Land Crabs: A New Resource Potential

PETER L. LUTZ
Rosenstiel School of Marine and Atmospheric Science
University of Miami
Miami, Florida 33149
and
C. BRUCE AUSTIN
South Atlantic Fisheries Management Council
Charleston, South Carolina 29407

ABSTRACT

Land crabs *(Cardisoma guanhumi)* are found throughout the Caribbean Basin. In the Bahamas and Colombia natural populations are intensively exploited as a prized food, but in the agricultural regions of Puerto Rico and urbanized south Florida they are considered pests.

Based on research done on Andros, Bahamas, and at the University of Miami, we describe the aquaculture potential of land crabs. The paper reviews the existing literature on life cycle, feeding and growth, habitat, and presents the most current research.

Information on potential yield from natural stocks and alternative types of "crab farming" ranging from simple natural habitat improvement to larvae rearing and high density grow-out in artificial habitats are discussed. Alternative labor intensive and mechanized methods of harvest and processing are also discussed. There is also a discussion of marketing opportunities for whole crabs, crab meat and processed products.

The conclusion is that further research is needed in two areas to make definitive statements about the profitability of crab farming. First, more laboratory research is required for larvae rearing, feeding, behavior and growth. Second, more research is needed on grow-out in natural mud burrows compared to various artificial habitats. Harvesting methods from mud burrows and processing techniques also need more investigation.

The authors are optimistic that an inexpensive source of food can be found in most Caribbean countries for these omnivores. Low cost suitable shoreline habitat will probably be a prerequisite. Land crabs are not an inexpensive source of animal protein except where natural populations can be readily exploited in limited numbers during summer migrations. Profitable crab farming will depend on producing a high quality product that will command a high price in high-value sea food markets.

The problem with aquaculture is water. It is very expensive to maintain water quality, water aeration and water temperature. Only part of the food added to ponds is eaten by the cultured species, the rest contributes to the pond ecosystem, so there is poor control and low conversion efficiency. Water is an ideal medium for the spreading of disease which can quickly wipe out the whole stock. And finally, constant vigilance must be maintained against invading "wild" species establishing themselves in the ponds.

A marine species that is an established popular food and that can be grown out of water clearly merits very serious attention, conditions satisfied by the land crab *Cardisoma guanhumi*. This species also possess some significant potential advantages for management. It can be grown on poor land and held in high densities. It is an omnivore and will eat almost any food. It has a high guaranteed cash value.

CURRENT COMMERCIAL EXPLOITATION

Cardisoma are actively sought and captured for private consumption and commercial sale throughout their range in the Caribbean, Central and South America. In most locations crabs are primarily captured by hand (with the aid of a stick, glove or net) when they are intercepted outside their burrows during the spawning season. When crabs are harvested during the remainder of the year, they are captured from their burrows by hand reaching into burrows (Taissoun, 1974) or with traps (Feliciano, 1962). Hand catching in burrows is restricted to relatively shallow burrows. Small traps that are set over individual burrows are limited to catching one crab per set; however, these traps can be set more than once per day. Mass impoundment type traps are dependent on baiting (e.g. mangoes in South America) to attract crabs.

Puerto Rico

In numerous Spanish Caribbean countries "cangrejo" or "juey" are marketed live and whole by sidewalk vendors. In Puerto Rico in 1956, 400 commercial crabbers produced approximately 672,000 crabs for a revenue of $70,000 which was 7% of the annual commercial fishery production value of Puerto Rico (Feliciano, 1962). Hand picked crab meat was frozen and canned by two firms. One of these firms imported live crabs from Santo Domingo and Venezuela because they were larger and cheaper than Puerto Rican crabs. In 1958, 29,736 cans of "crabmeat gumbo" were marketed in Puerto Rico and to the Puerto Rican colony in New York (Feliciano, 1962).

Since 1962 no published data on Puerto Rico are available; however, it is known that the crab industry is still very active with considerable imports of live crabs and canned crab meat from Venezuela (Taissoun, 1974). Fulltime crabbers report catching 60-84 crabs/day during non-spawning periods (Bonnefil, per. comm.).

Puerto Rican crabs, like those in South Florida and some other locations, conflict with other land use. A wide range of chemicals have been used to eradicate crabs in areas where they eat agricultural plants or are considered pests.

Venezuela

In 1973 Venezuela exported approximately 812,135 live whole crabs (or frozen crab meat) to Puerto Rico and the Puerto Rican colony in New York. Emphasis has been on live crabs because, at the prevailing prices, live crabs are more profitable and they can be readily sold in Puerto Rican markets.

Harvesters are transported to crabbing sites by truck and catch crabs by hand at a rate of 400 crabs/man/night in February, the month of lowest catches. Much higher harvest rates were reported during spawning migrations. Crabs are packed into burlap sacks and transported by truck to open 50 m^2 thatched-roof, metal-sided holding pens with concrete floors and a common water pond. Crabs are seldom held more than 15 days and are exported by air in 5,000 crabs lots. With minimal care and rather rough handling, only about 15% of the live crabs are lost from harvesting to retail sale.

During the holding period crabs are maintained on a wide variety of native vegetation. When fed corn meal, there is a rapid temporary weight gain for the first 7 days with the meat/body weight ratio increasing from an average of 21% to 25%. After 30 days meat/body weight ratios of crabs in captivity on various diets are the same 21-22% that occur in their natural habitat (Taissoun, 1974).

Average commercial exploited weight ranged during the year from 208-293 g. Females averaged from 167-277 g. These are larger than those reported being marketed in Puerto Rico (Feliciano, 1962). Both Puerto Rican and Venezuelan crabs are considerably smaller than Andros crabs marketed in the Bahamas.

Bahamas

Cardisoma ("white crabs") are actively sought for private consumption on many islands in the Bahamas. *Ucidea cordatus* (smaller "black crabs") are a highly desired species from southern Andros.

Both white and black crabs are primarily exploited on Andros from May through September. At the beginning of the rainy season in May, low lying mud burrow habitats are flooded and crabs move to higher rocky ground.

Most crabs are captured at night crossing roads or in the rocky crevices and potholes that act as transitory burrows. These temporary rock burrows normally contain fresh water during the rainy season. During the day, crabs are captured by hand from these rock burrows.

During July and August swarms of females cross roads to reach saltwater where they spawn. Andros residents do not harvest females that are externally carrying eggs; they are taken after they release their eggs. Male crabs are harvested whenever they are encountered. The majority of the commercial harvest is females because they are much easier to capture. Crabs are held in burlap bags and then transferred to pens. They are fed bread, coconuts, shepards needle *(Bidens pilosa)*, other native vegetation and table scraps. A water pan is maintained in each pen.

The appendages are normally removed ("clipped") at the crabbing site. This is done by breaking the appendages (including the claws) at the second joint from the body. The crab then immediately releases the remaining segment at the body. Consequently, all the breaks are where crabs release their appendages and not where they are foreceably broken. Clipped crabs are maintained alive by individual feeding of bread and water. They are regularly immersed in water to prevent desiccation. Andros residents have reported maintaining clipped crabs for as long as 6 months; they begin to regenerate their appendages after 3 months.

Most of the appendages are discarded. They are seldom eaten by local residents but some are utilized for fish bait. The meat in the base of the body is eaten, but the most sought component is the large hepatopancreas which is located in the upper part of the carapace and used as a flavoring ingredient.

BIOLOGY

Only those aspects of *Cardisoma* biology that are of direct relevance to the commercial exploitation of this crab are considered here.

Life History

The location and time of copulation is not known but has been observed outside the burrow (Taissoun, 1974). The sperm are carried by the female and fertilization of the eggs is internal (Gifford, 1962). Fertilized eggs are carried externally on the abdomen. Egg mass is related to body weight with 300-g females carrying approximately 300,000-700,000 eggs (Gifford, 1962; Feliciano, 1962; Taissoun, 1974).

Females lay their fertilized eggs in salt water along the coast. This occurs with lunar phases (nights preceding and after the full moon). The spawning season varies somewhat with geographic location; in South Florida it is July-October (Gifford, 1962), on Andros the season frequently ends by September and in Venezuela the season continues until later in the year (Taissoun, 1974). During the early evening there are mass migrations of ovigorous female to lay their eggs in coastal saltwater. Females may spawn several times during the season.

The eggs immediately hatch into free swimming larvae. Larval development proceeds through five zoeal and one megalopa stage (Costlow and Bookhout, 1968a). Under laboratory conditions 22-23 days were required to complete the zoeal stages, and approximately 19 days for the megalopa. Total larval development from hatching to first crab averaged 42.4 days in the laboratory (Costlow and Bookhout, 1968b). However, our field observations on Andros indicate that, under natural conditions, development time may be much less. Juvenile and adult life is on land with juveniles becoming adults at approximately 40 g (Gifford, 1962; Herried, 1967; Henning, 1975b).

On land, crabs dig burrows to the water table (salt or fresh) and must moisten their gills regularly (Gifford, 1962). Larger crabs tend to move further inland and dig burrows up to a maximum of 2.0 m (Feliciano, 1962; Herried and Gifford, 1963). However, where the terrain is low such as Venezuela (Taissoun, 1974) and Andros, marketable size crabs (over 350 g) are commonly found in shallow (less than 2 ft) burrows.

There is normally only one crab per burrow and one opening per burrow (Feliciano, 1962; Herried and Gifford, 1963; Taissoun, 1974). Crabs deposit their solid wastes at the entrance of their burrows which makes it easy to determine if the burrow is "active." Juvenile and adult crabs can live with either salt or fresh water (depending on the water table) in the burrows but larvae will develop only in salt water (Gifford, 1962).

Food and Feeding Habits

Cardisoma is a herbivore that feeds on a wide range of native vegetation (Herried, 1963; Henning, 1975a), and, in captivity, will eat almost any food (Feliciano, 1962; Taissoun, 1974). In the Bahamas and elsewhere they are maintained in captivity on corn meal, bread, various foliage, bananas, mangoes and vegetable scraps. In captivity at the University of Miami, crabs appeared to prefer decomposing seaweeds and seagrasses. Except during migrations, it is believed that crabs remain in close proximity to their burrows, darting out to retrieve fallen leaves and other foods then retreating quickly to their burrows (Herried, 1963; Henning 1975a). They have also been reported to eat filamentous algae (Herried, 1963). Large numbers of burrows have been observed near algae filled pools on Andros.

In many places people believe diet significantly influences the taste and coloration of the meat (Feliciano, 1962; Taissoun, 1974). In shaded areas crabs feed during the day; in areas exposed to direct sunlight, crabs feed more often at night (Herried, 1963).

Molting and Growth

Juveniles *Cardisoma* are brown with orange shaded legs. Adult males and females range from dark blue to various shades of brown to gray-white. Newly molted adults are normally shiny gray or brown. Ovigorous females are frequently light gray-white. The name "white crab" in the Bahamas is from the coloration of ovigorous females captured en route to laying their eggs in coastal salt water.

According to Henning (1975b), at the premolt stage crabs seal the opening of the burrow with mud and retreat to the end chambers, where they molt after 6-10 days. He believes that it is important that the end chamber contains sufficient water for full immersion. In Florida, it appears that crabs hibernate in the sealed burrows over winter, and in Puerto Rico closed burrows first appear at the end of November and are opened by April/May (Henning, 1975b). However in Colombia closed chambers are seen all the year round (Henning, 1975b) and it is possible that molting occurs through the year in warmer climates.

Under laboratory conditions Henning (1975b)found that the moulting frequency declined sharply with age and extrapolated that it required about 4 years to reach sexual maturity (ca. 40 g) and about 13 years to reach the largest size he observed (ca. 98 mm carapace width). However, it is likely that these values are excessively high, as molting may be inhibited or slowed under laboratory conditions. Molting in captivity appears to be very rare (Feliciano, 1962; Bliss, 1975).

It appears then, that at least for the field juvenile and adult, growth rates are not known; therefore, it is not known how long it takes for crabs to reach marketable size (approximately 350 g or 0.77 lb). However, it is expected that there may be significant differences in regional population growth rates. *Cardisoma* on Andros are considerably larger than crabs sold in Puerto Rico, Colombia or Venezuela. This could be the result of harvesting or different growth and mortality rates.

Physiology

Information on body composition, nutrition and growth are clearly basic to any assessment of the aquaculture potential of an innovative species and some start in this has been made in our laboratory at RSMAS. Muscle is about 21% body weight for intermolt *Cardisoma* (Table 1) i.e. a 35 g crab would have 73.5 g muscle tissue. The hepatopancreas occupies a considerable proportion of body weight (11.9%), has a much lower water content than muscle (41.1%) and is very high in fat (49.1%).

In a study of the bioenergetics of *Cardisoma*, Romero (1982) has shown that *Cardisoma* has an extremely high efficiency in assimilating the food constituents of corn meal. He also measured the maintenance energy requirements of this crab and comes to the conclusion that it has a very high scope for growth.

Table 1. Land crab body composition and water, ash, protein and lipid concentrations in the muscle and hepatopancreas expressed as percent (University of Miami unpublished data)

Component	n	$\bar{X}$	Range
Muscle as % of Body Weight	8	20.9	14.6 -25.9
Hepatopancreas as % of Body Weight	7	11.9	8.6 -14.5
	Muscle Composition		
% Water in Muscle	7	74.5	73.1 -75.6
% Ash in Muscle			
Dry Weight	7	3.2	0.4 - 8.1
Wet Weight	7	0.8	0.1 - 2.1
% Protein in Muscle			
Dry Weight	7	76.6	74.1 -77.8
Wet Weight	3	19.8	18.9 -19.8
% Lipid in Muscle			
Dry Weight	3	6.2	1.0 - 3.4
Wet Weight	3	1.6	0.7 - 2.5
	Hapatopancreas Composition		
% Water in Hepatopancreas	7	41.1	25.0 -63.9
% of Ash in Hepatopancreas			
Dry Weight	7	2.7	0.1 - 5.7
Wet Weight	7	1.8	0.1 - 3.8
% Protein in Hepatopancreas			
Dry Weight	3	13.9	11.3 -18.2
Wet Weight	3	9.4	7.6 -12.3
% Lipid in Hepatopancreas			
Dry Weight	3	33.2	28.1 -38.3
Wet Weight	3	49.1	19.0 -28.5

A CASE STUDY - ANDROS ISLAND, BAHAMAS

Field studies were conducted on Andros Island, Bahamas from 1977-1980 and coordinated with laboratory work at RSMAS.

Habitats and Density

Burrow densities are highest in firm "muddy" substrates. *Cardisoma* inhabiting swamp areas are frequently found with two other grapsoids, *Ucides cordutus* and *Goniopsis cruentata*. Along saltwater shorelines where *Cardisoma* are normally found they live in close association with fiddler crabs *(Uca pugnax rapax)*.

The size and density of crab colonies vary considerably. In all habitat types there appear to be identifiable colonies. In the Florida coastal zone Herried and Gifford (1963) report 7,500 burrows per acre (i.e. 1.8/m^2) and Gifford (1962) estimated a biomass of 2 metric tons per ha (1,780 lb/acre) in some Florida colonies. Taissoun (1974) estimated a standing crop of 63,664,000 crabs in an 83.4 km^2 commercially harvested area in Venezuela in 1973. Standing stocks of adults in favorable habitat on Andros reach or exceed densities of 1 crab /m^2.

The largest observed colonies of *Cardisoma* in the Bahamas are on Andros between Stafford Creek on the north and North Bight to the south. The area consists of three basic habitat types: (1) permanent marsh with grasses and small red mangrove *(Rhizophora mangle);* (2) low density shrub and red mangrove in white firm mud which is flooded during the rainy season; and (3) pine forest with some mixed broadleaf coppice (Caribbean Pine, *Pinus caribaea,* and cabbage palm, *Sabal palmetto,* predominate with poison wood, *Metopium toxiferum,* and various other broadleaf varieties occurring less frequently).

Few burrows were observed in habitat type 1 (permanent marsh). The highest burrow densities were observed in habitat type 2. Crevices and potholes in the pinnacle rock of habitat type 3 are occupied by crabs in great numbers during the rainy season (May-August).

There are approximately 45 km of type 2 habitat along the north and south shores of Fresh Creek and Twin Lakes. An additional 7 km^2 of island habitat brings the total to 52 km^2. Sampling indicated densities of approximately 1 burrow /m^2. Assuming one crab per burrow and extending this density over the 52,000,000 m^2 of similar habitat gives a standing stock estimate of 52 million crabs of all sizes. In these areas 50% of the burrows greater than 5 cm in diameter (the minimal size measured) were less than 7 cm in diameter; and only 6% were greater than 14 cm diameter.

Areas where the ground had been disturbed such as road beds and mud spoil banks along drainage canals supported colonies of large crabs with similar densities. These mounds were well shaded by vegetation and in close proximity to surface fresh water. In these habitats only 6% were less than 7 cm in diameter, 55% were greater than 11 cm and 15% greater than 14 cm in diameter.

Seasonal Migration Patterns

Annual reproductive cycles are correlated tightly with seasonal weather patterns. In May, heavy rains on Andros flood most of the high-density mud habitat. Crabs then migrate to the crevices and potholes of the higher pinelands which include the eastern coastal ridge of Andros.

There is rapid weight gain during the first weeks of active foraging. A random sample of white crabs collected from their burrows in February produced a mean weight (males and females with all appendages) of 365.7 g. A random sample of migrating crabs, collected on 26 May 1978, 2 days after the first heavy rains, showed a mean weight of 450.2 g. On 1 June, 1 week later, a random sample had an average mean weight of 597.7 g. However, the carapace dimensions of the crabs in all three samples were not significantly different.

Males and females were observed in aproximately equal numbers during this early migration, and mating is presumed to occur at this time. By mid-June most females were carrying eggs internally, and in July the egg masses became external.

During July and August, egg bearing females migrated enmass to salt water to spawn at times closely correlated with the full moon (2 days before and after).

It is likely that *Cardisoma* in the Fresh Creek area seek the nearest high rocky ground in the rainy season. Also, it seems probable that spawning females seek the nearest salt water (given required salinity threshhold levels) rather than the sea shore. Thus the colonies of crabs around western Fresh Creek and Twin Lakes retreat to the nearby pine forest to forage and mate during the rainy season and egg bearing females later probably migrate to the north and south sides of Fresh Creek were salinity levels are sufficiently high for spawning.

Resource Potential

Since age, growth and mortality rates of *Cardisoma* are not known, it is not possible to estimate potential yield by conventional fishery models such as yield per recruit (Ricker, 1975). Given high fecundity, it is not likely that recruitment overfishing would occur as long as the harvest does not target berried females during their spawning migrations. While these are frequently the easiest crabs to catch in Andros, berried females are not normally taken until after they release their eggs.

The opportunities for expanding the harvest of *Cardisoma* can occur from naturally occurring populations and utilizing various forms of enchancement. The problems of orderly harvesting and processing crabs are the major barriers preventing full utilization of natural population. These are also two of the serious obstacles for resource enhancement.

Exploiting Natural Population

Even where crabs are intensively exploited, it is likely that some colonies are intensively harvested, while other colonies are not harvested. This occurs because the migratory path of many colonies do not transverse the locations that are normally interrupted and there is no practical way to harvest crabs from their burrows.

There are no harvest data from Andros, but cargo estimates from the mail boats that carry crabs to market on the other islands suggest production could be considerably higher, not from colonies that are already exploited, but from colonies that are not encountered at the locations on eastern Andros where most of the harvest occurs. For example, based on a minimum carapace width of 9 cm (burrow size approximately 11 cm) there are an estimated 12.5 million crabs of exploitable stock could be harvested at a sustainable rate of 10% annually (extremely low by most commercial fisheries standards), 1.2 million crabs could be taken each year without depleting the resource if all the colonies were exploited.

The greatest limitation to uniformly harvesting all the colonies is that there is no effective way to harvest crabs all year from their burrows. The existing fisheries are dependent primarily on migrations that are concentrated on a few nights around full moons in the summertime. This requires substantial live inventory if processing and marketing is to be more than a short season product.

Numerous burrow harvesting experiments were tried on Andros and in South Florida. Emphasis was on readily available or easily adaptable technology and/or materials utilized to capture other animals. Standard (Havahart) small mammal traps have been tried in Florida. A major problem is predators, probably raccoons *(Procyon cancrivorus*, which are not prevalent on Andros). Commercial trapping of land crabs has been practiced for many years in Puerto Rico, but there are undoubtedly more efficient methods such as driving crabs from their burrows with some form of irritant. A mechanical "rake" that is inserted into the burrow and then expanded to "drag" crabs from their burrows was tested. Various hooking devices inserted into burrows have been used in Puerto Rico and South America, but none of these methods has proved successful. A primary drawback with any device that must be inserted in the burrow (e.g. electrical prod or rake) is that there is normally only one opening for each burrow and the tunnel has a 45 degree angle.

Flooding burrows had mixed results. *Cardisoma* can remain submerged for long periods, but spring rains that naturally flood burrows appear to bring crabs to the surface. The most useful development research at this time would be experimenting with ways to drive crabs from their burrows. This could lengthen the harvesting season and facilitate the orderly daylight harvest of more colonies. This has important implications for the types of businesses that would be feasible (discussed later).

The second obstacle, processing *Cardisoma*, is not unique to land crabs. The blue crab *(Callinectus sapida)* fisheries on the U.S. South Atlantic Coast have been experimenting for years with ways to mechanically pick crabs. *Cardisoma* is considerably larger than blue crab and a larger proportion of the flesh is in the appendages compared to the carapaces. Mechanically separating appendage meat from the shell has been more successful than mechanically extracting meat from the carapace.

Crab meat prices (hand picked or best quality mechanically separated) are traditionally slightly below cold water lobster *(Homarus americanus)* and above warm water lobster *(Parulirus argus)* and considerably above scallop and shrimp prices. In the last 2 years shrimp and scallop prices have risen, but crab meat remains a very high value preferred seafood product. Some crabs (e.g. Dungeness, *Cancer magister)* do not freeze well. Preliminary experiments indicate that the preferred texture and taste qualities of *Cardisoma* are not damaged by freezing which considerably widens the available markets.

LAND CRAB AS A RESOURCE POTENTIAL

Several key topics can be identified from the foregoing discussion.

Resource Enhancement

It is expected that suitable habitat, not spawning potential, is the limiting factor in many locations. However, in locations where reproduction is a limiting factor, larvae artificially hatched can be protected from predators through their most vulnerable period. Natural mortality is not known, but given fecundity (1 to 5 million eggs/female), mortality is expected to be very high.

A small number of *Cardisoma* have been successfully reared from egg to juvenile crab in the laboratory solely on *Artemia* (brine shrimp) with a 25% survival rate (Costlow and Bookhout, 1968a). It would not be necessary for crabs to mate in captivity because naturally occurring fertilized egg-bearing females can be easily captured, eggs removed and hatched into free swimming larvae in 2-3 days. In the laboratory five zoea and one megalopa larval stages preceding the first juvenile crab have taken 40-50 days (Costlow and Bookhout, 1968a).

Juvenile crabs could be released on land in appropriate mud-burrowing habitat. It is doubtful that juvenile and adult grow-out could be high in density in artificial burrows.

Habitat Enhancement

In places where there are large natural populations of land crabs on large tracts of land that have no apparent alternative economic use (e.g., Andros), it may be possible to substantially increase the yield of marketable size crabs or concentrate existing stocks to make harvesting more efficient solely by altering the burrowing ground. In Andros particularly, inadequate burrowing ground appears to be the limiting factor in many locations rather than food or predators. In substrates that are too coarse (sand like) burrows collapse and in many rocky areas there is not sufficient loose substrate for burrows. In areas where hard surfaces have been disturbed, such as the embankment of roads and drainage ditches, large crabs establish high density colonies.

An important consideration would be whether or not crabs would leave their mud burrows during the rainy season for higher rocky ground if constructed mud mounds were not flooded. Some burrows on natural mud mounds that are not flooded appear to remain occupied through the rainy season.

If constructed mud mounds result in signficantly higher density than supplemental feeding may be required. This could be various forms of plant material; partially decomposed seaweed appears to provide an adequate diet.

Ownership of Resources

If grow-out is in natural mud burrows on improved habitat, confinement depends on how crabs are harvested. Private businesses will not engage in habitat improvement or supplemental feeding if there is no assurance they can identify and retrieve their investment. Maximum natural burrow density of approximately only $1/m^2$ (somewhat higher on mud mounds) would make fencing compounds prohibitively expensive in most locations. If compounds could be fenced it would make harvesting migrations efficient because crabs can be funnelled through narrow openings and corralled like cattle.

If crabs are harvested from their burrows there may be no need for fencing. Crabs are territorial and occupy only one burrow. There is evidence (but not proof) that individuals return to the same burrow after spawning migrations. If crabs were only harvested from their burrows, crab farms could be dispersed low investment opportunities that engage in habitat improvement, supplemental feeding, perhaps stocking juveniles (raised in a larval rearing facility) and harvesting. Larval rearing (if necessary) and processing (mechanical meat separation and freezing) would be relatively high investment operations that would probably require centralization to benefit from economics of scale.

Conclusions

Produced consistently in quantity, the land crab *Cardisoma* has a commercial value equal to many other high demand crustacean. Potentially it offers outstanding advantages over other managed crustaceans in that its grow-out period is on land, therefore avoiding the problems of water management, it can be grown in high density in poor quality land and it is an ubiquitous omnivore.

The types of business opportunities are very much tied to method of harvesting. The advantage of continuing to harvest crabs during migrations are that it eliminates the need for developing methods to harvest crabs from their burrows and avoids the associated costs.

The disadvantages of harvesting migrating crabs are it requires live inventory control, larger processing and freezer capacities to handle irregular production and some form of investment identification and retrieval or there is no economic incentive for resource enhancement. Investment identification and retrieval is crucial. If crabs are not harvested from their burrows the only solution may be fenced compounds which would be prohibitively expensive in most locations. This has been the primary obstacle of finfish aquaculture and even less mobile species such as conch *(Strombis gigas).*

THE PROPERTY PROBLEM IN MARICULTURE

The production problems of mariculture that were discussed in the Introduction such as waterborne disease, food and waste removal, temperature control, predation and cannabalism are actually the *results* of the more general economic problem of property rights. The owners of the animals, whether individual or collective, have no economic incentive to enhance biological production if their investment cannot be captured. Mariculture has attempted, in most cases unsuccessfully, to assure capture by high density confinement which has caused the production problems.

The history of land animals tells us that the problem of property must be solved before resource enhancement can be a viable economic enterprise. Different animals have different solutions for assuring property rights. On land they have been as varied as individual animal identification (branding cattle), reduced mobility (birds that cannot fly) and the use of other animals for confinement barriers (sheep dogs).

Culturing marine animals, releasing them in the wild, and recapturing them at a central loçation (e.g. ocean salmon ranching) has been one approach to capturing the investment. If land animal history offers any lesson, it is that this solution is not viable on a large scale because "overgrazing" by the various enterprises takes place on the "common area" used by all. The Enclosure Movement in England had to eliminate common grazing of sheep and the same occured for cattle in the western United States.

Although the property problem is the same for mariculture and land animals, the different modes of production require different solutions. The thrust in land animal production is and has been towards higher density monoculture (e.g. cattle feed lots and chicken barns). But this approach is quite inappropriate for mariculture because of the characteristics of life in the medium of water. Establishing property rights (assuring recapture of the investment) in a low enough density to avoid production problems, but sufficient to ensure adequate return, is the real challenge of mariculture.

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