Animals Stocked	Stocking Density		Body Weight Distribution**			Survival (%)	
		Volume (liter ⁻¹)	Surface (meter ⁻²)	Mean (g)	S.D. (q)	P.C.V. %		Sk.
<u>No added substrate:</u>								
1	100	1	420	0.124 ^c	0.089 ^c	71.6 ^c	2.547 ^c	89
2	500	5	2100	0.090 ^b	0.050 ^b	55.5 ^b	1.582 ^b	74
3	1000	10	4200	0.064 ^a	0.023 ^a	35.6 ^a	1.203 ^a	72
=====								
<u>With added substrates:</u>								
4	100	1	84	0.290 ^d	0.226 ^d	77.95 ^d	3.635 ^d	85
5	500	5	420	0.127 ^c	0.093 ^c	73.1 ^c	2.336 ^c	87
6	1000	10	840	0.103 ^b	0.054 ^b	53.1 ^b	1.432 ^b	71

* Figures denoted by different superscripts are significantly different at the $\alpha = 0.01$ level; figures bearing the same superscript within the same parameter are not statistically different. (ANOVA, ONEWAY-RANGES, LSD-test, Nie et al., 1971).

** S.D. - Standard Deviation; P.C.V. - Percent Coefficient of Variation; Sk - Skewness.

Table 2 : Increase in average weights (g) of the largest (upper 10%), smallest (lowest 10%) and the median body weight experimental subjects reared under individual (I.G.) vs. communal (C.G.) growth conditions.

Days	After	10%	Largest	Median		10%	Smallest
		I.G. (N=10-12)	C.G. (N=16-18)	I.G.	C.G.	I.G. (N=10-12)	C.G. (N=16-18)
Metamorphosis							
	14	0.08*	0.15	0.031	0.041	0.017	0.018
	21	0.16*	0.25	0.066	0.063	0.031	0.027
	28	0.20*	0.39	0.080	0.073	0.042	0.031
	35	0.28*	0.47	0.109	0.103	0.061*	0.037
	42	0.38*	0.72	0.152	0.160	0.083*	0.062
	49	0.48*	0.87	0.177	0.191	0.097*	0.073
	56	0.55*	0.99	0.208	0.223	0.114*	0.081
	63	0.57*	1.19	0.227	0.252	0.138*	0.084

* Differences between means are statistically significant (t-test, $\alpha=0.05$).

TABLE 3 Stocking data for experiments on the effects of initial mean size on subsequent growth of juvenile Macrobrachium rosenbergii reared in nursery systems.

<u>Treatment Group</u>	<u>Prawn Size (orbital length, mm)</u>			
	<u>Experiment I</u>		<u>Experiment II</u>	
	<u>Mean</u>	<u>Range</u>	<u>Mean</u>	<u>Range</u>
A - Slow Growers	18.1	15-19	23.1	18-25
B - Average Growers	22.5	20-25	29.1	26-32
C - Fast Growers	28.5	25-42	37.4	33-47
D - Mixed Growers	23.0	15-42	29.8	13-61

Table 4 :

Yields obtained from a prawn monoculture system stocked with selected large juvenile vs. whole mixed population after 125 days growout period:

Pond #	Av. Weight (g.)		Stocking (No.)	Biomass (kg. ha ⁻¹)		Increase biomass (%)	Yields according to size classes (%)		Survival (%)	Food ¹⁾ Conversion
	stocked	harvested		stocked	harvested		< 25 g	> 40 g		
A. Ponds stocked with selected large juveniles ²⁾ :										
13	8.4	49.9	35000	294	1444.3	491	9	64	82.7	0.99
14	7.3	44.0	35000	255.5	1289.0	504	11	58	83.7	1.10
24 ³⁾	6.3	26.0	35000	220.5	646.1	293	42	36	71.0	2.68
Average ⁴⁾	7.8	46.9	35000	274.7	1366.6	497	10	61	83.2	1.04
B. Ponds stocked with mixed whole population of nursed juveniles:										
15	7.5	33.0	35000	262.5	877.8	334	17	45	76.0	1.85
16	7.0	41.0	35000	245.0	1234.1	503	19	47	86.0	1.15
17	7.0	46.0	30000	245.0	1269.6	518	12	52	92.0	1.11
Average	7.2	40.0	33333	250.8	1127.2	452	16	48	84.7	1.30

1) Food conversion was calculated according to amount added feed divided by gained weight, not including added dry chicken manure.

2) Large juveniles were selected out of a whole nursed juvenile prawns using a 5 mm mesh size net.

3) This pond contained wild spawning *Tilapia* fingerlings at a biomass of 400 kg.ha⁻¹ which caused a major disturbance for the development of prawns.

4) Average calculations do not include pond #24.

Table 5 :

Yields obtained in 125 growout days from a fish-prawn polyculture system stocked with selected small juvenile prawns¹⁾:

Pond #	Av. Weight (gr)		Stocking density (ha ⁻¹)	Biomass (kg.ha ⁻¹)		Increase biomass(%)	Survival (%)	Food conversion ²⁾
	stocked	harvested		stocked	harvested			
G.D - Prawns	5.2	52.1	5600	29.12	279.7	960	95.8	-
com.carp	234.0	800.0	4000	936.0	3200.0	342	100	2.43
G.H - Prawns	4.8	55.1	5200	24.96	219.3	879	76.5	-
com.carp	232.0	967.0	4000	928.0	3868.0	417	100	1.90
Average -								
prawns	5.0	53.6	5400	27.04	249.5	919	86.1	-
com.carp	233.0	883.5	4000	932.0	3534.0	379	100	2.16

- 1) Small juveniles were obtained after a selective removal of the larger juveniles by seining the pond with 5 mm mesh size nets.
- 2) Food conversion was calculated according to the amount of added feed through a demand feeder divided by the total gained weight of both prawns and fish.
- 3) All prawns were above the large market size (>40 gr).

TABLE 6. Sampling data from temperature study.

Treatment (C°)	Day	Survival		Mean Weight (g)	Standard Deviation	Variance
		No./Tank	Percent			
18-20	0	100.0	100.0	0.18	0.06	0.003
23-25	0	100.0	100.0	0.18	0.06	0.003
28-30	0	100.0	100.0	0.18	0.06	0.003
18-20	14	92.0	92.0	0.24	0.12	0.01
23-25	14	96.3	96.3	0.30	0.14	0.02
28-30	14	91.7	91.7	0.33	0.16	0.02
18-20	28	72.7	72.7	0.26	0.12	0.01
23-25	28	90.3	90.3	0.40	0.18	0.03
28-30	28	79.0	79.0	0.46	0.23	0.05
18-20	42	52.3	52.3	0.28	0.12	0.01
23-25	42	81.0	81.0	0.52	0.28	0.08
28-30	42	67.3	67.3	0.71	0.57	0.32
18-20	56	38.0	38.0	0.29	0.13	0.02
23-25	56	66.3	66.3	0.63	0.34	0.12
28-30	56	54.3	54.3	0.75	0.45	0.20
18-20	65	34.7	34.7	0.34	0.17	0.03
23-25	65	53.0	53.0	0.75	0.52	0.27
28-30	65	45.0	45.0	0.88	0.51	0.26
Animals restocked at 34/tank and temperatures slowly brought up to 28 - 30° in two lower temperature treatments						
18-20	65	34.0	100.0	0.34	0.17	0.03
23-25	65	34.0	100.0	0.75	0.52	0.27
28-30	65	34.0	100.0	0.88	0.51	0.26
18-20	79	32.0	94.1	0.56	0.24	0.06
23-25	79	27.0	79.4	0.99	0.71	0.50
28-30	79	26.0	76.5	1.06	0.62	0.38
18-20	93	28.3	83.4	0.86	0.41	0.17
23-25	93	22.7	66.7	1.20	0.90	0.81
28-30	93	18.3	53.9	1.23	0.76	0.58
18-20	107	26.0	76.0	1.49	1.18	1.39
23-25	107	18.3	55.8	1.21	0.88	0.77
28-30	107	14.3	40.6	1.53	0.81	0.66

Table 7 : Nursery Pond Types

<u>Pond Type</u>	<u>Energy Source</u>	<u>Ave. Temp. °C</u>	<u>Flow Rate m³/hr</u>	<u>Pond Measurement (m)</u>
Open geothermal earthen pond	Geothermal springs	23 - 25	50	80 x 30 x 1
Green house, plastic bottom, flowthrough	Geothermal springs	26 - 28	15	33 x 3 x 0.8
Green house, plastic bottom	Warm well water	19 - 24	2 - 3	37 x 4 x 0.9
Green house, cement bottom, close system	Artificially heated	25 - 26	Recirculating through biofilters	10 x 2 x 1
Fiberglass tanks, close system	Artificially heated	25 - 28	Recirculating through biofilters	2.1 x 1.5 x 0.7

Table 8: Production of nursed juveniles in various nursery types currently operated in Israel - winter '83 - '84

<u>Nursery Type</u>	<u>Unit Size</u>	<u>Total # of PL Stocked</u>	<u>Total # of Juveniles Produced</u>	<u>Survival %</u>	<u>Average Weight of Juveniles</u>
Cement ponds flowthrough	130 m ³ x 2 units	1,430,000 2,330,000	543,000 1,500,000	37 63	0.2 0.2
Earthen ponds flowthrough	0.15 ha 0.18 ha	190,000 480,000	100,000 330,000	53 79	1.0 1.7
Cement greenhouse pond, close, recirculating system	36 m ³ x 6 units	780,000 1,217,000	518,000 740,000	66 61	0.2 0.2
Solar greenhouses, close, recirculating system	150 m ³ x 1 unit	400,000 770,000	290,000 400,000	72 51.9	0.4 0.5
In-door tanks and biofilters	4.5 m ³ x 12 units	384,000 553,000	293,000 268,000	76 66.5	0.15 0.2
Solar greenhouse, close, recirculating system	100 m ³ x 1 unit	570,000	360,000	63	0.23

Note: Nursery duration in all cases varied from 60 -90 days

Figure 1: The life cycle of M. rosenbergii in nature and its simulation in aquaculture.

Fig. 2 : Frequency histograms of body weights of juveniles sampled at three times after metamorphosis.

Fig. 3 : Frequency histograms in $\ln$ (natural logarithm) transformed body weights of juveniles sampled at three times after metamorphosis.

Fig. 4 : Frequency histograms of body weights of juveniles stocked at various densities, sampled at selected times after metamorphosis. Note the development of skewness and the rapid overall growth at the lower densities.

Fig. 5 : Frequency histograms of body weights of post larvae reared under individual (I.G., N=120) and communal (C.G., N=180) growth conditions, at three times after metamorphosis.

Fig. 6 : Growth in average weight of individually (I.G.) and communally (C.G.) reared juvenile prawns. * Differences between means are statistically significant (t -test, $\alpha=0.05$).

Fig. 7 : Frequency distribution of relative growth rates (R) in individually and communally reared juvenile populations, two and seven weeks after metamorphosis.

Fig. 8 : The relation between initial body weight and the relative growth rate of juvenile prawns communally reared, at two time intervals after metamorphosis.

Fig. 9 : Frequency histograms of juveniles' body weight. Jumpers were defined for each population as shown, and selectively removed at 30 (PL₃₀), 60 (PL₆₀), and 90 (PL₉₀) days after metamorphosis.

Fig. 10 : Average weight of juvenile populations following selective removal of jumpers. (o—o) control, whole population, (—) 1st selective harvest (S.H.I.), (·····) 2nd selective harvest (S.H.II), (—) 3rd selective harvest (S.H.III).

Fig. 11 : The effect of social position, as measured by size ranking within the population, on the average weight of juvenile prawns.

Fig. 12 : Frequency histogram of body weights of post larvae (PL), reared under two different densities, 60 days after metamorphosis.

Fig. 13 : The effect of previous social position on further growth of juveniles selected from two distinct subpopulations, restocked in three combinations: jumpers alone, non-jumpers alone, and a mixed population.

FIGURE 14. Growth curves for two experiments concerning the comparative growth responses of size-segregated postlarvae of *Macrobrachium rosenbergii*. A - study conducted in 2,000-l fiberglass tanks; B - study conducted in 4,000-l concrete tanks.

FIGURE 15: Comparison of growth and survival of prawns of similar mean size and different ages reared in laboratory nursery tanks.

FIGURE 16: Growth curve for Temperature Study showing that "warehousing" does not permanently stunt growth.

F. DESCRIPTION OF THE COOPERATION

At the onset of this study, the Marine Resources Research Institute in South Carolina, was the main, if not the only institution in the USA, which considered the nursery phase as a main target for research and development.

Dr. Paul Sandifer has conducted preliminary work, which, together with our material, served as the basis for this proposal.

However, throughout the years of this program, there has occurred a shift in the intensity of prawn cultivation in South Carolina. Whereas in Israel the prawn branch developed, in South Carolina the emphasis went to other organisms. Possibly, the reason is the lack of fresh water pond infrastructure as opposed to ample amounts of brackish sources in that state.

The two research groups concentrated on different aspects of the problem, bringing about complementary results.

We wish to report that the Israeli researchers initiated the demonstration of prawn production at Louisiana State University. This 18 pond demonstration, in cooperation with Dr. James Avault, was based on the finding that stocking with nursed juvenile prawns is the key to achieving commercial yield in both mono and polyculture. Although this activity was not an integral part of this research program, it is a direct outcome, and serves to strengthen the cooperation between the two countries. Nursed juvenile prawns were shipped from the Nir David nursery in Israel and stocked at Louisiana State University on June 1983. The results are described in the annex 1.

A more extensive experiment was conducted in 1984 in Mississippi State University, with nursed juvenile prawns and with assistance of our

research group. Thus we can report that the results of this research program opened the way for prawn production in temperate zones of Israel and Southern USA.

G. BENEFIT TO AGRICULTURE

Table 9 summarizes the number of PL stocked in the nurseries mentioned above in 1984.

Throughout the period of this research (1980-1983) the export of prawns from Israel increased from about 7 tons to 40 tons. Increased production is expected because prawns are the main , realistic, export product from the fresh water aquaculture system in Israel and because the internal market is saturated with respect to all other products produced in this system.

The information gained in this research is already in the hands of the Fisheries Extension Service officers who are able to instruct farmers in the nursery production procedures and ensure that this phase of the production line is no longer an agricultural bottleneck.

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POLYCULTURE OF THE PRAWN, *Macrobrachium rosenbergii*, WITH FINGERLING AND ADULT CATFISH, *Ictalurus punctatus*, IN EARTHEN PONDS IN SOUTH LOUISIANA
M. Miltner*, A. Granados, R. Romaire, J. W. Avault, Jr., Ziva Ra'anan¹ and D. Cohen¹. Louisiana State University, Baton Rouge.

A study was conducted to determine the feasibility of growing the giant prawn (*M. rosenbergii*) in polyculture with channel catfish (*I. punctatus*) fingerlings and adults. The study was conducted in 18 0.04 ha ponds. Nursed juvenile prawns (averaging 28 mm total length) were stocked in all ponds at 2,471 per ha. Some ponds were stocked with 0.05 g catfish fry at 98,840/ha or 197,680/ha; other ponds received 13 g catfish fingerlings at 3,707 or 7,413/ha. Prawn survival from all ponds averaged 95.9%. Prawn survival was not affected by the presence of catfish fingerlings or adults nor was it correlated with catfish stocking density. Prawn yields after a 107-day grow-out period averaged 170 kg/ha, with harvested males averaging 11.5 individuals per kg and females averaging 20 per kg. Prawn yields and average weights were independent of the catfish production mode (fingerling or grow-out) and catfish stocking density. Maximum yield (203 kg/ha) and mean prawn weights (σ 97.1 g, ϕ 60.9 g) were obtained in one pond with prawns stocked alone, but lack of replication makes this inference inconclusive. Catfish fingerling survival and yield averaged 40.8% and 963 kg/ha in the "high" density treatment, and 50% and 603 kg/ha in the low density treatment. Mean catfish adult survival and yield were 51.9% and 1,305 kg/ha, and 51.2% and 735 kg/ha at the high and low stocking rates, respectively. Preliminary analysis of the data suggests the feasibility of integrating the prawn into catfish fingerling or grow-out production, contingent on the availability of nursed juvenile prawns.

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POLYCULTURE OF ALL MALE TILAPIA HYBRIDS WITH THE FRESHWATER PRAWN *MACROBRACHIUM ROSENBERGII*: EFFECT OF DENSITY ON YIELDS Dan Cohen and Ziva Raanan*, Aquaculture Production Technology (Israel) Ltd, Jerusalem.

The effect of stocking rates of both *Tilapia* male hybrids (*aureaxnilotica*) and juveniles of the freshwater prawn *Macrobrachium rosenbergii* was examined with respect to yield characteristics of both crops. We have examined two stocking rates of *Tilapia*: 3000/ha and 7500/ha, combined with three stocking rates of prawns: 5000/ha, 10000/ha and 15000/ha, in 22 earthen ponds of 400m² each.

It was found that the growth of *Tilapia* was strongly affected by its stocking density, while no effect on *Tilapia* growth was found at the various prawns stocking rates. The final *Tilapia* yields were 2738Kg/ha·yr and 4531Kg/ha·yr for the lower and higher stocking rates, respectively.

Prawn yields were independent of *Tilapia* stocking rates, but were strongly affected by the density of the prawn population. Prawn yields were: 586Kg/ha·yr, 1033Kg/ha·yr and 1430Kg/ha·yr for the low medium and high stocking rates respectively. The final average weight was inversely related to prawn stocking density and reached 35.0g, 31.0g and 26.1g, respectively. Survival rates of both *Tilapia* and prawns was above 85% in all cases.

The main conclusion of this study is that the combination of *Tilapia* male hybrids and *Macrobrachium rosenbergii* in a polyculture system is a promising possibility, since no interference between the two crops was found with regards to their respective growth performance.