THE POTENTIAL FOR AQUACULTURE OF CHERAX destructor (THE YABBIE).

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SUMMARY .

The current increased 'public interest in freshwater crayfish was 'highlighted. The Cherax genus was discussed in terms of its taxonomy and geographic distribution and the required characteristics of a cultured organism considered in relation to Cherax destructor. Aquacul-'ture facilities available at 'Hawkesbury Agricultural College were described. The marketability of Cherax destructor was considered and compared with marine crustaceans. Results of investigations of the sensory characteristics and yield of different portions of Cherax destructor were presented. The yield of edible meat and crustacean flavour of Cherax destructor were found to be less than in prawns.

The resistance of crayfish to pollution and disease was considered. 'It was noted that Cherax destructor is relatively free of disease. It is adapted to a wide range of habitats but does not tolerate many types of pollutants. The ease of breeding and rearing of. the crayfish larvae was discussed and a number of experiments conducted at Hawkesbury Agricultural College considered. These indicated the importance of water temperatures above 20°C for controlled breeding during the winter months and suggested the need for daylength control as well.

A trial investigating the nutritional value of four formulated feeds was described which resulted in an average increase in individual weight (on a meat meal based diet) of 17.4 g over a 15 week period. Other experiments investigating the effect of the type of bottom substrate and the presence or absence of shelters on the survivability of juvenile crayfish were described. The use of shelters and a sand bottom were advocated.

A summary of several investigations on growth. rate was given indicating that, growth was optimal above 20°C and a feed conversion efficiency of 2.8 : 1 or better, could be expected for animals on 'pelleted feed.

Recommendations were made for lighting, temperature, bottom substrate, filtration system, shelters, water quality, stocking density, mating ratio, selection methods, nutrition annd control of predation.

It was concluded that there were a number of problems that needed to be resolved before' the farming potential of Cherax destructor could be fully realised.

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I. INTRODUCTION

"It appears probable 'that as the population of Australia increases, the freshwater crayfish might assume as much importance as an article of food as the lobster in America and England.

It would probably be practical to farm these animals artificially in ponds. Much work would have to be done upon the habits, food, rate of growth etc, before the undertaking could be placed upon a practical footing, but the enquiry would be well worth undertaking". (Smith 1911).

Inspite of this' early observation on the farming potential of freshwater crayfish, very little progress has in fact 'been made. Presently the crayfish is experiencing a marked revival of interest by many members of the community. Hawkesbury Agricultural College has some 500 names and addresses of people who have made enquiries about crayfish and 170 people have attended the 2 weekend schools on Freshwater crayfish conducted at the College in 1979 and 1980. One must ask the question "is this interest misplaced or do crayfish in fact have a potential for farming." The answer to this question depends upon several factors including the characteristics of the crayfish being considered.

All crayfish belong to the Class CRUSTACEA Order DECAPODA and fre'shwater crayfish to the Super Family ASTACOIDEA. There are three families, two of which occur in the northern hemisphere (Cambaridae and Astacidae) and one which occurs in Australia and other areas of the southern hemisphere (Parastacidae) (Riek 1969).

It is members of the former two families which are eaten with great relish. by Europeans (particularly the Scandinavians) and by Americans and about which most of the available information is published.

Australia and America have the greatest diversity of freshwater crayfish, while the tropics from 10 degrees north latitude to 10 degrees south, are devoid of freshwater crayfish, as is the African continent.

There are,, according to Riek (1969), nine different genera in Australia containing 97 different species, though many. biologists argue that some of these species are. variants' within the one species. The distribution of these species is indicated in table 1.

Some of the Australian' freshwater crayfish are very large, reaching lengths of 40cm or more and liveweights of two to three kilograms. Astacopsis gouldi is the largest in the world, a fact which will probably ensure its extinction as it is hunted by gourmets who are ignorant of its' very slow growth rate and very specific environmental requirements.

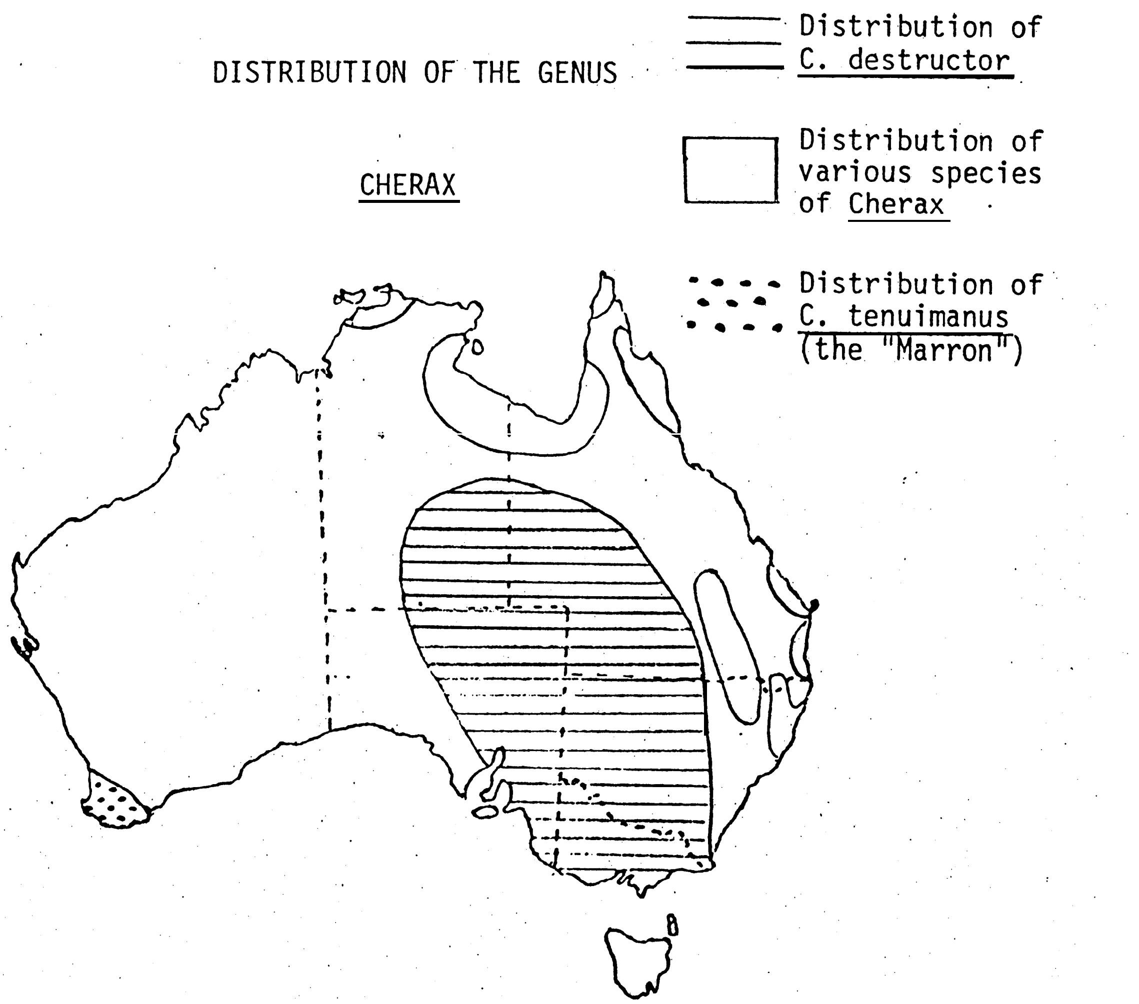
The genus Euastacus also contains some large specimens of which Euastacus armatus (the "Murray river lobster") is probably the best known. Members of this genus are very spiny and in the main prefer cool running water.. Although a 'large. animal with excellent flavour, the edible portions (tail and' chelae) are small in proportion to the overall size and meat yield is low.

TABLE I The distribution of the species of freshwater crayfish among the Nine Australian genera with indication of their location and size according to Riek (1969)

FAMILY	GENUS	SPECIES	OCCURRENCE	SIZE
Parastacidae	Engaeus	(23)	S. N.S.W., Vic., Tas.	2.5 - 8cm
	Tenuibranchiurus	glypticus	Qld.	2 - 2.5cm
	Engaewa	(2)	W.A.	Up to 4cm
	Geocharax	(2)	Vic., King I., Tas.	Up to 8.5cm
	Parastacoides	(6)	Tas.	Up to 6cm
	Euastacus	(27)	Vic., N.S.W., Qld.	6.3 to 30cm +
	Euastacoides	(3)	Qld.	Up to 7cm
	Astacopsis	(4)	Tas.	6 to 40cm
	Cherax	(27)	W.A., N.T., Qld, N.S.W., Vic., S.A.	6 to 40cm

The genus with the widest distribution and hence whose members are most commonly referred to as the "yabbie" is Cherax. Riek (1969) described 27 different species in this genus but the two of greatest importance are Cherax tenuimanus and Cherax destructor. The former,' commonly known as the Marron, only occurs in the south-western portion of Western Australia. It is the third largest crayfish in Australia reaching 38cm in length and attaining weights of 2 - 2.5kg. Cherax destructor has the widest distribution of all species of' Australian crayfish indicating its ability to adapt to a wide range of environ--mental conditions and habitats. It is found in South Australia, Victoria, New South Wales, Western Queensland and the Northern Territory where it not only occurs in natural streams and ponds, but is a frequent inhabitant of farm dams, 'bore-drains and irrigation canals.

MAP 1 Distribution of the genus Cherax in Australia according to Riek (1969)



The distribution boundaries in the above map should only be taken as a rough guide. Johnson (1978) indicated that the best natural crayfisheries in N.S.W. occurred in the Western districts of Buronga, Menindee, Balranald, Bourke and Condobolin. This crayfish has a smooth shell or' exoskeleton which may be one of a variety of colours ranging from greenish black, brown, browny green, browny red to blue and almost white. It is this colour variation which frequently causes speculation of a different species. The adult crayfish may be. 16cm long and weigh up to 280 gms though a more common weight is 60 to 100 gm.

There are a number of factors which must be considered when attempting to answer the question of the suitability of crayfish for 'farming.

Bardach et al (1972) described the desirable characteristics of a cultured organism which may be summarised 'as follows:-

(i) it must be marketable
('ii) it must be resistant to, pollution and disease
(iii) it must breed easily in captivity
(iv) its eggs and' larvae must be hardy and easy to culture
(v) it should be low on 'the food chain
(vi) it must be adaptable to crowding
(vii) it should have a rapid growth rate

The rest of this paper will discuss each of these characteristics in turn as they relate to Cherax destructor, citing investigations carried out at Hawkesbury Agricultural College. Participants at this school should understand that these investigations, normally of only one semester's duration, have in the main been conducted by undergraduate students while fulfilling their course requirements.

(a) Aquaculture facilities

Facilities available at Hawkesbury Agricultural College for these and other aquaculture projects include:

(i) A Fish laboratory which is air-conditioned to a maximum 20°C and contains some 60 aquaria ranging from"5 - 900 litre capacity. Power, water and compressed air lines are available at all points. in the laboratory. There is ample bench space for the use of the various pieces of equipment including a top-pan electronic balance, pH meters, Oxygen meter, thermistor thermometer, Hach Water Test Kits (spectrometer and smaller),, binocular microscope, etc.

(ii) Immediately outside the laboratory there are 15 x 10,000 l circular fish tanks which have access to air, water and power supplies and which are in a bird proof enclosure.

(iii) Other outside facilities include 2 crayfish ponds of 1,000 Kl capacity and several farm dams which range in size from 55 - 90 Ml. These are scattered over the 1,400 ha property of the College.

II. OBSERVATIONS AND DISCUSSION

(a) Marketability

Crustaceans in general supply some of the most sort after and expensive gourmet meats in the-world. The demand exceeds the supply and is increasing steadily. This is- reflected in the high prices which Australians pay for such food e.g. N.S.W. Fish Market prices in October 1979:-

School Prawns (cooked)	$3.72/kg
King Prawns (cooked)	$7.88/kg
Crabs (green)	$5.36/kg
Lobsters (cooked)	$10.87/kg

(Australian Fisheries 39; 57. 1980)

Some 77 percent of Australia's fish export earnings come from the export of crustaceans (chiefly lobsters and prawns) (Australian Fisheries 38; 52. 1979). A total of 21,500 tonnes of prawns were caught in Australia in 1978-9. Overseas prices for crustaceans are as high or higher, even in developing countries. For example in the Philippines the price of prawns was in the range of A$6 to A$10.20 per kilogram in 1979 (Carroll 1980).

The question is, can freshwater crayfish enjoy a similar demand and price structure? At present the availability of freshwater crayfish is very limited, small quantities trickling in to the Melbourne and Sydney Fish Markets during the summer months. These are usually live, poorly packed and of very variable quality. They are supplied by a number of mainly part-time fisherman from a variety of sources, and normally arrive by train packed in 20 to 30 kg lots in hessian bags.

The small demand comes mostly from a handful of restauranteurs (chiefly french) and is easily saturated. The great bulk of the Australian public have neither seen nor tasted freshwater crayfish and certainly are not aware of their occasional availability at the markets. Under these conditions the market price in Sydney has ranged between $4 and $5/kg (Ruello, personal communication) and in Melbourne between $2.20 and $6.60/kg (Mortimer, personal communication) during 1979-80.

Mr A. F. D'Mello* of Hawkesbury Agricultural College carried out taste testing programmes during both the 1979 and 1980 Freshwater Crayfish Schools. The first programme compared banana prawn meat with crayfish tail meat. No salt was used and cooking was standardised. One hundred panelists were involved. They were asked to rate the intensity of crustacean flavour using a 1 to 5 score where 5 indicated a very strong crustacean flavour and 1 an absence of such a flavour.

TABLE II Crustacean flavour of prawn and freshwater crayfish meat (Cherax destructor) as rated by 100 panelists in a taste test programme conducted by Mr A. F. D'Mello at Hawkesbury Agricultural College

CRUSTACEAN TASTE SCORE	1	2	3	4	5
	Percentage of Panelists				
FRESHWATER CRAYFISH	26	40	17	28	1
BANANA PRAWN	0	6	15	40	30

Quite clearly the freshwater crayfish used in this test were much milder in flavour than salt water prawns. The latter were also rated as having a firmer texture.. A subsequent taste testing pro-

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gramme comparing the tail meat of freshwater crayfish with meat from the chelae (claw) indicated that the latter may be quite strong in crustacean flavour and differed significantly from the tail meat.

Another taste test during the 1980 Freshwater Crayfish School used 70 panelists to establish a sensory profile for freshwater crayfish of the species Cherax destructor.

TABLE III Sensory. profile of the cooked meat of cherax destructor as determined. by a taste testing programme conducted by Mr A. F. D'Mello at Hawkesbury Agricultural College

SENSORY CHARACTERISTICS	SCORES 5	4	3	2	1	
Colour - Bright orange red	-	-	T C	-	-	Pale, dull
Odour - Strong crustacean odour	-	T	-	C	-	Weak crustacean odour
Flavours - Prawn flavour strong			T	C	-	Weak prawn flavour
lobster/crayfish flavour strong			C T	-	-	Weak lobster/crayfish flav.
Crablike flavour strong	-	-	C	T	-	Weak crab flav.
Texture - Moist	-	-	C T	-	-	Dry
Smooth		-	T	C	-	Crumbly
Firm/elastic		T	-	C	-	Soft

C = claw meat
T = Tail meat

The author recently carried out tests on the yield of marketable and edible portions of 54 specimens of Cherax destructor obtained live from Bourke in western N.S.W. The resulting yields are indicated in Table IV. Crayfish portions were cooked individually for a standard time (10 minutes) in 2% saline.

TABLE IV Yield of different portions of Cherax destructor in both the raw and cooked state. Average body weight 27.2 ± 8.5g

WHOLE ANIMAL PORTION	PERCENT OF WHOLE ANIMAL (UNFROZEN)
Whole Frozen	100.46
Whole Thawed	100.00
Chelae + arm	24.0
Chelae only	15.1
Tail	31.5
Head/Thorax/legs(i.e. waste)	44.5
Cooked Claw meat	4.5
Cooked Arm meat	0.9
Cooked Tail Meat	15.00
TOTAL COOKED MEAT	20.4

The proportion of edible meat (average 20.4%) from the freshwater crayfish Cherax destructor compares with 28 - 37% from' the 'prawns. The freshwater crayfish would appear to yield some 27 - 56% less edible portion than the prawn.

While this evidence might appear to put freshwater crayfish at a disadvantage compared to prawns and other' marine- crustaceans, many people who have eaten both under normal dining conditions, prefer the flavour and texture of the freshwater crayfish.

The Europeans have indicated their appreciation of' freshwater crayfish by paying. as much as $17 to $25 per kilogram in Sweden and France (Karlsson 1977) and $10.50 per kilogram in the United Kingdom (Richards and Fuke '1977). Freshwater crayfish are farmed in Europe but Sweden needs to import 2000 tonnes per year from Rumania and Turkey, to meet the demand.

By comparison, Australia's maximum recorded production to 197.9 'was approximately 300 tonnes caught from natural fisheries in 1973-4. Since that time 'there has been a steady decline' in production, most likely due to drought conditions which. have afflicted many of the natural production areas. Very little, if any of this production has come from crayfish farms. It is very difficult to obtain reliable information on the number of farms attempting to produce crayfish in Australia. Crayfish farming (Marron) was legalised in Western Australia in 1976. In New South Wales there were 17 licenced warm water-fish-farms (including 5 nominally for crayfish) registered with N.S.W. State Fisheries in 1979.

It should not be overlooked that crayfish are a valuable bait sought after by fishermen, and that the supply of bait could be an important part of the industry. In Melbourne they are worth 15c each as bait (Mortimer, personal communication). The export of crayfish to European markets is another possibility, though the requirement for a very high quality product, usually the intact animal, and the cost of packaging and. transport will create difficulties in establishing and maintaining this market outlet.

The size. of crayfish required varies with the market. A whole animal' weight of approximately 45g is preferred by the Swedes whereas larger animals of 60 - 100g or more are sought by Australian's and Americans.

The conclusion that can be made is that though the present local market is very small and specialised, it could, with appropriate market development, be expanded to support a moderately large local Industry. Intending. crayfish.' farmers would have to support this market with a reliable supply of a high quality product.. This could probably only be achieved by some form of cooperative development between intending producers, processors and marketeers.

(b) Resistance to pollution and disease,

The Australian freshwater crayfish would seem to be relatively free of disease. There 'have been no reports of the fungal disease Aphanomyces Astaci-schikora which is indigenous to the American continent and which has decimated the European crayfish to such an extent that areas are being repopulated with imported species from America (e.g. Orconectes' limosus and Pacifastacus leniusculus) which are resistant to this disease (Karlsson 1977)

There have been reports of a microsporidian parasite (Thelohania sp.) which parasitises the tail musculature and may become a problem when high densities of crayfish occur (Australian Fisheries 1978). A careful watch will need to be kept for this disease in any farming operation.

Infections with the common fungus, Saprolegnia sp, may occur if the water becomes highly polluted with organic matter. It primarily attacks sick or wounded animals, eggs & juvenile crayfish.

There is a flat worm, a commensal parasite (Temnocephala sp.), which is frequently found on crayfish caught in the wild. This parasite may cause mechanical interference with respiration when it lays its eggs in high densities on the gills. This organism does not appear to be a problem under culture conditions when water quality is controlled.

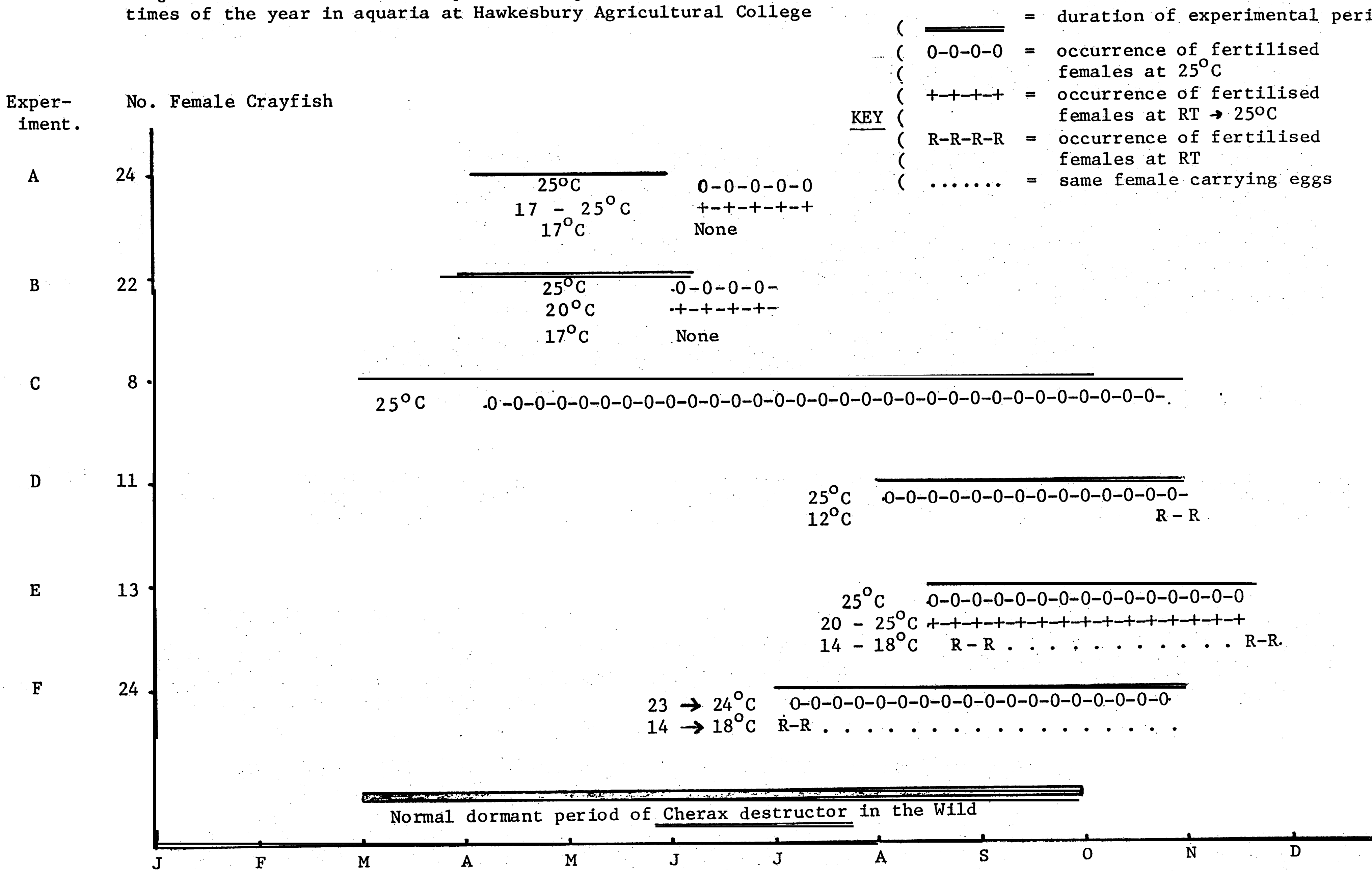
Freshwater crayfish are very susceptible to pollution of the water with chlorinated hydrocarbons (pesticides such as DDT or Dieldrin), oil and other petroleum products, creosote and heavy metals such as zinc and cadmium (South Australian Department of Agriculture and Fisheries, 1977).

Adult specimens of Cherax destructor would appear to be tolerant of very low levels of dissolved oxygen, frequently being found alive in water with a dissolved oxygen content of 0.5 mg/l. However experience at Hawkesbury Agricultural College has indicated that this tolerance to low oxygen level's is not shared by either the eggs or young crayfish. High mortalities to both of these have occurred when dissolved oxygen has been allowed to fall to low levels, with no apparent effect on adults present. There is a need for a proper study to be made on the oxygen requirements of crayfish eggs and young. In the meantime it is recommended that oxygen levels be maintained above 4mg/l in the breeding and nursery ponds or tanks.

(c) Ease of breeding and rearing of larvae

The normal, breeding of Cherax destructor in the wild is seasonal, with a peak in summer and no breeding in the winter months when these animals appear to hibernate. There is considerable variation between districts in the length of the growing and the breeding season (Johnson 1978). The water temperature would appear to be the critical factor controlling breeding. A number of experiments have been conducted at Hawkesbury Agricultural College since 1976 which investigated the effect of temperature on the breeding of Cherax destructor. All the experiments were conducted in 320 l glass aquaria with a floor area of 0.74m^2. The water was constantly filtered through a bottom-sand-bed filter using air-lift pumps to move the water; When required, the water was heated using 200W, thermostatically controlled, fish-tank heaters. Stocking density was commenced at six females and two males per tank. A total of 102 female crayfish have been used in six experiments. The treatments (in duplicate) were; water at room temperature, water at 25°C and water temperature varying between room temperature and 25°C. "Room temperature" was never above 20°C but in the winter months fell to a minimum of 11.0°C. For a summary of the results see Graph I.

GRAPH I Pattern of reproductive activity of female *Cherax destructor* subject to different water-temperature regimes at different times of the year in aquaria at Hawkesbury Agricultural College



. When the water temperature was falling and below 17°C, there was no breeding activity. A rising temperature and warmer temperatures stimulated gonadal development and general activity, see Table V.

TABLE V Effect of water temperature on the gonadal development of Cherax destructor over a period of 9 weeks in late Autumn (April, May, June)

WATER TEMPERATURE	17°C	17 - 25°C	25°C
COLOUR OF OVARIES	Pearly white	- dark aqua-blue-	
SIZE OF OVA	1 mm	2mm	2mm
OVARY WEIGHT AS % OF BODYWEIGHT	1.81%	3.58%	3.84%

Several weeks of treatment at elevated water temperatures were usually required before sexual activity (indicated by the occurrence of berried females i.e. females with eggs under the tail) was observed when experiments were commenced in March or April. However when experiments commenced in July or August, berried females were observed within' a few days. It is suggested that this was due primarily to the effect of rising water' temperatures, but that daylength patterns probably effect the rate of response to these changes to water temperature. An experiment using controlled daylength patterns is currently being conducted to investigate this effect.

Temperature markedly effects the rate of development of the eggs after fertilization, the size of the young at hatching, their subsequent growth rate, and the interval between egg production: An example of these effects is shown in Table VI.

TABLE VI Effect of Water temperature on the period of "berrying", the number of young produced and the weight of the young at the free swimming stage.

WATER TEMPERATURE	No. of females in sample *	Average length of berrying (days)	Average number of young produced /female	Average weight of young (g)
11.5°C rising	2	> 76	404	0.07
Varying 20 - 25°C	4	34	214	0.11
Constant 25°C	8	40	213	0.10

*20 - 45g weight

The higher water temperatures resulted in a greater number of "berried females, and a reduction in the incubation period by at least 50%. The apparent smaller number of young produced per batch at higher temperatures, was due to some problems with fungal attack on incubating eggs. The actual number of eggs produced per female averaged 450 but this varied considerably with the size of the female. The larger the female the greater the number of eggs she is, likely to carry. Females have become berried in their first year of life, at weights of, as little as 18g (length 7.5cm). The number of eggs at this weight is small (30 to 100).

Temperature also appears to have a marked effect on the "rest" interval between berryings and on the number of times an individual female becomes berried in a given period. This is indicated by the data described in Table VII.

TABLE VII The effect of water temperature on the interval between "berryings" and the occurrence of multiple berrying.

WATER TEMPERATURE	Average time interval between berryings (days)	Percent of females with eggs Overall	Twice	Thrice
11.5°C rising	87*	67	0	0
Varying 20 - 25°C	42	75	20	20
Constant 25°C	56	67	20	0

*berried in previous experiment.

In an earlier experiment in a constant water temperature of 25°C, the average interval between berryings was 60 days. Eighty, eight percent of the females were berried at least once during the-8 month period (March to November), 25% were berried three. times 'and '12% were berried four times. One female became berried again only 25 days after the release of her former batch.

There is considerable evidence that elevating the water temperature in the winter months, results in out-of-season breeding of Cherax destructor. Experiments need to be conducted on the effect of eye-stalk ablation on reproduction, as is commonly practised with the breeding of marine prawns in captivity. Development of controlled breeding programmes will be of great benefit to intensive crayfish-farming operations.

(d) Nutrition

Freshwater crayfish are essentially detritus feeders (Morrissy 1979) though they can be fed a wide range of material including grass, vegetables , grain, animal feed pellets, animal manure and fresh meat. There is very little published work on the nutrition of freshwater crayfish and there is a great need for studies in this area (Maguire 1980).

In 1978 an experiment was conducted- at Hawkesbury Agricultural College comparing formulated feeds made up 'with different sources'. of protein. Five treatments were run in triplicate over a 26 week period between May and October. The treatments were allotted at random in small ponds located- outside the building. Stocking density was seven per square metre. The five diets were:-

Natural feed
Ewos trout pellets
Soybean meal based diet
Fishmeal based diet
Meatmeal based diet

All diets except "natural feed" had a crude protein content of approximately 36%. The formulae of the diets made up at the College are shown in Table VIII. Prawnhead meal was included to act as an attractant.

TABLE VIII Formulae of crayfish diets tested at Hawkesbury Agricultural College.

DIET	INGREDIENT	INCLUSION RATE %
"FISHMEAL" DIET	Fishmeal	30
	Prawnhead meal	5
	Egg powder	3
	Wheat Bran	17
	Glucose	4
	Ground corn	10
	Torula yeast	5
	Wheat pollard	20
	Premix	1
	Gelatine	5
"SOYBEAN MEAL" DIET	Soybean meal	46
	Prawnhead meal	5
	Wheat flour	10
	Ground corn	26
	Brewers yeast	5
	Tricalcium phosphate	2
	Premix	1
	Gelatine	5
"MEATMEAL" DIET	Meatmeal	50
	Prawnhead meal	5
	Wheat flour	20
	Ground corn	17.6
	Iodised salt	0.4
	Premix	1
	Gelatine	5
		g/kg
PREMIX	p-aminobenzoic acid	1.5
	Biotin	0.05
	Inositol	7.5
	Nicotinic acid	10.0
	Calcium pantothenate	2.5
	Pyridoxine	0.75
	Riboflavin	1.25
	Thiamine	0.5
	Vitamin A	0.2
	Vitamin K	0.75
	Vitamin E	0.5
	Vitamin B_{12}	0.01
	Vitamin D_3	0.6
	Vitamin C	0.4
	Folic acid	0.2
	Choline chloride	15.0
	Ethoxyquin	6.0

The diets were fed at two rates; 10% of bodyweight per week during the winter months when water temperatures were below 16°C, and 20% of body weight when the water temperatures had increased above 16°C. Very little growth occurred at water temperatures below 16°C so that the effective duration of the experiment was only 15 weeks. The average weight increase per animal in each treatment is shown in Table VIX.

TABLE VIX Growth rate and feed. conversion ratio of crayfish fed five different diets. Initial weight approximately five grams.

DIET	Average weight increase g	Feed Conversion ratio
Fishmeal	12.64	2.6
Soybean meal	14.86	2.65
Meatmeal	16.29	2.3
Ewos	11.02	2.8
Natural feed	1.25	--

The only significant differences in weight increase (at the 5% level) were between soybean meal and meatmeal and between natural feed and the rest.

The maximum growth exhibited by any single animal during the trial was 23.2g and by any single replicate was 17.4g average. (both on meatmeal diet).. Some problems. were encountered with poor stability of the pellets, especially with the fishmeal and soybean diets. A more suitable binder than gelatine needs to be used.

Formulated diets for aquatic organisms are very expensive e.g. the above diets cost in the vicinity of $400 per tonne. It would be imperative to develop efficient farming systems for <u>Cherax destructor</u> before the use of such high cost feeds would be economic. Alternative, cheaper feeding-systems need to be developed to enable this industry to become established.

(e) <u>Adaptability to crowding</u>

Cannibalism is a constant problem with freshwater crayfish and perhaps is the greatest factor to be controlled before. successful farming of these animals can occur.

Observations at the College, indicate that. stocking density and temperature are not the only factors affecting this problem. Experience has shown that a stocking density for large animals. of 11 per square metre is normally permissable in the glass aquaria. However some tanks will contain "rogue" crayfish which will continue to cannibalise their, fellows until they themselves are removed. Other tank populations, under identical conditions, will remain static for months. It would appear that it may be worthwhile to select the more docile animals for breeding purposes.

An experiment investigating the type of substrate and the presence or absence of shelters, indicated that maximum growth rates and survivability were obtained with shelters (beer cans) on a sand bottom. The survival rates (at a stocking density of 175/m^2 and an average starting weight of 0.05g over a period of 11 weeks) are shown in Table X. High turbidity in the tanks with a dirt bottom appeared to reduce the need for shelters but made it more difficult to monitor water quality.,

TABLE X Effect of substrate and shelter on the survivability, over a 11 week period', of small Cherax destructor stocked in aquaria at a density of $175/m^2$.

SHELTER	PERCENTAGE SURVIVABILITY BOTTOM SUBSTRATE DIRT	SAND	GLASS	PLASTIC
Lengths of 2.5cm diam. PVC pipe	67%	100%	83%	50%
None	80%	60%	80%	40%

A subsequent experiment using only sand as the bottom substrate resulted in an average survival of 99.6% in tanks with shelter and 77.7% in tanks without. shelter. The stocking rate was 133 juvenile crayfish per square metre and the trial was conducted over a 7 week period. Water temperatures were $17^{o}C$.

An experiment is currently being conducted to investigate the effects of muitiple-storey shelters, similar to those used for crab farming in the Philippines, on survivability at high stocking densities. The stocking densities are $54/m^2$ of animals weighing two to four grams. Results to date indicate that the animals are using all levels of the multi-storey shelter.

Morrissy (1979) achieved overall survival rates in -his ponds stocked with Cherax tenuimanus (up to, $15/m^2$) of 80.5%. over a four month period, using shelters of rope-fibre or lengths of PVC pipe.

(f) Rapid growth rate

The growth rate of Cherax destructor is particularly influenced by water' temperature and nutrition but also by other factors such as bottom substrate, shelter. and stocking density. It is difficult to find definitive reports on the growth rates of this animal and estimates of the time taken to grow an animal to a marketable size vary between one and three years. Clearly, if the animal. is to be farmed successfully, the growth rate should be as rapid as possible.

Results obtained at the College indicate that there is' very little growth of Cherax destructor 'at water temperatures below $16^{o}C$. Frost (1973) reported that this species begins to aestivate when temperatures fall below this temperature. Morrissy (1976)' reported $12^{o}C$ as being the 'lower temperature limit for growth of Cherax tenuimanus. It. would therefore be imperative to select a site for farming these animals where' the water. temperature remains above $16^{o}C$ for as much of the year 'as possible.

As reported earlier in section (d) the maximum growth rate of a single animal over an effective 15 week growing period (i.e. water temperature above $16^{o}C$) obtained at the College was 23.2g, and the average for a group of animals was' 17.4 ± 4.0g (initial weight 6.4 ±

1.8g and final weight 23.8 ± 2.9g). Morrissy (1979) reported a growthrate for Cherax tenuimanus of 45g in 12 months and 120 g in two years. This would appear to indicate that Cherax destructor has a similar rate of growth to Cherax tenuimanus in the first year.

Growth trials with Cherax destructor conducted at the College, were normally only a few weeks in length. The results of several trials conducted with different sized animals, fed on a variety of feeds, in water at various temperatures, are summarised in Table XI.

These results suggest that crayfish growth rates are optimal'in water temperatures above 20°C when feed conversion efficiencies of the order of 2.8:1 or better, could be expected. A growth rate equivalent. to approximately 8% of the initial weight per week could be expected for crayfish with an initial weight between 10 - 30g. At smaller initial weights the growth rate is much faster and at larger initial weights it is slower.

(g) Recommendation

. Very little is really known about the habits and requirements of Cherax 'destructor. The current upsurge of public. interest in this animal makes it very easy for anyone with a little experience to become regarded as an expert. It is with this thought in mind that the following tentative recommendations and suggestions are made for the breeding and growing of the yabby.

(i) Lighting

It may be desirable to expose breeding crayfish to a constant or increasing daylength to ensure successful breeding in the winter months. The intensity of the light should perhaps be dim to simulate conditions at the bottom of a -muddy pond and to reduce agonistic behaviour.

(ii) Temperature

Water temperatures should be above 20°C and rising to 25°C in the breeding tanks. There is some evidence that a fluctuating temperature between 20 - -25°C may be more effective in inducing reproduction than a constant temperature of 25°C.

(iii) Bottom substrate .

Sand would appear 'to be the most desirable substrate in tanks used for controlled breeding, facilitating easier water management and self cleansing of the tank.

(iv) Filtration

Water in the breeding tanks should be' circulated through the sand filtration-bed on the bottom of the tank, using air-lift pumps to move the water through the system. This aids in the removal of organic matter from the environment of the crayfish, maintains oxygen levels and reduces the risk of fungal attack on eggs and juveniles.

TABLE XI Summary of trials on the growth rate of <u>Cherax destructor</u> conducted at Hawkesbury Agricultural College under a variety of conditions.

Water Temperature °C	No of crayfish[e] in trial	Type of Feed	FCR	Average initial weight g	Average final weight g	Average weight increase g	Percentage weight increase	Length of trial weeks
12.4 - 12.8	820[f]	Natural (in dam)	-	0.111	0.83[a]	0.719	648	6
11 - 20	10	Commercial[b] crayfish pellets	3.5	12.3	14.6	2.3	18.7	4
16 - 24	15	Meatmeal[b] based diet	2.3	6.4	23.8	17.4	272	15
17 - 20	4	Turkey pellets[b]	5.2	18.9	23.9	5.0	26.5	7
20 constant	4	Turkey pellets[b]	3.5	15.0	23.0	8.0	53.3	7
24 constant	5	Trout pellets[b]	2.1	11.6	14.9	3.3	28.5	3
25 constant	4	Turkey pellets[b]	3.1	16.3	25.6	9.3	57.1	7
25 constant	13	Trout pellets[b]	0.7[c]	23.2	31.3	8.13	35.0	5
25 constant	6	Meat & worms[b]	0.6[c]	18.6	25.8	7.2	38.7	5
25 constant	6	Trout pellets[b] high light intensity 1215 lux/m^2d	1.2[c]	35.1	40.4	5.32	15.2	5

a = representative sample only.
b = amount of feed adjusted regularly to maximise intake without waste.
c = considerable growth of algae, some cannibalism.
d = caused considerable increase in activity.
e = stocking density in range of 6 to $12/m^2$.
f = stocking density of one per square metre.

(v) Shelters

Cannibalism is markedly reduced by the provision of shelters in the form of aluminium drink cans or sections of PVC pipe. There should be at least one shelter for each animal. Stacking of shelters may allow an increase in stocking density though this needs further investigation.

(vi) Water quality

Maintenance of good water quality is essential, particularly in the breeding tanks. Oxygen levels should be maintained above 4mg/l and pH between 7.5 and 8.5. Crayfish require large amounts of calcium and water levels of this element should be no less than 20mg/l (Greenway, personal communication) and preferably above 100mg/l.

(vii) Stocking, density

Various conditions will determine the optimum stocking density, but a density of 10 - 15/m^2 would seem to be reasonable.

(viii) Mating ratio

In the wild it would appear that the mating ratio, approximates 1 :1 (Woodlands 1967). Breeding trials at Hawkesbury Agricultural College have been successful with ratios 'of one male to 3 females, provided there were at least two males in the harem. The- recommendation for a culture situation is 2 :4 or multiples there of.

(ix) Selection

In the absence of any evidence to suggest the contrary, it is recommended that breeding animals be selected on the basis of weight/-size-for-age and for docility. Clearly studies are needed in this area.

(x) Nutrition

It is difficult to make any firm'recommendations at this stage. Commercial trout pellets seem quite suitable as do other animal feed pellets, provided they are stable for some time in the water. Investigations are required, to determine the basic requirements of the crayfish and to find the' cheapest way of supplying these requirements; Animal and household wastes have been suggested as suitable material. A four week trial using solids from pig effluent clearly indicated that this, at least, is an unsatisfactory food source for crayfish.

Whatever the food source, 'it is most important that the animals are not over-fed. Excess feed quickly results in problems with water quality and disease.

(xi) Predation

Outside ponds will need to be controlled in some way to prevent predation. Many creatures, other than humans, favour a meal' of freshwater crayfish including heron, ibis, frogs, snails, platypus, water rat and many species of fish. It is recommended that the ubiquitous mosquito fish (Gambusia affinis) be kept out of the nursery ponds. Trials, at the College have resulted in 100% mortality of juvenile crayfish placed in aquaria, with gambusia. The most effective control measures are to net over the ponds and erect vertical barricades (0.5m high) around the edge of the pond. Some dry land should be left around the edge of the pond to allow the crayfish to move out of the water. Increased turbidity, of the water will offer some protection from predation.

III. CONCLUSION

The freshwater crayfish; Cherax destructor is regarded by many as a gourmet food. It is hardy, being tolerant of a wide range of conditions and it can be bred easily in captivity. Its life cycle is simple, the eggs hatching to produce virtually miniature adults which can eat the same food as their parents., This crayfish will eat a wide range of food. It tolerates a reasonable stocking density and its rate of growth is acceptable and can probably be improved by selection.

The main problems will be to create a large market demand which will ensure maintenance of an adequate market price, and to establish a farming system that allows a continuous production of a high-quality product to satisfy this demand'. This will include the maintenance of suitable water temperatures. Predation and cannibalism will cause problems and diseases, may become important. as intensive farming methods' develop. Appropriate methods of harvesting and post-harvest handling and processing, need to be developed as part of 'an efficient marketing programme. The present "go it alone and make a million dollars" attitude of 'some of the people presently attempting to enter this industry, will need to be *replaced by more cooperative ventures which include the research workers, farmers, processors and retailers. It may be desirable that farmers form cooperatives which handle and/or control production, processing and marketing and so retain the farmer's control over the industry.

'The reason for the avarice exhibited by some people can be shown by the following example:-

Assumptions:

Initial stocking density	$20/m^2$
Survivability	80%
Growth rate	60g in 14 months
Market price	$4/kg
FCR	3:1
Feed cost	$500/tonne

Yield: = 8229kg/ha/yr
Value: = $32,914/ha/yr
Feed Cost: = $12,343
Gross value - feed costs = $20,570/ha/yr

The author believes that the Australian freshwater crayfish, Cherax destructor has a great potential for aquaculture but there will be a great. deal more research, experimentation, pilot studies, market development and no doubt some burned' fingers before this potential is fully 'realised.

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