THE GOLDEN CRAB (GERYON FENNERI) FISHERY OF SOUTHEAST FLORIDA

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INTRODUCTION

The golden crab, Geryon fenneri (Manning and Holthuis, 1984) is a large brachyuran inhabiting the continental slope off the southeast United States including the eastern Gulf of Mexico. Prior to its description in 1984, studies in the eastern Gulf of Mexico by Otwell, Bellairs and Sweat (1984) examined the potential development of a trap fishery for this species in depths exceeding 210 meters. Various trap designs were tested along with methods of on-board handling and processing (Sweat and Otwell, 1983); Bellairs and Otwell, 1983). Particularly attractive was the reported high meat yield of male crabs, ranging from 17 to 23 percent of total body weight.

Interest in the commercial exploitation of golden crab led to three vessels (two from Alaska and one from New England) initiating a fishery along the west coast of Florida during late 1984. Male crabs were butchered, cooked and blast frozen at sea. The final product of clusters, cocktail claws and split legs were delivered frozen to the market. However, because of marketing problems, compounded by distances in excess of 100 miles to the fishing grounds, gear loss and the absence of information on the distribution and biology of this species, commercial operations in the eastern Gulf of Mexico ceased by mid-1985.

In late 1985, continued interest in the commercial potential for G. fenneri led to the initiation of exploratory fishing and research in Bermuda (Luckhurst, 1986), South Carolina (Wenner and Ulrich, 1986), Georgia (D. Harrington, personal communication) and Florida. Additionally, in late 1985 a small commercial fishery developed along the southeast Florida coast with the catch delivered live to a local market in Ft. Lauderdale, Florida.

In February 1986, we began a study of the biology of Geryon fenneri as collected from this southeast Florida fishery. Reproductive biology, size and weight relationships, trap design and catch per unit effort were examined to ascertain additional information relative to the study of this potentially valuable species.

METHODS

Gear previously utilized by the eastern Gulf of Mexico golden crab fishery consisted of deep water long lines of between 30 and 60 traps attached to a ground line connected via a float line to large floats and radar reflectors on the surface (Otwell, Bellairs and Sweat, 1984).
This method requires the capability to retrieve upwards of one mile of line from depths in excess of 250 meters. Trap designs have included Dungeness crab pots, King crab traps, New England and Florida lobster traps and plastic Fathoms Plus traps (Otwell, Bellairs and Sweat, 1984; Wenner and Ulrich, 1986). Three or four trap lines were fished with soak times averaging 24 hours between set and retrieval.

Because of the close proximity to shore (less than 10 miles) of water depths in excess of 200 meters, the small fishery that has developed in southeast Florida employs a different strategy in harvesting golden crab. Four to six large traps are attached approximately 140 to 180 meters apart to a ground line which is fitted with concrete weights on each end. The large traps called Neilson traps, measure approximately 6' x 3' x 3' and are made from steel round stock covered with 2" x 2" nylon stretch mesh (Figure 1). Traps are fitted with 5" diameter escape rings and a large side door providing access to the center bait well and easy removal of the catch. Four to six strings of traps may be fished, with each string reset immediately after it is pulled.

As the present fishing grounds are adjacent to commercial shipping lanes and affected by variable currents associated with the Gulf Stream, trap lines are deployed without a surface float system. Loran coordinates are recorded during deployment along with bottom profiles and relative position using shoreline landmarks. Soak time varies from three to six days depending on market demand. This allows the fishermen to pursue other commercial opportunities. Trap recovery involves grappling for the ground line, with the vessel moving from offshore to onshore and the grapnel dragged perpendicular to the ground line.

Samples were collected monthly during the period February 1986 through January 1987 from fishing depths ranging from 215 to 230 meters. Total numbers of crabs caught per trip were recorded in three categories: females, market size males in excess of 130 mm carapace width (CW), and small males less than 130 mm CW. Crabs were randomly selected from the catch, packed in crushed ice and returned live to the laboratory.

For each crab, carapace width (CW, the distance between the fifth lateral spine tips) and carapace length (CL, midline distance from the diastema between the rostral teeth to the posterior carapace edge) were recorded to the nearest millimeter. Weight was recorded to the nearest gram and missing appendages noted. The presence of eggs in pleopods were noted and molt stages were estimated according to a modification of stages presented in Byers and Wilke (1980) for G. quinquedens (probably G. maritae; see Manning and Holthus, 1981). Weight-width relationships of animals in the intermolt stage and with no appendages missing were calculated using a log-log transformation expressed in the form $Y = ax^b$. 

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Figure 1. Neilsen trap showing rough dimensions, placement of bait well and floats, and stretch mesh covering.
RESULTS

Throughout the study period, the catch of male crabs greatly outnumbered females. Size frequency distributions of 508 males and 347 females examined (Figure 2) indicates a unimodal distribution for each sex, with no suggestion of distinct year classes. Males are considerably larger than females, with overlap between the largest females and smallest males. Carapace width of males ranged from 111 to 190 mm with a mean of 158 mm, whereas females ranged from 89 to 156 mm with a mean of 123 mm. Animals less than 89 mm CW were not collected, possibly due to bias from trap design and the use of escape rings. The narrow range of fishing depths also precluded the collection of information on segregation of sex and size with depth as has been reported for other Geryon species (Byers and Wilke, 1980; Intes and Le Loueix, 1976; Haefner, 1978).

Monthly size frequency distribution of female crabs is shown in Figure 3. The incidence of ovigerous females collected throughout the study period indicates an annual reproductive cycle with a single brood of eggs produced each year. Oviposition begins in late August and continues through early October. Eggs are carried for six months until larvae hatch during late March and early April of the following spring. Eggs are dark purple following deposition, gradually becoming dark brown prior to hatching. Size range of ovigerous females examined ranged from 96 to 147 mm CW.

Figure 4 shows the monthly size frequency distribution of male crabs. Monthly mean carapace widths ranged between 152 and 162 mm; however, the incidence of smaller males decreased beginning in July 1986. This decrease in small males coincided with the fitting of all traps with 5" diameter escape rings. Although data collected precluded statistical analysis, it was apparent from the overall catch of both sexes that fewer females and small males were present in traps fitted with escape rings.

Weight frequency distributions of 262 males and 136 non-ovigerous females is shown in Figure 5. Weight of male crabs, ranging from 230 to 1930 g with a mean weight of 1116 g and greatly exceeded that of females. Mean weight of females was 449 g, ranging from 207 to 880 g. Although weights of both sexes show a unimodal distribution, the greater incidence of females in a narrower range of weight classes is due to the great increase in mass associated with developing ovarian stages. The largest male examined was 190 mm CW and weighed 1930 g while the largest non-ovigerous female was 156 mm CW and weighed 800 g.

Weight on carapace width relationships were calculated separately from each sex. The relationship for 262 males illustrated in Figure 6, is described by \( WT = 5.27 \times 10^{-3} \times (CW^{3.328}) \). The relationship for 136 females is \( WT = 5.599 \times 10^{-4} \times (CW^{2.812}) \) as shown in Figure 7.
Figure 2: Cumulative size frequency distribution of male and female Geryon femoral collected during the period February 1986 through January 1987, from Ft. Lauderdale, Florida.
Figure 3. Monthly size frequency distributions of female *Geryon fenneri* including number of individuals and mean carapace width. Ovigerous females are shaded.
Figure 4. Monthly size frequency distributions of male *Geryon fenneri* including number of individuals and mean carapace width.
Figure 5. Cumulative weight frequency distribution of male and female *Geryon fenneri* collected during the period February 1986 through January 1987 from Ft. Lauderdale, Florida.
Figure 6. Weight on carapace width relationship for 262 male *Geryon fennleri* as described by $WT = 5.27 \times 10^{-5} (CW^{3.328})$. 
Figure 7. Weight on carapace width relationship for 136 female *Ceryon fenneri* as described by $WT = 5.599 \times 10^{-4}(CW^{2.812})$.
DISCUSSION

Geryon fennieri is considerably larger than G. maritae and G. quinquepennatus, two additional species of commercial value. As male G. fennieri attain a maximum size in excess of 190 mm CW and weight up to 2000 g, interest in commercial utilization is warranted. At present, the small fishery for this species is unregulated, with no closed season, quota or minimum size limits on harvestable animals. In the southeastern Florida fishery, only males greater than 130 mm CW are utilized, and all females and small males returned to the water. Considering the annual reproductive pattern of females and the slow growth associated with organisms of large size from this deep water environment, the voluntary practice of selective harvest is undoubtedly of benefit in protecting the potential longevity of this fishery.

The strategy employed by the golden crab fishermen of southeast Florida has proven successful in providing a sufficient amount of product to local markets. The use un-buoyed trap lines with few large traps and long soak times has resulted in the development of a small scale local fishery, with fishermen able to pursue other commercial opportunities rather than fish crab exclusively. The close proximity of the fishing grounds to shore permits delivery of live product thus eliminating on-board processing and storage. This in turn reduces the cost per trip on the basis of fuel, labor and processing equipment. Live product is also more attractive to the consumer, who is able to purchase whole live crab or freshly butchered and cooked clusters rather than pre-cooked, frozen crab.

The full commercial potential of this species will remain unknown until such biological data as population density, reproduction patterns and geographical distribution, which are still under study, are collected and fully analyzed. Additionally, future research should continue to address gear development, trap design and the use of escape rings. Although the small southeast Florida fishery has been relatively successful, the longevity and potential expansion of the fishery for this valuable species remains unknown and over-capitalization by fishermen wishing to enter this fishery should be discouraged.

REFERENCES


**ACKNOWLEDGEMENTS**

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DEVELOPMENT OF A SWIMMING CRAB FISHERY IN ECUADOR

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INTRODUCTION

During the last decade, Ecuador's fisheries have been dominated by the explosive growth of the shrimp farming industry. In 1983, Ecuador became the world's leading producer of farmed shrimp with an estimated 36,600 mt production (Sonu, 1985). However, this increase in shrimp production has been accompanied by several depressions in the trend caused by environmental changes and technological problems. Since shrimp is Ecuador's leading non-petroleum export commodity this decrease has caused considerable concern and promoted the development of hatchery operations, as well as a search for alternative fisheries.

In 1986, a project was initiated by the University of Rhode Island (URI) with their Ecuadorean counterpart, Escuela Superior Politecnica del Litoral (ESPOL) to investigate the potential for the development of a fishery for underutilized species of swimming crabs. Based on previous field observations and conversations with commercial and artisanal fishermen, it appeared that swimming crabs were a non-utilized by-catch of the shrimp trawlers and artisanal fishermen. No information on the identification, life history, abundance and distribution of these crabs was available in Ecuador, nor were these crustaceans considered in previous investigations for the development of alternative fisheries of underutilized species (FAO, 1978; Moran and Lopez, 1984; U.S.Dept. of Commerce, 1982.)

Callinectes sapidus, a member of the Portunidae family or better known as the blue crab, is the basis for the third largest fishery of the United States which in 1985, produced more than 83,200 mt of hard crab with a landed value of 60 million dollars (Vondruska, 1986). Demand exceeds the supply of domestic crab meat and USA processors have supplemented their supply with imported crab meat from Brazil, Venezuela and Mexico (W.F.Conley, personal communication).
Several basic criteria must be satisfied before a successful crab fishery can be established (Van Engel, 1974): the species must be present in consistent levels of high abundance; the species should be vulnerable to fishing gear; the species must be relatively large, easy to handle, transport, process and market; and the product must have consumer acceptance and potential market. In order to evaluate each of these criteria the project was divided into two phases with the following objectives:

PHASE I

(a) conduct a preliminary resource survey of coastal and estuarine waters,
(b) study the abundance & distribution of swimming crabs in Guayas Estuary,
(c) determine the catchability of the swimming crabs in the Guayas Estuary using a variety of fishing gear.

PHASE II

(a) develop processing technology
(b) investigate potential markets for the product

Phase I is nearing the end of its first year of investigation, preliminary results are summarized in the sequel. Phase II initiation is dependent on the results of Phase I.

MATERIALS AND METHODS

Ecuador extends 950 kms along the western coast of South America between the latitudes of 1° 00' N to 3° 20' S (McPadden, 1985). The configuration of the coastline is irregular, terminating in the Guayas Estuary and the Gulf of Guayaquil (Figure 1), the largest estuarine system on the Pacific coast of South America (Murray, 1975). The ocean is defined as sub-tropical with water temperatures exceeding 25° C and salt content below 33.5 ppt. The climate, however, is considered tropical and is divided into two distinct seasons. The wet season is characterized by heavy rainfall and extends from December through April. The dry season is cooler and includes the period from May through November.

The preliminary resource survey was conducted during the dry season month of July, 1986. Seven locations were chosen as sampling sites along the Ecuadorian coast covering the 3 major estuarine systems: Esmeraldas (Esmeraldas River), Bahia de Caraquez (Chone River) and the Guayas Estuary (Guayas River). A total of 41 trap samplings were made in these areas. Biological
Figure 1. Map of Ecuador showing the three study areas.
and environmental data were recorded and crabs were identified according to available keys (Williams, 1974; Garth & Stevenson, 1966).

Experimental fishing for Callinectes spp. crabs was conducted in the Guayas Estuary during the wet season (January) and the dry season (June-August) of 1987. Sites were chosen in three areas based on expected salinity differences in the upper, middle and lower estuary (Figure 2). Four types of fishing gears were randomly fished at each site: Chesapeake Bay style crab traps (Van Engel, 1962), trotline, gillnet and lift nets. Five Chesapeake Bay style baited crab traps were constructed of locally available galvanized rectangular mesh wire with a mesh opening of 2.5 x 5 cm. Each trap measured 65 x 65 x 52.5 cm and had four entrance funnels. A smaller trap with a mesh size of 2.5 x 2.5 cm was also employed during the January sampling to capture juveniles, however, use of these was discontinued due to the possible exclusion of the larger animals. Two 30 m trotlines baited every 2 m were fished twice per hour. These were constructed of 1 cm diameter, hard lay nylon and anchored at both ends. Five baited lift nets were constructed with a square iron frame, covered with 1.2 cm webbing. These were lifted twice per hour. Two 30 m Gillnets with 7.6 cm stretched mesh were constructed of soft lay polyamide twine. Traps, trotlines and lift nets were baited for each set with locally available species. These included Chloroscombrus orquesta, Selene pervianae and Scomber japonicus. All gears were fished simultaneously for 3 hour periods. Unit fishing effort is expressed as gear-hour which represents one unit of gear with a one hour soak.

All crabs collected were identified, measured (carapace width) and weighed. Carapace width refers to the distance between the tips of the longest cephalothorax spines. General appearance of the crabs were noted including sex, maturity, and loss and regeneration of appendages. Environmental data including sediment type and bottom and surface temperature, salinity and dissolved oxygen levels were recorded.
Figure 2. Map of Guayas Estuary showing the sampling sites.
RESULTS AND DISCUSSION

Resource Survey

The existence of five species of Portunid crabs inhabiting the coastal and estuarine waters of Ecuador as suggested by Williams (1974) was confirmed during these investigations. Callinectes toxotes and Callinectes arcuatus were captured in estuarine areas while samples of Euphylax robustus, Portunus asper and Cronius ruber were obtained from fishermen working in offshore areas. Initial indications suggest that these latter three species are not of sufficient size or quantity to support a fishery. However, the apparent abundance and size of the two Callinectes species suggests the presence of a large unexploited resource in Ecuador.

Callinectes toxotes was the largest of the swimming crabs found in the Guayas Estuary and have been described as the largest species in the genus (Williams, 1974). The largest specimen captured measured 22 cm in width, and weighed 660 gr. The average size of C. toxotes captured was 14.5 cm, with average weight of 211 gr. Callinectes arcuatus, a smaller species, had mean carapace widths of 10.3 cm and weights of 60 gr. Average carapace width and weight for both species for each area are summarized in Table 1.

Table 1. Average Carapace Width (CW) in cm and Weight (WT) in gr for Callinectes toxotes (TOX) and Callinectes arcuatus (ARC) Crabs Captured by Site and Season.

<table>
<thead>
<tr>
<th>SITE</th>
<th>WET SEASON</th>
<th>DRY SEASON</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOX</td>
<td>ARC</td>
</tr>
<tr>
<td></td>
<td>CW WT</td>
<td>CW WT</td>
</tr>
<tr>
<td>UPPER GUAYAS</td>
<td>11.9 113</td>
<td>14.7 198</td>
</tr>
<tr>
<td>ESTUARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIDDLE GUAYAS</td>
<td>15.1 320</td>
<td>13.4 219</td>
</tr>
<tr>
<td>ESTUARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOWER GUAYAS</td>
<td>15.3 250</td>
<td>9.1 48.7</td>
</tr>
<tr>
<td>ESTUARY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Abundance and Distribution

A detailed investigation of the abundance and distribution of the Callinectes spp. in the Guayas Estuary is currently being conducted by ESPOL. However, limited observations to date have indicated that the species distribution found in Ecuador is similar to that described by Norse and Estevez (1977) along the Pacific coast of Columbia, where C.toxotes dominated the less saline estuarine areas but was replaced by C. arcuatus in the higher salinity areas with some overlap in intermediate and high salinity areas (Figure 3). They suggest that salinity plays an important role in the distribution of the Callinectes species and describes both as being euryhaline.

A spatial and temporal shift of the species distribution occurred during the wet season, presumably following the shift of the salinity structure of the estuary due to increased fresh water input from the rivers. At the beginning of the wet season while salinity was still high (19 ppt) large populations of C. arcuatus were found in the middle estuary. At the end of the season, salinity dropped (15-17 ppt) and the population consisted entirely of C. toxotes. No shift in species composition was seen in the fresher upper estuary (0.1-5 ppt), although there was an indication of size differences. No data is available for the wet season 1987 for the lower Guayas estuary.

If C. toxotes and C. arcuatus follow a similar pattern of distribution as Callinectes sapidus, a differential distribution by sex and maturity can be expected. Mating would occur in the fresher areas of the estuary, with females later migrating to estuary mouths to spawn resulting in the dispersion of the larvae into the offshore high salinity waters (Hall, 1984). Little data is available on the spawning habits of C. toxotes, although Williams (1974) mentions that the distribution of oviigerous females is presumed to be similar to that to C. sapidus.

Preliminary results indicate differential distribution of C. toxotes by sex and maturity in the three sites during the two seasons (Figure 4). In the wet season, immature males and females dominated the population in the upper estuary; while mature males and females were found in the middle estuary. During the dry season, mature males and females dominated in the upper estuary; while mature males were found in the middle estuary and the lower estuary. Preliminary data are insufficient to verify female
Figure 3. Species Composition in the Guayas Estuary.
Figure 4. Sex and Maturity of *Callinectes* spp. crabs in the Guayas Estuary.
migration to higher salinity areas for spawning. There appeared to be a greater number of immature females in the upper estuary during the wet season, and a larger number of mature females during the dry season. Very few ovigerous females have been captured to date.

The majority of the *C. arcuatus* captured were males; principally mature males were found in the middle Guayas estuary, and mature and immature males were found in the lower estuary. Very few females were captured which suggests their absence from the estuary areas sampled. Dittel and Epifanio (personal communication) in their investigations in Costa Rica, have captured mostly female *C. arcuatus* but their sampling has been conducted offshore in the Gulf of Nicoya area.

The offshore waters were not sampled but literature supports the theory that *C. arcuatus* and *C. toxotes* may form large breeding populations in coastal waters throughout the year (Rosales, 1976) and that the estuarine phase of the life cycle is a growth phase as suggested for *C. latimanus* in Ghana (Kwie, 1974). Paul (1982) found that in Mexico, the female *C. arcuatus* continue their migration out of the estuary and continue spawning on the continental shelf.

Catchability

The blue crab in the United States may be subject to the most diverse kinds of fishing gear for any single species (Haeftner, 1985). Gears can range from a simple baited hand line to the 50 kg crab dredge used in the winter months in the Chesapeake Bay. Only a few gears have proven to be economically practical on a commercial basis (Sholar, 1979): crab traps (80%) trotlines (10%) and dredges (10%). In Ecuador, there are technological, social, cultural and environmental factors that must be considered in the selection of the appropriate harvesting gear. The final recommendations for the most appropriate harvesting gear will be a compromise between these factors as well as catch per unit effort or performance data for each gear type in the Guayas Estuary.

Catch per unit effort for each gear type by site and season are summarized in Table 2. Environmental conditions caused great variability in the CPUE for some gears. The trotlines and lift nets worked best when fished in quiet waters such as protected mangrove areas or during slack
tides. Traps performed well until current reached speeds causing them to "walk" or vibrate. The Guayas estuary has a tidal range of between 4 and 5 meters and tidal currents often reach speeds of 2-3 knots. Gillnets could only be placed in carefully selected sites due to debris in the water, boat traffic or currents.

Table 2. Catch per Unit Effort (CPUE) by Gear Type and Size.

<table>
<thead>
<tr>
<th></th>
<th>WET SEASON</th>
<th>DRY SEASON</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>LRG MESH TRAPS</td>
<td>SML MESH TRAPS</td>
</tr>
<tr>
<td>UPPER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUAYAS ESTUARY</td>
<td>.27(4)</td>
<td>.094(2)</td>
</tr>
<tr>
<td>MIDDLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUAYAS ESTUARY</td>
<td>.82(7)</td>
<td>.95(5)</td>
</tr>
<tr>
<td>LOWER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUAYAS ESTUARY</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>AVERAGE CPUE</td>
<td>.62(11)</td>
<td>.70(7)</td>
</tr>
</tbody>
</table>

Note: Number of Replicates are indicated by parenthesis.

Traps and gillnets as passive gear offer the advantage of "self-fishing." Unless theft is a major problem in the area, these gears can remain unattended until the fisherman returns to remove the catch. US fishermen use a 24 hour soak for the traps, replacing the bait each time the trap is lifted. A 24 hour soak is not recommended for the gillnet since tidal currents and debris tend to cause the net to tangle. The trotline and lift nets must be continuously fished to harvest the crabs and the fisherman must remain the entire time with the gear. Therefore, a shorter total fishing time is recommended. CPUE may vary depending on soak time chosen for these gears.

If the assumption is made that the catch rate will be constant during the entire fishing time, ignoring effects of gear saturation, and species interaction, CPUE's can be extrapolated into expected daily catches for an artisanal
fishermen working from a non-motorized vessel such as a canoe, and for a small scale commercial fishermen with a motorized vessel less that 6 m in length (Table 3).

Table 3. Expected Catch

<table>
<thead>
<tr>
<th>GEAR</th>
<th>UNITS</th>
<th>SOAK TIME</th>
<th>CATCH</th>
<th>GEAR</th>
<th>UNITS</th>
<th>SOAK TIME</th>
<th>CATCH</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRAP</td>
<td>10</td>
<td>24</td>
<td>134</td>
<td>TRAP</td>
<td>100</td>
<td>24</td>
<td>1350</td>
</tr>
<tr>
<td>LIFTNETS</td>
<td>10</td>
<td>8</td>
<td>58</td>
<td>LIFTNETS</td>
<td>100</td>
<td>8</td>
<td>584</td>
</tr>
<tr>
<td>TROTLINE</td>
<td>200m</td>
<td>8</td>
<td>43</td>
<td>TROTLINE</td>
<td>1600m</td>
<td>8</td>
<td>376</td>
</tr>
<tr>
<td>GILLNET</td>
<td>200m</td>
<td>12</td>
<td>43</td>
<td>GILLNET</td>
<td>1600m</td>
<td>12</td>
<td>374</td>
</tr>
</tbody>
</table>

At present a very small local market exists for Callinectes spp. crabs. They are captured by handlines or lift nets by artisanal fishermen and vendors sell them on the streets of Guayaquil for 20 to 100 sucres each (10-50 cents US). Demand for swimming crab increases during the closed season of the preferred red mud crab, Ucides occidentalis, and prices up to 500 sucres each ($2.50 US) are common. Crab processors from the United States and Japan have visited Ecuador during this past year and a new Ecuadorian crab processing facility "Jaiba Azul", has recently received funding to begin operations.

It is difficult to ascertain the resource potential of Callinectes spp. from this preliminary study, although the results do offer some encouragement. Crabs were captured in all of the areas fished, although variability in the catch rates was due in large part to the exploratory nature of the investigation. From the preliminary data obtained thus far, the Callinectes spp. crab resource is sufficient to sustain an artisanal level fishery. However, it is recommended that more detailed investigations be conducted before any large scale commercial level fishery be established for this resource.

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EFFECTS OF PROCESSING ON THE QUALITY AND TENDERNESS OF THE FLESH OF THE COMMON WHELK (BUCCINUM UNDATUM L.)

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ABSTRACT

Three different cooking methods and six cooking times, mechanical tenderization and ten different salt solutions are investigated in an attempt to improve tenderness and shelf-life of whelk (Buccinum undatum L.) flesh. Tenderness, as evaluated by the Universal Testing Machine (INSTRON), was significantly influenced both by the duration and the method of cooking (Sheeffe Test P < 0.05). Samples tenderized mechanically by 200 g and 400 g loads were significantly more tender than untreated control and significantly less tender than hand tenderized samples (P < 0.05). Brines giving the lower microbial counts at 10ºC storage were NaCl (2%) and MgCl₂ (6%), NaCl (2%), MgCl₂ (2%) and KCl (2%) and NaCl (8%). But there were no significant differences between the ten brines investigated (P < 0.05).

INTRODUCTION

The common whelk (Buccinum undatum L.) is a carnivorous marine snail widely distributed throughout the North Atlantic and Arctic Oceans. It provides a locally important fishery on the Atlantic coasts of Canada, particularly in the St-Lawrence estuary, on the east and south coasts of Britain, and on the coasts of Normandy and Brittany. Santerelli and Gros (1986) estimated the French landings of whelk at 4 000 metric tons per year, with a commercial value of 17 millions french francs in 1983; Quebec landings are estimated at 300 metric tons per year with a commercial value of 100 000$ Can. (D.F.O. 1985).

In Quebec, the commercial forms of whelk are: untreated whelk (live in the shell); canned whelk (whelks are removed from the shell, canned and heat treated); and brined whelk (with about 8% NaCl) or preserved with vinegar. One of major characteristic of whelk is tough flesh texture and the consumer commonly complains of this. Like most gastropods, the locomotor activity of whelks is assumed by a pedal muscular organ. Such activity is energetically expensive (DaSilva and Hodgson, 1987) and implies a high degree of sophistication of the muscles. The organization of pedal muscles probably affects the tenderization modes during the processing.
Studies on the fine structure of the pedal musculature of gastropods are few and to date have been carried out either on terrestrial snails (Rogers, 1969) or on whelk (Hunt, 1976; DaSilva and Hodgson, 1987).

Salt, or sodium chloride (NaCl) is the most frequently used compound in food processing, and has been used for centuries for flavoring and as a bacteriostatic or bactericidal agent. The preservative effect of salt is primarily due to its ability to lower water activity by drawing water from tissue. In recent years sodium chloride consumption has become a major issue in the food industry, primarily because the sodium ion seems closely linked to human hypertension (Freis, 1976; Altschul and Grommet, 1980) and because the average consumption of sodium is 10-20 times that necessary for physiological balance (NAS, 1980). Sodium compounds occur naturally in many foods, including meats, fish, dairy products, grains, and vegetables. For the health of persons suffering from hypertension or other sodium related disorders FDA (1982), AMA (1972) and several other professional groups (Shank et al., 1983) have made formal recommendations concerning the use of sodium chloride. Some studies have been made concerning the optimization of functional and economic parameters when sodium chloride (NaCl) levels in processed foods are reduced by replacement with other chloride salts (Marsh, 1983, Maurer, 1983, Terrell, 1983).

It is known that some parameters such as: age (Snowden et al., 1978); muscle composition (Marsh et al., 1974, Marsh, 1977, Olson et Parrish, 1977), conservation processes (Bouton et al., 1973), cooking time and temperature (Bouton et al., 1981, Robertson et al., 1984, Findlay et Stanley, 1984) influence the toughness of animal muscle and therefore its texture.

The purpose of this paper is to report the effects of cooking methods, time/temperature parameters, enzymatic treatment and mechanical tenderization on the toughness of whelk flesh, as evaluated by the Universal Testing Machine. Some work was also done to evaluate the effect of partial replacement of sodium chloride by other chloride salts on the shelf-life of brined whelk.

MATERIALS AND METHODS

Sampling: Live whelks bought from local commercial fishermen (Pecherie Bocard of Matane, or Poissonnerie Lucien Doucet of Bic) were kept in cold storage (4°C) until experimentation. Only live whelks with total shell length of 7-9 cm, as measured with a vernier, were selected for experimentation as showed on the diagram of figure 1. Preliminary studies (Adambounou et al.) showed no significant difference between the tenderness of the pedal muscle of the samples of this group; while Santarelli and Gros (1986) reported the relationship between the age and shell length of the whelk.
Figure 1. Experimental diagram.
Cooking methods: three cooking methods were investigated:

1) Boiling in water: About twenty whelks weighing approximately of 1 500 g were boiled in 1 000 g water (100°C) for fixed times (10, 20, 30, 40, 50 or 60 minutes). Cooked whelk were removed from the shells with a table fork, and pedal muscles sampled with a knife, washed and brined in a glass jar with warm sodium chloride solution (8% and 80°C), cooled at ambient temperature (25°C) and stored at 4°C until evaluation of tenderness by Instron.

2) Ten minutes precooking followed by pressure cooking for various times. About 1 500 g of whelk were boiled in 1 000 g of water for ten minutes and the flesh removed from the shell with a table fork. Pedal muscles were sampled with a knife, washed and brined with warm 8% sodium chloride solution (80°C) in glass jars and pressure cooked (121°C, 15 lbs) for fixed times (10, 20, 30, 40, 50 or 60 minutes), cooled at ambient temperature (about 25°C) and stored at 4°C until evaluation of tenderness.

3) Pressure cooking (121°C, 15 lbs). 1 500 g of sample were pressure cooked for fixed times (10, 20, 30, 40, 50 or 60 minutes). Whelk were picked from the shell, brined in glass jars (8% NaCl, 80°C) cooled at 25°C and stored at 4°C for tenderness evaluation.

A control was prepared according to the cooking method (2) and the brine solution was replaced by distilled water.

Mechanical tenderization. Live whelk were obtained by breaking the shells with a hammer. Pedal muscles were selected, washed and kept in dilute sodium chloride solution (0.9%) at 0°C for 48 hours before mechanical tenderizing, with the apparatus shown in figure 2. The effect of two weights (400 g and 200 g), falling from a height of 80 cm was investigated; for comparison hand tenderizing was performed with a wooden mallet as used in the home for meat tenderizing. The samples were washed, slightly brined (NaCl solution 0.9% and 80°C) and pressure cooked for an hour (121°C, 15 lbs) in glass jars. They were cooled at 25°C and stored at 4°C until evaluation of tenderness.

Enzymatic tenderization. 1 500 g of whelk were boiled (100°C) in 1 000g of water for 10 minutes, removed from the shell with a table fork and the pedal muscle incubated at 80°C for fixed times (15, 30 or 45 minutes) in enzyme solution of various concentrations (15, 30 or 45 g/l). The two enzymes investigated were crude papain powder type II and crude ficin (Sigma Chemical Co. Ltd). Pintauro, 1979, reported that the optimum temperature of these enzymes was from 65°C to 80°C. Samples were then brined (8% NaCl, 80°C), cooled (25°C) and stored (4°C) until tenderness evaluation.
Tenderness evaluation. Compression measurements were made using an Instron (Universal Testing Machine) Model TMS equipped with a 2000 g load cell. For each treatment, thirty cylinders of 1.1 cm diameter were selected in the horizontal axis of pedal muscles with a circular knife and cut to 1.5 cm length. To eliminate sample movement during compression measurements, cylinders were placed in a plexiglass block drilled according the size of samples. The initial peak referred to as firmness was obtained by compressing cylinders to 90% of the original length. Preliminary investigations on calibration of Instron showed that 20 cm/min. is the optimal speed for both the crosshead and the chart (Lavallée et al., 1987). The method used was similar to the Instrumental Texture Profile Analysis with only the initial peak, referred to as firmness, being used (Breeene, 1975, Findlay and Stanley, 1984) (Figure 3).
Figure 3. Typical deformation curve observed on Instron.

Microbial analysis. To evaluate the effects of different brines on the shelf-life of whelk, a total plate count using P.C.A. was made on the sample prepared as in cooking method (2), stored at 10°C for 60 days. The plating were done on triplicate.

Experimental plan and statistical analysis. Complete Random Factorial experimental design was followed, and all analyses shown in the experimental diagram (Figure 1) and microbial analyses were done in duplicate and the entire experiment repeated twice. Data were analysed by standard parametric analysis of variance technique. Degrees of significance were evaluated by the Scheffe test (Kirk, 1968).

RESULTS AND DISCUSSION

Effect of enzymatic treatment. The influence of enzyme concentration on whelk toughness is shown in figures 4 and 5. The combination of 15 minutes incubation time and 15 g/l papain gave a acceptable tenderness of whelk (Figure 4). The tenderness of whelk flesh increase significantly (P < 0.5) with increasing papain concentration, whereas increasing the time of incubation decreases tenderness. In the
case of ficin, increasing either incubation time or enzyme concentration increases significantly the firmness of whelk (Figure 5). After 15 minutes incubation, both enzymes (papain or ficin) rendered whelk flesh more tender, as compared to untreated samples (Figures 4 and 5). The increase in firmness as function of duration of thermal treatment agrees with the results of Martens et al. (1982). This change of texture depends of the composition of muscle (Khan, 1977). Enzyme treatment decreases pigmentation and this appearance might possibly influence the consumer.

Figure 4. Influence of papain concentration and incubation time on whelk firmness.

Figure 5. Influence of ficin concentration and incubation time on whelk firmness.
Effect of cooking time. For the three cooking methods investigated, the compression values of whelk decreased significantly after 20 minutes and after 40 minutes (Table 1). There is no significant difference between 10 and 20 minutes, nor between 30 and 40 minutes, nor between 50 and 60 minutes (P < 0.05). However in the case of cooking method (1), the difference was not significant between 40 and 60 minutes. These findings agree with those of Bouton and Harris (1972). These results indicate the longer the cooking time, the more tender whelk flesh becomes. This is not the case for enzyme treated flesh, where restructuration phenomena of hydrolysed tissue constituents probably take place with the duration of incubation.

Table 1. Influence of cooking times on whelk tenderness for different cooking methods.

<table>
<thead>
<tr>
<th>COOKING METHODS</th>
<th>TIMES (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 20 30 40 50 60</td>
</tr>
<tr>
<td>Boiling water</td>
<td>.775a(1) .758a .614b .565b .567b .572b</td>
</tr>
<tr>
<td></td>
<td>.146a(2) .142a .120b .107c .106c .106c</td>
</tr>
<tr>
<td>Whole + pressure cooking</td>
<td>.765a .757a .741a .689b .538c .496d</td>
</tr>
<tr>
<td></td>
<td>.136a .128a .125a .118b .101c .098c</td>
</tr>
<tr>
<td>Decorticate + pressure cooking</td>
<td>.779a .785a .765a .690b .630c .513d</td>
</tr>
<tr>
<td></td>
<td>.149a .151a .152a .134b .128c .108c</td>
</tr>
</tbody>
</table>

(1) Firmness in MPa  
(2) Deformation modulus in MPa  

Any means in the same horizontal line with same superscript are not significantly different (Scheffe Multiple Range Test) at P < 0.05.

Effect of cooking method. The results obtained for the firmness and deformation modulus, indicate no significant difference (P < 0.05) between the three cooking methods for 10 minutes cooking time (Table 2). For 30 and 40 minutes, cooking in boiling water made whelk significantly (P < 0.05) more tender than cooking methods 2 and 3. For 50 minutes, pressure cooking (method 3) gave the best results for the firmness and deformation modulus. According to these results (Tables 1 and 2), decorticating whelks before pressure cooking increased firmness of samples. Between 30 and 40 minutes cooking whole whelk in boiling water gave the most tender flesh. In the pressure cooking method with decorticated whelks, the increase of flesh toughness could be related to the increasing rigidity of myofibrillar structure which is a function of cooking temperature (Bouton and Khan, 1975). In the case of cooking method (2),
the shell could reduce the effect of temperature on denaturation of myofibrillar proteins by reducing the rate of heat transfer.

Table 2. Influence of cooking methods on whelk tenderness for different times.

<table>
<thead>
<tr>
<th>Tenderness Parameters</th>
<th>Cooking Method (**)</th>
<th>Time (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>TB (in MPa)</td>
<td>1</td>
<td>.774</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>.765</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>.779</td>
</tr>
<tr>
<td>ME (in MPa)</td>
<td>1</td>
<td>.146</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>.135</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>.148</td>
</tr>
</tbody>
</table>

(**) 1 = whole whelk cook in boiling water  
2 = whole whelk cook in a pressure cooker  
3 = pre-cooked 10 min., decorticate and cook in a pressure cooker

a Any means in same vertical line with same superscript are not significantly different (Scheffe Multiple Range Test) at P < 0.05.

Effect of sodium chloride. Table 3 shows the effect of sodium chloride in cooking water on whelk firmness. These results agree with those of others who have demonstrated the use of salt to improve food texture or as a binding agent (Marsh, 1983). Sodium chloride interacts with proteins and other constituents to improve the texture of foods (Whiting and Richards, 1978).

Mechanical tenderization. The results obtained from mechanical treatments indicate no significant difference between the 200 g load and 400 g load (Figure 6), but both treatments rendered whelk flesh significantly more tender than untreated control and significantly less tender than hand tenderized (P < 0.05). There were no visual differences between the mechanically tenderized whelk and the untreated controls.
Table 3. Influence of NaCl in the cooking water on whelk tenderness.

<table>
<thead>
<tr>
<th>TENDERNESSE PARAMETERS</th>
<th>COOKING METHODS(*)</th>
<th>TIME (min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>TB (in MPa)</td>
<td>1</td>
<td>0.631&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.787&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>ME (in MPa)</td>
<td>1</td>
<td>0.115&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.151&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

(*) 1 pressure cooking in a glass jar with water only.
2 pressure cooking in a glass jar with NaCl 8%.

Any means in the same vertical line with the same superscript are not significantly different (Sheffe Multiple Range Test) at P < 0.05.

---

Figure 6. Effect of mechanical treatments on whelk firmness
A - control, B - Stroked with 200 g weight, C - stroked with 400 g weight, D - hand hammering.
Effect of various brines on whelk shelf-life. As shown in figure 7, the maximum shelf-life is seven days. The microbial count increases exponentially from 7 days to 30 days and becomes stable thereafter. The exponential proliferation of microorganisms could be related to osmotic phenomena: the extraction of water from tissue by the salt involves the diffusion of water soluble nutrients into the brine, and this provides the medium supporting the typical pattern of microbial growth. No significant difference was observed concerning the preservative effect of the ten salts investigated. In other words, sodium chloride could be partially replaced effectively by any of the other salts. This agree with the finding of various authors (Marsh, 1983, Seman et al, 1980, Seperich et al, 1983).

Figure 7. Effect of different salts on total microbial counts (PCA) for whelks stored during a 60 days period at 10°C.

- 6% NaCl + 2% CaCl₂;
- 6% NaCl + 2% KCl;
- 2% NaCl + 6% MgCl₂;
- 8% NaCl;
- 6% NaCl + 2% MgCl₂;
- 4% NaCl + 4% KCl;
- 4% NaCl + 2% MgCl₂ + 2% KCl;
- 2% NaCl + 4% MgCl₂ + 2% KCl;
CONCLUSION

Optimal tenderizing of whelk can be obtained by cooking in boiling water for 30-40 minutes. Tenderness is better if whelk is mechanically tenderized. Enzymatic tenderizing reserves some surprises (effective concentration of enzyme, overall cost for industrial production and final appearance of the product). Some correlation with sensorial tests are needed before final conclusions can be drawn. The microbial test conducted in this work confirmed the possibility of partial replacement of sodium chloride by other chloride salts without affecting the duration of shelf-life of brined whelk.

REFERENCES


ACKNOWLEDGMENTS

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EVALUATION OF A CONTAINERIZED SYSTEM
FOR THE RELAYING OF POLLUTED CLAMS (Mercenaria mercenaria)

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INTRODUCTION

Bivalve molluscs are well-known for their ability to bio-concentrate polluting microorganisms and their equal capability to cleanse themselves when placed in unpolluted environments. This latter fact has led to the development of entire industries based upon taking shellfish from marginally polluted water and either moving them to approved harvesting areas for natural cleansing (termed relaying) or sending them to onshore depuration facilities where water quality can be rigorously controlled.

Of the two processes, depuration has received the greater emphasis from scientists, industry and regulatory agencies as evidenced by the volume of information available (for examples see Arcisz & Kelly 1955, Furfari 1966, Haven et al. 1978 and Neilson et al. 1978). The reasons for this include the shorter periods of time involved to depurate compared to relaying (48-72 hours versus 15 days or longer), ease of operation and product recovery, and a greater assurance for a cleansed product. Relaying, on the other hand, has received only limited attention, despite the fact that it is widely practiced in both the oyster and hard clam industries (Blogoslawski and Stewart 1983).

The relaying of hard clams (Mercenaria mercenaria) from marginally polluted waters to approved harvesting waters for natural cleansing represents a multi-million dollar fishery in Virginia. By law, relaying has been confined to direct on-bottom placement of clams in approved areas. This process is extremely inefficient and prone to product losses as high as 30% owing to mortality associated with handling, predation, stressful environmental conditions and inherently poor recovery procedures. This loss is significant considering that approximately 25 million clams were harvested and relayed in Virginia during 1986 (Virginia Marine Resources Commission). Containerized relaying offers a potentially superior alternative to natural relaying. However, prior to 1987, it had not been approved by the Virginia Department of Health due to lack of documentation on effective purification of hard clams within containers. All previous containerized relaying experiments have been conducted using oysters (Crassostrea virginica or C. gigas).

One of the earliest studies to employ containers in a relaying study was conducted using oysters (C. virginica) in Biloxi Bay (Cook and
Childers 1968). While containerization demonstration was not an objective of the study, their use of 30 x 18 x 3-inch racks covered with 1-inch wire mesh yielded valuable data on the potential for container relaying. When racks with 6-inch legs to support the rack off-bottom were compared to racks placed directly on a mud bottom, no significant differences were found and cleansing was complete by the eighth day. Similarly there was no difference between oysters held in racks and oysters placed directly on mud bottom. However, cleansing was not completed until the tenth day, indicating that cleansing may proceed faster in racks.

Quayle and Bernard (1976) used wire-mesh baskets to demonstrate coliform bacteria purification of Pacific oysters (*Crassostrea gigas*). Open top galvanized iron mesh baskets 62 x 62 x 30 cm (24 x 24 x 12 in), containing approximately 55 kilograms (121 pounds) of oysters were used. Within 48 hours of being placed on the bottom, the oysters reached an equilibrium with ambient bacteriological conditions. Ninety percent of the original bacterial load was eliminated within 24 hours and an additional 8% reduction experienced by 48 hours after being placed in approved harvesting waters. Oysters sampled from varying depths within the basket should no statistically significant differences between samples. The authors suggested that containerization offered an economical alternative to traditional on-bottom relaying.

Supan and Cake (1982) determined the effects of containerized relaying on oyster (*C. virginica*) survival and purification under varying environmental conditions, differing seasons and different loading configuration; and, to investigate various designs of rafts, racks, trays and other containers for commercial relaying. They categorized their container systems as suspension relaying, on bottom (longline) relaying, or rack-relaying. Successful cleansing varied, but according to the authors, commercial quantities of oysters in multilayers could eliminate indicator bacteria.

In an effort to document the effectiveness of bacterial cleansing of hard clams when held in containers, a series of experiments were conducted during 1985 and 1986 (Kator and Rhodes, unpublished data). This project had two main objectives: document the bacteriological cleansing of containerized hard clams in a commercial setting and demonstrate the commercial advantages of containerized relaying over traditional on-bottom relaying. In this paper the authors will summarize the bacteriological results and concentrate on the results that relate to advantages over traditional relaying.

**MATERIALS AND METHODS**

The full-scale commercial container relaying experiments were conducted in cooperation with an established industry relayer using the traditional on-bottom method. Containers were built of expanded steel, diamond shaped mesh (2.54 cm along longest axis) supported on a
framework of 2.54 cm L-shaped steel bars. The containers measured 1.2 x 1.2 x .3 m (4 x 4 x 1 ft) and were fitted with 2, 15.2 x 15.2 cm (6 x 6 in) wooden skids on the bottom to support the container off the bottom. The container was constructed with a hinged edge midway across the top to permit one half of the top to be raised. The free edge of the top was fitted with a hasp closure to facilitate a seal for the container.

Results from the preliminary packing experiment indicated that hard clams representative of the size to be relayed (littlenecks and cherrystones) should not be packed more than 15.2 cm (6 in.) deep (Kator and Rhodes, unpublished data). Packing to this depth, each container held approximately 4500-5000 hard clams.

During the 1986 relaying season, five experiments were conducted utilizing naturally contaminated hard clams. Containers were deployed on approved bottom adjacent to ongoing bottom relaying operations. On the day of deployment, clams were randomly selected and returned to the laboratory for bacterial analysis. Water temperature and salinity were measured and a water sample taken for bacterial analysis. After a minimum of 14 days purification time, bagged clam samples were retrieved for analysis and the container returned to the bottom. If, upon analysis, the bagged clams met a product standard of 50 fecal coliform per 100 g of meats, then the remainder of the clams in the container were released for sale.

Once a container was released for sale, all clams were removed and counted to determine mortalities. Clams were separated into the following categories:

1. Marketable - no shell damage; still alive
2. Dead Clams - shells with both valves intact and attached;
3. Broken Clams, Old - broken shells with both valves attached, no meat inside; assumed damaged at time of harvest or packing in containers.
4. Broken Clams, New - broken shells with both valves attached, with meat inside; assumed damaged during reharvesting operation.

RESULTS AND DISCUSSION

Results of the bacterial analysis (Kator and Rhodes, unpublished data) for the five deployments of the relaying container indicated that effective depuration was accomplished. When containers were carefully deployed and clams exposed to favorable water quality, a product standard of 50 fecal coliforms/100 g meats was met.

Water temperatures fluctuated during the course of the experiments between a low of 17.5°C (63.5°F) on May 6, 1987 and a high of 29.5°C (85.1°F) on July 29, 1987. Salinity ranged from 18 and 22 ppt. Recovery data for 5 experiments using naturally polluted clams are
presented in Table 1. Results of each individual experiment will be discussed separately prior to summarization.

Experiment 1, May 6-27, 1986

The total number of clams held within the container was 4,835. This included 585 clams held in bags for microbiological analysis. Twenty-one days after initial placement, 4250 clams were released to market. For this experiment, distinctions between dead clams and old broken clams were not made. The significance of distinguishing dead from broken (old and new) is an indication of mortality that can be attributed directly to handling (initial harvest, placement in container or harvest from container) and other sources of mortality (smothering in container or unexplained). Excluding bagged clams for microbiological analysis, total mortality was 3.89%. Water temperature (17.5°C) and salinity (18.0 ppt) were recorded during this experiment.

Experiment 2, June 10-30, 1986

Container loading, deployment and retrieval went smoothly. A total of 4615 clams (585 held in sample bags) were loaded into the container. Upon release, 4030 clams were marketed. For this experiment, mortalities were separated into dead clams (43), old broken clams (114) and new broken clams (21). Total mortality (excluding bagged samples) was 4.23%. Of this total mortality, 3.21% could be attributed to handling effects.

Experiment 3, June 24-July 11, 1986

Results from this experiment are very similar to the previous one. A total of 4645 clams, including sample clams, were held in the container. At the end of 17 days 4060 clams were retrieved. Dead clams numbered 64; old broken clams, 90; and new broken clams, 31. Total mortality, excluding samples, was 4.36%. Mortality from handling was 2.85%.

Experiment 4, July 15-August 1, 1986

During the initial loading and deployment of the container, a mechanical problem caused the clams within the container to shift position on two occasions. Each time this happened the container had to be reopened, the bagged clams for microbiological analysis were repositioned and remaining clams redistributed. The increased handling was reflected in higher mortalities. Additionally, this sampling period experienced the highest water temperatures (29.0°C - 29.5°C), potentially stressing the clams and adding to the mortality. A total of 4723 clams were held in the container. Seventeen days later 4138 were released for sale. Total mortality was 6.84%. The number of dead clams increased to 123, about double the previous experiment; old broken clams increased to 151 (67% higher than the previous experiment); and there
Table 1. Recovery data for naturally polluted clams held in containers.

<table>
<thead>
<tr>
<th>Sampling Period (Days Cage On-Bottom)</th>
<th>Total # Clams&lt;sub&gt;1&lt;/sub&gt; in Cage</th>
<th>Total # Mortalities</th>
<th># Of &quot;Dead&quot; Clams&lt;sub&gt;2&lt;/sub&gt;</th>
<th># Of &quot;Old&quot; Broken Shells&lt;sub&gt;3&lt;/sub&gt;</th>
<th># Of New Broken Shells&lt;sub&gt;4&lt;/sub&gt;</th>
<th>% Handling Mortality&lt;sub&gt;5&lt;/sub&gt;</th>
<th>% Total Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAY 6-27 (21)</td>
<td>4,250</td>
<td>172</td>
<td>-</td>
<td>132</td>
<td>40</td>
<td>3.89</td>
<td>-</td>
</tr>
<tr>
<td>JUNE 10-30 (20)</td>
<td>4,030</td>
<td>178</td>
<td>43</td>
<td>114</td>
<td>21</td>
<td>4.23</td>
<td>3.21</td>
</tr>
<tr>
<td>JUNE 24-JULY 11 (17)</td>
<td>4,060</td>
<td>185</td>
<td>64</td>
<td>90</td>
<td>31</td>
<td>4.36</td>
<td>2.85</td>
</tr>
<tr>
<td>JULY 15-AUG 1 (17)</td>
<td>4,138</td>
<td>304</td>
<td>123</td>
<td>151</td>
<td>30</td>
<td>6.84</td>
<td>4.07</td>
</tr>
<tr>
<td>AUG 5-28 (23)</td>
<td>3,881</td>
<td>339</td>
<td>114</td>
<td>207</td>
<td>18</td>
<td>8.03</td>
<td>5.33</td>
</tr>
<tr>
<td>TOTAL</td>
<td>20,359</td>
<td>1,178</td>
<td>334</td>
<td>694</td>
<td>140</td>
<td>5.47</td>
<td>3.87</td>
</tr>
</tbody>
</table>

1. Does not include clams used for microbiological analysis.
2. "Dead" clams, valves intact, no broken pieces.
3. "Old" broken shells, valves attached, no meat inside.
4. "New" broken shells, valves attached, with meat inside.
5. Broken clams are indicative of handling mortality - a distinction could be made between initial harvesting/cage loading and cage harvesting by looking at "old" and "new."
were 30 new broken clams (similar to the previous experiment). Handling mortality increased to 4.07% mainly on the basis of old broken clams. The higher number of old broken clams was attributed to the container shifts during initial deployment.

Experiment 5, August 5-August 28, 1986

This experiment was also beset with complications caused by unusually heavy rainfall. For a six-day period (August 11 - August 17), the relaying site and surrounding area experienced heavy rainfall associated with a passing tropical depression. As a possible consequence, sampled clams failed to reach acceptable fecal coliform levels and, therefore, were not released for sale. The entire container was left on the bottom for an additional 7 days, after which more clams were sampled for microbiological analysis. After this additional cleansing time, the acceptable fecal coliform level was achieved and the remaining clams released for sale. However, this entire procedure increased the amount of handling, disturbance and increased the length of time that the clams were held (23 days). Together, the increased handling and length of holding, combined to yield the highest total mortality and handling mortality. Initial clam container stocking was 4526. After 23 days and the removal of 2 samples, 3881 clams were marketed. Total mortality for the period was 8.03%. Dead clams numbered 114, old broken clams 207 and new broken clams 18. Handling mortality was 5.33%.

SUMMARY

The use of containers for relaying clams clearly is superior to direct on-bottom relaying in terms of recovery rate and ease of recovery. Over the course of the container experiments, average total mortality was 5.5%. During the 1986 relaying season, the adjacent on-bottom relayed clam loss was 22% (personal communication, Roy Davis Seafood). The term "loss" as opposed to mortality is used when referring to on-bottom clams because a distinction cannot be made between clams that actually died and clams that failed to be reharvested.

This difference in losses amounts to sizeable sums of money when large numbers of clams are involved. Over the course of a season a large scale relaying operation can relay 8 million clams. Using the simplest of economic evaluations employing only total gross sales loss without taking into account labor or other operating expenses the magnitude of this monetary loss may be illustrated. A comparison based upon 8 million relayed clams can be made between a totally containerized operation with a 5.5% loss and a totally on-bottom operation with a 22% loss. A 5.5% loss from 8 million clams represent a loss of 440,000 clams; at 22%, 1,760,000 clams are lost; a difference of 1,320,000 clams. If we assume a $0.15 per clam sales price, the on-bottom
operation had a total gross sales loss of $198,000 greater than the containerized operation.

Other benefits would accrue from containerization, one of which would be labor reduction at reharvesting. Current on-bottom reharvesting requires extensive man-hour expenditures using either hand tongs (shaft tongs) or patent tongs. With a container, close to 5000 clams can be harvested in a matter of a few minutes. The actual savings in time and labor expense must be examined more closely in order to obtain a more accurate accounting.

An outgrowth of the ease of recovery would be a more efficient business plan in terms of sales planning or in meeting unforeseen sales opportunities. By knowing the number of clams needed to meet a day’s sales, it would be a simple matter of harvesting the required number of containers. Additional sales requests could be quickly met merely by increasing the number of containers harvested.

An additional benefit from containerization comes from the overall appearance and condition of the clams. On-bottom clams, as a result of their physical contact with the sediment, can become discolored (shells darkened) and take on a gritty taste. On the other hand, containerized clams, since they never come in direct contact with the sediment, have cleaner, whiter shells and none of the grit problem associated with clams taken directly from the bottom. These points, in themselves, could be used as marketing tools, perhaps resulting in a premium price being received for containerized clams.

In conclusion, containerization of relayed clams can reduce clam losses and hence, increase revenues. In addition, containerization can offer to the market a superior product in appearance and taste, while satisfying health and regulatory requirements.
LITERATURE CITED


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