OPPORTUNITIES FOR GENETIC IMPROVEMENT IN CRUSTACEAN SPECIES

D.R. Jerry, I.W. Purvis and L.R. Piper

CSIRO Livestock Industries, Locked Bag 1, Armidale, NSW 2350

SUMMARY

Breeding programs have been successfully developed and applied to fish. However, their application to the genetic improvement of crustaceans for improving productivity has been rare. The slow adoption of breeding technology in crustacean aquaculture is largely a consequence of peculiarities unique to this group of animals. These include a paucity of knowledge of animal husbandry, immaturity of industries, a lack of information on biological characteristics influencing productivity, unreliable genetic parameter sets and an inability to reliably identify individuals. Despite these impediments, data from improvement programs with fish and several crustacean species indicate that there is potential for rapid genetic gain, with responses to selection of over 10% per generation possible. Problems with breeding program design for crustaceans are discussed.
Keywords: Crustaceans, breeding programs, response to selection.

INTRODUCTION

Worldwide declines from capture fisheries over the past two decades have stimulated increased participation in aquaculture. Since 1990, production levels from aquaculture have steadily increased by around 10% per year, with most of this increased production coming from countries such as China, Russia, Israel and the United States (FAO website). Associated with the growth of aquaculture industries comes the opportunity to increase production through genetic improvement. Most of the larger finfish (ie Atlantic salmon, channel catfish and tilapia) and mollusc (ie oysters) aquaculture industries have embraced genetic improvement programs as a way of boosting productivity. However, the application of breeding technologies to crustacean aquaculture species has been slow. This paper outlines the problems that exist in the design of breeding programs for crustaceans compared with those involving fish and highlights the opportunities available for genetic improvement of traits such as growth rate.

Lessons from fish genetic improvement programs. Breeding programs with fish have highlighted the potential existing for genetic improvement, with genetic increases in growth rate of between 10-20% per generation achieved in many species (Gjedrem 1997). However, before successful breeding programs for fish were achieved individual fish industries had to develop to a stage of maturity where sufficient knowledge of the husbandry of the target species was developed and to a size where the necessary and substantial infrastructure investment could be supported. For example, reproductive biology and husbandry practices for Atlantic salmon were well known when farming of this species first began. However, it took another ten years to develop the infrastructure and knowledge to warrant the instigation of a genetic improvement program (Gjedrem 1997).

After industry accepted that increased production would be gained through selection, breeding objectives identifying the biological traits influencing productivity were defined. Genetic parameters for each of the traits defined in the breeding objective, and potentially useful as selection criteria, were then estimated. For example, growth rate and age at sexual maturity were identified as traits that substantially influence productivity in Atlantic salmon, while heritability estimates indicated genetic improvement could be achieved if these traits were used as selection criteria (Gjerde 1986). Only once breeding objectives were defined and genetic parameters estimated, were breeding programs in fish instigated. These programs were often started with government support.

Development of crustacean genetic improvement programs. Factors limiting the instigation of improvement programs in crustaceans are as follows:

Maturity of industries. Although some crustacean species have been farmed for over twenty years (ie prawns, yabbies), few have reached a stage of industry maturity where genetic improvement programs are seen as a high priority. Most industries are still small and in the development stage. In addition, crustacean aquaculture is commonly fragmented, with little co-operation among farmers at the operational level. Consequently, the industries cannot support the substantial costs associated with developing and conducting successful breeding programs.

Domestication. One of the most important prerequisites for inclusion of any new species in a genetic improvement program is that the lifecycle is closed sufficiently to allow progeny to be bred. Many commercially important crustacean species such as prawns, lobsters and mudcrabs have very complex lifecycles that involve several larval stages, with each stage requiring different rearing conditions. Moreover, many species will not breed in captivity due to imprecise environmental cues, or stress related factors. As a consequence, current aquaculture practices in these species are based on the harvest of wild pre-mated broodstock, or stocking commercial ponds with wild juveniles. The application of genetic improvement programs to these crustacean species is not feasible until domestication occurs. Encouragingly, recent breakthroughs in the reproductive husbandry of several prawn species appear likely to remove this impediment (N. Preston, *pers.comm*).

Definition of breeding objectives. Henryon *et al.* (1999) highlighted the importance of defining breeding objectives for commercial production of the freshwater marron *Cherax tenuimanus*. In that study increases in traits such as growth rate and survival of juveniles were demonstrated to significantly increase overall profitability of marron culture. Improvements in other traits such as growth rate of broodstock and growth rate of the claws decreased profitability. This type of analysis immediately allows long-term breeding goals to be set and predicts what the economic outcome may be if market preferences change in the future. However, the problem with setting breeding objectives in most crustaceans is that information on the relative economic importance of production traits is limited, or unavailable. Most crustaceans are sold as whole animals and their market price is significantly determined by non-genetic factors such as visual appearance (ie degree of shell fouling; loss of limbs). For instance, there appears to be little market information on how a consumer would accept a freshwater crayfish that has more meat in its claw. Until this information is obtained through comprehensive market surveys, reliable estimates of economic parameters remain unavailable. The consequence of not having these estimates at the start of a breeding program for crustaceans is that simple objectives such as body weight, or age at reproductive maturity, will often be the sole goals for improvement programs.

Genetic parameter estimates. Reliable estimates of genetic parameters are essential to the design and conduct of improvement programs. However, obtaining accurate genetic parameter sets in crustaceans, poses a particular problem for researchers. Crustaceans grow by moulting their exoskeleton. This means that crustaceans throughout the moulting process do not retain the external identification tags routinely used to identify fish and molluscs. Several internal markers are available (ie elastomer dyes, numbered tags, passive transponders), however, they cannot be utilized if the breeding program is run in conjunction with commercial farming, as insertion of tags makes the end product unsaleable. Since crustaceans do not retain their identity when reared communally, the establishment of complex facilities that allow family lines to be maintained separately are required. Such facilities complicate parameter estimation due to confounding of tank and maternal effects. It is particularly difficult to obtain animal model estimates or half-sib family genetic variances. As a consequence, published estimates of the heritability of traits tend to be based on variation among full-sib families and are upwardly biased due to maternal effects. Unless technologies are utilized that permit individuals to be identified when reared communally (i.e. elastomer tags, DNA pedigrees) the researcher has to accept that genetic parameter estimates will be biased by maternal and/or environmental effects, or wait to obtain estimates from an actual selection program.

Expected responses to selection. The few examples where genetic parameters have been estimated for crustaceans, and where selective breeding trials have been performed, have established that response to selection for growth rate was high. Jones *et al*. (2000), in an improvement program for redclaw (*Cherax quadricarinatus*) achieved a response to selection of 9.5% per generation. Likewise, Hetzel *et al*. (2000) demonstrated an average direct response to one generation of selection in high and low growth lines in the Kuruma prawn of 10.7%. When viewed in conjunction with the high rates of genetic progress so far achieved in most fish and molluscs, it is possible that responses to selection for growth rate of around 10% per generation are achievable for crustaceans.

There are several reasons why a high response to selection for growth rate can be expected in crustaceans. Crustaceans demonstrate large phenotypic variances for growth. For example, *Penaeus japonicus* males in tank experiments exhibit coefficients of variation for growth rate of around 60% (Hetzel *et al*. 2000). Similar coefficients of variation in growth are observed within family lines of the freshwater yabby (*Cherax destructor*) (D. R. Jerry *et al.* unpublished data). Secondly, generation intervals in many crustacean species (ie prawns, redclaw, yabbies) are a year or less. This permits the annual response to selection to be maximised. However, the major contributing factor to achieving high rates of response to selection in crustaceans and other aquaculture species is linked to their fecundity. Most species have large numbers of offspring. This may range from a few hundred progeny in Australian freshwater crayfish, to tens of thousands in prawns. This permits extreme selection intensities to be applied facilitating the total response to selection.

Breeding program designs for crustaceans. Inability to reliably identify individual crustaceans poses difficulties in designing breeding programs. This is particularly so where industry is involved and the non-selected individuals are to be sold. In most instances, family selection will not be feasible unless individual families are caged, or DNA pedigreeing technology applied. This will require complex and large infrastructure and is not practical on a medium sized commercial farm. Consequently, individual or mass selection will be the most realistic alternative. Due to its simplicity, mass selection is often perceived as inferior to family selection. However, the opposite is often true if the trait exhibits moderate heritability (eg, as for growth rate) (Falconer and Mackay 1996). The major disadvantage of mass selection over within-family selection in crustacean improvement programs is that it is particularly hard to control the rate of inbreeding due to an inability to obtain pedigree information. The ability to control inbreeding is especially pertinent to selection programs involving highly fecund species like prawns, where upwards of 100,000 larvae can be reared from a single female spawning. If several family lines have exceptional genetic merit for the trait under selection, then the top performing animals selected to act as the next generation's broodstock may actually be derived from only a few sire-dam matings. This will result in a significant reduction in effective population size and increase the rate of inbreeding to unacceptable levels. Therefore, breeding programs with crustaceans that exhibit high fecundity need to ensure that adequate numbers of families are represented in each round of selection.

CONCLUSION

Although the application of breeding technologies to crustaceans has been rare, responses to selection for growth rate of 10% per generation in other aquaculture species highlight the potential for genetic improvement. The trials to date on crustacean species appear to agree with these estimates. However, before genetic improvement programs in crustaceans become common place each species will have to be domesticated, the traits affecting productivity identified, breeding objectives defined and genetic parameters estimated.

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