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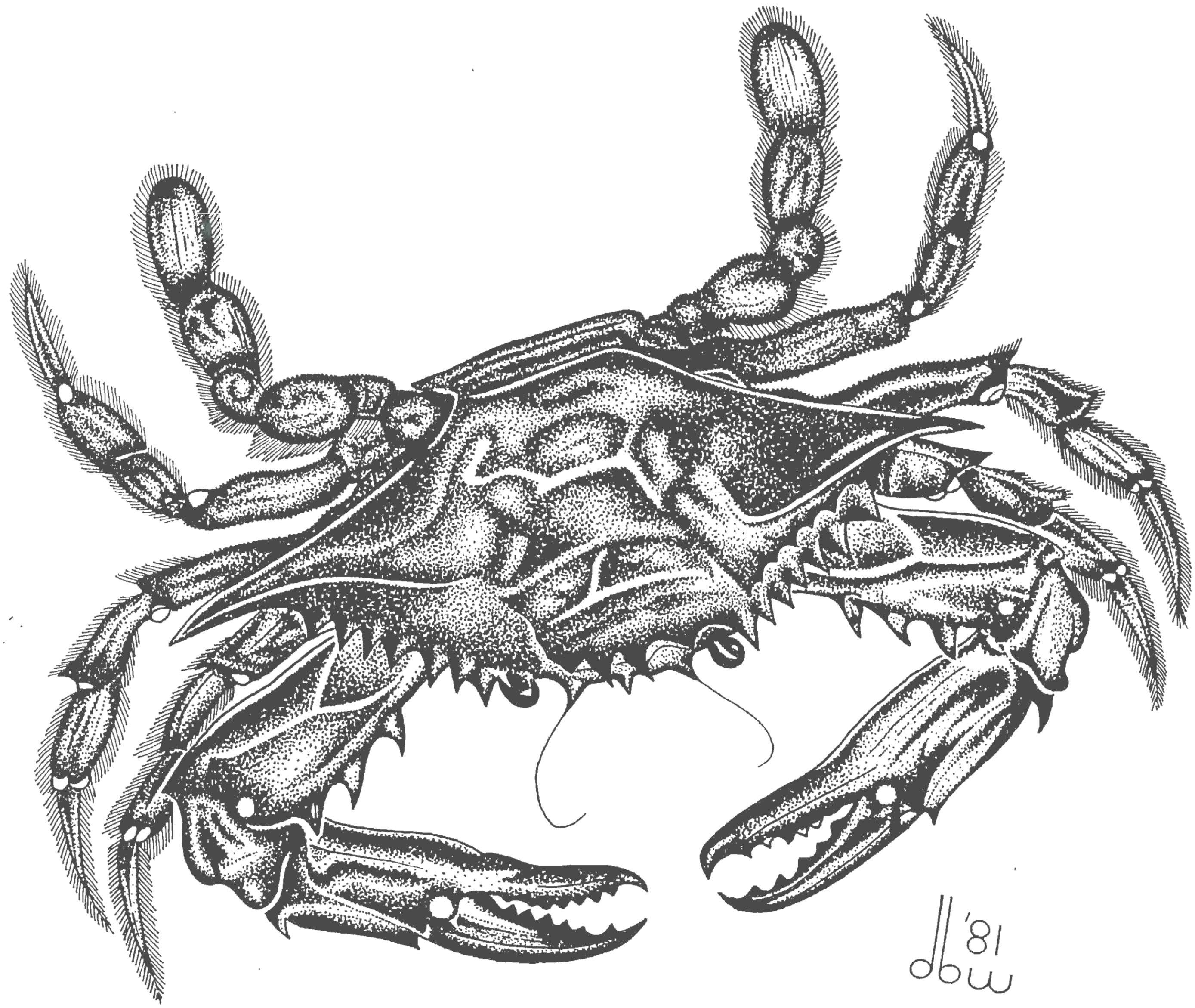
Proceedings:

BLUE CRAB COLLOQUIUM



Gulf States Marine Fisheries Commission

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PROCEEDINGS OF THE BLUE CRAB COLLOQUIUM

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Sponsored by

GULF STATES MARINE FISHERIES COMMISSION
30th Annual Fall Meeting
Biloxi, Mississippi

October 16–19, 1979

PREFACE

A colloquium on the blue crab, *Callinectes sapidus*, was held in conjunction with the 30th Annual Fall Meeting of the Gulf States Marine Fisheries Commission in Biloxi, Mississippi, on October 16–19, 1979. Topics addressed included aspects of the biology of the blue crab, economics, processing technology, harvesting, and the fishery for soft-shell crabs. The proceedings were recorded on tape, however, participants were asked to submit papers. With the overwhelming positive response to the colloquium, and the limited time available for oral presentations, it soon became evident that all participants would not have the opportunity to address the session. For that reason, several of the topics were presented as an overview with contributed papers published in this proceedings.

Appreciation is extended to Mr. Charles Lyles, Director of the Gulf States Marine Fisheries Commission, and to Mrs. Virginia Herring, his administrative assistant, who were instrumental in organizing the colloquium. A special thanks to Mr. Larry Simpson, Assistant to the Director of the Gulf States Marine Fisheries Commission, for his patience and understanding during the preparation of this volume.

Others who helped to make the colloquium a success include Kenneth Stuck of the Gulf Coast Research Laboratory, and Tommy VanDevender, formerly of the Gulf Coast Research Laboratory. Dottie Neely, publications specialist, of Ocean Springs, MS, typeset and formatted the camera-ready copy from the manuscripts for publication.

Finally, we apologize for the inordinate amount of time required to prepare this volume, but we biologists are known to be terrible procrastinators when forced to take up the pen.

The Editors

INTRODUCTORY REMARKS

CHARLES H. LYLES
Executive Director
Gulf States Marine Fisheries Commission

The blue crab fishery of the Gulf of Mexico is the area's third most important fishery in both volume and value being excluded only by menhaden and shrimp. It provides jobs for thousands of persons in catching, processing, marketing, and in supply services to this important fishery. It is prosecuted almost exclusively in state waters, the only Fisheries Conservation Zone catch being that small quantity taken by trawls as incidental catch.

Little research has been directed to this important fishery in the Gulf of Mexico by either the state or federal fishery agencies. This has doubtless resulted in some very serious problems which continue to surface in this fishery. These problems relate mostly to the economics of the processing operation, which is largely hand work in an era of machine mass production. Other problems relate to fluctuations in the fishery, and to sociological problems concerned with certain harvesting practices.

This colloquium attempts to bring together in one document the state of knowledge of the animal, and the fishery as it relates to the Gulf of Mexico and to other regions where this resource is harvested. It is hoped this document will serve as a reference for the caretakers of this important resource. The Gulf States Marine Fisheries Commission is grateful to those scientists who assisted in developing this colloquium.

WELCOMING ADDRESS

REPRESENTATIVE LEROY J. WIETING, CHAIRMAN
Gulf States Marine Fisheries Commission

Good morning. I am Leroy Wieting and I wish to welcome you to the 30th Annual Fall Meeting of the Gulf States Marine Fisheries Commission. The Commission is made up of three members from each of the five Gulf states. One is the head of the resource agency in charge of fisheries, another is a member of the state legislature, and the third is an interested private citizen of that state. That is the composition of the Commission. I would like to take this time to say that it has been a great year for me, since tomorrow will be my last day to serve as Chairman. It has been a tremendous year and I appreciate the opportunity to work with each of you. Having served on the Commission for 5 or 6 years, afforded the chance to learn more about fishery resources. I appreciate it.

At this time, I would like to give special recognition to some people who have certainly helped me. I have been involved in the legislative process for 17 or 18 years, so, I think I can speak with some authority. The people who really make government go in our offices and in other places of business are the people who work for us. In all my legislative service I know no one who has done a better job of performing the duties of the office than Charlie Lyles. Charlie is the Executive Director. He is one who speaks out. If it's right he tells you about it. This is something that I appreciate. If you made our party last night and enjoyed it, all the smoked mullet and shrimp were provided by Charlie. I just want to let you know I didn't cook all this up; Charlie did. Charlie, we do appreciate you. We were all thinking of you and the others as the hurricane came through here and we certainly continue to pray for you.

We appreciate all these people who work for us in the office and what they have done in helping us in the Commission.

I would like to say a word or two about Larry Simpson. He is the Assistant Director. We appreciate Larry and I know that as you get to know him more you will be aware of the work he does.

Also, Mrs. Virginia Herring, who is our administrative assistant, does a great job for us.

At this time I also want to mention some of my general thoughts and feelings as outgoing Chairman. My concern as outgoing Chairman is this. I feel each state should continue to get more legislative involvement in the meetings of the Commission. It does not make any difference how much we talk about things that involve our states, if the legislatures are uninformed. For the Commission to function as

Congress intended for it to, we should implement recommendations that come from these meetings. Unless we have the state legislatures involved, it just will not work. This is why I feel that for our program in 1982, we should meet in Austin, Texas, when the legislature meets in the middle of March. This is so we can get the legislative members involved, particularly in my state and, hopefully, in each of your states.

Again, we're glad you are here and we believe that you will benefit from this meeting. I think it is a very important gathering, particularly if you have an interest in blue crabs. This meeting will be devoted to a colloquium on this crustacean, sometimes referred to as a delicacy in armor. But the real reason for the colloquium is to review the state of knowledge of this animal to provide for its management and utilization. It is an important marine animal of the Gulf coast states, being utilized for both commercial and recreational purposes. As I said earlier, I feel like this is one of the most important colloquiums that the Commission has sponsored, although we have had others that have been very informative. In keeping with the dictates of PL 94–265, which requires that management of state coastal waters conform to the principles laid down in the federal statutes, this Commission began in 1976 to prepare management plans for the major species that inhabit the coastal waters of the five Gulf states. The first of these plans were for the shrimp and menhaden fisheries, our two most valuable marine resources. These plans have been completed and published, and some implementation of these plans has already occurred. Following closely on the heels of the menhaden and the shrimp plans came the planning for spotted seatrout and red drum. Almost all the harvest of these species occurs within the state territorial sea and inland waters. Consequently, this Commission sponsored a colloquium in Tampa, Florida, last October, and began work on a planning document for these species. The profile and the proceedings of that colloquium are presently being edited and will be published in the near future.

That brings us to the present Blue Crab Colloquium which will be followed by a management profile on the animal. All of these species represent about 90% of the fish taken in state waters. I might say that each one of these species is tremendously important. You cannot only look at one fishery when you start dealing with marine life, you have to look at all of them. As you know better than I, one species depends on the other and if we make a drastic move in one area, we shift a whole set of marine problems.

Today's program is under the joint chairmanship of Mrs. Harriet Perry of the Gulf Coast Research Laboratory, and Mr. W. A. Van Engel of the Virginia Institute of Marine Science. Mrs. Perry has done considerable research on blue crabs in Mississippi. Mr. Van Engel is well known for his work on the Atlantic Coast, particularly in the Chesapeake Bay. I certainly want to take this opportunity to thank both of them for their generosity in agreeing to co-chair this colloquium.

At this time, I would like to turn it over to Mrs. Perry and Mr. Van Engel.

Thank you very much for coming.

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GEOGRAPHICAL ECOLOGY AND EVOLUTIONARY RELATIONSHIPS IN *CALLINECTES* SPP. (BRACHYURA: PORTUNIDAE)

ELLIOTT A. NORSE[1] AND VIRGINIA FOX-NORSE
Executive Office of the President, Council on Environmental Quality, 722 Jackson Place NW, Washington, D.C. 20006, and U.S. Environmental Protection Agency, A-104, 401 M Street SW, Washington, D.C. 20460

DEDICATION In countless ways, our ideas have been shaped by the beautiful insights of five people: crustacean systematist/biogeographer John S. Garth, geographical-evolutionary ecologist Robert H. MacArthur, benthic community ecologist Howard L. Sanders, crustacean systematist/benthic community ecologist William Stephenson, and plant community ecologist Robert H. Whittaker. We dedicate this work to them.

INTRODUCTION

The 14 or so living species in the genus *Callinectes* are only a tiny fraction of the roughly 4,500 species of true crabs (Brachyura), and are numerically insignificant among the world's several million arthropod species. Even so, they are prominent in our mental landscapes because of their exceptional size, abundance, accessibility, and value in both the cookpot and the laboratory. They are fished by subsistence and commercial crabbers throughout much of their range, and are the basis for one of the most important United States fisheries. Not surprisingly, they occupy major roles in their ecosystems (Peterson 1979, Virnstein 1977, Woodin 1978). Yet, there is a great deal about blue crabs that we do not know. Scientists know some of the species mainly as faded specimens in alcohol. Most have yet to receive even modest attention from researchers, and we have only begun looking for answers to some questions about the best-known *Callinectes* species.

In this paper, we will examine some aspects of geographical ecology and evolutionary patterns in *Callinectes* spp., and their relevance to blue crab fishery research.

DISTRIBUTIONS AND EVOLUTIONARY RELATIONSHIPS

Callinectes is a warm-water genus in the predominantly tropical family Portunidae. The poleward distribution of the genus appears to be limited by summer temperatures, with no species occurring regularly where peak temperatures fail to approach 20°C (Norse 1977), below which larvae may be unable to metamorphose. While there is little evidence that blue crabs occur naturally in the Indo-West Pacific, where most other portunids are found (Stephenson 1972, 1976), *Callinectes* are abundant in tropical and some temperate coastal regions of the Atlantic and East Pacific oceans. The East Pacific Ocean has three species. Two species, *C. bellicosus* (Stimpson) and *C. toxotes* Ordway are parapatric (having abutting, but essentially nonoverlapping geographic distributions). The third species, *C. arcuatus* Ordway, is sympatric (geographically overlapping) with both *C. bellicosus* and *C. toxotes* (Garth and Stephenson 1966, Williams 1974).

There are nine *Callinectes* species in the West Atlantic Ocean: *C. bocourti* A. Milne Edwards, *C. maracaiboensis* Taissoun, *C. rathbunae* Contreras, *C. sapidus* Rathbun, *C. danae* Smith, *C. similis* Williams, *C. ornatus* Ordway, *C. marginatus* (A. Milne Edwards), and *C. exasperatus* (Gerstaecker). In this century, probably with man's assistance, *C. sapidus* has extended beyond its natural range. It has been recorded sporadically on the Atlantic coast of Europe (Christiansen 1969) and in the Black Sea (Bulgurkov 1968), and is firmly established in the eastern Mediterranean (Halim 1975, Holthuis and Gottlieb 1955, Shaheen and Yosef 1979). *Callinectes marginatus* (apparently naturally) also occurs in the East Atlantic Ocean, where it is sympatric with *C. latimanus* Rathbun and *C. gladiator* Benedict (Monod 1956, Rathbun 1921, Williams 1974).

The evolutionary relationships within the genus *Callinectes* are not entirely clear. Stephenson et al. (1968) used numerical taxonomic methods to examine morphological similarities within the genus, but they produced several sets of conflicting results. Williams (1974) reported that numerical taxonomic methods did not give results consistent with interpretations of relationships based on classical taxonomic methods. Figure 1 gives a preliminary view of evolutionary relationships in the genus *Callinectes*, based on both classical taxonomic methods and our experience with live specimens of 11 of the 12 American species.

Six species comprise what we call the "*bocourti* group" (Figures 2–5). Males in all species of this group have convergent or crossing first gonopods that extend well past the suture between the fifth and fourth thoracic sternites. The intramedial area of the carapace tends to be narrower and longer than that of the other species groups, and the granulations on the carapace tend to be quite coarse or variable in size, sparse, uneven, and absent from large areas. The merus of the swimming leg may be more elongate than in

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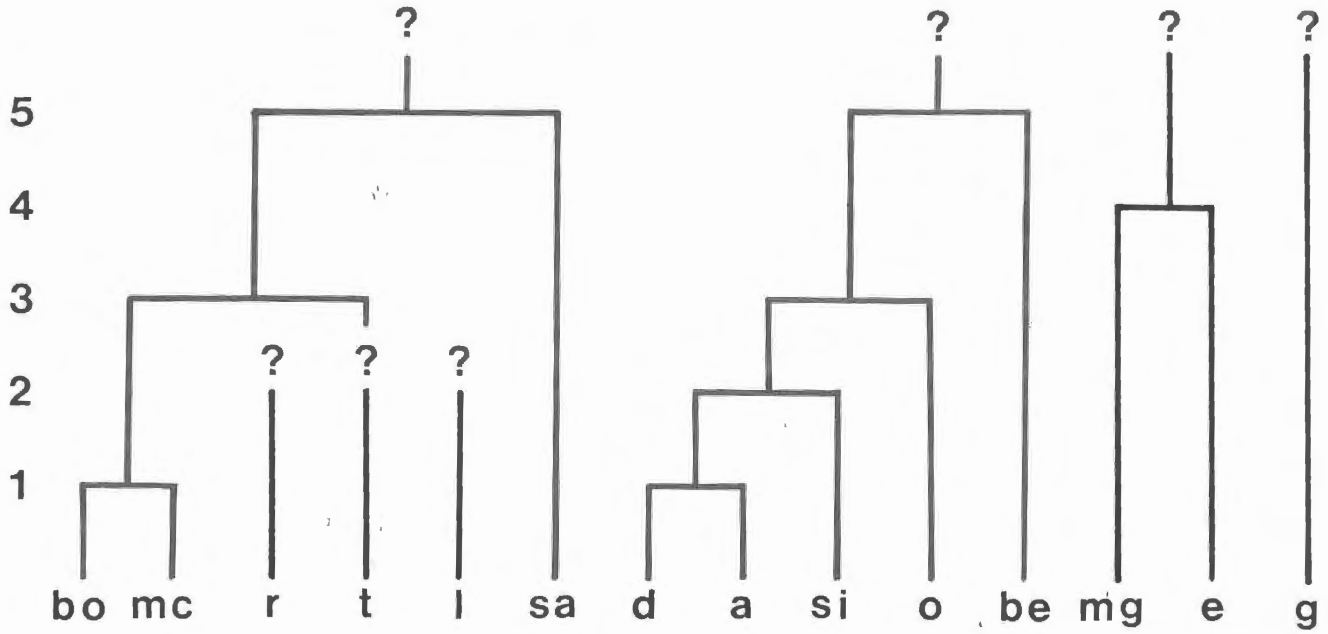

Figure 1. Dendrogram of hypothesized relationships among *Callinectes* spp. Species linked at level 1 are the closest relatives. Question marks signify uncertainty about relationships at that level or higher. Legend: bo–*C. bocourti*; mc–*C. maracaiboensis;* r–*C. rathbunae;* t–*C. toxotes;* l–*C. latimanus*; sa–*C. sapidus;* d–*C. danae;* a–*C. arcuatus;* si–*C. similis;* o–*C. ornatus;* be–*C. bellicosus;* mg–*C. marginatus;* e–*C. exasperatus;* and g–*C. gladiator.*

the "*danae* group," but is less elongate than in the "*marginatus* group." *Callinectes bocourti* and *C. maracaiboensis* are so similar in alcohol that only availability of fresh specimens enabled Taissoun (1969, 1972) to recognize them as distinct species. Somewhat less similar are *C. rathbunae, C. toxotes,* and *C. latimanus. Callinectes sapidus* is the most distinct among the six species, although clearly sharing numerous characters with the rest. Williams (1974) listed the species in this group consecutively, and discussed possible relationships among some of them.

The "*marginatus* group" includes *C. marginatus* and *C. exasperatus* (Figures 6 and 7). Despite dissimilarities that are probably evolutionarily labile (size, color, length of ninth anterolateral spine), they both have forward-sweeping first through eighth anterolateral teeth whose posterior margins tend to be unbroken curves, rather than straight, angled, or sinuous. Carapace granulations are raised, coarse, and evenly distributed. The chelae are robust, with fingers often symmetrically arched; fixed fingers are prominently grooved. The swimming leg meri are more elongate than those of species in the other groups.

Five species comprise the "*danae* group" (Figures 8–12). The leading edge of the dorsal surface of the merus of the cheliped is intensely blue or purple in this group. The intramedial area of the carapace tends to be broader and shorter than that of the other species groups, and the granulations on the carapace tend to be fairly uniformly medium to fine in size and evenly dense. The merus of the swimming leg is quite round. Williams (1974) commented on the strong similarity between *C. danae* and *C. arcuatus. Callinectes similis* (as its name implies) is also quite similar, with *C. ornatus* only slightly less so. Substantially further removed from these species is *C. bellicosus.*

In the "*gladiator* group," the only species, *C. gladiator,* is undoubtedly a *Callinectes,* but seemingly without particularly strong resemblance to any of its congeners. This tentative assessment could well result from our relative inexperience with living or preserved specimens of *C. gladiator.*

Of course, morphological similarities do not necessarily reflect common evolutionary origins. Similar-looking species may actually have converged evolutionarily due to selection by similar environmental forces. Conversely, dissimilar-looking species actually may have arisen from the same stock recently (in evolutionary time) as a result of sharply divergent selective forces. In the genus *Callinectes,* however, we feel that the species groupings probably reflect actual evolutionary groups, in part because we have deemphasized morphological characters likely to be evolutionarily labile (e.g., claw robustness, as discussed by Vermeij [1977]), and have emphasized characters presumed to be conservative because their selective value is less obvious [e.g., the shape of the merus of the swimming leg (Figure 13)]. Still, other types of corroborating evidence would be valuable. No one has yet built biochemical phylogenies of blue crab species to compare with schemes based on morphology, as Avise and Smith (1974) did with sunfishes in the genus *Lepomis.* But the literature and our research have yielded evidence from both the ecological distributions and ecophysiological tolerances of the species which tends to corroborate the evolutionary relationships as outlined above.

Figure 2. *Callinectes bocourti* male; Jamaica (Kodak Ektachrome X).

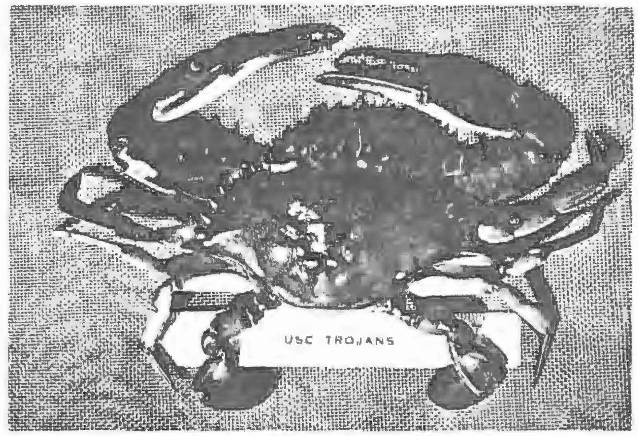

Figure 3. *Callinectes maracaiboensis* male; Jamaica (Kodak Ektachrome X).

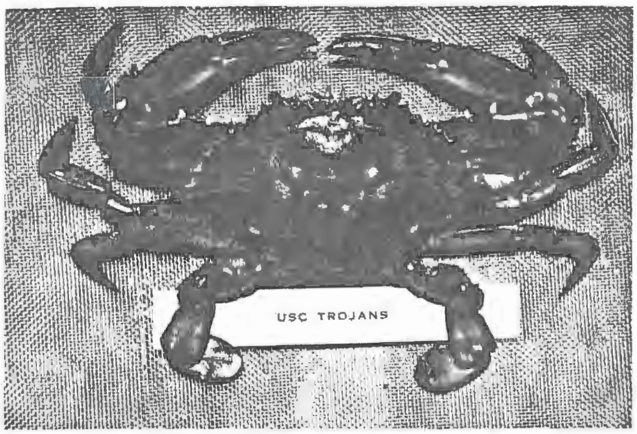

Figure 4. *Callinectes sapidus* male; Jamaica (Kodak Kodachrome X).

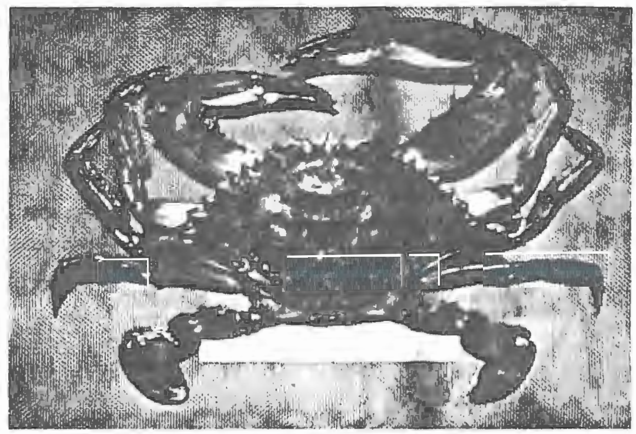

Figure 5. *Callinectes toxotes* male; Pacific coast of Colombia (Kodak High-speed Ektachrome).

Figures 2 through 5: Species comprising the "*bocourti* group;" *C. latimanus* and *C. rathbunae* not pictured.

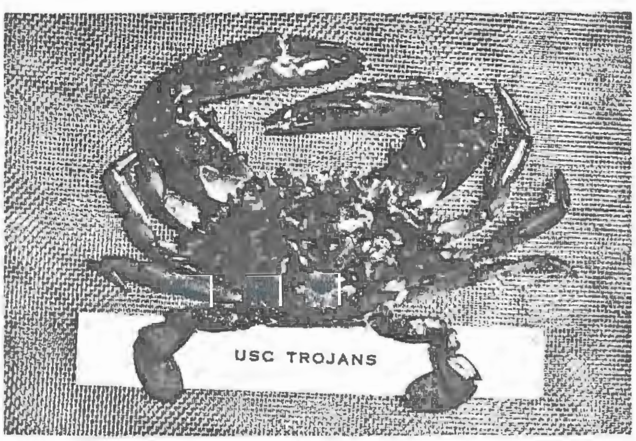

Figure 6. *Callinectes marginatus* male; Jamaica (Kodak Ektachrome X).

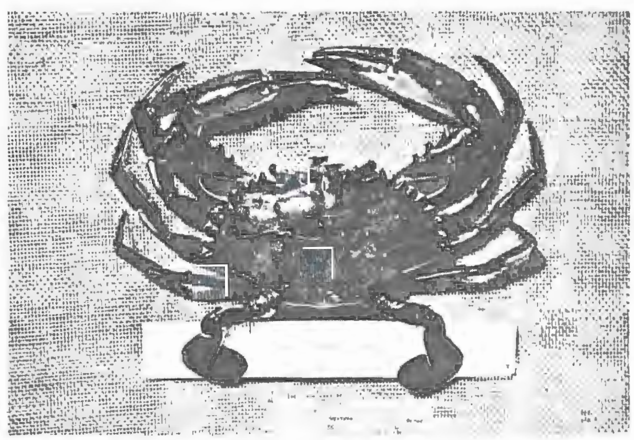

Figure 7. *Callinectes exasperatus* male; Jamaica (Kodak Ektachrome X).

Figures 6 and 7: Species comprising the "*marginatus* group."

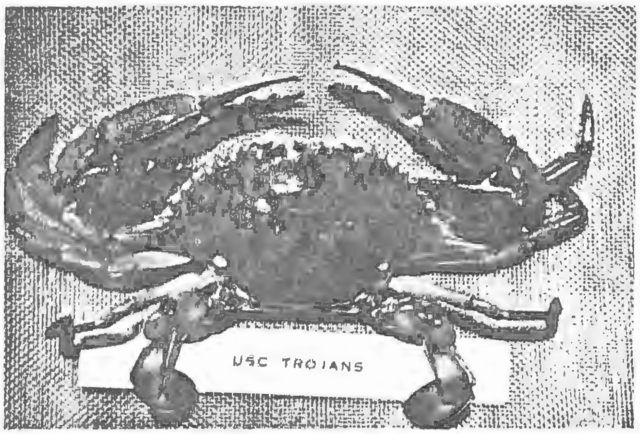

Figure 8. *Callinectes danae* male; Jamaica (Kodak Ektachrome X).

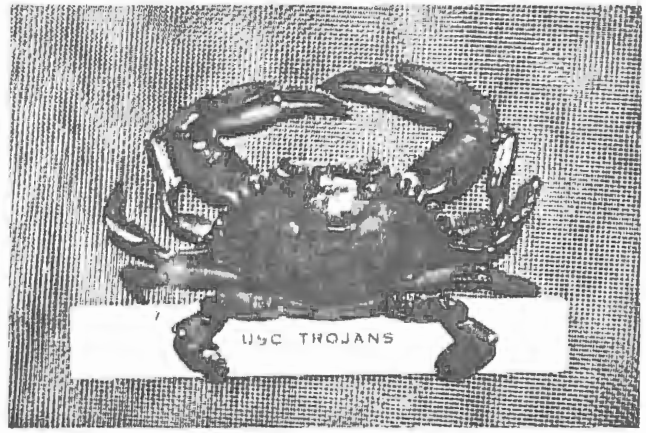

Figure 9. *Callinectes arcuatus* male; Pacific coast of Colombia (Kodak High-speed Ektachrome).

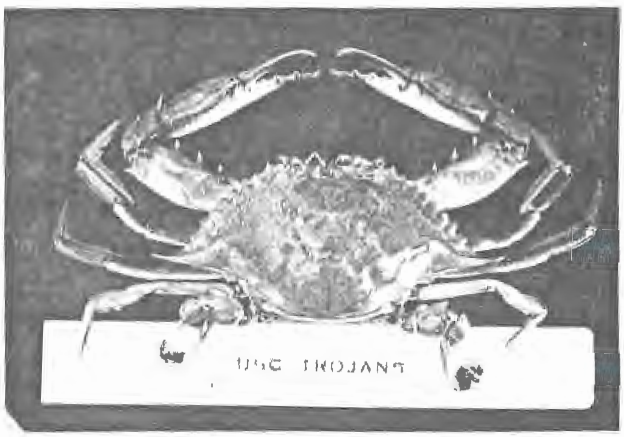

Figure 10. *Callinectes similis* male; Miami, Florida (Kodak Kodachrome X).

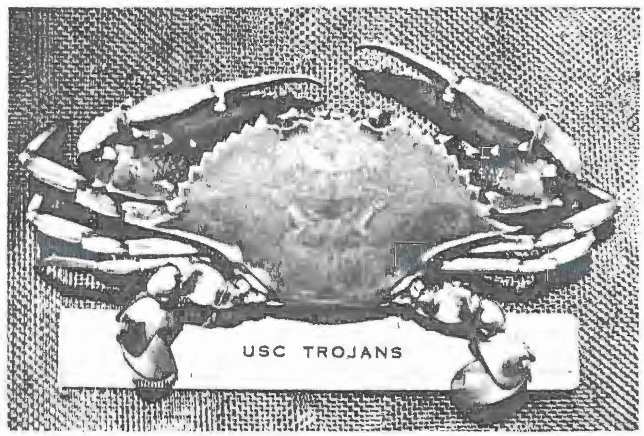

Figure 11. *Callinectes ornatus* male; Jamaica (Kodak Ektachrome X).

Figure 12. *Callinectes bellicosus* male; La Paz, Baja California, Mexico (film unknown).

Figure 13. (Left) Round swimming leg merus of *Callinectes danae* (*danae* group), and (right) elongate swimming leg merus of *Callinectes exasperatus* (*marginatus* group) (Kodak Ektachrome X).

Figures 8 through 12: Species comprising the "*danae* group."

Along all three ocean borders where blue crabs occur, there are large inshore species and small offshore species (Table 1). Some areas have only two or three sympatric *Callinectes* spp. On the East Pacific coast of Colombia, the colossal *C. toxotes* is most abundant in upper estuarine reaches and decreases towards shallow shelf waters, while the small *C. arcuatus* appears in mid-estuary and reaches peak densities in shallow shelf waters (Norse and Estevez 1977).

In the northern Gulf of Mexico, *C. sapidus* is the large estuarine species and *C. similis* is the small offshore species (Perry 1975). Another small offshore species, *C. ornatus,* may be sympatric with *C. sapidus* and *C. similis* in the Carolinas (Williams 1974; C. G. Bookhout and P. Perschbacher, personal communication). Accounts in Williams (1974) hint that *C. sapidus* and *C. rathbunae* are the estuarine species in the state of Tamaulipas, Mexico, and possibly more southerly coastal areas of the Gulf of Mexico, with *C. similis* occurring in somewhat higher salinities there, as in the United States. We identified the same three species from Frontera, Tabasco, Mexico, in collections by R. and I. Marin (which extends the known range of *C. rathbunae* southward by about 100 km).

Similarly in West Africa, the estuarine species is the large *C. latimanus,* and the more marine species are the smaller *C. marginatus* and *C. gladiator* (Capart 1951, Kwei 1978, Williams 1974).

Thus, these data suggest a common pattern in each of the above coastal regions: the species in the freshest and most stressful waters is (are) the largest and belongs to the *bocourti* group, while less terrestrially influenced waters have smaller species in other species groups. In the Caribbean and tropical West Atlantic coast of South America, where up to seven species may occur sympatrically, the pattern is similar. The large *bocourti* group species (*C. bocourti, C. maracaiboensis,* and *C. sapidus*) dominate the freshest waters or those most susceptible to severely dropping salinities, and the smaller *danae* and *marginatus* group species dominate climatically less stressful waters (Coelho 1967a,b; Holthuis 1959; Norse 1975, 1977, 1978a,b; Taissoun 1969, 1972).

These ecological patterns, and the geographical patterns Norse (1977) discussed, suggested that the species have different abilities to withstand the physical and chemical conditions in the spectrum of biotopes they inhabit. Laboratory experiments confirmed this. Among Jamaican *Callinectes,* there are significant differences in tolerance of desiccation and high temperature (Norse 1975), but these differences appear to be of minor importance compared with differences in tolerance of low salinity.

Norse (1978a) found that species' hyposalinity tolerances vary almost exactly as would be predicted from the salinity regimes of their respective habitats. The *bocourti* group species are the most euryhaline Jamaican *Callinectes,* while sympatric *danae* and *marginatus* group species are less so. Similarly, Engel (1977) found that North Carolinian *C. sapidus* are significantly more tolerant of reduced salinity than *C. similis.* The aquatic climates of the habitats of the *bocourti* group species suggest that *bocourti* group species are probably the most dilution-tolerant blue crabs wherever they occur.

The *bocourti* group species share another salinity-related attribute. Colombian *C. toxotes* and Jamaican *C. bocourti, C. maracaiboensis* and *C. sapidus* have distributions suggesting that they are catadromous, storing energy primarily in low-salinity waters but spawning and hatching zoeae only in higher salinities. In each case, adult females occur mainly in higher salinities than males, and ovigerous females are limited to the higher end of their range (Norse 1977, 1978a; Norse and Estevez 1977). Kwei (1978) observed no recruitment of *C. latimanus* in a hyposaline Ghanaian coastal lagoon when it was cut off from the sea, suggesting that *C. latimanus* may also be catadromous. These findings from tropical species parallel the well-known catadromous migratory pattern in temperate *C. sapidus* (e.g., Hay 1905; Van Engel 1958). In the *danae, marginatus,* and *gladiator* species groups, there is clear evidence for catadromy only in *C. arcuatus* (Norse and Estevez 1977). Species which do not penetrate low-salinity waters may not undertake spawning migrations.

Although Jamaican *bocourti* group species have similar salinity distributions and hyposalinity tolerances, the pattern of close taxonomical and ecophysiological correspondence breaks down in the other groups. *Callinectes exasperatus* and *C. danae* tolerate low salinities better than *C. marginatus* and *C. ornatus* (Norse 1978a). However, the substrates occupied tend to be similar within groups and different between the *marginatus* and *danae* groups. Both Jamaican *danae* group species occur mainly on penetrable mud or sand bottoms with little or no vertical features (seagrasses, mangrove roots, corals, or rocks). At salinities above 30 ppt, "brown" featureless bottoms (terrigenous sediments and/or those with high organic contents) are dominated (43% of all *Callinectes*) by *C. danae,* while "white" featureless bottoms (carbonate sands and muds) are dominated (75%) by *C. ornatus.* In contrast, both *marginatus* group species live mainly on heterogeneous or three-dimensional bottoms. Mangrove roots in waters above 30 ppt are dominated (75%) by *C. exasperatus,* while seagrass (*Thalassia* and *Halodule*) beds are dominated (68%) by *C. marginatus.* These substrate-related distribution patterns reinforce the hypothesis that the species groups are indeed evolutionarily based.

The evidence presented so far suggests that the species groups share more than similar appearances. The *bocourti* group species are all large, occur in rivers, estuaries, and bays especially subject to severely lowered salinities, and are catadromous. The three species tested thus far have similar ecophysiological tolerances. Species in other groups

TABLE 1.

Relationship between position along inshore-offshore gradient and size among *Callinectes* spp.*

Locality/Species	Mean Carapace Length (mm)		Locality/Species	Mean Carapace Length (mm)		Locality/Species	Mean Carapace Length (mm)
EAST PACIFIC			WEST ATLANTIC (Cont)			WEST ATLANTIC (Cont)	
Sonora, Mexico[1]			Jamaica[4]			Curaçao[8]	
bellicosus[b]	58.5		*bocourti*[a]	55.0	(72.1)	*bocourti*[a]	55.0
arcuatus[b]	42.3		*maracaiboensis*[a]	57.8	(64.3)	*maracaiboensis*[a]	57.8
			sapidus[a]	63.2	(68.3)	*exasperatus*[c]	52.6
Cauca, Colombia[2]			*exasperatus*[c]	52.6	(59.1)	*danae*[b]	46.5
toxotes[a]	71.3	(87.3)	*danae*[b]	46.5	(53.8)	*marginatus*[c]	42.6
arcuatus[b]	42.3	(49.0)	*marginatus*[c]	42.6	(44.1)	*ornatus*[b]	41.6
			ornatus[b]	41.6	(47.2)		
WEST ATLANTIC						Suriname[9]	
North Carolina, USA[3]			Magdalena, Colombia[4]			*bocourti*[a]	55.0
sapidus[a]	63.2		*bocourti*[a]	55.0		*danae*[b]	46.5
similis[b]	43.3		*maracaiboensis*[a]	57.8		*ornatus*[b]	41.6
ornatus[b]	41.6		*sapidus*[a]	63.2			
			danae[b]	46.5		Pernambuco, Brazil[10]	
Florida Keys, USA[4]			*marginatus*[c]	42.6		*bocourti*[a]	55.0
sapidus[a]	63.2		*ornatus*[b]	41.6		*danae*[b]	46.5
exasperatus[c]	52.6					*exasperatus*[c]	52.6
marginatus[c]	42.6		Zulia, Venezuela[7]			*marginatus*[c]	42.6
ornatus[b]	41.6		*bocourti*[a]	55.0		*ornatus*[b]	41.6
			maracaiboensis[a]	57.8			
Mississippi, USA[5]			*sapidus*[a]	63.2		EAST ATLANTIC	
sapidus[a]	63.2		*exasperatus*[c]	52.6		Zaire[11]	
similis[b]	43.3		*danae*[b]	46.5		*latimanus*[a]	53.9
			ornatus[b]	41.6		*marginatus*[c]	42.6
Tamaulipas, Mexico[6]						*gladiator*[d]	35.0
sapidus[a]	63.2						
rathbunae[a]	52.8						
similis[b]	43.3						

*NOTE: For each locality, the uppermost species occupies the most terrestrially influenced (freshest or most variable) habitats; the lowest occupies the least-climatically stressful waters. Vertical bars link species whose habitats are not known to differ in stressfulness. Sizes in parentheses are mean carapace lengths of males in the largest third of specimens from Cauca, Colombia and Jamaica. All other sizes are mean carapace lengths of males whose abdomens detached freely from the sternum, from collections throughout the species' ranges from Williams (1974).

Sources of zonation data:

[1] Norse (1978b)
[2] Estevez (1972), Norse and Estevez (1977), Norse (1978b)
[3] C. G. Bookhout and P. Perschbacher, personal communication
[4] Norse (1975, 1977, 1978a,b)
[5] Perry (1975)
[6] Williams (1974)
[7] Taissoun (1969, 1972)
[8] Norse (1977, 1978a,b)
[9] Holthuis (1959)
[10] Coelho (1967a,b)
[11] Capart (1951)

Callinectes species groups:

[a] *bocourti*
[b] *danae*
[c] *marginatus*
[d] *gladiator*

are smaller, occur in higher and more constant salinities, and are less euryhaline. In the Caribbean, the *marginatus* group specializes in more heterogeneous (and less penetrable substrates than the *danae* group.

This neat picture is only slightly blurred by the pattern in the one region where the species dominating the most terrestrially influenced waters is not a member of the *bocourti* group. In the Gulf of California and the Pacific coast of Baja California, Mexico, the inshore species, *C. bellicosus*, belongs to the *danae* group. *Callinectes bellicosus* has converged with the *bocourti* group in size, and like them, is fished commercially. Its habitats usually differ from those of the *bocourti* group by having higher salinities and possibly less risk of severe dilution, because rainfall in northwestern Mexico is much lower and permanent streams are much fewer than in most areas where *bocourti* group species occur. Perhaps *C. bellicosus* is more tolerant of hyposalinities than other *danae* group species, but we would guess that it is probably much less tolerant than the *bocourti* group species. Instead, the aquatic climates and tidal regimes in *C. bellicosus*' habitats would select more for tolerance of hypersalinities and frequent stranding and desiccation. If so, this could be a boon to fisheries because exceptional desiccation tolerance would facilitate transportation of live crabs in this arid area.

While hyposalinity tolerances may differ between *C. bellicosus* and the *bocourti* group species, *C. bellicosus* is among the largest *Callinectes* spp., suggesting that large size is a fundamental attribute of inshore blue crabs, in both wet and dry regions. This is equally true in areas where there are no *Callinectes*. On the mainlands and islands of the Indo-West Pacific, *Scylla serrata* (Forskal), the largest species of portunid, occupies more terrestrially influenced biotopes, while smaller *Portunus*, *Charybdis*, and *Thalamita* spp. live in less terrestrially influenced waters. For some reason or combination of reasons, catadromous portunids must be large (Norse and Fox-Norse, in preparation).

Recognizing the evolutionary groupings of *Callinectes* spp. is not only a rewarding exercise for systematists–it has practical value. Related species tend to do things similarly–that is, they have similar niche dimensions. But because selection can favor evolutionary divergence (termed "character displacement" by Brown and Wilson [1956]) in sympatric, closely related species to avoid competition, biological similarities are likely to be greatest among closely related species that are allopatric (occurring in separate regions) or parapatric. Because the need to conduct preliminary studies increases time and money costs of in-depth research programs, lessons learned from one species that can be tentatively extrapolated to closely related parapatric or allopatric species can save time and money. Understanding the ecology of *C. rathbunae* or *C. latimanus* should be much easier when there is an understanding of *C. toxotes* or *C. sapidus*.

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NOTE ADDED IN PROOF:

Following Manning and Holthuis' (1981) reexamination of the taxonomy of East Atlantic (West African) *Callinectes*, the following changes in this paper are necessary:

1. The name *C. amnicola* (De Rochebrune, 1883) has priority over *C. latimanus* Rathbun, 1897, and should be used throughout.

2. The name *C. pallidus* (De Rochebrune, 1883) has priority over *C. gladiator* Benedict, 1893, and should be used throughout.

3. Consistent differences between the West Atlantic and East Atlantic populations of "*C. marginatus*" suggest that they should be considered separate species, with the name *C. marginatus* (A. Milne Edwards, 1861) retained for the East Atlantic species and the name *C. larvatus* Ordway, 1863 given to the West Atlantic species. These names should be used throughout. Thus, there are some 15 valid species in the genus *Callinectes*, rather than 14.

The similarities between *C. marginatus* and *C. larvatus* suggest that they are among the most closely related species in the genus, along with the pairs *C. danae* and *C. arcuatus*, and *C. bocourti* and *C. maracaiboensis.*

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DISCUSSION

Q. W. A. Van Engel: In regard to the preferences for low salinities or high salinities that you observed, are these characteristics you have found in large size adult crabs? It would not necessarily be true, say, of juvenile stages and larvae?

A. Elliott Norse: True. Maybe I should be a little clearer. I hadn't meant to give you the impression that I am speaking of preferences per se. Preference implies behavior; in other words you prefer steak to chicken or chicken to steak. It is not that crabs are always where they ***prefer*** to be, but rather where you find them is often a function of where they ***can*** be. Maybe the freshwater species of the blue crab would rather be in waters of higher salinities in some ways but there are things that prevent them from going into the higher salinities. That is one of the things that my research has been attempting to get at. The different kinds of distributions you find usually are the result of the factors that are pushing on the crabs and the crabs are pushing back; it is sort of a dynamic battle going on between the crab and the environment. For juveniles it will not be quite the same. Typically you find juveniles in really shallow water. Maybe the best thing I can say about juvenile crabs is you find them wherever you don't find the big ones. Where big crabs occur little ones do not, and that is why your nursery grounds are usually the places where there is a lot of thick vegetation.

Q. Van Engel: I would like to emphasize a comment that

Elliott made earlier, and that is the interest of these different species to industry often looking for new sources of crabs to be used for crabmeat production. Are the edibility characteristics of these different species pretty similar?

A. **Norse**: To the horror of some of my friends, I have done a great deal of field work on that and there is variation in the edibility of blue crabs. A really old crab of any species that is heavily encrusted with fouling organisms is likely to have flesh that does not taste as good as that of a crab that is a little younger and fresher perhaps. However, I have not been able to detect any differences among the species as far as edibility is concerned. Some of the largest crabs I've ever seen are *Callinectes toxotes* from the west coast of the Americas. I believe they beat even the Texas crabs in size. *Callinectes toxotes* is the subject of a local commercial fishery. It's almost a subsistence fishery in that the people who catch them tend to be poor people who have little boats and who catch their crabs mainly by trotlining. They send them to the market in baskets with leaves. It is a pretty primitive operation. So far as I know, there is no picking anywhere, no processing of any kind. It is all live crabs and they are delicious.

Q. **Harry Schafer**: Are there any differences in distribution patterns between males and females?

A. **Norse**: Yes, there are differences in the patterns of distribution of the freshwater blue crabs. By that I mean *C. sapidus, C. bocourti* and *C. maracaiboensis* in the Caribbean and *C. toxotes* in the Pacific. The males are typically found in fresher waters than the females; the females are found in somewhat higher salinities. All blue crabs have to release their eggs in near-marine salinities, so even in the species that occur primarily in low salinities, like *C. sapidus,* in all cases the females migrate towards the somewhat higher salinities, so that they can spawn and release their eggs. Larval development takes place in the sea.

Q. **Van Engel**: How do you distinguish between *Callinectes* and *Portunus*?

A. **Norse**: One way you can separate *Callinectes* from crabs in the genus *Portunus,* is that there is an absence of a spine on the dorsal inner edge of the chelar propodus, in other words, the inner part of the hand, the claw of the animal. *Portunus* always has a strong spine there.

Comment–Norse: Before you go running off and become experts on tropical *Callinectes,* I would like to warn you about a couple of things. One is that the species I have been showing you can be easy to distinguish under the right circumstances because their coloration is rather different; however, coloration can be a very, very treacherous key character and I'll tell you why. For one thing, crabs are sexually dichromatic. There is a difference in coloration between males and females. In *C. exasperatus*, males are mostly blue and females are mostly brown. To take that a little further, not only are crabs sexually dichromatic, but they have ontogenetic color changes as well. *Callinectes marginatus* as a young crab is a pale brown animal with very slight signs of mottling. As it gets larger and larger the mottling becomes more pronounced, black enters, a greenish color enters and blue develops on the claws. So they are sexually dichromatic and have ontogenetic variations of coloration. And finally there is just plain variation from individual to individual. You get some *Callinectes exasperatus* that are blue and some of them that are brown, even fully adult males. Coloration is a bit of a dangerous thing to look at if you are trying to identify these critters. On the other hand, hard parts are a more reliable indicator. In *Callinectes danae*, for example, like *C. sapidus,* the ninth anterior lateral spine is really strong, really long and sharp–you know it is a fish gig. There have been reports of birds, for example, and fish that have died with blue crabs stuck in their throats. It is a method of deterring predators. But never the less, not all species of *Callinectes* have long spines like that. If you look at *Callinectes exasperatus,* it has little short ones. The reason for that became fairly clear to me when my wife and I were working at the Pigeon Key Laboratory. She dropped a species of *Callinectes* that had long spines; it fell to the floor and stuck into it. That ninth anterior lateral spine was like a little knife. I realized that with *C. exasperatus* you couldn't do that because the spines were too short. Indeed, when *C. exasperatus* moves around among the mangrove roots, it would not behoove the crab to get hung up.

Finally, I'd like to tell you one more thing about the living critters. You all know the *Callinectes* are swimming crabs and that the last couple of segments of their swimming legs are flattened for moving rather quickly. But *Callinectes* are also digging crabs. For example, if you disturb an individual like *Callinectes bellicosus*, in a fraction of a second later he will be nothing but a pair of eyes and antennules sticking out of the bottom and this functionally has a lot of significance for benthic communities.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 11–12.

BLUE CRAB BIOLOGY – GULF COAST*
An Overview

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The blue crab fishery in the northern Gulf of Mexico in 1978 contributed approximately 38,305,000 pounds of hard crabs with an ex-vessel value of $8,309,000, and 157,000 pounds of soft crabs worth $304,000 dockside. Landings ranged from a high of 15,207,000 pounds of hard crabs in Louisiana to a low of 1,940,000 pounds landed in Mississippi. Values paid to the fishermen ranged from $0.268 per pound in Texas to $0.191 per pound in Florida. Louisiana is the major supplier of soft crabs to the southern states. Harvest of blue crabs continues year-round in all Gulf states with peak landings usually recorded in the summer. Fluctuations in catch occur in all states in response to changing environmental or biological conditions and/or socio-economic factors.

The life history of the blue crab is similar in all Gulf states. Spawning of blue crabs is extended, with egg-bearing females occurring in coastal Gulf and estuarine waters in the spring, summer, and fall (Gunter 1950, Daugherty 1952, More 1969, Adkins 1972, Perry 1975). Additionally, Adkins (1972) found evidence of winter spawning in offshore Louisiana waters based on commercial catches of "berry" crabs in December, January and February, and Daugherty (1952) noted that crabs in southern Texas may spawn year-round in mild winters.

Callinectes megalopae have been reported to occur throughout the year. Perry (1975) found megalopae in Mississippi Sound in all months with peak abundance in the late summer-early fall and in February. In Texas coastal waters, *Callinectes* megalopae have been found in all seasons (Daugherty 1952, More 1969, King 1971). King (1971) noted three waves of megalopae in Cedar Bayou, the first from January through March, the second in May and June, and the third in October. Recruitment to the estuary occurs during the megalopal stage.

Young juvenile crabs move to shallow estuaries, mature, and enter the adult population in approximately one year. Marketable size is normally attained upon reaching maturity.

Male crabs are found predominantly in fresh to brackish water areas of the estuary, while females remain in high-salinity waters. Movements are usually associated with mating, spawning, and water temperature fluctuations. Tagging studies in the Gulf include those of More (1969), Perry (1975), and Oesterling and Evink (1977). Migrational patterns observed by More (1969) and Perry (1975) were typical of the onshore/offshore movements as characterized in previous studies (Van Engel 1958, Tagatz 1968). Oesterling and Evink (1977) provided evidence of an along-shore movement of females in Florida coastal waters. Migratory patterns observed in their study demonstrated movement of females to sites north of their mating estuary with the Apalachicola Bay region appearing to be a primary spawning ground for crabs along the Florida peninsular Gulf coast.

Production statistics reflect that crabbing is a secondary fishery. Fishermen move in and out of the fishery depending on what opportunities are offered by other industries, such as shrimping or oystering. Additionally, many shift workers in petroleum or petroleum-service companies enter the fishery during their time off. Full-time crab fishermen do exist in each state, though few in number.

Reported landings for hard and soft crabs are at best poor estimates of the annual catch. Crabs going to out-of-state buyers, the general public, and to the restaurant or retail trade go unreported.

While accurate data on the recreational catch of crabs in the Gulf are lacking, the sport fishery is thought to contribute significantly to total fishing pressure. Estimates of the impact of recreational fishing on the resource vary widely.

In Louisiana, the sport fishery landings were estimated to exceed the commercial fishery landings by three times. A sport crab survey conducted by the Bureau of Sports Fisheries and Wildlife in 1968 estimated the recreational catch of blue crabs in Louisiana to be 28 million pounds compared to hard and soft crab landings of 9.5 million pounds and 284,000 pounds, respectively (Jaworski 1971). Total Gulf landings for the survey period were 25.8 million pounds, thus the estimated recreational catch in Louisiana alone exceeded the reported hard carb landings from all states in 1968.

Tatum (personal observation) conservatively estimated that the recreational catch in Alabama equaled approximately 20% of the annual commercial catch.

Based on interviews with 810 sports fishermen in the Mississippi Coastal Zone, Herring and Christmas (1974) reported a recreational catch of 50,000 pounds of hard crabs in 1971. Compared to commercial landings of 1.3 million pounds that year, the sports catch represented

*Modified from a review of the blue crab fishery of the Gulf of Mexico prepared by the Blue Crab Subcommittee of the Gulf States Marine Fisheries Commission and presented to the Technical Coordinating Committee of that same organization. Mr. Adkins, chairman of the Subcommittee at that time, presented this summary.

less than 4% of the total. Data from a recreational survey of Galveston Bay, TX, produced similar results. Benefield (1968) estimated the recreational catch of blue crabs from Galveston Bay to be 33,125 pounds or 5.9% of the commercial harvest from that area. The need for accurate landings data and catch/effort data is evident in all sectors of the fishery.

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LIFE HISTORY OF THE BLUE CRAB, *CALLINECTES SAPIDUS* RATHBUN, ALONG THE TEXAS COAST

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The blue crab, *Callinectes sapidus* Rathbun, occurs along the entire Texas coast. Daugherty (1952) and More (1969) found that blue crabs spawn from March through September with peaks occurring during March-April and July-August. More (1969) felt that spawning could take place year-round during mild winters. Most spawning occurs in the Gulf of Mexico, but More (1969) noted that spawning has occurred in lower Galveston Bay when salinities were greater than 20 ppt.

Apparently all zoeal stages of the blue crab are completed in the Gulf of Mexico before the larvae migrate into the bays. Neither More (1969) nor King (1971) caught zoea during their tidal pass sampling studies. Both, however, noted the migration of megalops through the tidal passes. Peak abundance of megalops occurred during February-March, May-June, and October-November. The greatest density of megalops was taken in surface samples in the middle of the pass. King (1971) also found that the greatest catch of megalops was positively correlated with increasing salinity and current velocity.

More (1969) found that juvenile blue crabs were present in the bays during every month, but peaks in abundance occurred during fall and winter. Winter catches of crabs over 30 mm were low at shoreline stations. More (1965) indicated that small crabs congregated in areas where salinities were low (under 10 ppt), and bottom types consisted of combinations of mud, clay, and sand. These areas generally were associated with tidal marshes, secondary bays, rivers, and bayous.

Adult blue crabs can be found throughout a bay system, but after mating, they generally distribute themselves with respect to salinity and sex. More and Moffett (1964) found that adult male crabs tend to remain in low salinity ($<$ 10 ppt) areas while mated females move to higher salinity ($>$ 20 ppt) areas of the bay. Peaks in sponge crab abundance occurred during spring and summer. More (1969) discovered that female crabs maturing in the spring were most abundant in the Gulf and had not produced sponge. Crabs maturing during the summer, however, were most abundant in the lower bay areas.

Migrations of blue crabs generally occur in two stages. First, larval crabs enter the bays from the Gulf and as they grow, distribute themselves throughout the bay system. Second, mated females migrate to lower bay and Gulf areas to spawn. Juvenile and adult male crabs generally make random movements within the bays and estuaries (More 1969, Schmidt 1972).

More (1969) estimated the growth rate of juvenile crabs to be 15.3 to 18.5 mm per month. The total time from hatching to commercial size (127 mm) is about 10 to 15 months. In Florida, according to Tagatz (1968), the average increase in size of a crab at each molt was approximately 30%. This is probably comparable to crabs in Texas.

The most prominent factor affecting blue crab abundance in Texas bays is generally considered to be salinity (Gunter 1950, More 1969, Simmons 1957). Hoese (1960) noted declines in crab populations in association with drought conditions, and a corresponding increase in abundance after the drought had passed.

Water temperature generally affects growth and movement of blue crabs. Most crabs migrate to deeper channels and possibly bury in the mud as water temperatures decline (More 1969).

The greatest crab productivity has always come from bay systems receiving high inflows of fresh water such as Galveston and San Antonio bays (More 1969). This inflow has contributed greatly to the marsh productivity in these bay systems.

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THE BLUE CRAB FISHERY OF LOUISIANA

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ABSTRACT The blue crab commercial fishery has, for the past decade, contributed an average of 9,032,520 pounds of hard-shell crabs annually with an average dockside value of $621,025 to Louisiana's seafood industry.

Blue crabs are taken commercially by three major gear types in Louisiana: (1) trotlines, (2) trawls, and (3) pots. Pots account for the greatest percent of the catch, with trawls contributing substantially during December and January.

Adult blue crabs were taken in sampling gear during all months of the year and in all recorded salinities and temperatures. Megalopae were taken in all months, with larger catches occurring during late winter and spring.

Juvenile crabs (less than 50 mm carapace width) occurred in greatest numbers during winter and early spring, with the largest catches occurring in low salinity waters. Juvenile crabs grew at an approximate rate of 14 mm per month until late summer; the period of greatest growth was February to May.

Male crabs dominated fresher waters; females tended to move back and forth within the sampling area dependent upon hydrological conditions and spawning periods. Berry crabs were more numerous at the southernmost stations.

INTRODUCTION

The blue crab fishery ranks third in value of all food fisheries of the Gulf of Mexico, following shrimp and oysters (Rees 1969), and this species supports the largest crab fishery in the United States (Williams 1965). Louisiana waters annually produce approximately 21% of the total blue crab landings in the Gulf of Mexico, although little intensive effort goes into the states' blue crab fishery. Ninety-three percent of Louisiana's blue crab harvest comes from inshore waters (Lindall and Hall 1970).

In addition to the commercial crab fishery, Louisiana waters support a large sport crab fishery. Results of a U.S. Bureau of Sport Fisheries and Wildlife telephone survey indicated that the annual sport catch exceeded the commercial catch by almost four times (sport catch–29,250,000 pounds; commercial catch–7,528,000 pounds). At almost any time during spring, summer, and early fall, many families fish for crabs along roadside bayous and drainage canals. Normal equipment consists of an icebox, lines, dip nets, and bait. This activity provides outdoor recreation plus an opportunity for securing a delightful seafood at little expense. Louisiana waters are not as heavily utilized by sports fishermen as other Gulf states, because much of the coastal area is inaccessible by automobile.

Louisiana's current blue crab yield is thus on the order of 37 million pounds a year (Lindall and Hall 1970).

Data in this paper are summarized from a comprehensive study by Adkins (1972) of the blue crab (*Callinectes sapidus* Rathbun) in the waters of coastal Louisiana. Samples were taken weekly, monthly, and quarterly at various stations with 16- and 6-foot otter trawls, 1/2-meter plankton nets, and large-meshed 22-foot trawls. The study area included Terrebonne and Lafourche parishes.

LIFE HISTORY

Coastal Louisiana is characterized by mid to low (5–20 ppt) salinities, extensive shallow-water areas, winding bayous, rivers, numerous bays and lakes, and is influenced by the largest river in North America, the Mississippi. The habitat utilized by blue crabs ranged from southerly Gulf waters to the more northern areas of fresh river water of the Atchafalaya.

Megalopal stage blue crabs were found during all months of the year, with peak catches recorded in February and November. Megalopae were found in the shallow, low-salinity areas of the estuary, characterized by rapid growth and maturation, as well as by ongoing recruitment. Juvenile crabs inhabited the same areas, with a dense population of juvenile crabs being recorded from November to May, as the fall and spring movement of larval crabs overlapped.

Movement from these areas seemed to occur from February to June, and again in July and August. This movement appeared to be temperature related, as it usually occurred when temperatures approached 30°C in the shallow marsh areas. This population of blue crabs averaged 100 to 125 mm in September, October or November, dependent upon sampling location, indicating a growth rate of approximately 14 mm per month for 8 months. Based on these data, the majority of megalopae which enter estuaries in February approach harvestable size by fall. Some of these crabs remain in the nursery areas, overwinter, and enter the spawning population during the following summer. The megalopae which enter estuaries during November settle out, grow through the winter (although very slowly), and enter the spawning population during the following July to August. Because of overlapping of populations, exact growth data were very difficult to determine.

After reaching maturity, blue crabs were found to inhabit all locations sampled; largest catches were generally recorded from mid-salinity (15–25 ppt) waters. Peak catches of adult crabs normally occurred during warmer months. Sponge or "pom-pom" crabs were recorded most frequently from the catch in higher salinity (15-25 ppt) waters. They were seasonally abundant during July, August, and September. Few male crabs were found in these areas, and those caught were normally taken at the peak of mating activity (June, July). In freshwater areas, only male crabs were captured, indicating a general separation of sexes except during reproductive cycles.

Movements of blue crab were determined to be responsive to (1) reproduction, and (2) water temperature. As previously stated, movement of both sexes was recorded during warmer months as spawning activities intensified, and mass movements were noted when cold fronts passed through the area in the fall. This was especially noticeable during November, when mass movements made shrimp fishing difficult. This movement was normally over by early December, when water temperatures had usually decreased to approximately 15°C.

During the study, some parasitism of blue crabs was observed. The most notable was the rhizocephalan parasite (*Loxothylacus texanus* Boschma). The highest percentage of infested crabs was recorded during warmer months, July through October. Some "buck shot" crabs were also noted, as were crabs fouled by barnacles, usually *Balanus* spp.

Most hard-shell crabs are now taken commercially by Chesapeake Bay-type crab traps, although some continue to fish with trotlines and trawls. Trotlines and trawls are by far in the minority, however.

A large soft-shell industry also exists in Louisiana, although many studies indicate a rapid decline due to increasingly poor water quality, time involved in production, and the unavailability of labor.

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THE LIFE HISTORY OF THE BLUE CRAB IN MISSISSIPPI WITH NOTES ON LARVAL DISTRIBUTION

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ABSTRACT Data are presented on various aspects of the life history of *Callinectes sapidus* in Mississippi Sound including mating and spawning, juvenile distribution, trophic relationships, growth, parasites and epizoans, and migration. The seasonal, areal, and vertical distributions of *Callinectes* larvae in the northern Gulf of Mexico are reviewed in reference to problems in the separation of the zoeae and megalopae of *C. similis* and *C. sapidus.*

INTRODUCTION

Commercial fishing for blue crabs in Mississippi began in the late 1800's with landings of 38,000 pounds recorded for the year 1887 (Lyles 1969). The use of more efficient gear, greater fishing effort, larger processing capacity and market demand increased Mississippi's landings to an average of over 1,570,833 pounds a year for the 10-year period 1970 to 1979 (U.S. Department of Commerce, Mississippi Landings, 1970–1979). In addition to the commercial fishery, the blue crab supports a recreational fishery (Herring and Christmas 1974), and a subsistance fishery with landings averaging over 100,000 pounds (Weaver and Christmas 1977).

Perry (1975) provided a detailed study of the fishery for blue crabs in Mississippi. The present paper reviews that work, updating it with information gathered during the course of an Assessment and Monitoring Program (Project 2–296–R, under Public Law 88–309).

DESCRIPTION OF THE HABITAT

General Description

Mississippi Sound is a shallow lagoon adjoined by a system of estuaries (Stevenson 1968). The Sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The complexity of the system does not readily lend itself to concise hydrological classification. Both north-south and east-west salinity gradients exist in addition to vertical gradients. While areas of the Sound are stratified aperiodically, Eleuterius (1978), based on the ratio of surface-to-bottom salinity in 2,421 paired observations, found that Mississippi Sound generally varies between a partially mixed and a well-mixed estuary.

Seasonally, salinities are lowest in the early spring, rise sporadically through the summer, and peak in the fall. Temperatures follow expected seasonal trends, with lowest averages in January or February and highest averages in July or August. Levels of dissolved oxygen are usually above lethal limits. Temporary oxygen depletion may occur in deep holes and behind sills in river channels. Anoxia, resulting from excessive biological oxygen demand, occurs periodically in waters near heavily populated areas and in waters subject to industrial outfalls. In some years, the presence of Yucatan Loop waters has been detected near the barrier islands. This water mass, characterized by high salinities, below-average temperatures, and extremely low levels of dissolved oxygen, may remain in the area through the late summer months and at times penetrate into Mississippi Sound in the vicinity of the island passes.

Tides in Mississippi Sound are diurnal, with an average range of 55 centimeters (Eleuterius 1976).

LIFE HISTORY

Mating and Spawning

Mating and spawning normally occur in Mississippi waters from March through November. Spawning takes place throughout the Sound with females usually moving to high salinity waters near the barrier islands when the eggs are ready to hatch. Females that mature and mate in the spring and summer normally spawn within 2 months, but those that mate in the fall may not spawn until the following spring. Perry (1975), using the classification of ovarian stages described by Hard (1942), defined the reproductive potential of the blue crab population in Mississippi. Recently mated females (Stage I) and crabs with developing ovaries (Stage II) were found in the spring, summer and fall. Females with mature ovaries (Stage III) occurred throughout the year. The appearance of berried females (Stage IV) in March and April indicated that overwintering Stage III females spawned when water temperatures began to rise in the spring. Stage IV crabs were most abundant in the middle and late summer, corresponding with the influx of "Gulf" crabs from offshore waters. Stage V crabs appeared during the summer providing evidence that some females spawned twice in the study area.

Large numbers of spent females occasionally litter barrier island beaches during the late summer. These crabs are usually heavily infested with the parasites *Carcinonemertes carcinophila* and *Octolasmis lowei* and most are fouled with acorn barnacles.

Larval Distribution

The larval life history of *Callinectes sapidus* in the Gulf of Mexico is poorly understood. Although Daugherty (1952), Menzel (1964), and Adkins (1972) specifically discussed the distribution of blue crab larvae, the possibility of co-occurrence of the larvae of *C. similis* must be considered. The temporal and spatial overlap in spawning habits of the two species (Perry 1975), coupled with the difficulty in using the early morphological descriptions of *C. sapidus* (Costlow and Bookhout 1959) to reliably identify Gulf blue crab larvae, suggest that these published accounts of the seasonality of *C. sapidus* are questionable. Recognizing the difficulty in separating the two species, King (1971), Perry (1975), and Andryszak (1979) did not differentiate between the larvae of *C. sapidus* and *C. similis*.

The authors have observed early stage *Callinectes* zoeae (I and II) in Mississippi coastal waters in the spring, summer and fall (unpublished data, Gulf Coast Research Laboratory [GCRL]), and Perry (1975) noted that the seasonal pattern of zoeal occurrence and abundance was coincident with the appearance of berried female blue crabs in Gulf and estuarine waters. Adkins (1972) reported *Callinectes sapidus* larvae present year-round in Louisiana, but did not separate the zoeal and megalopal stages. The sampling programs of Menzel (1964) and Andryszak (1979) were of limited duration with no seasonal distribution data available. The authors (unpublished data, GCRL) and Andryszak (1979) found only the early stage zoeae abundant nearshore.

Callinectes megalopae have been reported to occur throughout the year. Perry (1975) found megalopae in Mississippi Sound in all months with peak abundance in the late summer-early fall and in February. In Texas coastal waters, *Callinectes* megalopae have been found in all seasons (Daugherty 1952, More 1969, King 1971). King (1971) noted three waves of megalopae in Cedar Bayou, the first from January through March, the second in May and June, and the third in October.

The authors' initial attempts to separate the larvae of *C. sapidus* from *C. similis*, using the characters developed by Bookhout and Costlow (1977), were unsuccessful due to apparent morphological differences in larvae from the Gulf and Atlantic. A rearing program in which megalopae from plankton samples were carried through early crab stages, provided characters useful in distinguishing the two species. Subsequent analysis of archived plankton samples from Mississippi coastal waters provided information on the seasonality of *C. sapidus* and *C. similis* megalopae in the northern Gulf.

Callinectes similis megalopae were found in samples year-round, peaking in abundance in February and March. Perry (1975), based on the identification of first crabs reared from megalopae, reported a February occurrence of *C. sapidus*. Reexamination of these specimens found them to be *C. similis*. These data suggest that the reported winter peaks of *Callinectes* larvae in the northern Gulf are, in all probability, referable to *C. similis*.

Little is known concerning mechanisms of larval transport and dispersal of blue crab zoeae in the northern Gulf. Based on our observations and on the data of Menzel (1964) and of Andryszak (1979), it would appear that development through the late zoeal stages (III through VII) takes place in offshore waters. At this time, the larvae are subject to currents and may be transported considerable distances. Recruitment of larvae back into coastal waters occurs during the megalopal stage. Oesterling and Evink (1977) proposed a mechanism for larval dispersal in northeastern Gulf waters in which blue crab larvae were transported distances of 300 km or more. If such transport mechanisms do exist in the Gulf, then larvae produced by spawning females in one state may in fact be responsible for recruitment in adjoining states. Alabama and Mississippi with their limited coastlines may be largely dependent on the spawning success of females from outside areas.

Juvenile Distribution

The distribution of juvenile blue crabs in relation to salinity and temperature was discussed by Perry and Herring (1976) and is summarized below. Using data collected over a 3-year period (October 1973--September 1976), diagrams were plotted showing the numbers of blue crabs in temperature and salinity ranges (Figure 1). First and early crab stages (3.0 to 10.0 mm) were widely distributed in Mississippi waters, with the greatest percentage of the catch occurring in salinities from 15.0 to 20.0 ppt. These small juveniles were collected over the entire range of observed temperature, but most were taken when water temperatures were between 15.0 and 30.0°C.

Crabs from 10.0+ to 20.0 mm were most abundant in salinities below 10.0 ppt although large catches were also made in salinities between 15.0 and 20.0 ppt. Peak catches in colder temperatures (below 15.0°C) occurred at low salinities (0.0 to 5.0 ppt). Abundance shifted from 5.0 to 10.0 ppt in temperatures between 20.0 and 25.0°C, and from 15.0 to 20.0 ppt in temperatures from 25.0 to 30.0°C.

Maximum numbers of crabs from 20.0+ to 40.0 mm were taken in salinities below 5.0 ppt, with smaller catches made in salinities from 15.0 to 20.0 ppt. Although crabs in this size range were collected in temperatures from 7.0 to 30.0+°C, most were taken in water temperatures below 20.0°C.

The distribution of late juveniles (40.0+ to 60.0 mm) showed peak catches in salinities from 0.0 to 5.0 ppt in temperatures between 15.0 and 20.0°C and in salinities from 15.0 to 20.0 ppt when temperatures were between 20.0 and 25.0°C. Crabs above 60.0 mm carapace width were most abundant in salinities from 15.0 to 20.0 ppt and in temperatures from 20.0 to 25.0°C.

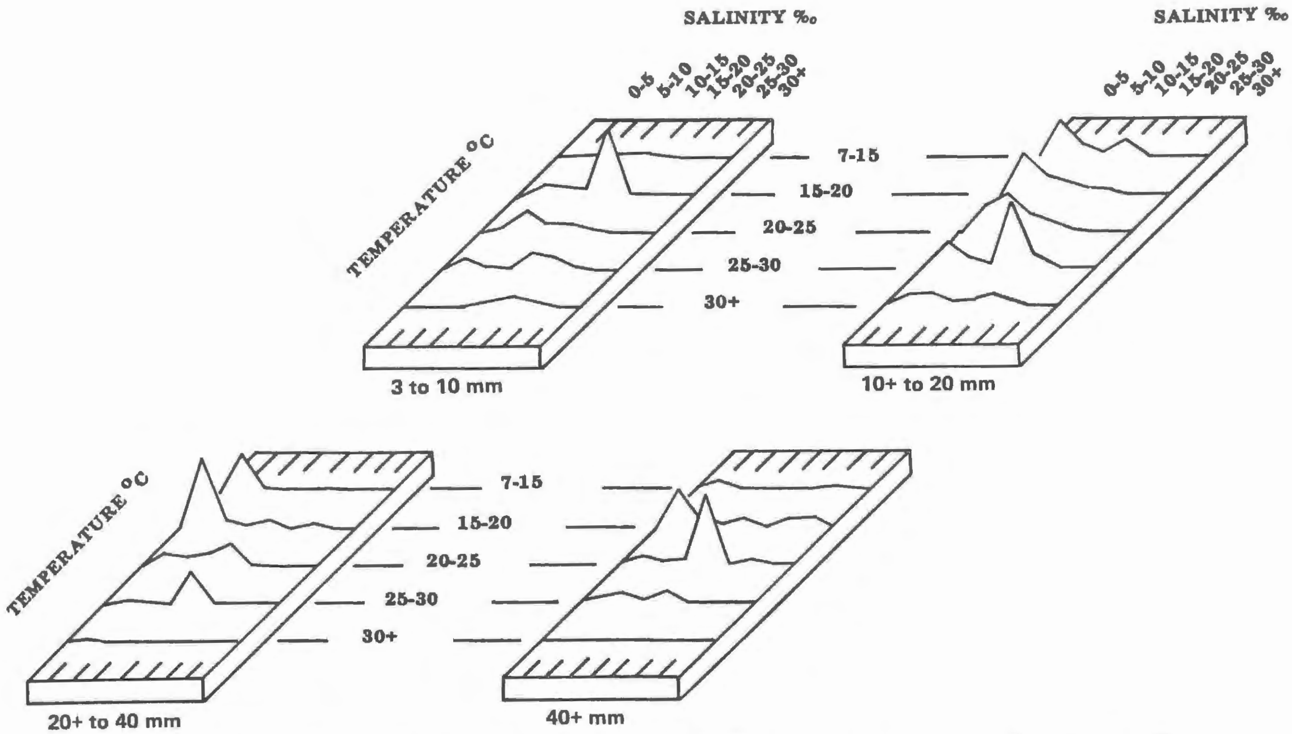

Figure 1. Distribution of blue crabs in relation to temperature and salinity. Viewing: angle of rotation, 45°; elevation, 45°. Vertical scale dependent on group size.

Young blue crabs occur in estuarine waters year-round. Although catches from month to month are variable, both Perry (1975) and Perry and Herring (1976) found juveniles most abundant in the winter and summer. Catches of young blue crabs rose through the fall, peaked in the winter, and declined in the spring. A secondary peak occurred in the summer. In both studies, first crab stages were taken in all seasons indicating continual recruitment to the juvenile population.

Although juvenile blue crabs exhibit wide areal distribution in Mississippi coastal waters, maximum numbers occur in coastal bays and in the Sound proper north of the Intracoastal Waterway. Perry (1975) noted that small crabs were consistently taken in waters adjacent to marsh habitats, although variations in abundance were evident. Shore stations with beaches grading to soft mud or to beds of *Ruppia maritima* were more productive than those stations with beaches adjacent to sand bottoms. Crabs in deeper waters were more abundant in navigational channels than in open water areas. More (1969), Holland et al. (1971), Adkins (1972), and Evink (1976) also suggested that bottom type was an important factor in the distribution of juvenile crabs; maximum numbers being associated with soft sediments.

While physical and chemical environmental parameters undoubtedly play a role in the distribution of young blue crabs, recent studies conducted in Apalachicola Bay, FL, have provided valuable insight into the factors that help to determine the temporal and spatial distributions of estuarine fishes and invertebrates.

Sheridan and Livingston (1979) noted the general lack of success of statistical verification of direct association of population changes with key physico-chemical functions. Livingston et al. (1976) noted that it is possible trophic relationships and reproductive cycles are of critical importance in determining the temporal and spatial distributions of estuarine organisms. In the latter study, they found distribution associated with species-specific reproductive cycles, trophic relationships, and habitat preference. They found a distinct correlation with factors related to trophic phenomena, indicating that biological functions play an important role in determining population shifts.

Trophic Relationships

Darnell (1958), in a study of the food habits of fishes and invertebrates of Lake Pontchartrain, LA, found blue crabs, mud crabs (*Rhithropanopeus harrisii*), unidentified crustacean pieces, molluscs, fish remains, vegetation and detritus among the diet of *C. sapidus*. He noted that while food differences between adults and young were not pronounced, as crabs exceeded 124.0 mm carapace width, molluscs became the dominant food item. Although no data exist on the feeding habits of blue crabs in Mississippi waters, the senior author has observed adult blue crabs from Horn Island with their stomachs full of small gastropods (*Nassarius acutus*).

Evink (1976) listed mammals, birds, fish and other macroinvertebrates as predators on blue crabs. Darnell (1958) reported 13 species of fish among the predators of blue crabs including the alligator gar (*Lepisosteus spatula*), spotted gar (*L. oculatus*), sea catfish (*Arius felis*), Atlantic croaker (*Micropogonias undulatus*), silver perch (*Bairdiella chrysura*), red drum (*Sciaenops ocellata*), southern flounder (*Paralichthys lethostigma*), pinfish (*Lagodon rhomboides*), and sheepshead (*Archosargus probatocephalus*). Gunter (1945) found many of the same species preying on the blue crab in Texas adding the spotted seatrout (*Cynoscion nebulosus*), gafftopsail catfish (*Bagre marinus*), bonnethead shark (*Sphyrna tiburo*), tripletail (*Lobotes surinamensis*), and black drum (*Pogonias cromis*).

Overstreet and Heard (1978a) noted that blue crabs were common components of the diet of red drum in Mississippi and reported that they were found in 17.3% of the fish examined. In a study of the food habits of the Atlantic croaker in Mississippi Sound and the Gulf of Mexico, Overstreet and Heard (1978b) found blue crabs in 8.0% of the fish examined from the Sound with the percent occurrence decreasing as the size of croaker increased. They also noted that blue crabs occurred less frequently in croaker taken from open Gulf waters and no croaker taken from depths in excess of 30 meters contained *C. sapidus.* Additional species of fish from Mississippi coastal waters found feeding on blue crabs include the sand seatrout (*Cynoscion arenarius*), cravalle jack (*Caranx hippos*), cobia (*Rachycentron canadum*), southern flounder, sheepshead, spotted seatrout, and black drum (Overstreet, personal communication).

Growth

Perry (1975) estimated growth by tracing modal progressions in monthly width-frequency distributions for crabs in Mississippi Sound. The estimated growth rate of 24.0 to 25.0 mm/month is somewhat higher than rates found in other Gulf estuaries. Adkins (1972) found growth in Louisiana waters to be approximately 14.0 mm/month for young crabs, with slightly higher rates (15.0 to 20.0 mm/month) as crabs exceeded 85.0 mm in carapace width. Darnell's (1959) growth estimate of 17.6 mm/month for crabs in Lake Pontchartrain falls within the average of Adkins (1972). More (1969) noted a growth rate of 15.3 to 18.5 mm/month in Texas. Tatum (personal communication) found seasonal changes in the rate of growth of young blue crabs in Mobile Bay, AL. He observed monthly rates of 19.0, 10.0, and 5.0 mm for crabs recruited in April, August, and December, respectively.

Parasites and Epizoans

Perry (1975) and Overstreet (1978) discussed the parasites and epizoans of blue crabs from Mississippi and the northern Gulf of Mexico, respectively.

Metacercariae of the microphallid trematode *Microphallus basodactylophallus* (as *Carneophallus basodactylophallus*, Perry 1975) infected with the haplosporidan hyperparasite *Urosporidium crescens* occur in the hepatopancreas and musculature of blue crabs from local waters. Metacercariae containing this hyperparasite cause the condition known as "buckshot" by crab fishermen. These crabs are also called "pepper" crabs. Infected individuals are found year-round, with infections present in mature and immature crabs of both sexes. Overstreet (1978) described the life cycle of this trematode. Metacercariae of the microphallid trematode *Levinseniella (Monarrhenos) capitanea* are less common, occurring with more frequency in crabs from Alabama and northwestern Florida (Overstreet, personal communication). Overstreet and Perry (1972) described this species from blue crabs collected in lower Lake Borgne and western Mississippi Sound.

The pedunculate barnacle *Octolasmis muelleri* (as *O. lowei*, Perry 1975) occurs on the gills and in the gill chamber of *C. sapidus.* Most infestations are observed on mature individuals. Perry (1975) noted that these barnacles occur on male and female crabs from waters of higher salinity.

Blue crabs infected with the rhizocephalan parasite *Loxothylacus texanus* are becoming more prevalent in Mississippi coastal waters. Christmas (1969) noted that the rate of infection in the Sound was negligible in 1966. Perry (1975) reported that the barnacle was found on less than 1.0% of the crabs collected in 1971 and 1972, and Perry and Herring (1976) noted that 0.1% of the crabs taken in samples from October 1973 through September 1976 carried an externa or had a modified apron. Since these data were collected, the incidence of parasitism has risen to over 4.0% (unpublished data, GCRL). Additionally, parasitized crabs now show wider areal distribution in Mississippi Sound. From 1971 through 1976, catches of parasitized crabs were highest in the western portion of Mississippi Sound. Subsequently, infected crabs have been collected throughout local waters. Overstreet (1978) noted that over half of the crabs taken aboard a shrimp trawler in July 1977 exhibited infections.

Other species of barnacles associated with the blue crab include *Balanus venustus niveus* and *Chelonibia patula* (Overstreet 1978).

Carcinonemertes carcinophila, a parasitic nemertean, is commonly found within the gill lamellae and egg masses of mature female crabs. While the blue crab is the usual host for this species, other portunids may also occasionally harbor the worm (Overstreet 1978).

Leeches (*Myzobdella lugubris*) and the branchiobdellid annelid *Cambarincola vitreus* are found on crabs in low salinity and freshwater habitats. Neither species appears to harm its host.

Cook and Lofton (1973) in their study of the chitinoclastic bacteria associated with the blue crab and penaeid shrimp isolated one strain (*Beneckea* type I) from all necrotic lesions but noted that in all cases there was no penetration of the epicuticle by the bacteria.

Vibrio parahaemolyticus is present in Mississippi waters and its incidence of occurrence has been related to temperature and distance from land (Keel and Cook 1975). Overstreet (1978) reported its presence in blue crabs and noted that crabs occasionally die from these infections. Cook and Lofton (1973) found *Vibrio* sp. associated with shell disease in the blue crab.

Although not common in Mississippi Sound, the microsporidan protozoan *Ameson michaelis* has been identified from the muscle tissue of local blue crabs. According to Overstreet (1978) heavy infections can be recognized by the chalky appearance of the muscle tissue in the joints of the appendages. Microsporidan infections result in the breakdown of the muscle tissue which weakens the crab making it more vulnerable to stress and predation.

Migration

There are two major movements of blue crabs into Mississippi Sound; the first in the late fall and the second in the summer. Perry (1975) documented the fall migration of crabs into western Mississippi Sound from Lake Pontchartrain and Lake Borgne with the advent of cold weather, noting that these crabs were primarily gravid females seeking high salinity water when temperatures began to drop. These crabs were tagged and released at three locations in Lake Borgne and one location in Mississippi Sound. Approximately 90% of the recaptures were in the Pass Marianne–Cat Island area (Figure 2). Crabs remained in the western Sound through the winter moving to nearshore waters as temperatures began to rise in the spring. The winter crab fishery in Mississippi is dependent upon this annual, seasonal migration and environmental conditions that alter this migratory pattern may be reflected in the commercial landings for the state (Overstreet 1978).

The migratory history of the "school" or "Gulf" crabs that move into Mississippi Sound in the summer is unknown. These crabs are mature females that have had one or more sponges. Many are fouled with epizoans and are heavily parasitized.

There is little movement of blue crabs between estuaries in Mississippi in the spring and summer. Perry (1975) and Perry and Herring (1976) found that blue crabs tended to move randomly within estuarine systems with no discernable migratory pattern.

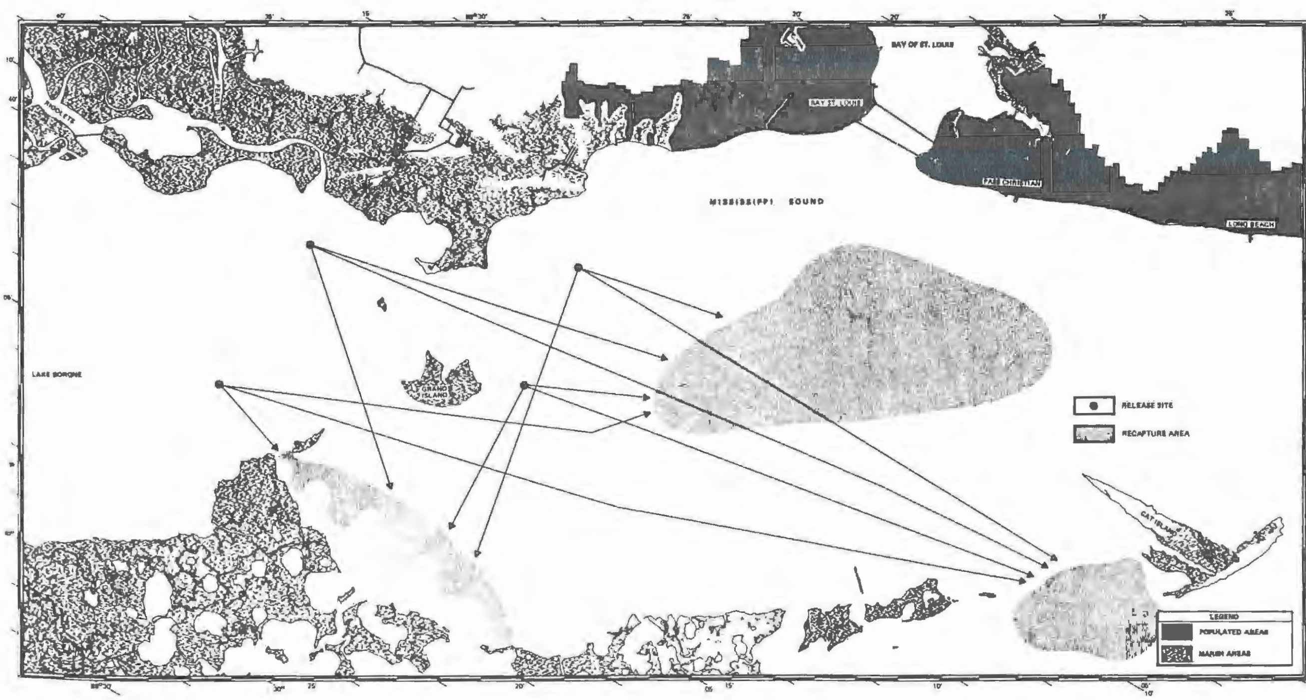

Figure 2. Locations of release and recapture areas for crabs tagged in the fall of 1971.

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THE BLUE CRAB FISHERY OF ALABAMA

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ABSTRACT The earliest available record of blue crab (*Callinectes sapidus*) landings in Alabama was 1888 when 43.6 metric tons were harvested. Many problems which faced early crab fishermen have been solved but many remain.

Blue crabs mate and ovulate in Mobile Bay but normally egg hatching occurs when ovigerous females migrate offshore. Larval development, metamorphosis to first crab, and growth to harvestable size generally are accomplished in a 12-month period. Fish are a major food item for all crab sizes, but are more important to crabs over 40 mm (1.6 inches) in carapace width. Oyster spat, although present in the stomach of crabs over 50 mm (2.0 inches), do not constitute a major food item for blue crabs.

Blue crabs are infected by numerous parasites and diseases, including viruses, bacteria, protozoans and metazoans. Many of these infections are temporarily eliminated in the molting process.

Associated problems with the crab fishery in Alabama include fluctuating landings, unknown user density, low dissolved oxygen, lack of recreational catch statistics, by-catch from nondirected fisheries, lack of information on developing soft-shell industry, and labor problems in the commercial fishery.

This paper presents limited data on the biology and life history of the blue crab in Mobile Bay.

INTRODUCTION

The earliest reported commercial landings of blue crab (*Callinectes sapidus*) from Mobile Bay, Alabama, were in 1888 when 43.6 t [t = metric ton (2,204.6 lbs)] (96,000 lbs) were harvested. During the early years of the Alabama crab industry, trotlines baited principally with beef tripe were set from wooden rowboats and the daily catch cooked in barrels on the shore near the landing areas. The cooked crab was then transported to the fishermen's homes where the meat was picked by hand and stored for marketing or barter (Buddy Zirlott, Zirlott Seafood, Fowl River, personal communication). The industry has revolutionized in the past 90 years with traps replacing trotlines; fiberglass boats equipped with fast outboard or inboard engines replacing wooden rowboats; sterile, stainless steel cooking pots replacing the old cooking barrels; and sanitary processing rooms replacing the fishermen's kitchen or backyard "crab picking" areas.

Many of the problems that plagued early crab fishermen have been systematically solved as technology evolved but other problems continue to plague contemporary crab fishermen. Mechanical meat separators have not developed adequately to replace expensive and uncertain hand labor. During the peak harvest months of July, August, and September, there are days and often weeks in which unpredictable masses of oxygen-deficient water completely engulf trap lines, killing and rendering useless the trapped crabs. Peak crab-harvest months occur simultaneously with peak shrimping months which often divert fishermen and crab pickers to the more lucrative shrimp fishery and associated processing plants. Crab harvesting in Mobile Bay is extremely seasonal with virtually no fall and winter fishery. The annual crab harvest is variable with no particular trends to adequately forecast available stocks.

BIOLOGY

Life History

For most marine species, mating and spawning are synonymous; however, the two events occur at different times for the blue crab. Mating occurs after the juvenile female has had her terminal molt (ecdysis). The male assumes a protective position over the juvenile female immediately prior to the terminal molt. After molting, the male implants the female's seminal receptacles with sperm-bearing semen and retains his protective position until the new chitinous shell hardens (Leary 1964, Oesterling 1976, Tagatz 1968). Spawning may occur until the female dies but mating occurs only once. Ovulation (spawning) usually occurs within two months after mating, but may be delayed for as long as five months depending upon water temperature. During ovulation, eggs are forced from the ovaries through the seminal receptacles containing spermatozoa where they are fertilized. Then they are exuded onto fine hairs located on the abdominal swimmerettes. The eggs form a mass which occupies a space approximately 33% of the size of the crab and forces the abdomen, normally folded under the cephalothorax (carapace), away from the carapace area (Figure 1).

Spawning normally takes place in the lower estuary where the salinity is over 20 ppt and in the Gulf of Mexico. Extreme drought conditions with subsequent high salinities may expand the estuarine area where successful hatching can take place (Harriet Perry, Gulf Coast Research Laboratory, personal communication). When first deposited the eggs are light, yellow-orange in color, turning darker to a black color, as the yolk is absorbed by the developing unhatched larvae.

The first larval stages of the blue crab, usually found offshore, are called zoeae (Figure 2). There are seven molts in the zoeal stage, and each molt results in a slight morphological

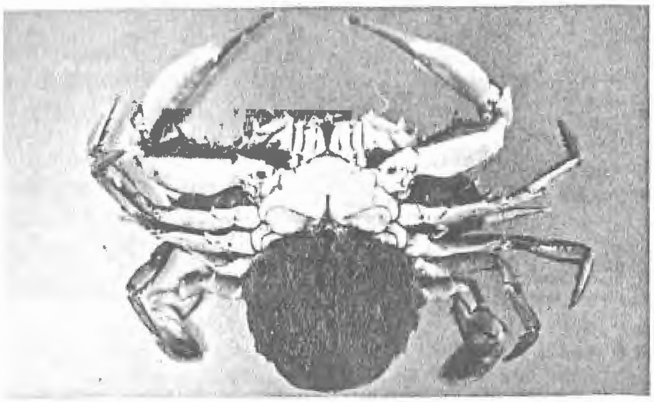

Figure 1. Female blue crab with eggs attached to fine hairs of the abdominal swimmerettes.

change. Blue crab zoeae are approximately 1 mm (0.04 inch) in length and in no way resemble the adult crab. Blue crabs remain in this planktonic stage for 31 to 49 days (dependent upon water temperature and salinity), and their principal movement during this period is related to tidal action, oceanic currents, and wind currents (Tagatz 1968). Zoeal stages of blue crab rarely complete the first molt in salinities lower than 20 ppt (Costlow and Bookhout 1959), and consequently are rarely found in the inside waters of Mobile Bay.

The second larval blue crab stage is called the megalopa (Figure 3). It is during this stage when they first enter the estuarine area. Blue crab megalopae are 2 to 4 mm (0.08 to 0.2 inch) total length and approximately 1 mm (0.04 inch) wide. They remain in this stage for 6 to 20 days (Costlow and Bookhout 1959), which again is dependent upon water temperature and salinity, after which they metamorphose to the first crab stage.

Growth

Growth is quite rapid after metamorphosis. In Alabama, the legal harvestable size of 10.2 cm (4 inches), measured from the widest point on the carapace, is attainable within one year.

More (1969), estimating blue crab growth from Galveston Bay, Texas, reported monthly size increases of 15.3 to 18.5 mm (0.6 to 0.7 inch). He indicated similar growth of juveniles recruited during the months of February, March, and July. Based on data collected in 1968 and 1969 (Swingle 1971), there appear to be three major juvenile crab recruitment peaks in Alabama (April, August, and December) with crab growth among periods differing greatly. Juvenile crabs recruited in April, August, and December grew at monthly rates of 19, 10, and 5 mm (0.75, 0.4, and 0.2 inch), respectively (Figure 4). Juvenile crabs recruited in April are likely the progeny of late fall spawns. One would expect the growth from both the latter two spawns to pick up considerably and equal the former as spring approaches and the water begins to warm.

Food Habits

Tagatz (1968) conducted extensive food habit studies of the blue crab from St. John's River, Florida, and summarized previous studies by other workers. Principal factors that influenced blue crab food intake included crab size, food abundance, and size of food particles. Tagatz's work is summarized in Table 1. The principal food items for all crabs sampled were mollusks, organic debris, fish, and crustaceans, respectively. Fish were a major food item for all crab sizes examined but appeared more important for crabs over 40 mm (1.6 inches) wide. Organic debris was found in all sizes examined but was more abundant in crabs less than 40 mm (1.6 inches).

Mollusks were found in all crabs examined and included mussels, clams, oysters, and snails. Clams, principally *Rangia cuneata* and *Mulinia lateralis*, were found in the

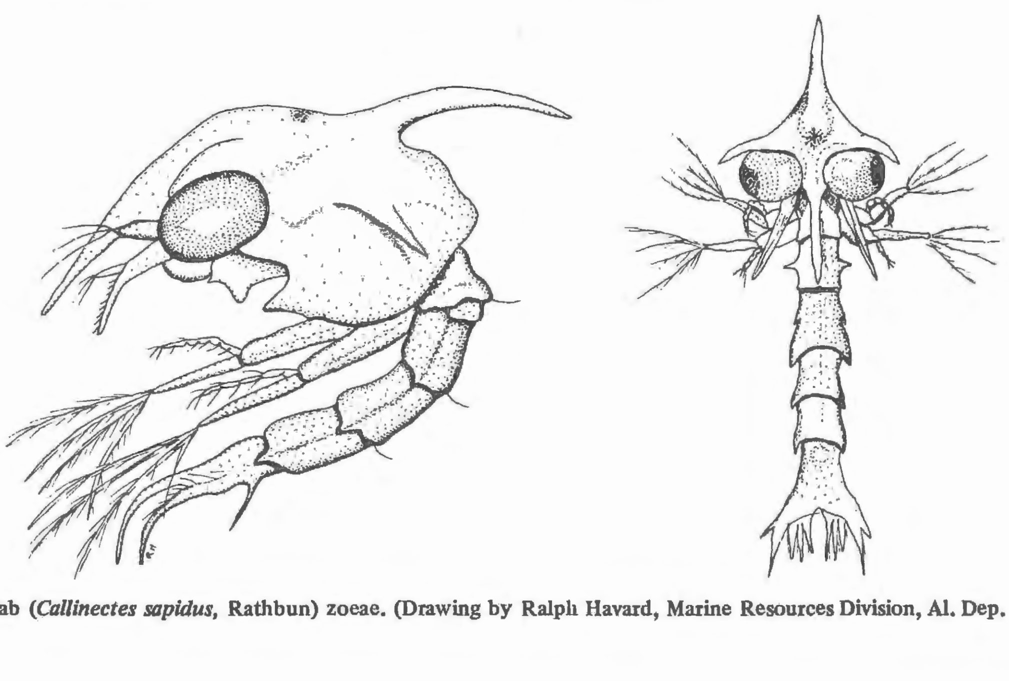

Figure 2. Blue crab (*Callinectes sapidus*, Rathbun) zoeae. (Drawing by Ralph Havard, Marine Resources Division, Al. Dep. Con. Nat. Res.)

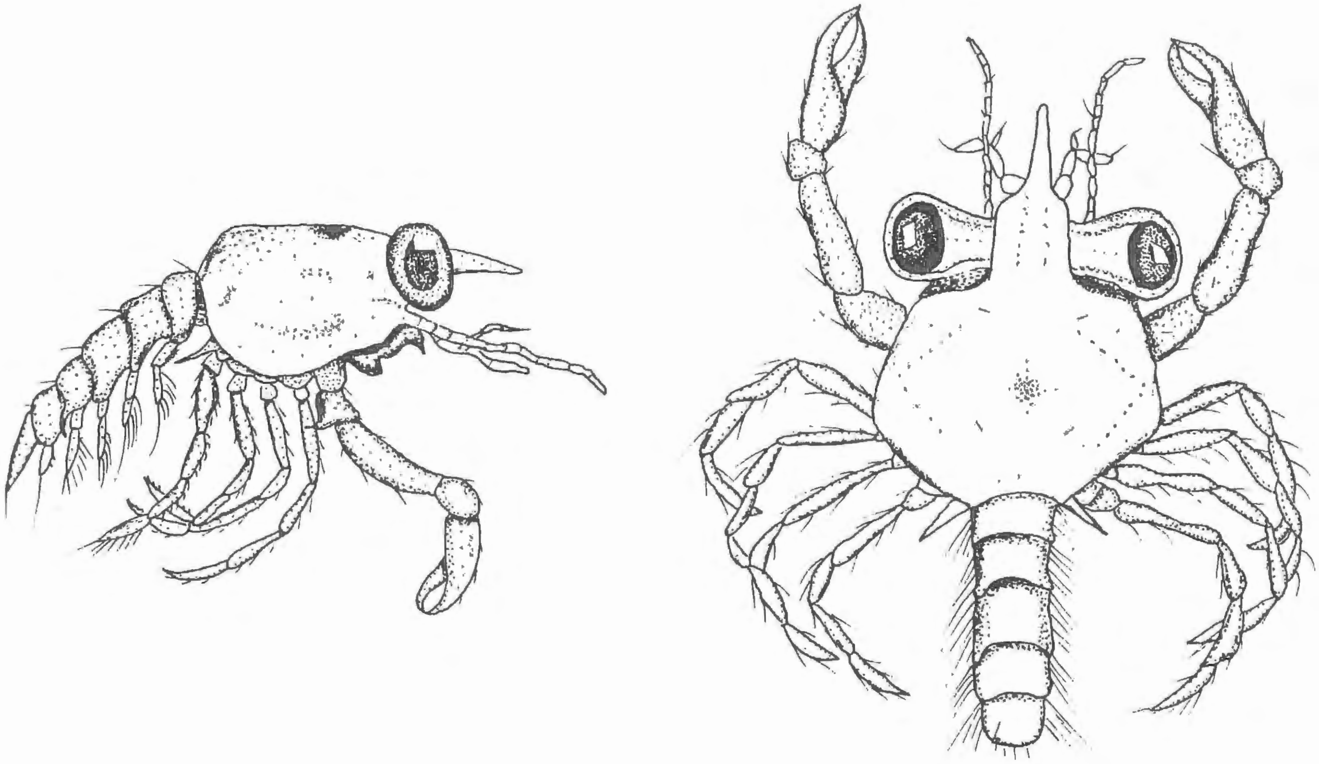

Figure 3. Blue crab (*Callinectes sapidus*, Rathbun) megalopae. (Drawing by Ralph Havard, Marine Resources Division, Al. Dep. Con. Nat. Res.)

stomach of all sizes examined. Mussels and snails were not found in crabs under 21 mm (0.8 inch) wide but were major items for larger crabs. Oyster spat, although present in the stomachs of crabs over 50 mm (2.0 inches) wide, did not constitute a major food item of those examined. Amphipods and small crabs were the dominant crustaceans eaten by all crabs examined; amphipods were found in all sizes examined, and small crabs were found only in crabs larger than 10 mm (0.4 inch).

Parasites and Diseases

Overstreet (1978) listed a wide variety of parasite and disease organisms which infect blue crabs including viruses, bacteria, protozoans, and metazoans. Overstreet points out that while the blue crab is host to many parasite and disease organisms, many of the infections are temporarily eliminated in the molting process. Examples of some of the more important and more evident parasite and disease organisms include:

Ameson michaelis, a microsporidan protozoan, produces symptoms in blue crabs referred to by fishermen as "sick crabs." According to Overstreet (1978), infestation of this organism produces a chalky appearance in the appendage joints, and the abdominal area usually turns grayish. The muscle tissue of the blue crab is invaded by this host-specific microsporidian and in some infestations a large portion of the hosts' musculature is replaced by the parasite.

Vibrio parahaemolyticus, a bacterial infection, produces large, jelly-like blood clots or white nodules on the gills of infected crabs. It readily causes mortality among its hosts, and can bring about a form of food poisoning in man. Overstreet (1978) points out that food poisoning in man by this organism can be prevented with minimal heating of the crab meat.

Urosporidium crescens, a hyperparasitic, haplosporidan protozoan, infects encysted worms in the blue crab musculature. The protozoan undergoes extensive multiplication, produces spores, and a condition referred to as "pepper crabs." According to Overstreet (1978), the spores harm neither man nor the infected crab.

Chelonibia patula, an external barnacle symbiont, demonstrates host-specificity for a small group of crabs, including the blue crab. Mature female crabs particularly are affected by this organism since they cannot shed the infestation. The weight of large barnacle sets produces severe strain on the crab host.

Octolasmis muelleri, a pedunculate (gooseneck) barnacle, infects the gill region of the blue crab. Infections from this organism have been observed on emigrating female blue crabs, producing lethargic effects on its host. Overstreet (1978) has observed over 1,000 gooseneck barnacles in a single gill chamber. Although the barnacle is not reported to receive nourishment from the crab, its presence undoubtedly affects the crab's respiratory capacity.

Overstreet (1978) mentioned other parasites and diseases that, although present on the eastern coast of the United States, have not been implicated in Gulf coast crab mortalities. Among those included were *Paramoeba perniciosa*

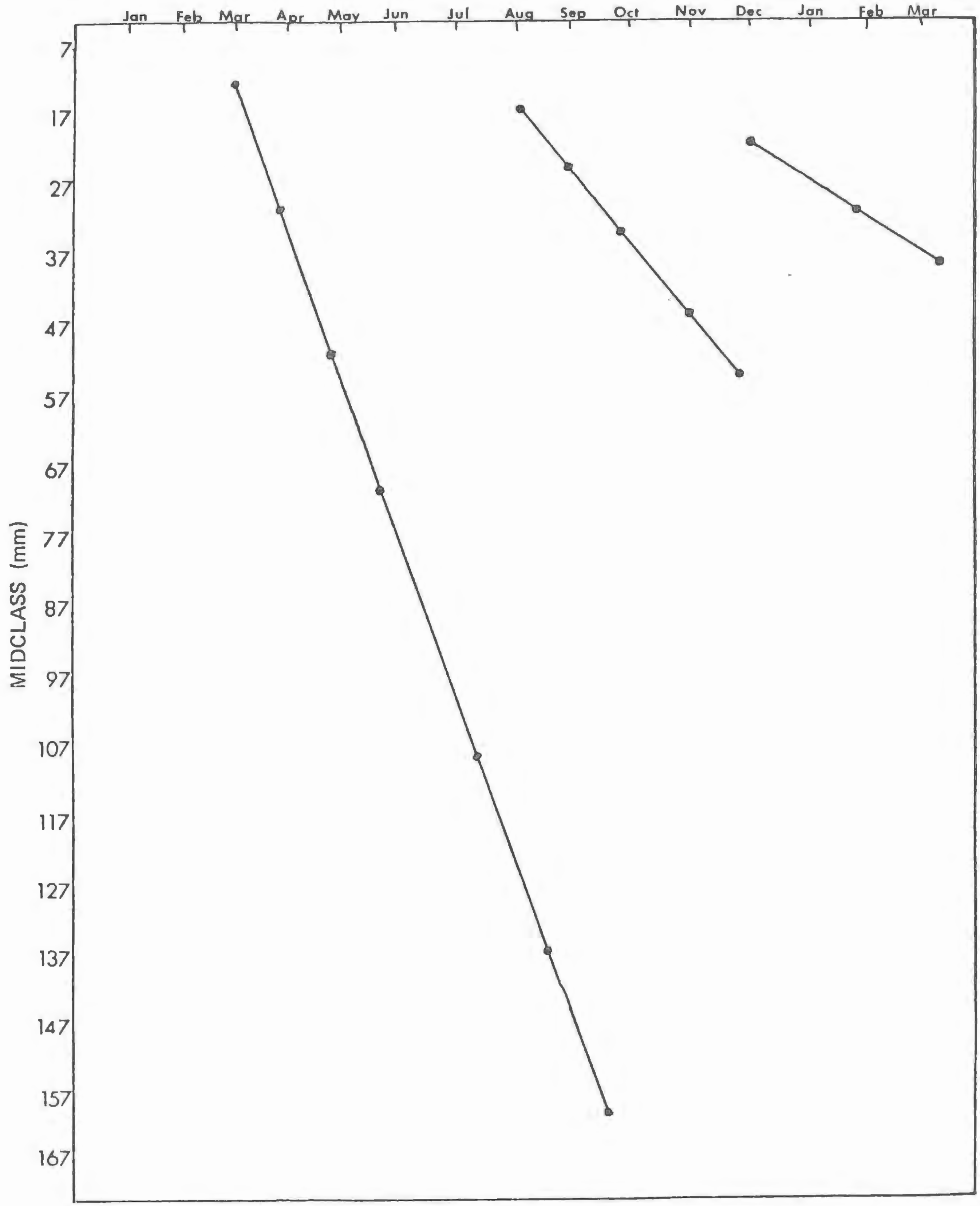

Figure 4. Monthly size distribution of *Callinectes sapidus* taken in Alabama during 1968 and 1969 (adapted from Swingle 1971).

TABLE 1.

Class of food found in blue crab stomachs in St. John's River, Florida (Tagatz 1968).

Food Item	Percent
Mollusks	39.0
Organic debris	19.8
Fish	19.4
Crustaceans	15.0
Plants	3.9
Annelids	1.8
Insects	0.9
Bryozoan	0.1
Total	99.9

commonly called "gray crab disease," a "herpes-like" virus and one of four viruses isolated recently from the blue crab; *Epistylis* sp., a stalked ciliate, that attaches to the gill lamellae; and *Lagenophrys callinectes,* a ciliate that also attaches to the gill lamellae.

PROBLEMS RELATED TO BLUE CRAB FISHERY AND POSSIBLE SOLUTIONS

Fluctuating Landings

Since 1963 the general catch trend for blue crab is considered to be stable, although there are year-to-year landing fluctuations. The crab catch in 1977 was 60% greater than the 1976 catch; however, the 1977 catch was approximately the same as the catches in 1945, 1966, and 1967. Therefore, a question arises as to whether annual commercial blue crab landings actually reflect the general condition of the crab population, or the economics of the crab fishery in Mobile Bay.

If processors are unable to quickly handle crab catches during peak-production months, crab fishermen simply slow down their harvesting. This decrease in effort is reflected in the monthly catch statistics as a production drop, and can easily be misrepresented as a biological problem. If catch statistics are to be used effectively, they must demonstrate catch-per-unit-effort (CPUE), which is not misleading. If a crab fisherman catches a consistent or increasing weight of crabs per pot, then the fishery is stable or expanding, respectively. If the CPUE is dropping over a period of time, biological instability or increased user density is implicated.

Unknown User Density

There is no license requirement for commercial or recreational crab fishermen in Alabama. The number of fishermen (full time, part time, or recreational) participating in the fishery, as well as the number of fishing units used, are unknown. Knowledge of user and gear density is fundamental in fishery management, and licensing is the most effective means of gaining this knowledge. Commercial crab fishermen support such a license, and also support regulations for trap markers to enable enforcement officers to quickly match fishermen and their traps.

Lack of Blue Crab Monitoring and Assessment Program

A sound blue crab assessment and monitoring program is extremely important to all users of this resource. Although the blue crab life history and biological requirements for growth and reproduction are similar throughout its range, there exists some degree of uniqueness within each estuarine system. These unique estuarine characteristics must be identified to effectively regulate and manage the resource.

A monitoring and assessment program is quite expensive requiring obligated personnel and equipment. The Alabama crab fishery, although important to those who depend on the resource for their livelihood, represented only 4.5% of the total weight of seafood landed, and 1.1% of the total seafood value in 1972 (Alabama/Mississippi Sea Grant Advisory Service). In Alabama, the most equitable means of initiating an ongoing blue crab monitoring and assessment program was to incorporate this fishery into a total resource monitoring and assessment program.

Low Dissolved Oxygen

Extensive areas of bottom water in Mobile Bay suffer oxygen depletion during the summer months, particularly during August. Extensive oxygen depletion in the bottom waters of Mobile Bay occurred in July and August 1971, where values of 1.0 ppm or below were found at various locations on 75% of the days sampled (May 1973). At that time, low-oxygen waters (3.0 ppm or less) covered an area of 44,541 ha (111,353 acres) or 44% of Mobile Bay including Bon Secour Bay. Included in this area were 22,655 ha (56,288 acres) containing dissolved oxygen of 1.0 ppm or less. This phenomenon, although not unique in Mobile Bay, has been implicated by May (1973) and Loesch (1960) as a precursor for mass shoreward migrations of demersal fishes in Mobile Bay, known locally as "jubilees."

Usually free-swimming crabs are able to avoid oxygen-deficient bottom waters by either swimming shoreward or moving to the surface. Trapped crabs, however, are killed and rendered useless when they are engulfed by waters of low-dissolved oxygen. Some area crab fishermen indicated that 75% of their midsummer catch died, and some fishermen ceased their crabbing altogether during July and August because of heavy die-offs or reduced catch. On a positive note, Melvin Plash (Plash Seafood, personal communication) has indicated a trapped-crab mortality decline in recent years. Oxygen-deficient waters still occur in Mobile Bay, presenting a constant threat to the crab fishery. A study to identify the cause of this phenomenon and to seek a resolution of the problem is badly needed.

Lack of Recreational Catch Statistics

In order to completely evaluate the exploitation rate of blue crabs, some estimate of the number of users and catch per annum is essential. Tatum (unpublished) estimated that approximately 20% of the annual commercial crab catch is harvested by recreational crabbers and, therefore, unrecorded. This estimate was very conservative, based on the number of estuarine waterfront parcels in Mobile and Baldwin counties, and on blue crab by-catch estimates from recreational shrimping intensity (Swingle et al. 1976).

Recreational catch of blue crab easily could be higher than estimated and, therefore, could play a significant role in the total harvest. Resource managers must be aware of user intensity if they are to equitably manage crab stocks. Recreational licensing of these users and periodic user surveys would be helpful in identifying the intensity of these user groups.

Shrimp Trawl By-Catch and Destruction of Blue Crabs

Trawl-caught crabs represent approximately 5% of the total commercial crab landings in Alabama. This area of the fishery is very important since it sustains the crab processing plants during periods when trap catches are low. Trawl-caught crabs are seldom used during peak trapping months, and are usually returned to the bay. Damage imposed on these unused and frequently undersized crabs likely plays an important role in the overall crab fishery. Although the areas are presently undocumented, there are juvenile blue crab staging grounds in Mobile Bay which should be protected during periods of high utilization by undersized crabs. An assessment program can identify these areas and document high-use periods by juvenile crabs.

Soft-Shell Crab Industry

One of the more lucrative sidelines of the blue crab fishery is in the landing of soft-shell crabs. To a large extent, commercial and recreational crabbers consider this valuable product incidental to the hard-shell crab, and presently there is no fishery directed specifically toward the soft-shell crabs. One processor in Baldwin County has constructed holding facilities for crabs exhibiting premolting signs, but his use of this system is infrequent and his supply undependable.

A technique for economically operating a crab-shedding house should be developed. Some work along this line has been done by the Gulf Coast Research Laboratory (Harriet Perry, personal communication).

Labor Problems in Commercial Fishery

Although mechanical crabmeat separators are available that reduce labor in crab processing plants, the quality of meat produced by mechanical means is not equal to that produced by hand labor. One mechanical separator in use in Alabama requires initial blanching prior to introduction to the automatic separator; afterwhich, the separated meat must be completely cooked. The industry is in need of a separator which will produce quality meat at a rapid rate.

During good shrimping years, there is much pressure to divert the crab processing labor force to both the shrimp fishery and its associated processing plants. If the shop happens to be multifishery oriented, there is no problem since the shopowner places processing emphasis on the most important immediate product. If, however, the processing plant handles only crab products, the effects of the diverted labor force from his plant can be catastrophic. This reemphasizes the immediate need for advanced technology in crab processing.

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Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 29–35.

A SYNOPSIS OF THE BIOLOGY OF THE BLUE CRAB *CALLINECTES SAPIDUS* RATHBUN IN FLORIDA

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INTRODUCTION

The blue crab *Callinectes sapidus* constitutes the third largest commercial food fishery in Florida, preceded only by shrimp and mullet. Principally a shallow water (<35 m) species, the blue crab ranges from Gulf waters of 34 ppt salinity to freshwater rivers up to 195 km from the coast (Tagatz 1968a).

Blue crabs are landed commercially in most Florida coastal counties (Figure 1), but landings have been greatest in those above 28°N latitude during 1967–1978 (Table 1).

Figure 1. Average annual blue crab landings (pounds $\times 10^5$) for Florida coastal counties, 1967–1978.

TABLE 1.

Total blue crab landings by county ($\times 10^4$ pounds).

County	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Wakulla	263	132	151	313	356	291	336	387	355	209	228	242
Brevard	364	145	210	237	358	239	206	319	210	157	159	146
Pasco-Citrus	227	157	284	350	303	229	164	168	151	209	261	133
Dixie-Taylor	246	172	175	187	157	135	143	187	245	236	453	275
Levy	232	191	207	156	102	77	51	71	198	254	392	257
Franklin	119	8	71	131	111	215	192	144	165	174	110	88
St. Johns	175	238	116	184	194	160	25	69	4	2	0	20
Nassau	90	69	92	133	94	75	73	87	65	90	100	123
Putnam	82	30	12	26	60	42	18	176	100	104	51	41
Charlotte	73	49	80	105	66	42	34	32	25	55	66	74
Indian River	123	51	70	87	91	55	33	53	5	< 1	2	15
Lee	139	45	72	157	89	23	10	0	2	7	2	11
Duval	55	91	45	74	94	41	19	18	13	15	13	16
Hillsborough	64	19	16	40	25	32	5	3	44	5	3	13
Bay-Washington	3	1	36	6	3	11	9	7	21	28	53	51
Volusia	37	26	12	7	4	4	5	18	18	26	12	26
Escambia	7	10	32	3	3	4	6	2	6	2	4	4
Martin	3	6	11	24	15	9	7	2	< 1	0	0	0
Walton	3	21	22	< 1	0	0	0	3	3	0	< 1	< 1
Manatee	1	1	2	3	2	1	1	2	17	17	< 1	< 1
Collier	4	5	1	20	2	0	0	< 1	3	0	0	< 1
Pinellas	9	2	1	0	0	0	< 1	< 1	20	< 1	< 1	9
Sarasota	0	0	< 1	0	< 1	< 1	< 1	0	15	< 1	< 1	0
Santa Rosa	< 1	< 1	< 1	< 1	< 1	2	1	1	1	1	2	3
Okaloosa	1	< 1	< 1	1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1
St. Lucie	< 1	< 1	< 1	0	0	0	< 1	< 1	< 1	< 1	< 1	< 1
Dade	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Gulf	0	0	< 1	0	0	0	0	< 1	< 1	< 1	< 1	1
Monroe	< 1	< 1	< 1	0	< 1	< 1	0	< 1	0	0	0	< 1
Palm Beach	0	0	0	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Broward	< 1	0	0	0	0	0	0	0	0	0	0	0

West of Cape San Blas on the western coast of Florida, Escambia, Santa Rosa, Okaloosa, Walton, Bay, and Gulf counties (the Florida Panhandle) each generally produce less than 500,000 pounds annually. Southeastward from Cape San Blas, Franklin, Wakulla, Taylor-Dixie, Levy, and Citrus-Pasco counties each generally produce over 1 million pounds annually. Wakulla County, bordering on Apalachee Bay, ranks first in the state with annual landings exceeding 2.5 million pounds. Below 28°N, from Pinellas and Hillsborough counties southward through the Florida Keys (Monroe County), landings are considerably lower except in the Charlotte Harbor bay system (Charlotte-Lee counties) which produces approximately 1 million pounds annually.

Along the eastern coast of Florida, Brevard County annual landings average 2 million pounds, and rank second in the state. Nassau and Duval counties rank eighth and thirteenth, respectively, in the state, averaging approximately 900,000 and 400,000 pounds. St. Johns County landings have declined from a high of approximately 2.4 million pounds in 1968 to 200,000 pounds in 1978, principally due to the relocation of processing plants to Putnam County, an inland county bordering on St. Johns River. From St. Lucie County south to Dade County (all below 28°N), landings have been consistently low.

Commercial crab landings in Florida increased from 9.8 million pounds in 1954 to 26.5 million pounds in 1965 (Figure 2). Landings have since declined and now average 17 million pounds per year since 1967. Increases during the late 1950s and early 1960s were principally the result of fishery expansion on the west coast. East coast landings were relatively stable at approximately 7 million pounds during that time. After 1965, annual west coast landings declined sharply to a low of 9 million pounds (1968). Since 1968, landings have stabilized at approximately 13 million pounds. East coast landings, however, have continued a gradual decline since the late 1960s. Considerable fluctuations in annual landings have occurred in both the east and west coast fisheries.

Peak landings occur during early summer (May –June), on the west coast, while east coast landings generally remain high from summer through fall (May–October) (Figure 3).

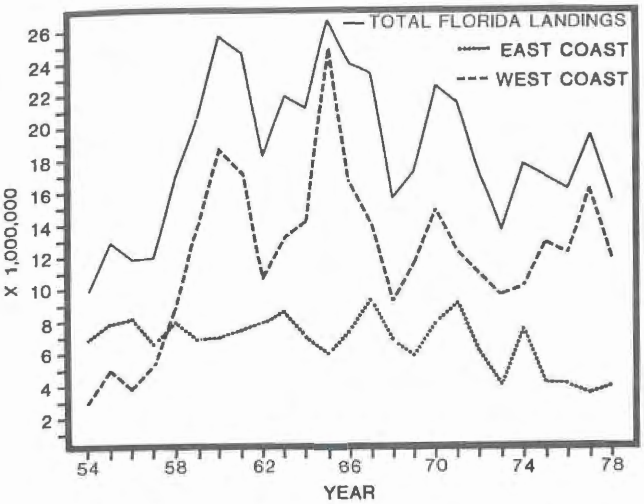

Figure 2. Florida annual blue crab landings, 1954–1978.

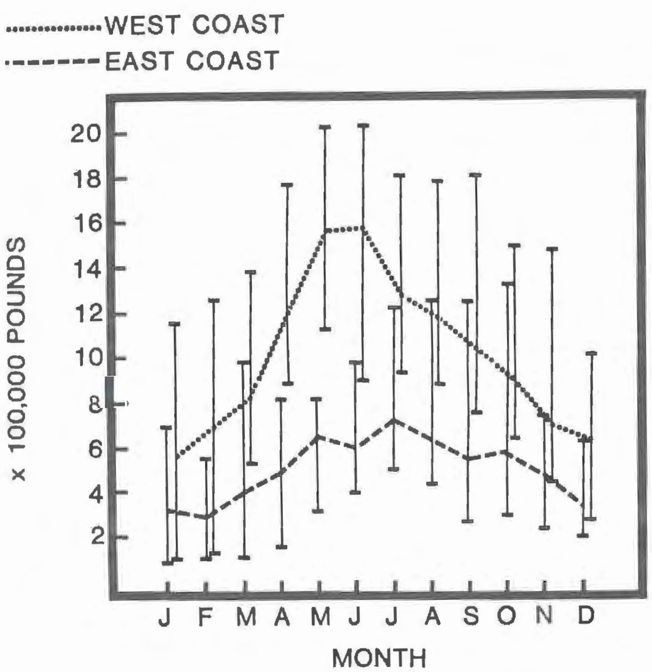

Figure 3. Average monthly Florida blue crab landings by west coast and east coast, 1967–1979.

LIFE HISTORY

Reproduction and Migration

Blue crabs mate from March to December in Florida when water temperatures exceed 22°C. Females mate once during their lifetime, after the last in a series of molts (terminal molt); males may mate during the last three or four growth stages (Truitt 1939). Size at sexual maturity varies for both males and females; sexually mature females as small as 52 mm carapace width (CW) have been reported (Fischler and Walburg 1962), although Tagatz (1968a) reported immature females as large as 177 mm CW. Crabs mature at smaller sizes in high salinity waters (Tagatz 1968a). Regardless of size, female blue crabs usually mature sexually after 18 to 20 molts (Van Engel 1958).

Prior to attaining terminal molt, the female travels to brackish waters in upper estuarine or marsh areas to mate. The female crab couples with a male, and is carried beneath him for one or two days while she sheds her immature shell. "Cradling" of the female during this soft-shell stage provides protection and assures insemination at the only time possible during her life. Sperm are transferred to the spermathecae of the female where they remain viable for a year or more, enabling some females to spawn at least twice (Tagatz 1968a). After mating, the male continues to carry the female for a day or so until shell hardening has completed. The female then begins a migration back to high-salinity waters to spawn. Salinity is a dominant factor affecting hatching, larval development, and survival (Costlow and Bookhout 1959).

Heape (1931) described three types of migration: alimental, based upon food availability; climatic, in response to climatological changes; and gametic, involving reproduction and spawning. Previous migrational studies conducted in Gulf coast states include: Texas (Moore 1969), Louisiana (Darnell 1959, Adkins 1972, Jaworski 1972), Mississippi (Perry 1975), and Florida (Osterling 1976, Evink 1976). All investigators reported gametic migration from the estuary to nearshore Gulf of Mexico waters of higher salinity. Little or no movement between estuarine systems was indicated except in Florida.

Tagging studies conducted by Osterling (1976) and Evink (1976) in ten Florida estuaries indicated that, prior to spawning, female blue crabs exhibited not only the well-known onshore/offshore migration to areas of higher salinity, but also engaged in offshore/along-shore movements between estuarine systems. After mating, some females migrated in a northerly direction toward northwestern Florida, in particular toward the Apalachicola Bay system. One female, tagged by Osterling (1976), traveled northward 297 miles in 71 days from Punta Gorda to Panacea, passing seven estuarine systems along the way. Such long-distance migration past major estuarine systems and toward northwestern Florida could indicate that this region is a major spawning area for the Gulf coast of Florida. Questionnaire surveys of local fishermen (Evink 1976) supported this, suggesting a greater number of gravid females in that area than in other west-coast areas. Both investigators maintained that this northward migration of females was timed to coincide with greatest annual river discharge during spring; discharge from a major river such as the Apalachicola (Figure 4) could provide possible larval transport mechanisms for reaching offshore waters more suitable for larval growth and development. Transport of larvae offshore to major current systems (e.g., Loop Current) could assure a stable temperature and salinity environment, and provide a means of ensuring gametic mixing with downstream populations.

Spawning occurs near all major estuarine systems along the western coast of Florida (Osterling 1976), although the

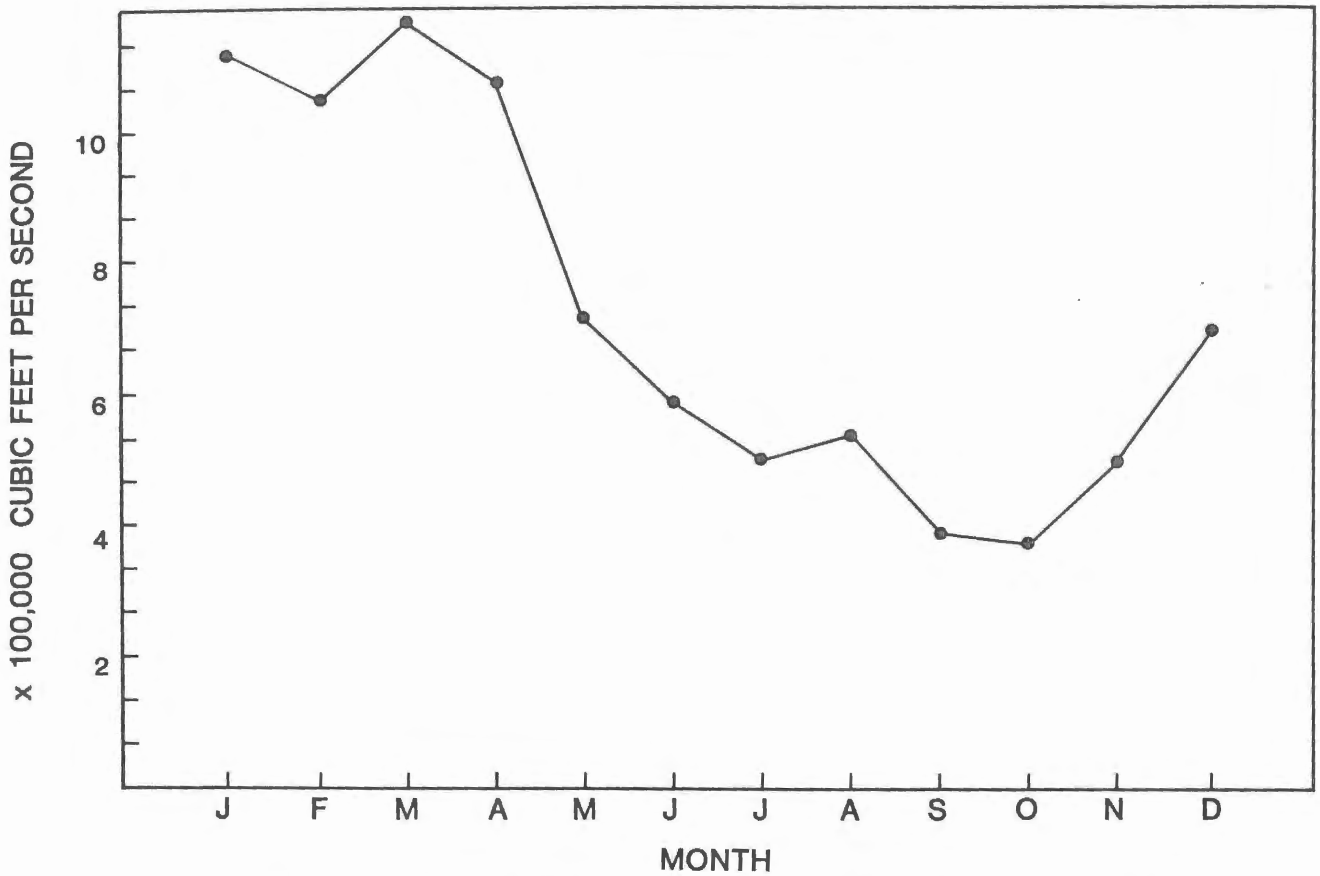

Figure 4. Monthly mean river discharge of Apalachicola River at Chattahoochee, Florida, 1951–1979.

number of females that spawn may be greater in northwestern Florida than elsewhere. Spawning on the eastern coast of Florida occurs in high salinity, nearshore waters with little or no movement between estuarine systems (Tagatz 1968a).

Intervals between mating and spawning of blue crabs, as well as migrations preparatory to spawning, vary with season. Two to nine months may elapse between mating and egg extrusion (Churchill 1919). Tagatz (1968a) found that spawning in St. Johns River in northeastern Florida usually occurred one or two months after mating during spring and summer. However, if crabs mated during fall or winter, spawning was delayed until warmer temperatures occurred during the following spring. Because females store sperm which are viable for at least a year, they may be capable of spawning twice during a season (Tagatz 1968a).

During the one- or two-week incubation period, eggs change color from bright orange to brown through absorption of the yolk sac by the embryo and development of dark pigmentation in the eyes (Van Engle 1958). The number of eggs in a "sponge" or egg mass varies from 700,000 to 2 million (Churchill 1919, Robertson 1938, Truitt 1939). Pre-zoeal stage hatching must occur between salinities of 23 to 33 ppt and temperatures of 19 to 29°C to ensure survival (Sandoz and Rogers 1944). Even if these hatching conditions occur, survival is low at best. Many eggs do not hatch, and still fewer larvae and small crabs survive. Only one ten-thousandth of 1% (0.000001) of viable eggs survive to become adults; the remainder perish from fungal infections, from predation, or from excessively high or low temperatures or salinities (Van Engel 1958).

Larval Development

Larvae reared *in vitro* by Costlow and Bookhout (1959) indicated that blue crabs have seven zoeal stages, together lasting 31 to 49 days, and one megalopal stage lasting 6 to 20 days. Locations of zoeae and megalopae in the water column vary, but Tagatz (1968a) found more *C. sapidus* zoeae (first to second stages) near the surface than at the bottom. The proportion of second- to first-stage zoeae in plankton tows was 1:323, whereas that of megalopae to zoeae was 1:164. Zoeae and megalopae were found during all months between April and October. Some first- and second-stage zoeae were found 40 kms upstream from the mouth of St. Johns River, but most were found near the coast in higher salinity waters. Few third- to seventh-stage zoeae were found near the coast, suggesting that later larval development may take place further offshore. Some megalopae also were found upriver, but highest concentration occurred near the coast and extended to 96 kms offshore. Megalopae are thought to take advantage of tidal currents to return to the estuary where they molt into the first crab stage and begin juvenile growth.

Growth

Like most crustaceans, the blue crab has a rigid shell that must be shed in order for the crab to grow. The shell itself is composed of chitin strengthened by deposits of calcium salts (Rees 1963). Prior to molting, a new shell is formed beneath the old exoskeleton, which is then loosened and cast off. The new shell initially is soft, but expands and hardens in a few hours. First stage crabs (2 mm CW) grow to adult size (100 to 240 mm CW) after 18 to 20 molts (Van Engel 1958).

Tagatz (1968b) found that juvenile crabs in northeastern Florida exhibited more growth per molt in waters of higher salinity. However, studies by Newcombe (1942), Cargo (1958), Van Engle (1958), and Tagatz (1968b) also found crabs occurring in brackish or nearly fresh water (< 5 ppt) were larger than adults found in waters of higher salinity, prompting speculation that greater intake of fresh water during each molt may result in greater adult size. Tagatz (1968b) found molt intervals were three or four times longer during winter (46 to 124 days) than during summer (11 to 42 days). Sizes of crabs and water temperatures were dominant factors affecting molting frequency. Most blue crabs in St. Johns River reach harvestable size (≥ 127 mm CW) one year after hatching, but some may survive to 4 years of age (Tagatz 1968a).

Evink (1976) reported carapace widths of crabs in the commercial catch from the Gulf coast of Florida (91 to 205 mm CW) were similar to those from Louisiana (125 to 205 mm), Mississippi (112 to 204 mm), and Texas (95 to 228 mm). More small males (116 to 145 mm CW) than females were taken in the commercial harvest on the western coast of Florida during April–December because females have moved offshore to high-salinity waters, and were not subject to the intense fishing pressure taking place in nearshore waters; such segregation has been observed in other Gulf states fisheries (Darnell 1959, Moore 1969, Perry 1975).

Diet

Fish, aquatic vegetation, mollusks (clams, mussels, snails), crustaceans (amphipods, isopods), insects, and annelid worms are commonly eaten by blue crabs. Boyd and Goodyear (1972) reported blue crabs obtained much of their protein requirements from animal tissue, and their energy requirements from plant tissue. Stomach content analyses of 695 blue crabs in St. Johns River revealed the following (after Tagatz 1968a):

	Mean Percentage	
Food Item	Amount of Food Volume	Frequency of Occurence
Mollusks	39.0	32.4
Organic debris	19.8	17.0
Fish	19.4	15.6
Crustaceans	15.0	19.4
Plants	3.9	8.5
Annelids	1.8	5.0
Insects	0.9	1.4
Bryozoans	0.1	0.6

Little is known of the food requirements of larval crabs, but laboratory-maintained larvae have been successfully reared on photosynthetic dinoflagellates, brine shrimp (*Artemia*), and sea urchin eggs (*Arbacia*) (Sandoz and Rogers 1944). Megalopae are omnivorous and will eat fish, shellfish, and aquatic plants (Van Engel 1958).

Predators

Blue crabs are an important link in the basic food chain of mammals, birds, and larger fishes (Darnell 1959, Bateman 1965, Day et al. 1973). The primary mammalian predator is the raccoon (*Procyon lotor*), and avian predators include clapper rail (*Rallus longirostris*), great blue heron (*Ardea herodias*), American merganser (*Mergus merganser americanus*), and hooded merganser (*Lophodytes cucullatus*).

Juvenile crabs are an important item in the diet of many larger forage fishes such as spotted sea trout (*Cynoscion nebulosus*), red drum (*Scianops ocellata*), Atlantic croaker (*Micropogon undulatus*), black drum (*Pogonias cromis*), and sheepshead (*Archosargus probatocephalus*). Blue crab larvae are eaten by Florida pompano (*Trachinotus carolinus*), and other large fish and the eggs of females in "berry" are subject to attack by triggerfish (*Balistes* spp.) (from Adkins 1972).

Diseases and Parasites

Blue crabs serve as hosts to a great number of parasites and pathogens which cause disease both in crabs and in humans. Probably the most serious disease affecting blue crabs is "grey crab disease" which results from infection by the amoeba *Paramoeba perniciosa.* Although unknown in the Gulf of Mexico (Overstreet and Cook 1972), *P. perniciosa* has been responsible for massive crab mortalities reported along the eastern seaboard (Mahood et al. 1970).

Gills of blue crabs may be infested with numerous parasites including peritrichous ciliates, nemerteans (*Carcinonemertes carcinophila*), and a goose-necked barnacle (*Octolasmis lowei*). Crabs living in low-salinity waters are at times found with the brown leech (*Myzobdella lugubris*) clinging to the abdomen and appendages (Overstreet and Cook 1972). In brackish waters, the branchiobdellid worm (*Cambarincola* sp.) may be found on dorsal parts of the crab shell and in the gill chambers.

The sacculinid barnacle (*Loxothylacus texanus*) is another parasite associated with blue crabs in Florida waters. This parasite is mostly internal but has an enormous sac (externa) which protrudes from the crab's abdomen, prohibiting the crab from molting, and modifying the secondary sex characteristics.

Microsporidan protozoans infect muscles of blue crabs, turning the tissue white. "Sick crabs," as these animals are called by local fishermen, are infected by protozoan spores transmitted to the crab by feeding on other sick crabs. Infected crabs, when cooked, have a cotton-like texture. Protozoans responsible are *Ameson sapidi, A. michaelis,* and *Pleistophora cargoi.*

Larval helminths and trematodes (flukes) are found in blue crabs. Trematodes in the family Microphallidae encyst in blue crabs, using them as intermediate hosts. These cysts when hyperparasitized by a haplosporidan protozoan cause the condition known as "buckshot" by commercial fishermen.

Bacterial and fungal infections also are known in blue crabs. *Vibrio cholerae* strains have been responsible for outbreaks in some Gulf states due to poor sanitary practices in home-cooked crabs. This was caused by reinfection of cooked crabs by putting them back into the original contaminated container.

ADVERSE ENVIRONMENTAL PARAMETERS

Flood

Avoidance responses of blue crabs to storm-water runoff have been documented in Florida; Livingston et al. (1976) reported avoidance responses by juvenile blue crabs held in the laboratory to runoff waters having a pH lower than 6.0 or 7.0. However, field studies in Apalachicola Bay indicated that although adult crabs actively avoided waters with low pH caused by high spring/summer runoff, juveniles actually increased in abundance under similar conditions of low pH.

Pesticides

Pesticide levels lethal to blue crabs are difficult to estimate in the natural environment. However, concentration of pesticides through the food chain to levels higher than those present in the natural environment affect crab spawning, hatching, and larval and juvenile development.

Bookhout et al. (1979), reporting chronic effects of Kepone on early development of *C. sapidus,* found concentrations of Kepone sublethal from 0.1 to 0.75 ppb but lethal at 1.0 ppb for larval crabs through the first crab stage.

Bookhout and Costlow (1976) found concentrations of Mirex from 0.01 to 10.0 ppb had no effect on mortality of blue crab larvae for 5 days after hatching. Thereafter, significantly greater mortality of larvae occurred in zoeal stages III and VII, and megalopae at 0.1 ppb, in zoeal stages II and III at 1.0 ppb, and in zoeal stages I and II at 10.0 ppb than in other stages. Concentrations of Methoxychlor between 1.3 and 1.9 ppb were lethal for *C. sapidus.*

Mahood et al. (1970) found crabs to be less tolerant of pesticides (DDT, DDD, DDE, Mirex, and Dieldrin) at low salinities and high temperatures, and at high salinities and low temperatures. Initial tests with DDT and Toxaphene indicated that concentrations of 1.0 and 10.0 ppm were 100% lethal to adult blue crabs after 24 and 72 hours. Mirex, if ingested, was found to be toxic to juvenile blue crabs.

CONCLUSIONS

Commercial fisheries landings of blue crabs in Florida have fluctuated widely since the late 1940s because of variations in year-class strength and distribution of stocks, both of which are determined by density-independent environmental parameters. Although exact mechanisms by which these parameters affect year classes are yet undetermined, they occur at critical times in the life cycle, and affect (1) egg extrusion (spawning), hatching, growth, survival, and distribution of larvae; (2) early postlarval (megalopal) distribution and survival; (3) juvenile distribution and survival; and (4) adult distribution and survival (W. A. Van Engel, personal communication).

Salinity, temperature, pollutants, predation, disease, habitat loss, and food supply all affect blue crab survival. The diversity of parameters and their probable synergistic effects preclude the identification of any one of these as having the greatest effect. Concentrations of industrial and residential pollution, landfills, drainage alterations, and alteration of freshwater inflow into the estuary must be carefully monitored and controlled if survival of the blue crab is to be ensured.

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MIGRATION OF BLUE CRABS ALONG FLORIDA'S GULF COAST

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ABSTRACT The primary objective of this study was to document the unusual migratory habits and reevaluate the known life history of *Callinectes sapidus* Rathbun. The blue crab is common in all nearshore, estuarine environments of the Atlantic seaboard and the Gulf coast, and is a major fishery. Previous studies of blue crab migration have showed that males exhibit only local, random movements whereas the females migrate offshore to spawn after mating. Recent studies, however, present conclusive evidence that the females exhibit along-shore migration which is north along Florida's Gulf coast.

Data obtained from these studies present the possibility that blue crabs along the Gulf coast of Florida may exhibit a migrational pattern decidedly contrary to that described by previous investigators. This has been interpreted from a tag-recapture program. Migration distances of up to 499 km (310 miles) have been recorded for crabs along the Gulf coast. Migration has been observed toward the Apalachicola Bay region in panhandle Florida. Associated with these movements is the appearance of large congregations of "sponge" (egg-laden) crabs in the panhandle region of northwestern Florida. With this and similar evidence in mind, source areas for blue crab fisheries may, in fact, be many miles from the actual harvest areas, and there may be "spawning grounds" that serve to repopulate large sections of the fishery.

INTRODUCTION

The blue crab *Callinectes sapidus* Rathbun is common in all nearshore estuarine environments of the western Atlantic seaboard and the Gulf of Mexico. In the Gulf of Mexico, the blue crab fishery ranks third in value of all food fisheries (Adkins 1972, Perry 1975). The abundance of blue crabs in Florida waters is reflected in state-wide commercial landings of almost 17 million pounds for 1975 (Fla. Dep. Nat. Res. 1976). Of this, 13 million pounds came from Florida's Gulf coast fishery. Besides supporting a large commercial fishery, the blue crab also is a major recreational fishing species.

As with other important commercial species, the life history and fishery for the blue crab have been extensively investigated. With the center of abundance for the blue crab in the Chesapeake Bay region, which annually produces approximately 50% of the national catch (Lippson 1971), the majority of earlier investigations on the life history of the blue crab had been conducted in that area (Hay 1905, Churchill 1919, Pearson 1948, Pyle and Cronin 1950, Van Engel 1958). More recently, studies have been conducted in North Carolina (Judy and Dudley 1970, Dudley and Judy 1971), Georgia (Palmer 1974), Mississippi (Perry 1975), Louisiana (Adkins 1972, Jaworski 1972), and Texas (More 1969, Gallaway and Strawn 1972).

To better manage existing stocks of blue crabs, it is vital to have knowledge of the movement and migrations of blue crab populations. Local movements in blue crab populations have been well documented by previous studies (Cargo 1958, Van Engel 1958, Darnell 1959, Fischler and Walburg 1962, Tagatz 1968, Judy and Dudley 1970). These are not full population migrations, but are dominated by the female component of the population only. Female blue crabs have been found to have a definite migrational pattern related to their life-cycle stage. Just before their last juvenile molt into the adult, female blue crabs move into lower salinity waters (shoreward, and into creeks and marshes). At that time they pair with a male for mating and are carried underneath the male until time for the females' terminal molt. Following the final molt and copulation, female blue crabs will move to higher salinity waters offshore for spawning. Male blue crabs generally show no trend in their movements, but rather have a nondirectional and random movement pattern (Cargo 1958).

The net result of the female blue crab's migrations could be described as a movement toward and away from the shoreline. This would tend to keep crabs from one estuarine system from mixing with those of adjacent systems. Cargo (1958) found that crabs may scatter widely within their respective habitats (i.e., estuaries), but show only limited movement to other inland and coastal waters. According to Fischler and Walburg (1962) in South Carolina, commercial size crabs do not migrate between estuaries but limit their movement to the estuary or adjacent coastal area. Similar conclusions were reached by Judy and Dudley (1970) in North Carolina. Thus, commercial fisheries in these areas must depend upon blue crabs that mature within the system and not on crabs recruited from adjacent (or widespread) estuarine systems. Based on the known life history and migrational habits of blue crabs elsewhere, there has been no reason to dispute the suggestions that each major estuarine area in Florida contained its own discrete crab population, and that these populations did not migrate into other estuarine areas or mix with other distant crab populations. In essence, each geographic component of the industry exploits blue crab populations unique to the local area. These notions were supported by research reports which emphasized the local population/life-history aspects.

Although this pattern may hold true for the regions in which it was described, this appears not to be the case for populations of blue crabs along Florida's peninsular Gulf coast. The basic pattern of mating in lower salinities and spawning in higher salinities still applies, but the classic onshore-offshore movement does not. Instead, there is an onshore-alongshore movement where, following mating, females move along the coastline to specific spawning areas.

MATERIALS AND METHODS

A study was conducted to (1) determine the peninsular Gulf coast migrational patterns of marketable-size Florida blue crabs, (2) determine the source areas for the peninsular Florida fisheries, and (3) provide basic population data for future management programs using a tag-recapture program.

Past tagging studies have been directed toward determining movements of adult blue crabs in bays and in the lower parts of estuaries. This study was concerned with the entire Gulf coast of Florida. Because of the wide variations in environmental parameters which occurred from area to area, a general description of the study area was impossible. Since commercial fishing pressures also vary from area to area, actual release sites were, of necessity, chosen corresponding to major blue crab fisheries. Sites selected as release points were (from south to north along the coast): Chokoloskee Bay, Fort Myers, Punta Gorda, New Port Richey, Crystal River, Horseshoe Beach, Steinhatchee, Keaton Beach, Panacea, and Apalachicola (Figure 1).

The tag-recapture program entailed tagging a crab and releasing it for recapture at some future date. Arrangements were made at each tagging site to purchase 500 to 600 live, unculled, blue crabs either from a local processing house or from an individual crabber with the stipulations that the

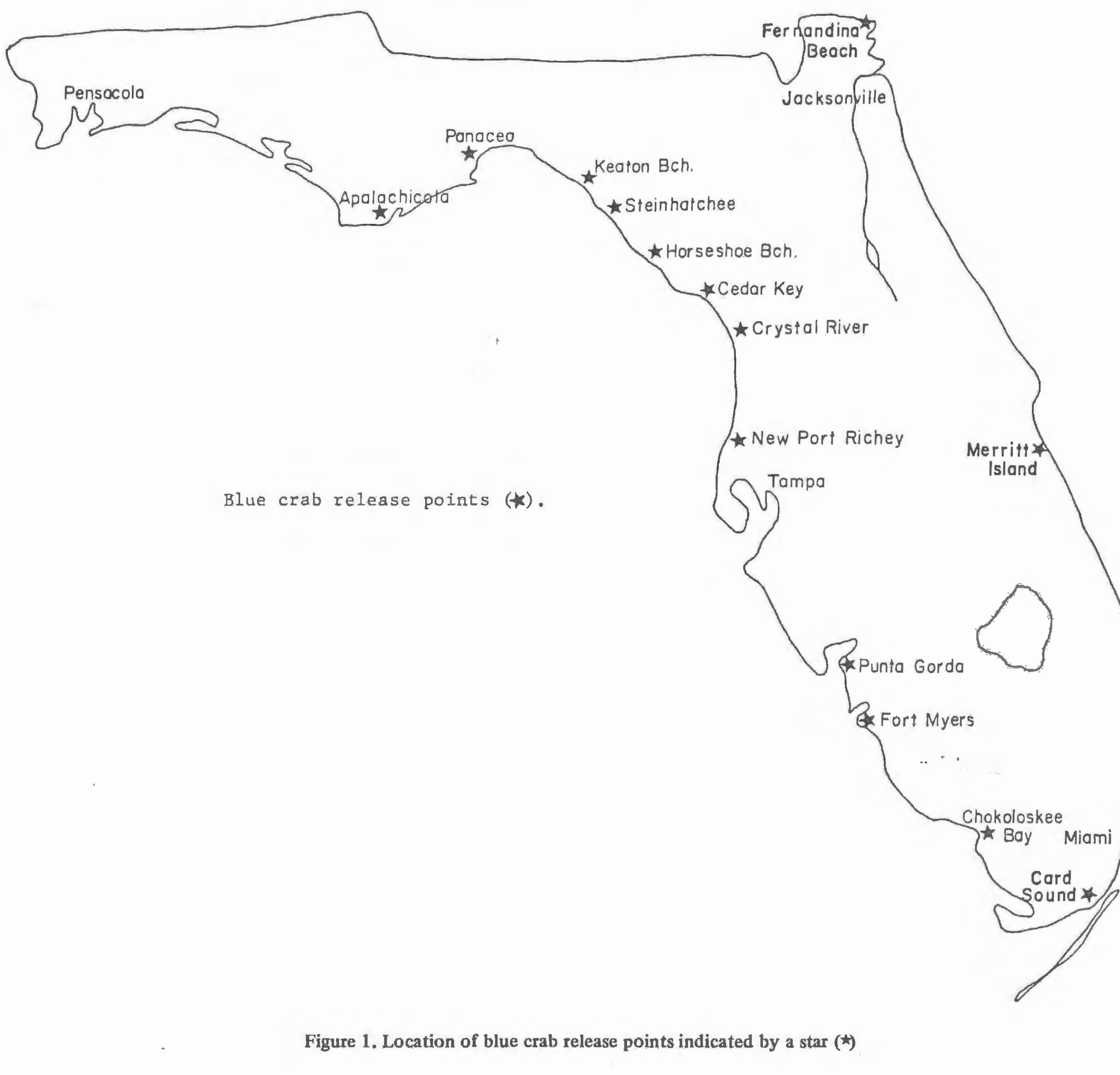


Figure 1. Location of blue crab release points indicated by a star (★)

crabs were caught in the immediate vicinity and immediately preceeding the scheduled tagging. Crabs were tagged with an orange plastic dorsal carapace tag (Figure 2). Each tag included a sequence number, the address and telephone number to contact upon recapture, and data requested concerning the recapture (date, site). Data recorded for each crab tagged included the tag number, sex (determined by abdomen shape), carapace width (mm) measured dorsally from lateral spine tip to lateral spine tip, and general condition (e.g., missing limbs or evidence of parasitism). Tagged crabs were released in the same general area of capture, but a distance from existing traplines to assure adequate mixing with the untagged population, and to avoid excessive immediate recaptures.

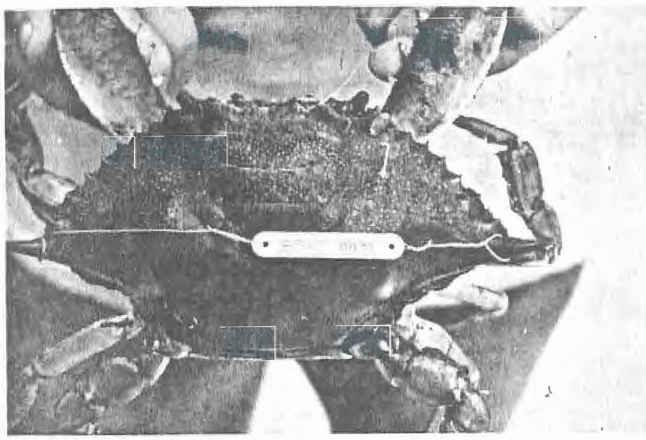


Figure 2. Placement of carapace tag on blue crab. The tag itself is made of orange plastic with black lettering and is held on the crab with stainless steel, monel wire (diameter 0.8128 mm). Visible on the tag is the sequence number (0070) identifying the crab, and the address to be contacted upon recapture. The reverse of the tag instructed the finder as to what data were requested, and provided a phone number to call (collect) to report the recapture.

The majority of tagging sessions (16 of 18) were conducted from September through March. It appeared that the greatest portion of the female migration took place during that time. In a preliminary study (Oesterling 1976), taggings were conducted throughout all months of the year. During the warmest months (May through August), there were no long distance movements observed. Therefore, to focus efforts on the most productive periods, taggings were conducted only in the fall/winter/early spring.

Besides the actual field work, an extensive public notification program was conducted. Notices of the project, its purpose, and what to do with a tagged crab, were sent to licensed commercial crabbers, processing houses, marine patrol agents, newspapers in coastal counties, and the scientific community along the Florida Gulf coast. Although no reward was offered for the return of a tagged crab, there was excellent cooperation from the commercial interests along the coast, with approximately 90% of all returns coming from the commercial community. Persons or agencies submitting return data were individually acknowledged with a letter describing the program and the tagging history of the captured crab.

RESULTS

During the time period May 1974 through December 1975, 18 blue crab taggings were conducted at ten different sites along the Gulf coast of Florida. There was a total of 6,953 crabs tagged and released: 3,834 (55.1%) males, and 3,119 (44.9%) females (Table 1). There have been 857 total reported returns for a return rate of 12.3%. Of the recaptures, 51.6% (442) were females. There were several notable returns and return trends.

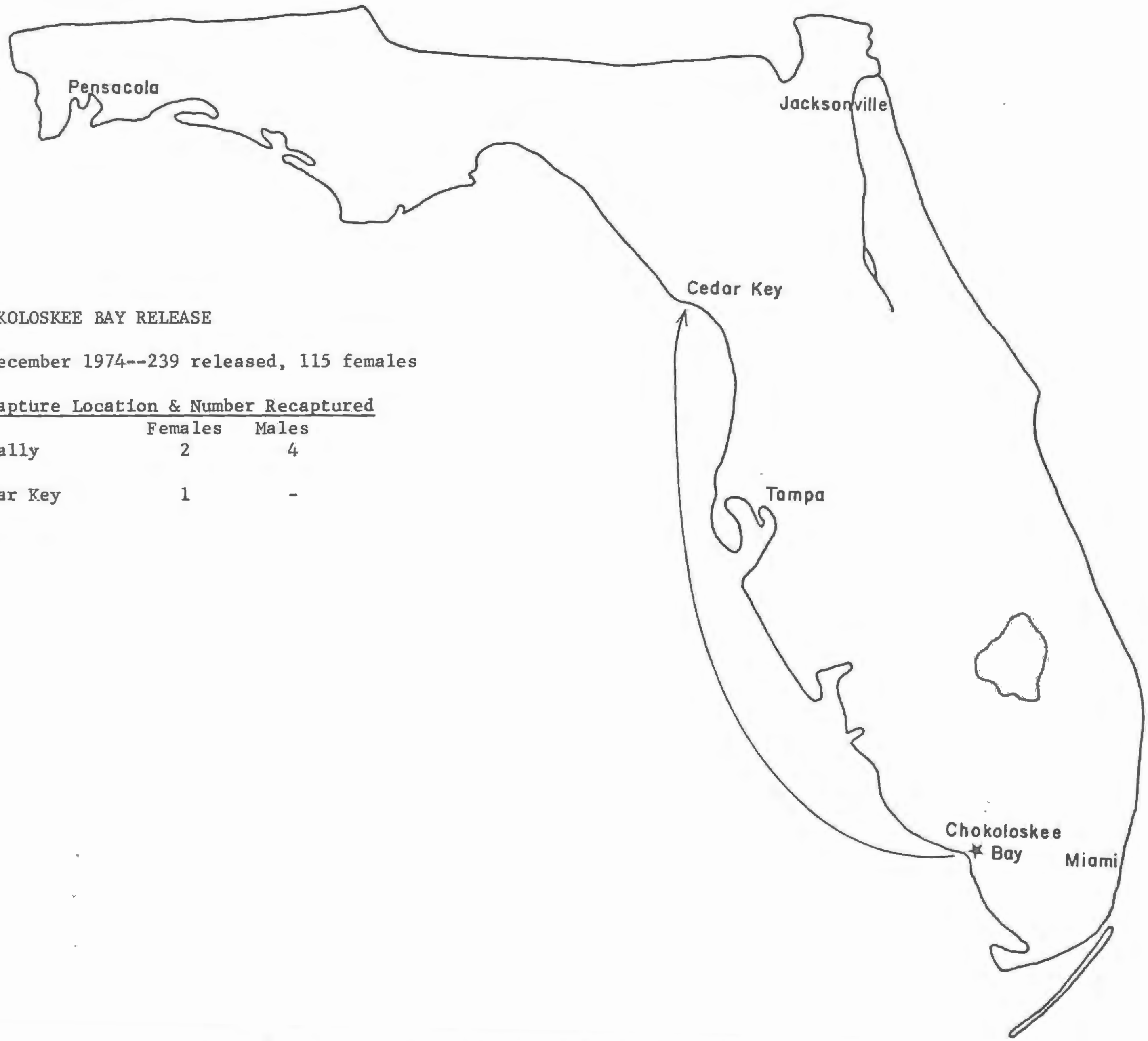
By and large, females traveled the greatest distances (Figures 3 through 12). Approximately 24.8% (110) of recaptured females moved distances greater than 48 km (30 miles) (Table 2), and 42.7% (189) moved out of the local area (defined as being within 16 km [10 miles] of the release site). The extensive range of female movement was evidenced by 18 crabs (4% of female recaptures) which had traveled over 322 km (200 miles), and by three individuals which traveled as far as 499 km (310 miles).

TABLE 1.

Tagging sites and dates, and numbers of crabs tagged. Release sites are listed from south to north along coast.

Tagging Site	Tagging Date	Number Tagged Males	Number Tagged Females	Total
Chokoloskee Bay	6 December 1975	124	115	239
Fort Myers	14 October 1975	472	85	57
Punta Gorda	7 February 1975	435	108	543
	13 October 1975	416	97	513
New Port Richey	21 May 1974	156	21	177
	6 November 1974	230	90	320
	28 January 1975	155	15	170
	23 September 1975	248	19	267
Crystal River	21 January 1975	126	358	484
Horseshoe Beach	30 January 1975	4	303	307
Steinhatchee	24 May 1974	439	39	478
	25 November 1974	230	291	521
	3 October 1975	135	63	198
	29 October 1975	251	74	325
Keaton Beach	29 January 1975	19	336	355
Panacea	16 January 1975	33	669	702
Apalachicola	11 March 1975	114	224	338
	28 October 1975	247	212	459
Total		3,834	3,119	6,953

In contrast, 96.4% (401) of males recaptured were returned from within 16 km (10 miles) of the release site (Table 2). The limited movement of male crabs was further substantiated by two males which were recaptured 205 and 245 days after release but within several kilometers (6.4 km [less than 4 miles]) of their release site. Statistical treatment of return data indicated a highly significant difference in

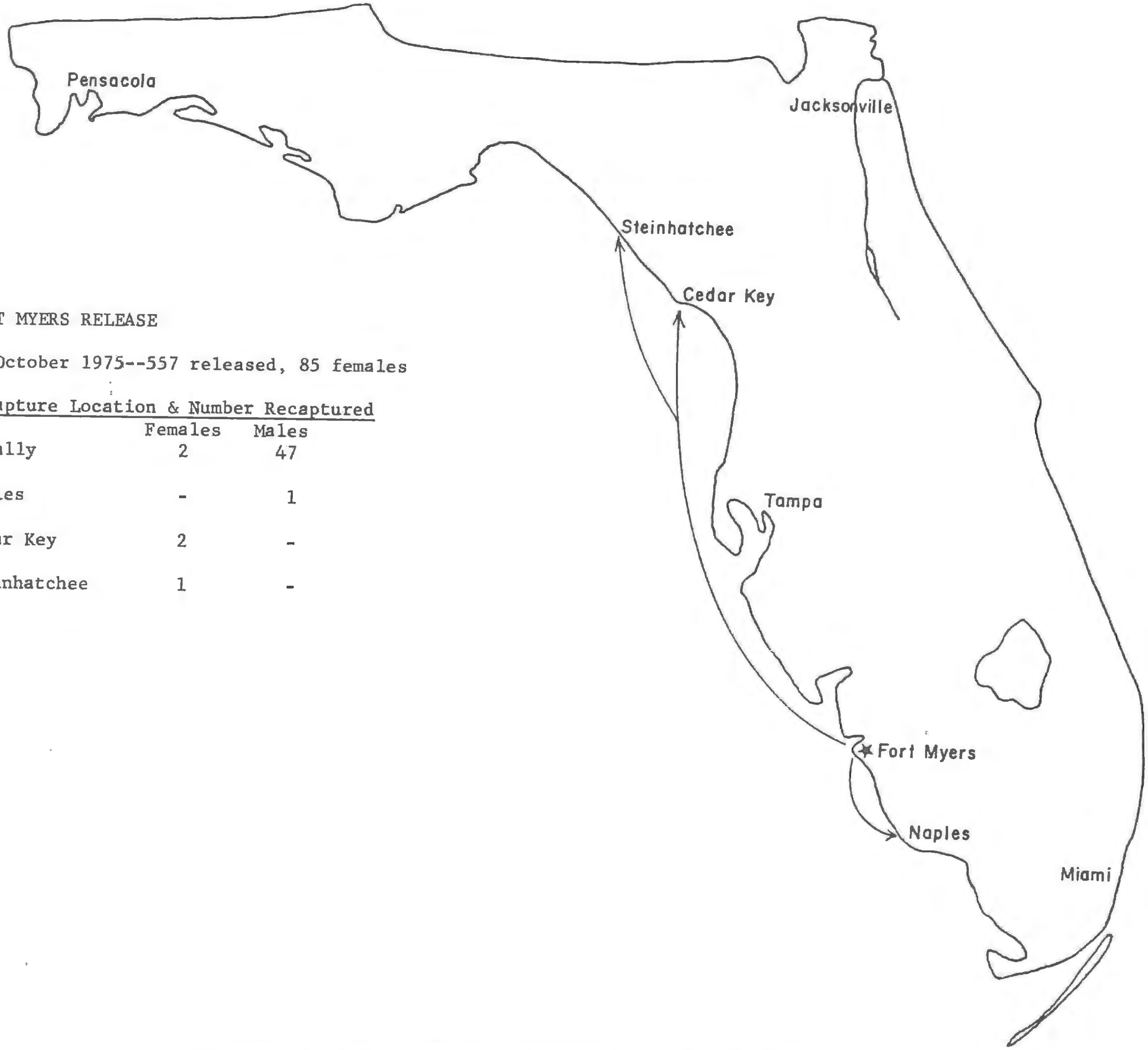


CHOKOLOSKEE BAY RELEASE

6 December 1974--239 released, 115 females

Recapture Location & Number Recaptured	Females	Males
Locally	2	4
Cedar Key	1	-

Figure 3. Blue crab release made at Chokoloskee Bay showing sites of major recaptures.

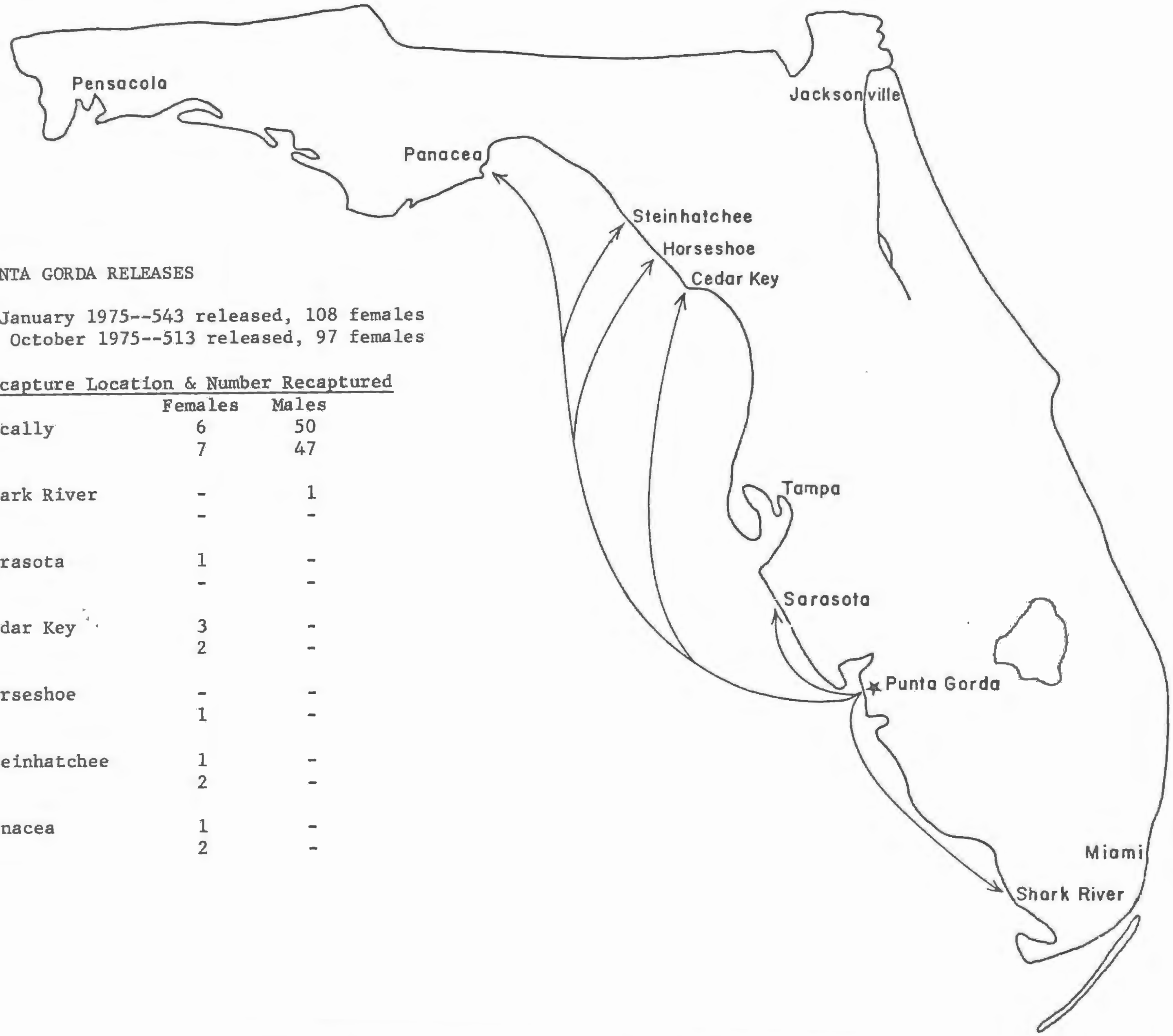


FORT MYERS RELEASE

14 October 1975--557 released, 85 females

Recapture Location & Number Recaptured	Females	Males
Locally	2	47
Naples	-	1
Cedar Key	2	-
Steinhatchee	1	-

Figure 4. Blue crab release made at Fort Myers showing sites of major recaptures.



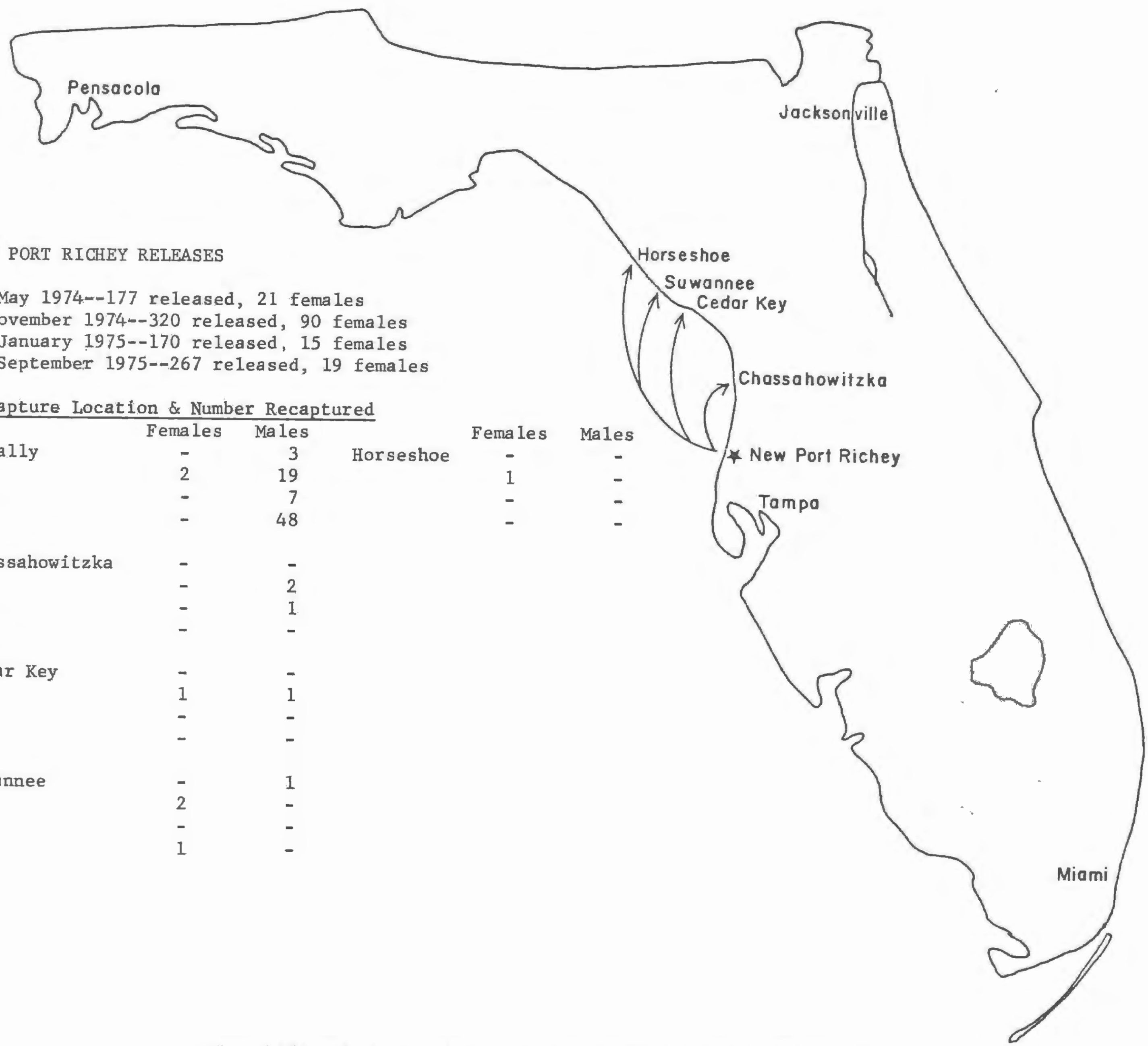
PUNTA GORDA RELEASES

7 January 1975--543 released, 108 females
13 October 1975--513 released, 97 females

Recapture Location & Number Recaptured

	Females	Males
Locally	6	50
	7	47
Shark River	-	1
	-	-
Sarasota	1	-
	-	-
Cedar Key	3	-
	2	-
Horseshoe	-	-
	1	-
Steinhatchee	1	-
	2	-
Panacea	1	-
	2	-

Figure 5. Blue crab releases made at Punta Gorda showing sites of major recaptures.



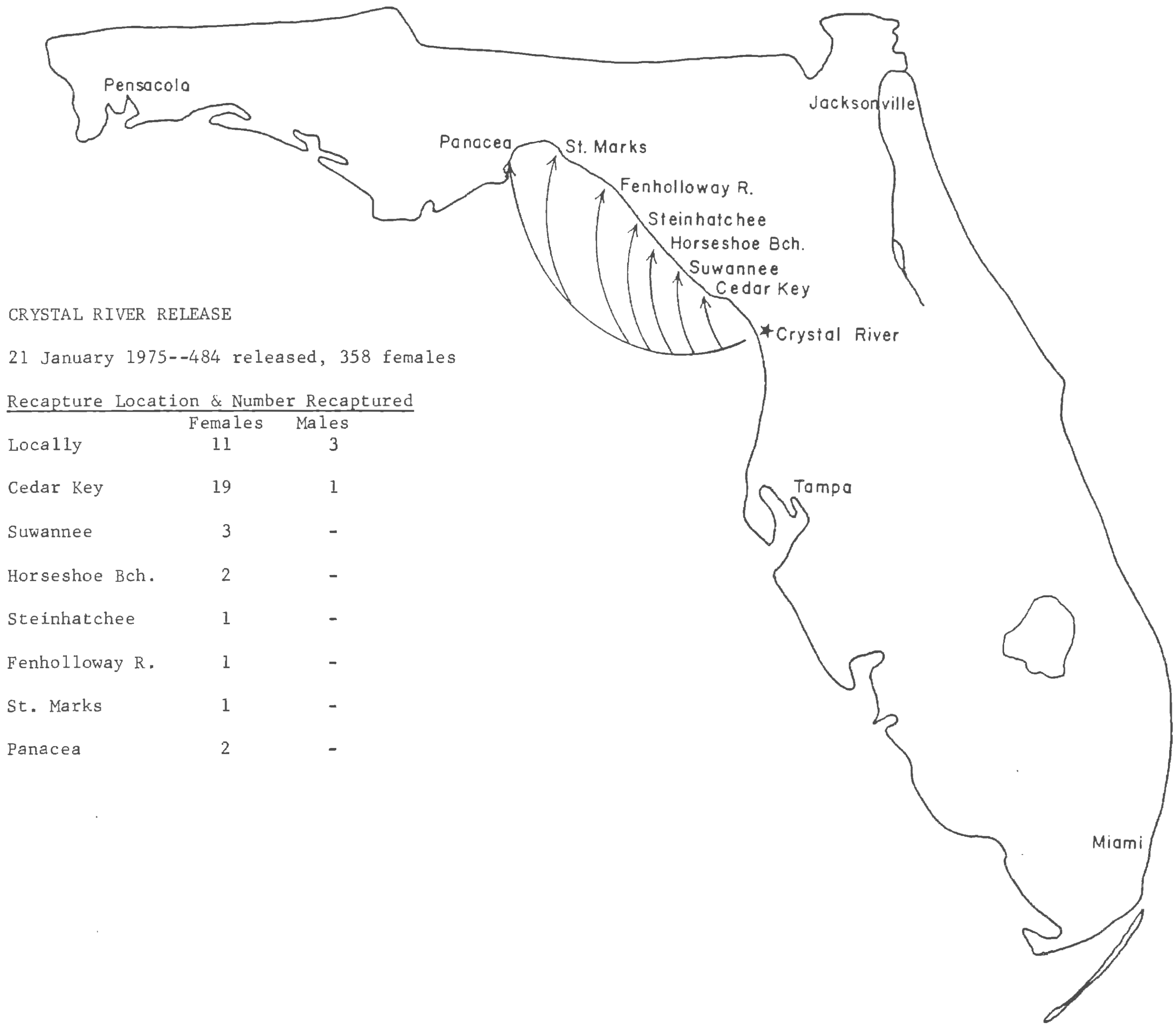
NEW PORT RICHEY RELEASES

21 May 1974--177 released, 21 females
6 November 1974--320 released, 90 females
28 January 1975--170 released, 15 females
23 September 1975--267 released, 19 females

<u>Recapture Location & Number Recaptured</u>

	Females	Males
Locally	-	3
	2	19
	-	7
	-	48
Chassahowitzka	-	-
	-	2
	-	1
	-	-
Cedar Key	-	-
	1	1
	-	-
	-	-
Suwannee	-	1
	2	-
	-	-
	1	-
Horseshoe	-	-
	1	-
	-	-
	-	-

Figure 6. Blue crab releases made at New Port Richey showing sites of major recaptures.



CRYSTAL RIVER RELEASE

21 January 1975--484 released, 358 females

Recapture Location & Number Recaptured	Females	Males
Locally	11	3
Cedar Key	19	1
Suwannee	3	-
Horseshoe Bch.	2	-
Steinhatchee	1	-
Fenholloway R.	1	-
St. Marks	1	-
Panacea	2	-

Figure 7. Blue crab releases made at Crystal River showing sites of major recaptures.

HORSESHOE BEACH RELEASE

30 January 1975--307 released, 303 females

Recapture Location & Number Recaptured	Females	Males
Locally	6	1
Steinhatchee	12	-
Keaton Beach	1	-
Fenholloway R.	10	-
St. Marks	4	-
Panacea	1	-
Apalachicola	1	-

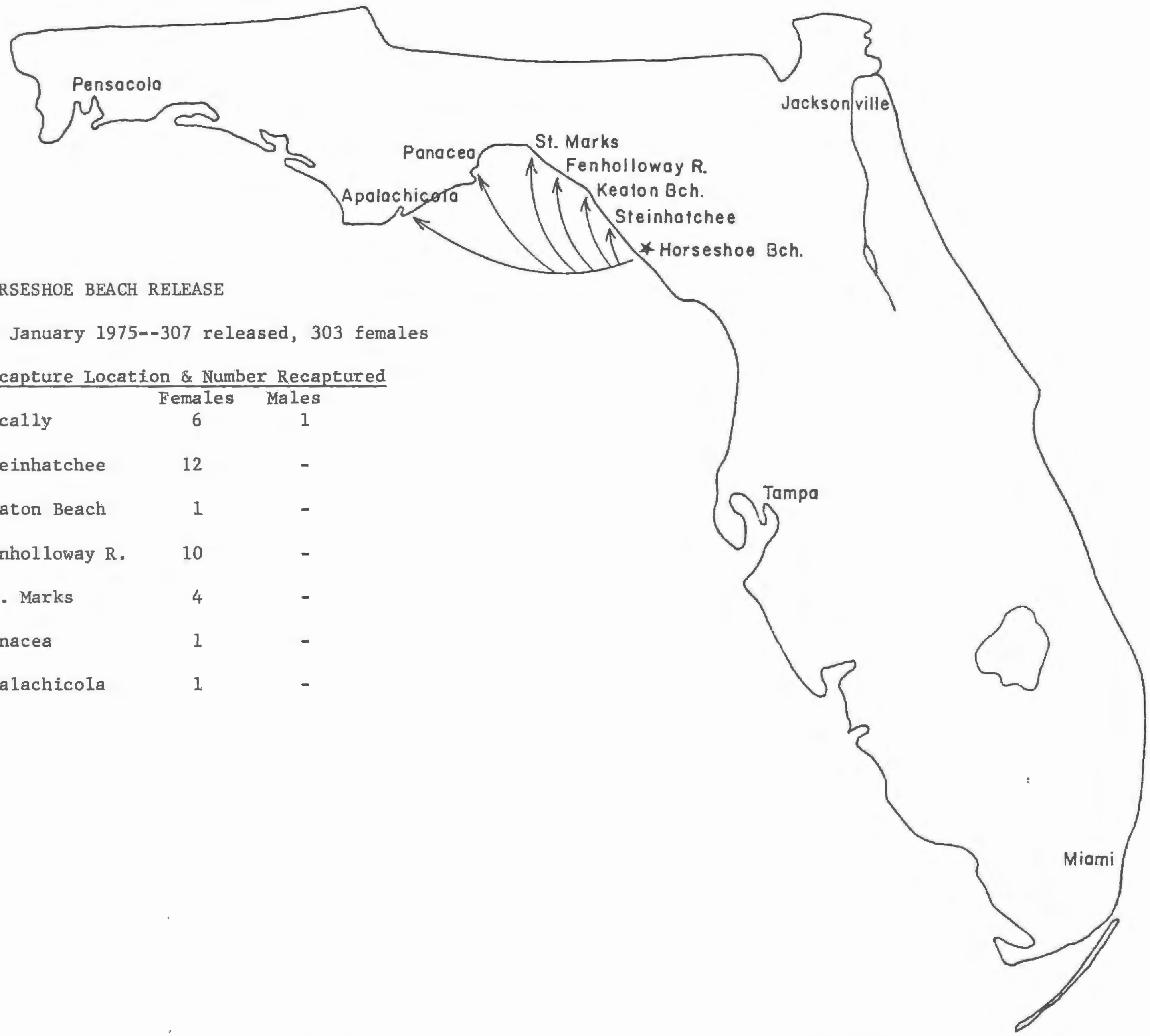
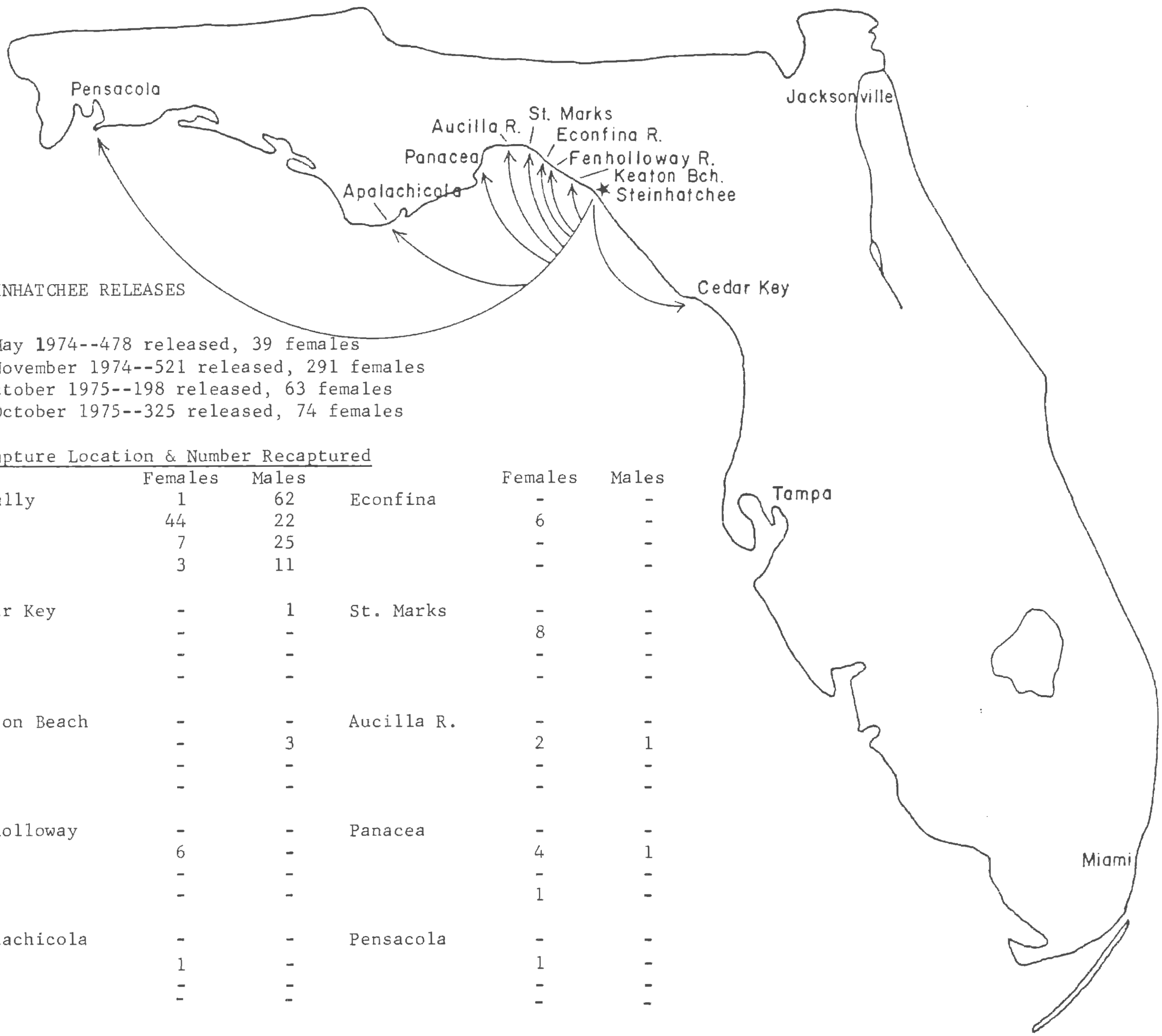


Figure 8. Blue crab releases made at Horseshoe Beach showing sites of major recaptures.



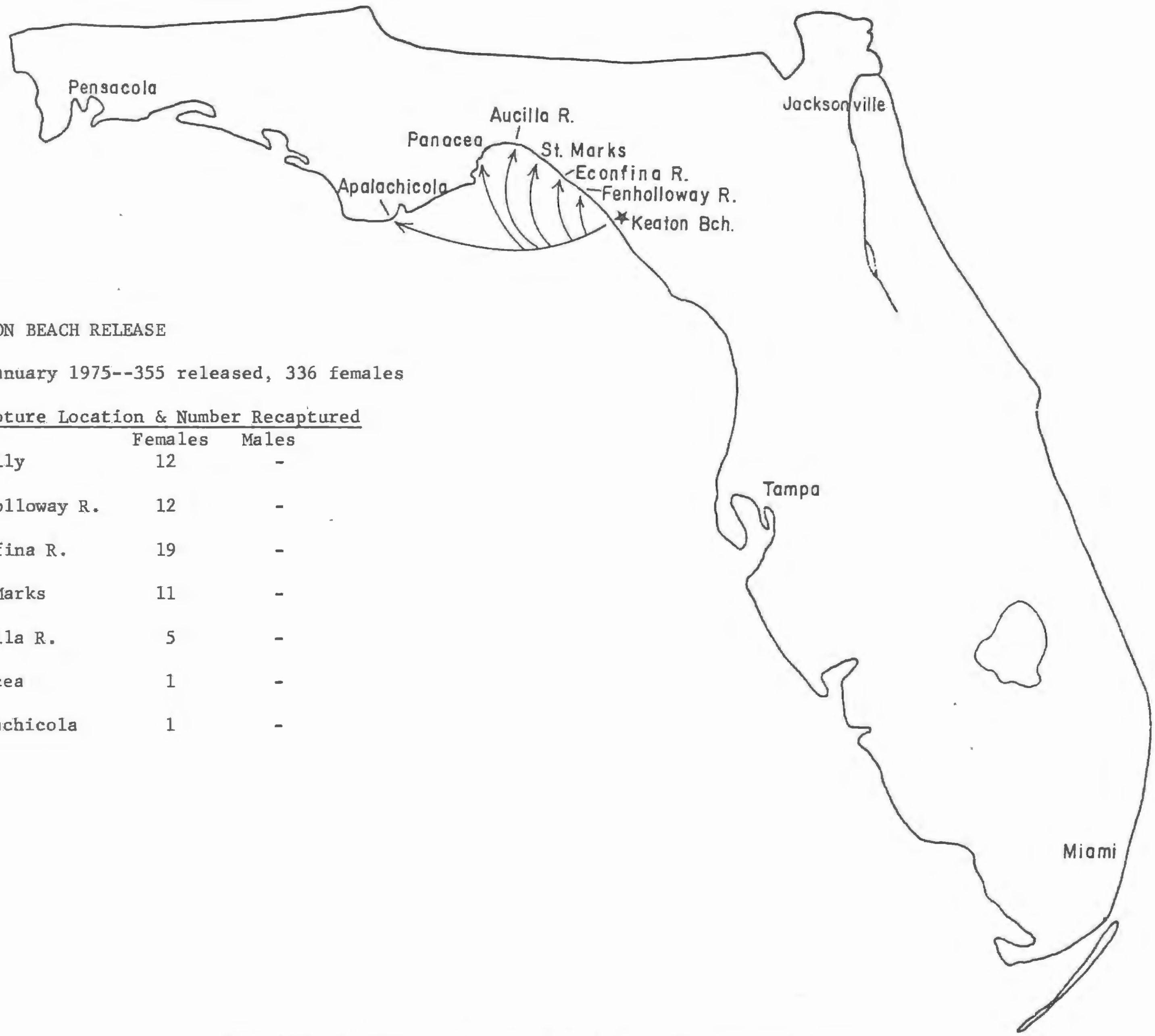
STEINHATCHEE RELEASES

24 May 1974--478 released, 39 females
25 November 1974--521 released, 291 females
3 October 1975--198 released, 63 females
29 October 1975--325 released, 74 females

Recapture Location & Number Recaptured

	Females	Males		Females	Males
Locally	1	62	Econfina	-	-
	44	22		6	-
	7	25		-	-
	3	11		-	-
Cedar Key	-	1	St. Marks	-	-
	-	-		8	-
	-	-		-	-
	-	-		-	-
Keaton Beach	-	-	Aucilla R.	-	-
	-	3		2	1
	-	-		-	-
	-	-		-	-
Fenholloway	-	-	Panacea	-	-
	6	-		4	1
	-	-		-	-
	-	-		1	-
Apalachicola	-	-	Pensacola	-	-
	1	-		1	-
	-	-		-	-
	-	-		-	-

Figure 9. Blue crab releases made at Steinhatchee showing sites of major recaptures.

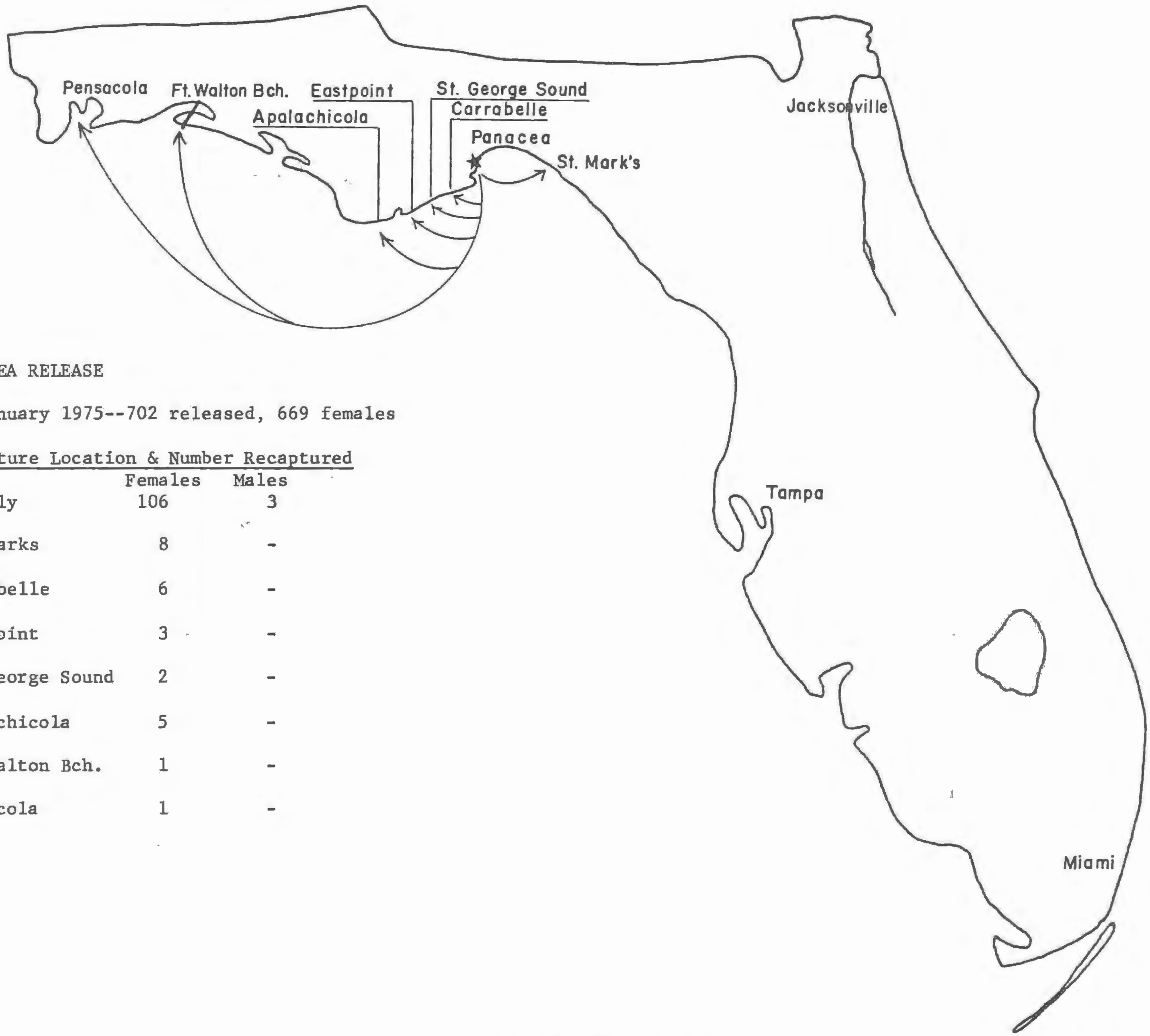


KEATON BEACH RELEASE

29 January 1975--355 released, 336 females

Recapture Location & Number Recaptured	Females	Males
Locally	12	-
Fenholloway R.	12	-
Econfina R.	19	-
St. Marks	11	-
Aucilla R.	5	-
Panacea	1	-
Apalachicola	1	-

Figure 10. Blue crab release made at Keaton Beach showing sites of major recaptures.

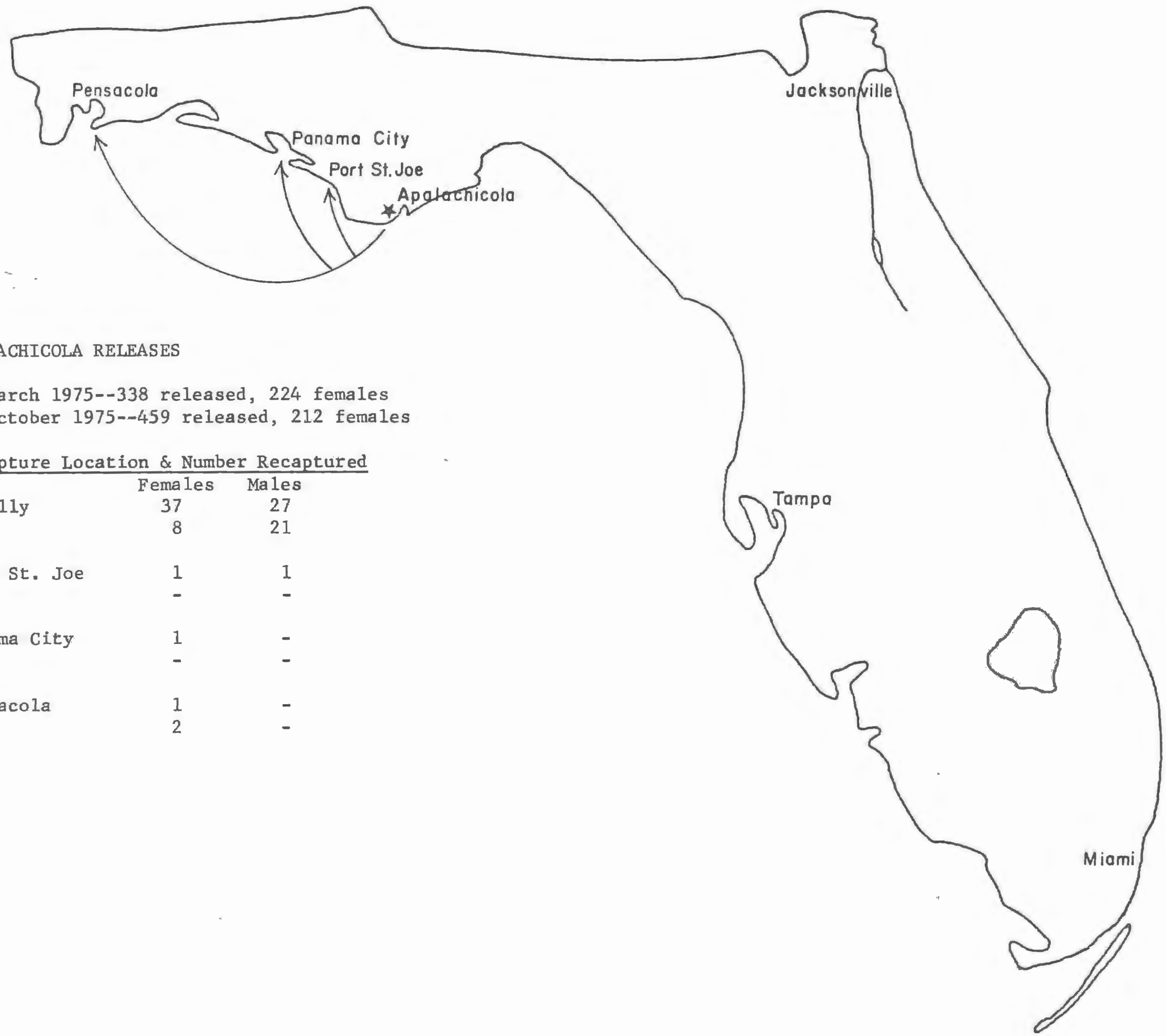


PANACEA RELEASE

16 January 1975--702 released, 669 females

Recapture Location & Number Recaptured	Females	Males
Locally	106	3
St. Marks	8	-
Carrabelle	6	-
Eastpoint	3	-
St. George Sound	2	-
Apalachicola	5	-
Ft. Walton Bch.	1	-
Pensacola	1	-

Figure 11. Blue crab release made at Panacea showing sites of major recaptures.



APALACHICOLA RELEASES

11 March 1975--338 released, 224 females
28 October 1975--459 released, 212 females

Recapture Location & Number Recaptured

	Females	Males
Locally	37	27
	8	21
Port St. Joe	1	1
	-	-
Panama City	1	-
	-	-
Pensacola	1	-
	2	-

Figure 12. Blue crab releases made at Apalachicola showing sites of major recaptures.

distances traveled by males and females (student t–test, 1% level of confidence). Male crabs exhibited no real trend in their movement, remaining in their "home territory."

TABLE 2.

Distances traveled by recaptured crabs.

Distance Traveled*		Number of Recaptured Crabs		Cumulative % Returns	
Kilometers	Miles	Males	Females	Males	Females
0 – 8.0	0 – 5	348	232	83.9	52.5
9.7 – 16.0	6 – 10	47	24	95.2	57.9
17.7 – 24.1	11 – 15	4	11	96.1	60.4
25.7 – 32.2	16 – 20	3	21	96.9	65.2
33.8 – 40.2	21 – 25	4	41	97.8	74.4
41.8 – 48.3	26 – 30	2	10	98.3	76.7
49.9 – 64.4	31 – 40	2	30	98.8	83.5
66.0 – 80.5	41 – 50	1	8	99.0	85.3
82.1 – 96.5	51 – 60	1	22	99.8	90.3
98.1 – 112.6	61 – 70		10		92.5
114.2 – 128.7	71 – 80		3		93.2
130.3 – 144.8	81 – 90		1		93.4
146.4 – 160.9	91 – 100		3		94.1
162.5 – 177.0	101 – 110		1		94.3
178.6 – 193.1	111 – 120		1		94.6
210.8 – 225.3	131 – 140	1	5	100.0	95.7
275.1 – 289.6	171 – 180		1		95.9
323.4 – 337.9	201 - 210		7		98.1
339.5 – 354.0	211 – 220		1		97.7
355.6 – 370.1	221 – 230		1		98.0
387.8 – 402.3	241 – 250		4		98.9
419.9 – 434.4	261 – 270		1		99.1
436.0 – 450.5	271 – 280		1		99.3
468.2 – 482.7	291 – 300		1		99.5
484.3 – 498.8	301 – 310		2		100.0

*Note the concentration of males recaptured under 16 km (10 miles) distance from the release site and the spread of females up to 499 km (310 miles).

The most notable return trend (in other words, *migration* trend) is represented graphically in Figures 3 through 12. These figures depict the release sites and capture points for tag returns. No inference should be made as to the actual pathway taken by migrating crabs (i.e., arrows on the maps only indicate direction). Note that the sex of these migrants was female, with just 15 males exhibiting any movement outside of local waters. With only eight exceptions, all non-local female movement was in a northerly direction along the peninsular portion of the state and westerly along the panhandle.

These directional trends would appear to be the result of female blue crabs migrating toward a spawning area following mating. The Apalachicola Bay system (Panacea westward through Apalachicola Bay to Cape San Blas) could be the major spawning area (source area) for the Florida penisular Gulf coast blue crab fishery. This has led us to develop the following hypothesis:

Adult female blue crabs, moving into Florida's coastal waters, exhibit a direct, along-shore migration toward spawning areas. Within these regions of spawning activity, *Callinectes* zoeal populations become entrained into nearby major river runoff. The zoea, carried by this river discharge to areas of major offshore water currents, are subsequently distributed along the Florida peninsula. As the larval stages develop to the megalops and early crab forms, they are recruited into estuaries at a distance from the site of spawning.

DISCUSSION

In this study, male crabs exhibited no real trend in their movements, remaining in their "home estuary." When they did travel, it was not as dramatic as the females (Table 2). Although one male did travel 212 km (132 miles) south of the release site, generally there was a tendency to disperse back into the surrounding creeks and marshes. This is in keeping with Cargo's (1958) Virginia findings–that males exhibit a nondirectional and random movement within their home estuary. Further substantiation of this was the two male crabs caught only a short distance from the initial release point, 205 and 245 days, respectively, after tagging.

In North Carolina, Judy and Dudley (1970) found that crabs may "scatter widely within their respective habitats [estuaries] but show only limited movement to other inland and coastal waters." Florida's peninsular Gulf coast blue crab population does not migrate in that fashion; the inshore/offshore movement was not evident. Rather, along-shore migrations were documented. Figures 3 through 12 clearly indicate that female blue crabs moved out of the estuaries in which they were tagged, and were subject to mixing with adjacent stocks. The distances traveled (up to 499 km [310 miles]) by females indicate that these migrants were more than "scattered widely" (Table 2). We must assume that these crabs have indeed moved along shore into (or through) a neighboring estuarine area. In the case of the three crabs that moved from Punta Gorda to the Panacea area (Figure 5), at least seven estuarine areas were traversed.

It has been pointed out previously that migrations of females are directly linked to reproduction. The migrations observed in this study correspond to movement towards the spawning area after mating. In the classic description, this movement would be to "offshore," higher-salinity waters. Migrations, observed along the peninsular Florida Gulf coast, demonstrated that movement would be to a site, or sites, north of the mating estuary. The Apalachicola Bay region (defined as being from Panacea through Apalachicola Bay to Cape San Blas) appeared to be a primary spawning ground for the blue crab along the Florida penisular Gulf Coast. In recaptures from the Gulf coast, only nine crabs (of 857 tagged or about 1%) moved to the west of Apalachicola Bay (Figures 3 through 12). The majority of recaptures either seemed to be heading toward or to be terminating in the Apalachicola Bay region.

Personal communications with local crabbers and shrimpers in the Apalachicola area, and results from a questionnaire survey of commercial crabbers, support the hypothesis that this area is a major spawning area for Gulf coast blue crabs. Fishermen have reported great concentrations of egg-bearing crabs. Further corroboration of the importance of this area occurred in the return of tagged ovigerous crabs from the Apalachicola Bay region. Tagged crabs were caught bearing egg masses which were not present at the time of tagging. These egg masses were all orange, indicating they had been laid only recently (Van Engel 1958, Darnell 1959). No other tagged ovigerous crabs were returned from any other location along the Gulf coast. This is not to say that blue crab spawning does not occur along the entire length of the west coast of Florida; for indeed it does. However, the concentrations of spawning (egg-bearing) blue crabs along the Florida Gulf coast apparently did not approach the large numbers of ovigerous blue crabs found in the Apalachicola Bay area.

We have presented strong evidence suggesting that ovigerous crabs concentrate in the Apalachicola Bay region. Such a trend, without continued recruitment in southwestern Florida, would result in declining stocks in that area. Landing statistics indicate no significant decline. Thus, recruitment along the southwestern coast can be assumed.

For the blue crab, life begins as a planktonic zoeal larva (Costlow and Bookhout 1959). Because of their planktonic nature, zoeae are carried along with prevailing currents. It is not inconceivable that larvae could be transported to an area unassociated with the spawning area. Following development (31 to 49 days), zoea metamorphose into the megalopal stage which has both planktonic and benthic features (Williams 1971, Sulkin 1974). The megalopal stage persists for 6 to 20 days after which it molts into the first crab stage (Costlow and Bookhout 1959). Evidence indicates that hatching and molting of blue crab larval stages might proceed most efficiently in waters of salinities found outside river outfalls (Sandoz and Rogers 1944).

Classically, blue crab larval development has been considered to take place "offshore" in more saline waters than within the confines of the estuary. Young crabs, however, spend the majority of their growing life within estuarine nursery grounds. To reach these areas, there must be some mechanism to return larvae/young crabs to the estuaries. This appears to be accomplished during the megalops and first few crab stages by way of a "directed migration" shoreward (Van Engel 1958, Darnell 1959, Tagatz 1968, Sulkin 1974, Williams 1974). It has been suggested that the megalops takes advantage of incoming tidal currents by rising into the water column during flood tide, settling and holding to the bottom during ebb tide, and thus eventually reaching the estuary (Williams 1971, Sulkin 1974).

For that system to work, there must be some mechanism to redistribute the zoeal larvae if the major spawning occurs in the Apalachicola Bay region. This appears to function via the water current system of the Apalachicola River and the eastern Gulf of Mexico.

The Apalachicola River outfall has been thoroughly studied (Livingston 1974). The Apalachicola River has the largest drainage area (764 km^2, 19,600 mi^2), and the greatest mean-water-discharge rate (25,000 cfs) of any river in Florida. The "influence" of the River extends as far as 257 km (160 miles) seaward into the Gulf of Mexico (Livingston 1974).

From gauge station data, the maximum mean-discharge rate of the Apalachicola River generally occurs during the month of March. This conclusion is based on 13 years of data for the Chattahoochee, Florida, gauging station, and 8 years of data for the Blountstown, Florida, gauging station. According to local sources in the Apalachicola Bay region, the first "big run" of female blue crabs during 1975 began in mid-January. As of March 1975, sponge crabs were appearing in catches from Apalachicola Bay. The maximum water output from the Apalachicola River thus occurs within a period of six to eight weeks after the first "runs" of female blue crabs into Apalachicola Bay, and at about the same time as the advent of spawning.

Oceanographic studies indicate the presence of a large, but somewhat ephemeral clockwise current, known as the Gulf Loop Current, within the Gulf of Mexico. This current enters the Gulf near the Yucatan Peninsula, and may travel northward as far as the Mississippi River Delta before turning east and south to exit via the Florida Straits.

Current patterns in the Gulf of Mexico generally are known (Leipper 1954, Curl 1969, Gaul and Boykin 1964, Leipper 1970, Austin 1971, Nowlin 1971, Ichiye et al. 1973, Jones et al. 1973, Maul 1974, Murphy et al. 1975). These studies have described general patterns of surface circulation in the Gulf of Mexico. During spring, the Gulf Loop Current encroaches increasingly northward (Figure 13), reaches maximum penetration by fall, and recedes during winter (Leipper 1970, Maul 1974). Sometimes gyres from the main current body detach as eddies and wash onto the Florida shelf (Jones et al. 1973). Gaul and Boykin (1964), Nowlin (1971), and Ichiye et al. (1973) have illustrated Loop Current-related circulation patterns in the northeastern Gulf of Mexico.

Jones et al. (1973) state that "except for gross generalities and studies limited to small selected areas, little has been published on the circulation patterns of the western Florida shelf." Nautical pilot charts, prepared from ships' log data, show a northward inshore current most of the year. The Gulf Loop Current, known to have an annual growth and decay pattern of high variability, has a major influence over long-term circulation. Although the major shallow-water factor to induce water motion is wind stress, Maul (1974) pointed out that the Loop Current "interacts to exchange waters and hence, particles and organisms." Leipper (1954) stated that the Loop Current generates "single and multiple cyclonic eddies" in the shelf waters which are modified by winds, and these eddies, in turn, generate the nearshore current.

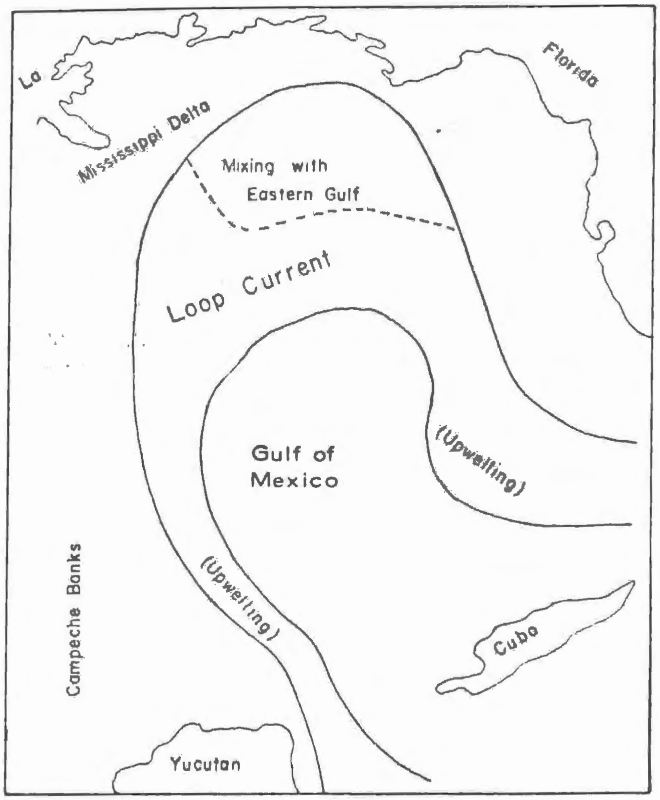


Figure 13. General location of Gulf Loop Current with the Gulf of Mexico. Also indicated are areas of upwelling and mixing.

Drift-bottle recovery data reported by Gaul and Boykin (1964) and Ichiye et al. (1973) indicate that waters near the Florida panhandle, once integrated with the Gulf Loop Current and the Gulf Stream, may be transported to both the Gulf and Atlantic coasts of Florida (Figure 14). Gaul and Boykin (1964) drift-bottle releases during April/May 1963, at the approximate time of blue crab spawning in Apalachicola Bay, resulted in recoveries within 35 to 47 days.

Since Apalachicola River waters are flushed offshore, eventually they could become integrated with the current system of the eastern Gulf of Mexico. Similarly, planktonic organisms would be entrained. Previous studies indicated that blue crab spawning occurred most often near river mouths (Sandoz and Rogers 1944, Tagatz 1968). Blue crab zoeae spawned in the Bay would become entrained in the discharge of the Apalachicola River and carried offshore. Once in the current pattern of the eastern Gulf of Mexico, they would be carried southward. Larvae would be separated out by generated eddy currents and transported nearer to shore, as demonstrated by the drift-bottle recoveries of Ichiye et al. (1973) (Figure 14). Moreover, the drift-bottle recoveries of Gaul and Boykin (1964) generally were within the period of blue crab larval development to the megalops stage (31 to 49 days) (Costlow and Bookhout 1959). Therefore, one could assume that zoeae would be spread along the entire coast before the megalopae settle and proceed to the estuaries. This is one possible mechanism for the redistribution of blue crabs via the current systems of Apalachicola Bay and Gulf of Mexico.

SUMMARY

Evidence accumulated during this study indicated that the blue crab may provide the first (and only) example of sex-determined, long-range emigration within the life span of a species. Tagging-recapture data indicated that female blue crabs along Florida's peninsular Gulf of Mexico coastal waters follow a circular migration pattern, leaving (as larvae) and returning (as adults) to specific spawning areas. Male blue crabs, however, apparently emigrate from these spawning areas as larvae, or in the early developmental stages, mature, mate, and ultimately die in nearshore areas, possibly hundreds of kilometers removed from the spawning area. Emigration, the permanent "one-way" movement away from a territory, is relatively rare in nature, having been described in the European eel (*Anguilla anguilla*), lemmings (*Lemmus* sp.), the Norway rat (*Rattus norvegicus*), and the gray squirrel (*Sciurus cardinensis*) (Hickman, 1966).

The blue crab population along Florida's peninsular Gulf coast appears to behave contrary to previous studies in regards to their migratory habits. Instead of the classic description of an inshore/offshore pattern, an inshore/alongshore type movement was described where, following mating, female blue crabs leave the mating estuary and move toward specific spawning areas. For the Florida peninsular Gulf coast, there appeared to be a primary spawning ground located in the Apalachicola Bay region that served as a source area for the entire Florida peninsular Gulf coast blue crab fishery. A hypothesis for redistribution of larvae to southwestern Florida includes transport through surface circulation patterns associated with the Loop Current and the Apalachicola River.

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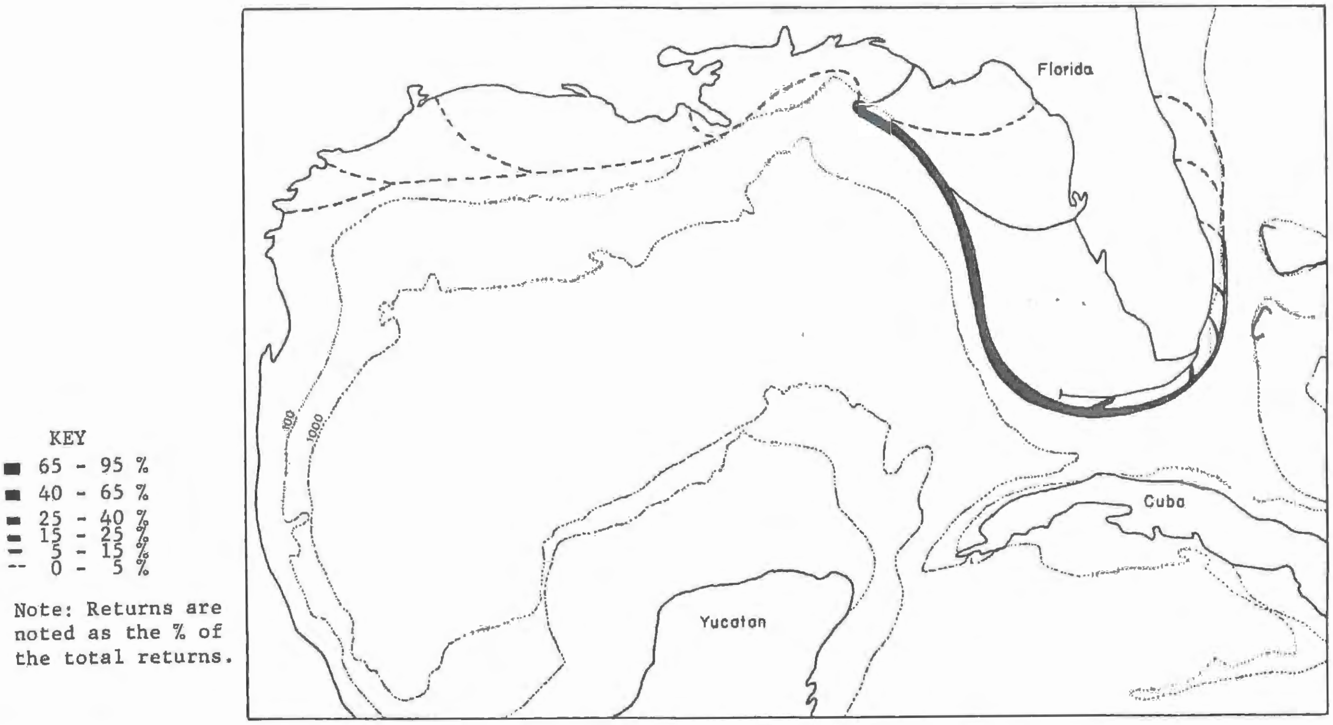

Figure 14. Drift-bottle returns from releases made by Ichiye et al. (1973) on April 9 and 16, 1963. There were 119 (24.8%) returns from 480 released. (Figure drawn after Ichiye et al. 1973.)

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DISCUSSION

Q. **Random DuBois**: I would like to ask two questions. There is a lot of distrust that exists between New England fishermen and scientists and politicians. I was wondering how you can explain such a high level of cooperation as evidenced by your high percentage of returns of your tags. Is it a result of methodology, your high levels of awareness in the blue crab industry? The other question I have is of the four or five individuals that traveled 200 to 300 miles, is the distance substantiated in literature?

A. **Mike Oesterling**: Your first question is how did we get such good cooperation, and my answer is that there was a lot of leg work and a lot of being just good friends to the fishermen. We spent quite a bit of time out on the waterfront talking to the crabbers before we ever did any tagging, letting them know what was going on so that they knew that we were trying to do something that would hopefully help their fishery. The second question about the long distant movements, there have been instances of long distance movements along the eastern coast, but not, I don't believe, to the extent we saw.

Q. **DuBois**: Are you satisfied that the 4 or 5 individuals that traveled 200 to 300 miles are representative of the population as a whole?

A. **Oesterling**: Actually about 30 crabs traveled over 200 miles, representing about 5% of the tagged crabs.

Q. **Corky Perret**: With the Punta Gorda tagging program, I think you indicated you had a rather large movement from that area to the north, and I think you indicated that these crabs may have moved through several different estuarine systems. When you say estuarine, do you mean from offshore to inshore, a back-off, in-off kind of thing?

A. **Oesterling**: No sir. We cannot make any inference as to their absolute pathway. What we are saying is that there are different estuaries along the coast that they could have passed through or may have passed through. As I said, we cannot really say what their actual path was, we can give you the starting point and the ending point.

Q. **Perret**: One other brief question. On your returns, were any or many taken outside of Florida's territorial waters in the FCZ [fisheries conservation zone]?

A. **Oesterling**: No sir.

Q. **Paul Hammerschmidt**: On your migrations of 200 miles plus, what is the time frame involved in that? My other question is, with the river flow of the Apalachicola, what is your harvest information on drought and nondrought periods?

A. **Oesterling**: On the second question about harvest with drought and nondrought, I cannot answer that question; I am sorry. However, in the time frame we are talking about, anywhere from 70 days, from Punta Gorda, FL, to Panacea, which is a pretty fast rate, to about 150 days for the longest. Obviously the shorter distances, where crabs that moved, say from Steinhatchee to

Apalachicola, were traveled in fewer days. There were cases where it was reversed, however. As far as absolute time, I cannot give you that right now. I can talk to you later about it though.

Q. Edwin Joyce: Do you think that the erratic nature of the Loop Current, unpredictable as it is, might explain some of the variations and abundance of blue crabs in the lower section of the state?

A. Oesterling: Definitely. Especially in some cases. I have talked with Charlie Futch [Florida Department of Natural Resources] very extensively about 1975 when the Loop Current really didn't even come up into the Gulf of Mexico very much. But there still is a basic southern offshore current that would carry them down. I also think that another reason why the Panhandle has such a large number of crabs, is that quite a few of the larvae do not get transported out of the area, but stay right in that area.

Comment–Elliott Norse: The information you have shown is some of the most satisfying I have ever seen in contributing to our understanding of migration; animal migration, and why it happens. People that have been studying migration, typically have been looking at the mechanism. People want to know how salmon, for example, find their way to their home stream; what pigeons use to navigate; but they do not look sufficiently often at the whys. What you have here, I think, is a brilliant example of how an organism is, in some ways, a prisoner of its own biology and, in some ways, can use features of his own biology, his behavior, to get around problems that it has. An organism that has a long planktonic life has a blessing and a curse. The blessing is if things get really bad where he lives, if there is a disaster, his young, if he releases them on time, will be able to disperse far enough so that he has a chance to pass on his genes. He has a future, that is a good thing. But the bad thing is, if things stay good where he is, most of his young are likely to be swept to a place where they are wasted. Organisms that have planktonic larvae have lots and lots of young and, by pure dumb luck, some of them find their way into places that are helpful. But people have been finding that it is not just dumb luck. In estuaries, if I remember correctly, barnacle larvae and cladocerans take the surface tides out during the day and take the ebb currents up at night, and your vertical migration keeps them within the estuary instead of getting swept out to sea where they would be unsuited. We have a beautiful example, which seems to be the same case here. You don't have surface and deep currents that are flowing, let's say southeasterly and a counter current going westerly, so you have the adults doing the same kind of thing. I imagine if a female spawned in Shark River, most of her larvae would be carried through the passes and most of them would wind up in the Atlantic. The continental shelf on the eastern coast of Florida is sort of narrow and when it came time for the larvae to metamorphose, they would find themselves in 10,000 feet of water and that is unsuitable for blue crabs. So this is a beautiful way that these critters can increase their chances (over what they have randomly) by a behavioral mechanism–migration. They release their larvae in waters so that when the time is right for the young to settle, they will be in pretty friendly territory. The shelf is pretty broad there, young blue crabs can live and start their migration inward to the estuaries. This is very appealing and the best evidence I have ever seen that there are real populations, localized populations of these organisms rather than the random mix that people have cited in literature in the past.

For fisheries other than the blue crab then, this has a lot of implications because the longer an organism stays in the planktonic stage, the worse is its problem of wasting all of its larvae, so I think what we have to do is, for organisms of long planktonic life, look for the kind of mechanism that Mike has discovered here, and there are lots of implications to that.

Q. (Unidentified): From your tagging and recapture data, did you make any total population estimates?

A. Oesterling: No. We did not.

Q. (Unidentified): What about fishing mortality–I mean do you assume the fishermen are catching the same percentage as your returns?

A. Oesterling: I am not sure I understand your question. Do you mean are the fishermen removing 12.3% of the population? We did not make any inference on that either. We were strictly concerned with migration, we did not want to get into the number games.

Q. Kimbal Brown: It occurs to me that it might be interesting to have a comment from Mr. Van Engel [discussion moderator]. Is there any parallel between the circulation patterns in the Chesapeake Bay and the adjacent areas to what has been described in this talk?

A. Willard Van Engel: I will have to think about that one. I do have, however, some other things on my mind. I have some serious criticisms of this, with some of the things that Mike has said. I would like to throw them out to see if others share them or . . . let's have some argumentation. First of all what I think we have here is an exaggerated picture of migration. Mike has described what he has called the individuals that have moved the greatest distance. I would like to see a pattern, a picture, showing where the majority of the females *did* get recovered. Now we are talking about perhaps, what would you say are the returns, maybe 10%, 5%, 1%, of the releases from an area; I do not know what percentage.

What percentage would you say is the average percent of returns from the area in which you released them?

A. Oesterling: Okay, I told you that number. The number was 25%. No wait, excuse me, 45% of the females recaptured were recaptured within 10 miles of the release site, which we defined as the local area.

Q. Van Engel: Forty-five percent. What percentage then would you say of those that were released, were recovered more than 10 miles? Certainly not 55%.

A. Oesterling: Yes.

Q. Van Engel: Fifty-five percent then were recovered over 10 miles from the release site of those that were recovered at all?

A. Oesterling: Yes, of the females.

Q. Van Engel: Of those that you tagged, what percentage were returned within 10 miles?

A. Oesterling: Forty-five percent.

Q. Van Engel: Are you saying that you got all the tags back that you released?

A. Oesterling: No.

Q. Van Engel: That is what I am asking. What percentage of those that you tagged did you get back? And then, what percentage of those that you got back were within 10 miles?

A. Oesterling: Total tags returned were 12.3%. Now, I would have to sit down for a bit and breakout which were females and which were males, and also do some other calculations on the 10 miles. If you will give me a little while, I'll do that and get back to you.

Comment—Van Engel: My thoughts are these. Not a very large segment of the population is actually making long distance movement. Perhaps Ed Joyce's comment certainly would be a greatly important one if a very large segment of the population which was tagged, was recovered some distance away, but in the beginning phases of this study, I think what we must be very cautious of is saying we can't believe that all the females are moving. Fifty-five percent of those that had been tagged are being recovered some distance away. Therefore, my feeling is that this is highly exciting, but the question is really how might this be related to the eventual fate of a fishery in the area. Now what we must also consider here then is, if this is even a small part of the population which is moving that far north and spawning in the Apalachicola Bay area, the question is environmental degradation of the Apalachicola River? If this is then a very important river as far as the survival of the blue crab stocks along the coast is concerned, then we certainly have got to look afield to things like the fate of the Apalachicola River and those who are in governmental administration or conservation or ecology must ensure that places like the Apalachicola will survive.

Comment—Oesterling: Let me respond with a couple of things. First of all, I would like to reiterate that we are not saying that all blue crab spawning takes place in the Apalachicola Bay. Obviously it does not. There has to be spawning that takes place along the whole coast because some of these crabs just do not make it the entire way to Apalachicola by the time they put their sponge out or by the time they are ready to put their sponge out. Obviously some of them probably find that a river mouth along the way is acceptable to them, the Suwannee, the Steinhatchee, what have you. They may stop and that would obviously have an effect on the local fisheries. What we are saying is that a sizable portion of the population is at least trying to get to the Apalachicola Bay to spawn. Does that belay some of your fears?

Comment—Van Engel: Okay. I think another point needs to be emphasized here. It has been said that Mike did repeat the work system done by Dudley and Judy and Fischler and Walburg along the Atlantic coast. We know that there is very little contribution to the adult stocks from one estuary to another. We believe this to be the case; we think there is very little intermixing of the adults from one estuary to another. Therefore, the question is, if you have an area which is repopulated, where is the population coming from? I think what is happening here is that Mike Oesterling has suggested a very good picture of a possible mechanism of redistribution which is not known in any detail, but is suspected for, say, the Atlantic coast. This is something much better known to the Gulf and I think we ought to thank Mike for pointing this out. Here is a very good example of possible redistribution of stocks far distant from the point of origin where the juveniles grew up. I see Elliot Norse has a comment he would like to make.

Comment—Elliot Norse: I think, Van, what you say and what Mike says may be reconcilable if you consider the possibility that you may have two migrating types in these organisms. You have a nonmigrating genetic type and a migrating genetic type. It is known in many other species where people have looked into it. The reason this would happen is because critters have to gamble on their future. If you do one thing and you lose, you got a problem. If you do the other thing and you lose, you got a problem; so life is a gamble. For an organism that was a migrator, in the year that the Loop comes strong to the southeast, it would be very advantageous for an individual of that phenotype. On the other hand, in the years when the Loop Current is not going to the southeast, but maybe it is going in the other direction, he is in trouble. To the organism that is a nonmigrator, in the years when the Loop Current is weak, he has the advantages over the other, he passes on more of his genes, which is the name of the whole game. So if you have a really constant current, you might find that all of them are migrators, but because the Loop Current is so variable, there might be room for both kinds, migratory and nonmigratory females.

Comment–Van Engel: Perhaps. Getting back to Kimbal Brown's question–was there any parallel between the circulation patterns in the Chesapeake Bay and adjacent area to what we see here? I think what we are looking at is that we don't know about the circulation pattern over the continental shelf off the mid-Atlantic states. I think, very likely, that they may be more complex than the one Mike has described in the Gulf. It might be identical, who knows? We just don't know much about it. But within the Chesapeake Bay, we have a different circulation pattern which is a circulation pattern all of its own, where water entering into the mouth of the Bay does move up to the Bay and it is the mechanism of redistributing the megalopae to the fresher water. So we have perhaps two circulation patterns in the Chesapeake region: one is the shelf circulation, and the other is the Bay circulation.

Comment–Dr. Gordon Gunter: I want to call attention to the fact that these crabs are quite capable of moving long distances as shown by the distances they traveled within the Chesapeake Bay itself. Now the Marylanders know that crabs don't always stay in Virginia; they have to go quite a distance. In Louisiana, we have taken crabs in the Atchafalaya River, 150 miles from the sea. I think that these animals can ride the currents because they are generally found after the spring floods. Somehow or other, they will breast a very strong current and you have all sorts of eddies in the rivers which these animals apparently can take advantage of and I don't see why they couldn't do it in the open ocean, too.

Comment–Van Engel: I agree 100%. I also agree that there are long distance movements which may occur within river systems and within bay systems, but I think those are the more classic descriptions I was getting at before–the toward shore and away from shore with the same system. What I was trying to get at here was that they actually move out of the main estuary and go elsewhere. Quite obviously, those that went along the shore did not walk the entire way nor did they swim the whole way. They had to have taken advantage of some prevailing currents which were in the northward direction along the nearshore coast.

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LIFE HISTORY, ECOLOGY, AND STOCK ASSESSMENT OF THE BLUE CRAB *CALLINECTES SAPIDUS* OF THE UNITED STATES ATLANTIC COAST–A REVIEW*

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INTRODUCTION

The blue crab is found along the Atlantic coast of the United States from Maine to southern Florida. It is uncommon north of Cape Cod and is most abundant in the Chesapeake Bay where almost half of the United States commercial blue crab landings occur.

The Chesapeake Bay has the largest semi-confined area for blue crab spawning, more nursery area and probably the best mix of environmental conditions for blue crab along the United States eastern coast. In addition, an intensive commercial fishery enables the Chesapeake Bay region to be the area of highest blue crab production.

There are many basic similarities in the life history of the blue crab all along the Atlantic coast. Some differences do occur, however, in timing of some of the life processes, probably due to the different temperature regimes that exist along the coast.

The biology of the blue crab in the Chesapeake Bay has been described by several authors: Churchill (1919, 1942), Robertson (1938), Truitt (1939), and Van Engel (1958). Summarization of their studies leads to a model of the life history and ecology of the blue crab along the eastern coast. Geographic variations on this general life history and ecological pattern for blue crab stocks north and south of Chesapeake Bay are considered in this review.

LIFE HISTORY AND ECOLOGY

Blue crabs inhabit the entire salinity regime in our model estuary, the Chesapeake Bay. They are found from the fresh waters of the northern section of the bay to the high salinity waters in the southern part of the bay and the adjacent Atlantic Ocean.

Mating in blue crabs occurs in the moderate-to-low-salinity waters of the bay between early spring and fall. Males, also known as jimmy crabs, are in the hard-shelled condition when mating, while females are in the soft-shelled condition. Females do not molt again, but males may molt several times more after mating.

Several days prior to her terminal molt, the female is attracted to the male by a pheromone, a sex hormone that the male releases (Gleeson 1977). The interest of the male in the female is sustained by a pheromone which is released by her near the time of her molt. He cradle-carries his prospective mate under his body for several days before she molts (Williams 1965). These pairs of crabs are called "buck and rider" or "doublers."

After the female molts, copulation occurs, which may last for several hours, and the male again cradle-carries his mate until her shell hardens. All the eggs that the female later produces will be fertilized by sperm transferred in this single mating.

Ovarian development in female blue crabs may take from as little as 2 months to as much as 9 months after mating. Environmental conditions, especially temperature, play a role in determining the length of time it takes for the ovary to develop. Warmer temperatures speed development. Time of mating is another factor in determining the length of time it takes the ovary to develop. If mating occurs in late spring or early summer, the ovary should be well developed and ready for egg extrusion by late summer. If mating occurs late in the summer or early in the fall, the ovary develops during the winter and egg extrusion does not occur until late spring to mid-summer of the following year.

Females spawn in moderate to higher salinity portions of the bay and just outside the mouth of the bay from early May through September, although most spawn between June and August. The ovary may regenerate very quickly. Females that spawn in late spring may spawn again later in that same year and may spawn once again late the following spring.

Spawning consists of two distinct phases. The first, egg extrusion, is the process in which eggs pass from the ovaries, are fertilized as they go through the seminal receptacles, and are attached to the pleopods of the abdomen. The second spawning phase is egg carrying. Eggs are attached on the abdomen of the female for approximately 7 to 10 days before hatching. Females with external eggs are known as berried females, busted sooks or sponge crabs. The egg mass contains from three-quarters of a million to 2 million eggs each time the female spawns.

*Based on a talk given at the Blue Crab Colloquium sponsored by the Gulf States Marine Fisheries Commission, October 18, 1979, Biloxi, Mississippi.

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Four distinct stages occur in the life history of the blue crab, the egg, zoea, megalopa, and true crab forms. The embryos change in color from orange to black as they develop on the abdomen of the female. Eggs are initially orange because of their high yolk content. As the yolk is absorbed by the developing embryo and as the eye spots appear, the egg mass appears almost black prior to hatching. Optimum conditions for the development and survival of blue crab eggs are 20 to 30 ppt salinity and from 20 to 30°C temperature.

Upon hatching from the egg, the crab reaches the zoeal stage. Prezoeae are nonviable forms from eggs that have hatched prematurely, usually because development has occurred in unfavorable environmental conditions, particularly in low salinity. For instance, if eggs hatch in the middle portion of the bay where salinity is 15 to 20 ppt, this premature stage will predominate, and survival is likely to be low.

Normal egg development and hatching produces zoeae which have seven or eight stages. Zoeae are initially found in the surface layers; as they advance through the various stages, they generally move lower in the water column. Optimum salinity and temperature for zoeal development and survival are, as for the egg, 20 to 30 ppt and 20 to 30°C. Development through the shrimp-like zoeal stages until transformation to the megalopal stage occurs takes about 1 month. Megalopae are usually found in the bottom waters in the high salinity areas. Peak occurrence of megalopae is usually in August about 1 to 2 months after peak spawning time. During their approximately 1 week of existence in this stage of development, megalopae generally feed on larval molluscs or other larvae. Again, 20 to 30 ppt salinity and 20 to 30°C temperature are optimum for blue crab megalopae as well as eggs and zoeae.

About 1 to 2 months after hatching from the egg, the true crab form is attained. Immature (juvenile) crabs migrate with flood currents to their "nursery grounds" into the tributaries and up the bay in search of food, protection from predation, and optimum hydrographic conditions for their growth and survival.

Nursery grounds are usually tidal marshlands and areas of muddy substrate. Prime nursery areas in the Chesapeake Bay occur where there are concentrations of submerged aquatic vegetation, most notably *Zostera marina,* the eelgrass. Eelgrass beds presently occur in the southwestern portions of the bay, around the mouths of the major rivers, and in the middle portions of the bay in the Tangier and Smith Island areas (Rooney-Char and Ayers 1978). The locations are the beds that survived a massive reduction in acreage that began in the early 1970's. With the reduction in eelgrass acreage in the Chesapeake Bay in the early 1930's and early 1970's, there was a decline in crab abundance. Other factors may have been involved, but we at least have circumstantial evidence that the quality of the nursery areas is very important in determining the level of crab abundance.

Growth of a crab is usually initiated when water temperature is about 15°C; molting occurs at varying time intervals depending on the size of the crab. Molting in the smallest crabs, those 1/10 to 1/2-inch carapace width, occurs every 3 to 5 days. As the crabs get larger, the frequency of molting decreases; with crabs of from 1/2 to 1 inch in width, molting occurs every 1 to 2 weeks, and larger crabs molt at intervals of 3 to 7 weeks until low water temperatures cause cessation of shedding.

Growth increment in width at each molt varies from 1/4 to 1/3 of the original size. Both sexes shed from 18 to 20 times after the megalopal stage to reach their largest size. Females reach sexual maturity at their terminal molt while males may continue to shed another three to four times after reaching maturity. Jimmy crabs generally remain in brackish waters throughout their adult life while females, after reaching sexual maturity and mating, migrate toward the "spawning grounds."

Variations from this life history model occur in blue crab stocks north and south of the Chesapeake Bay.

North of Cape Cod, blue crabs are so rare that distribution and migration patterns cannot be recognized. Blue crabs were, however, numerous along the southwestern coast of Maine in the abnormally warm years of 1948–1956. Scattergood (1960) suggested that these crabs could have migrated from the Cape Cod region to the southwestern coast of Maine during the summer, possibly wintering in Maine waters and becoming active again as the water temperatures increased in summer and fall. All blue crabs reported by Scattergood (1960) and those reported by Krouse (1979) as recently as 1977 were adult crabs caught incidental to the inshore lobster trap fishery in Maine.

Blue crabs are commonly found along the southern New England coast where their mating, spawning, and growth seasons are contracted in comparison to those in the Chesapeake Bay: mating of blue crabs occurs only in the summer months; spawning in eastern Long Island Sound and Narragansett Bay occurs primarily in August and early September; and molting occurs from the last of April through the summer months. Blue crab larval distribution patterns in this area are virtually unknown.

Nursery grounds and migration patterns of blue crabs along the southern New England coast are similar to those in Chesapeake Bay (Michael Fogarty, Northeast Fisheries Center, Woods Hole, MA; David Chadwick, Massachusetts Division of Marine Fisheries; Philip Briggs, New York State Department of Environmental Conservation; and Eric Smith, Connecticut Department of Environmental Protection; personal communications).

The Delaware Bay has almost the same characteristics as the Chesapeake except that it is not vegetated as heavily with *Zostera*, and extremely low winter temperatures lead to more frequent crab kills (Richard Cole, Delaware Department of Natural Resources and Environmental Control, personal communication).

Blue crab stocks south of the Chesapeake tend to have protracted times of mating, spawning, and growth. In the St. Johns River, Florida, blue crabs mate from March to July, and from October to December, mating not being common in August and September. Crabs spawn from February until October. Molting occurs throughout the year but the time interval between molts increases during the winter months (Tagatz 1968).

Along the South Atlantic coast, blue crab spawning areas are not as confined as those of the Chesapeake Bay. Apparently, larvae become more at the mercy of currents in this area than in the Chesapeake. According to Nichols and Keney (1963) in their analysis of plankton from cruises of the M/V THEODORE N. GILL, *Callinectes* zoeae and megalopae, not identified to species, were found as far as 40 miles offshore. Early stage zoeae were more abundant near the shore, while more advanced zoeal stages and megalopae were more abundant offshore. The greatest concentrations of all stages of zoeae and megalopae were at stations 20 miles off the coast. There are several species of the genus *Callinectes* found in this area and their larvae cannot be distinguished, so the percentage of larvae which were *Callinectes sapidus* could not be determined.

In the southeast, nursery areas are similar to those in the Chesapeake in that bottom types are muddy. *Zostera* is found in North Carolina, but the St. Johns River, Florida, is vegetated with *Ceratophyllum,* commonly known as coontail, and *Vallisneria,* known as eelgrass or tapegrass (Terry Sholar, North Carolina Division of Marine Fisheries, personal communication; Tagatz 1968).

The same migration patterns exist along the South Atlantic coast as have been described for the Chesapeake Bay area.

ASSESSMENT

Currently along the east coast, blue crab assessment work is being done from Delaware through Georgia, and there is interest in getting programs started in New Jersey and Florida. Nursery and spawning grounds are being identified so that anticipated encroachment on those areas by industrial, agricultural, residential, or other developments can be evaluated. Abundance estimates are being made to determine current year-class strength and its relation to that of prior years. Commercial catch predictions are being made, using knowledge of year-class strength and environmental conditions which affect survival at various growth stages. These predictions are a service to industry to assist them in planning their fishing and marketing activities.

Knowledge of the life history stages and ecology of blue crabs in relation to research and commercial gear is essential for the crab assessment surveys. A generalized time schedule for this relationship has been developed for the Chesapeake Bay area, showing the assumed relationship between the 1978 year-class (hatch) of crabs, juvenile crab abundance surveys made by the Virginia Institute of Marine Science (VIMS), and the Chesapeake Bay crab fisheries (Figure 1).

1. The peak of egg extrusion and egg carrying occurs from June through August (1978).
2. Eggs hatch in about 2 weeks so peak larval abundance is in July and August (1978).
3. Juvenile crabs of the new (1978) year-class first become available to our research trawl survey gear in September. Throughout the fall, September–November, we catch the new (1978) year-class of crabs which are 1/2 to 2 inches carapace width, and some older and larger crabs of the 1977 year-class.
4. Preliminary abundance estimates are made after our fall survey work.
5. During the winter, crabs are not vulnerable to our survey gear because low temperatures inhibit crab movement.
6. The 1978 year-class of crabs is available to our trawls from May through August of 1979. At this time the crabs are being caught in the peeler fishery.
7. Examination of the size composition and numbers of crabs in the fall, spring, and summer survey work leads to an update of abundance estimates.
8. The 1978 year-class of crabs is available to the pot fishery in late August or September 1979, when the crabs are about 15 months old.
9. Many of the females, recently mated, will migrate toward the higher salinity areas in late fall to become the bulk of the winter dredge fishery in December 1979 through March 1980.
10. In the spring of 1980, there should be a continued migration to higher salinity waters of those females which did not make the trip to the southern portion of the Bay the previous fall.

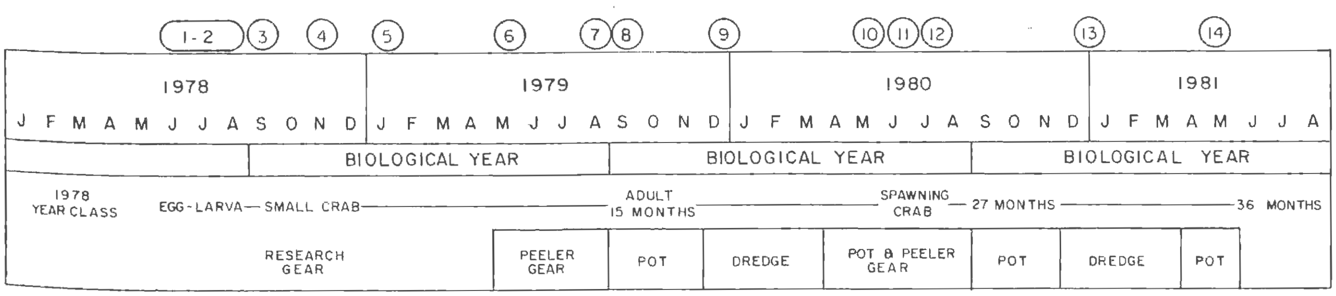

Figure 1. Generalized time relationship between blue crab life history stages and vulnerability to research and commercial fishing gears.

11. Both sexes of crabs of the 1978 year-class will comprise a small portion of the summer and fall crab pot fishery of 1980.
12. Each female may spawn once or twice during the summer when they are about 2 years old.
13. The females, about 2 1/2 years old, will be a very small percentage of the 1980–1981 winter dredge fishery.
14. The remaining crabs of both sexes of the 1978 year-class will contribute very little to the 1981 pot fishery in their third and final year of life.

I suggest that we, whether as scientists, administrators, or industry representatives, consider several things to get a better handle on variations in crab catches and to protect as well as we can this valuable resource.

There should be better coordination among the various blue crab assessment agencies. Improvements in crab survey gear and sampling techniques should be made along with comparison of indexes of abundance.

To improve our catch prediction capabilities, we should concentrate research in several areas. Density-independent environmental factors, such as temperature, salinity, and water-transport mechanisms, and density-dependent factors, such as food availability and predation, should be investigated more completely as to what affect they may have on various stages in the life history of the blue crab. Particular emphasis should be put on studying those factors which most affect the survival of egg, larval, and juvenile forms.

SUMMARY

Blue crabs inhabit various portions of an estuary at different stages in their life cycle. Mating occurs in the lower salinity areas. Females move to the high salinity portions of the estuary and adjacent ocean to spawn. Early zoeal stages are found in surface layers gradually moving deeper in the water column as they develop and become demersal when reaching the megalopal stage. Juvenile crabs move toward the lower salinity nursery areas as they grow. Adult males tend to remain in the brackish waters, while the adult females move to the spawning grounds. Migration between estuaries appears to be infrequent.

A prediction and management strategy for the blue crab should be developed in which consideration is given to the discreteness of the crab stocks at the various life-history stages, the short-lived nature of the species, and the fluctuations in abundance due to climatological factors and environmental alteration.

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DISCUSSION

Comment–Elliott Norse: I have worked on hatching out a number of species of *Callinectes.* I hatched out nine of the American species to get the first larvae. One of the things I found was that prezoeae were indicative of something wrong, but not necessarily just salinity. It could also be pollution. I found this out by pure dumb luck, the way I find out most things. If I kept ovigerous blue crabs with eggs ready to hatch in a vessel with circulating sea water, an open seawater system, I virtually never got hatching as prezoeae unless I greatly disturbed the females. If, however, I kept the female in a bucket of water overnight and the eggs hatched, they almost always hatched as prezoeae. This is something that was not generally realized in many of the crab-hatching studies in the past 10 years or so. In some cases, a prezoea may be a normal larva for other kinds of crabs; however, in the case of blue crabs, I strongly suspect that it is not.

Q. Kimball Brown: Is it true, in the fall as the Bay water temperature declines, if the watermen start dredging for crabs before the crabs have gone into hibernation, that it will cause them to disperse and will cause it to be a poor dredging season?

A. Robert (Bob) Harris: I would ask Van to comment on that.

Comment–Willard Van Engel: So called hibernation in which the crab is fairly immobile occurs when the water temperature is about 47°F. But temperatures in the Chesapeake region do not reach that low level until sometime after the end of December. Therefore, hibernation, as we might call it, or the slowing down of activity, or the "bedding in," of crabs in the lower Chesapeake cannot occur in December if that kind of temperature control mechanism is the thing that makes them stay where they are. If the fishery wanted to have a situation where no crabs would get up and move when the dredges pass over them, then the fishery would have to wait until after the first of January to start its operation. Economically this would be disastrous to the fishery, but temperature data for the Bay are not very large in number. We have been getting, as Bob said, some data from selected stations; we will be getting additional information out later.

Q. (Unidentified): Bob, what sort of effect does the crab dredging during the winter have on the spring spawning?

A. Harris: This has been a big controversy in Maryland and Virginia for quite sometime. Maybe Van would like to comment on that, too.

Comment–Van Engel: About 85 to 95% of the winter dredge catch consists of the adult females, which have not yet spawned. They have mated in the previous fall and will spawn next summer. The commercial fishery, the dredge fishery, takes an average of 10 million pounds of crabs. If we assume that all of these are adult females which have not spawned before, then about 2½ million pounds of adult female crabs are taken each month during the 4-month winter fishery. Of course, this is not spread out evenly that way; December taking almost half or 40% of the 4-month catch. During the remaining 8 months, the total landings in the Chesapeake average about 60,000 million pounds. If you say, one half of them are males, that means 30,000 million pounds of females are taken out of the Chesapeake in a year. Take 10 million off of that for the winter dredge fishery and you have 20,000 million pounds less spread over 8 months. So really there is no great threat; in fact a lesser threat by the winter dredge fishery in taking adult females than by the pot and trotline fisheries of Maryland and Virginia. I think the sentiment is misplaced; if you look at the statistics, the dredge fishery is taking crabs prior to a time when they could be spawning. Now the question might be . . . these females have not yet spawned. True, but in the fall fishery (September, October, November), there are heavy catches in the Chesapeake of females that have not yet spawned, and in May and June, there are many females taken that have not yet spawned. When you take them in the middle of their adult life or early in adult life, it makes no difference. Just based on figures, I don't think there is any basis for an argument that the winter dredge fishery is harmful.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 65–69.

ZOONOTIC DISEASES

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INTRODUCTION

Recent events have linked Gulf coast blue crabs with the transmission of cholera to humans. Before the Louisiana cholera outbreak, there had been only two isolations of *Vibrio cholerae* from humans in the United States during the past decade; one in Alabama, and the other in Texas (Center for Disease Control 1978a). No cluster of indigenous cases of cholera had been reported in this country since 1911 (Center for Disease Control 1978b).

In addition to cholera, other food-borne illnesses can be transmitted to humans if mishandling of the live and processed crabs occurs. It is the purpose of this paper to briefly review human diseases for which crabs may serve as a vector.

FOOD-BORNE ILLNESSES

Most bacterial diseases transmitted from crabs to humans are a result of eating the crab or crab products. These bacterial diseases are referred to as food-borne illnesses. In addition, bacterial diseases may be transmitted to man through wounds produced by handling crabs or crab products.

There are two major categories of food-borne illnesses: (1) food poisoning, and (2) food infection. Food poisonings result when food in which certain bacteria have grown and produced toxic substances is consumed. *Staphylococcus aureus* and *Clostridium* spp. are bacteria known to be responsible for food poisoning. Food infections, on the other hand, are induced in man by the consumption of living pathogenic organisms that grow and produce toxic substances in the body. Food is usually the vehicle for such pathogenic organisms. *Salmonella* and *Vibrio* are examples of bacteria that may cause food infections.

Pathogenic organisms may contaminate crabs and crab products in several ways, depending upon the source of bacteria. For example, organisms such as *S. aureus* and *Salmonella* are usually introduced as a result of improper human-handling practices. About 20% of all food-borne illnesses are the result of human-handling problems such as poor hygiene, infected cuts and wounds, and poor sanitary practices. *Salmonella* can be, and presently is, a significant problem in seafoods. Early this year [1979], the Federal Food and Drug Administration (FDA) blocklisted (automatic detention) shrimp imported from India because of *Salmonella* contamination. *Vibrio* and *Clostridium* species usually contaminate seafoods as a result of harvesting the seafood from waters that have a population of such organisms. Recent events in Louisiana show that *V. cholerae* may be a particularly serious bacterial contamination in crabs. Evidence seems to indicate, however, that vibrios may become a hazard to man only when the crab or crab products are grossly mishandled.

Figure 1 explains major points in the processing scheme of blue crab where contamination may take place.

THE CHOLERA OUTBREAK

On August 10, 1978, a 44-year-old man became ill with water diarrhea, chills, fever, and nausea. The patient was admitted to a hospital on August 13, as a result of dehydration. The hospital laboratory observed the strange occurrence of a pure culture of hemolytic colonies from a stool culture. An interested technologist continued to pursue the identification of the organism and, through biochemical reaction, it was determined that the bacterium was a *Vibrio*. A culture was sent to the state laboratory where it was further identified as *V. cholerae* and forwarded to the National Center for Disease Control (CDC) for typing. The CDC confirmed the isolate as *Vibrio cholerae* 0-1, biotype El Tor, serotype Inaba. It is interesting to note, as reported in *Morbidity and Mortality Weekly Report* (Center for Disease Control 1978a), that the patient had recently eaten boiled shrimp and boiled crabs.

Health officials believed at the time that this was an isolated case and, consequently, did not expect additional cases. However, additional cases did begin to surface. The fifth suspected case was announced on September 25, 1978. CDC officials stated that all five persons had consumed boiled or steamed crabs within 5 days before becoming ill. It should be noted, however, that the crabs were harvested from different locations along 60 miles of the Louisiana Gulf coast (Center for Disease Control 1978d).

In the September 29, 1978, edition of *Morbidity and Mortality Weekly Report* (Center for Disease Control 1978c), CDC officials announced that the United States would now be listed by the World Health Organization as having a cholera-infected area (Center for Disease Control 1978c). According to that same report, an area is considered infected until 10 days have passed since the last case identified has died, recovered, or has been isolated, and there is no epidemiological evidence of spread of that disease to any contiguous area.

a. Improper steaming or boiling.

b. Crabs put back into original container. Cross contaminate cooked crabs with live crabs.

c. Crabs maintained warm for an extended period of time.

Figure 1. Major points in the processing scheme of blue crab where contamination may take place.

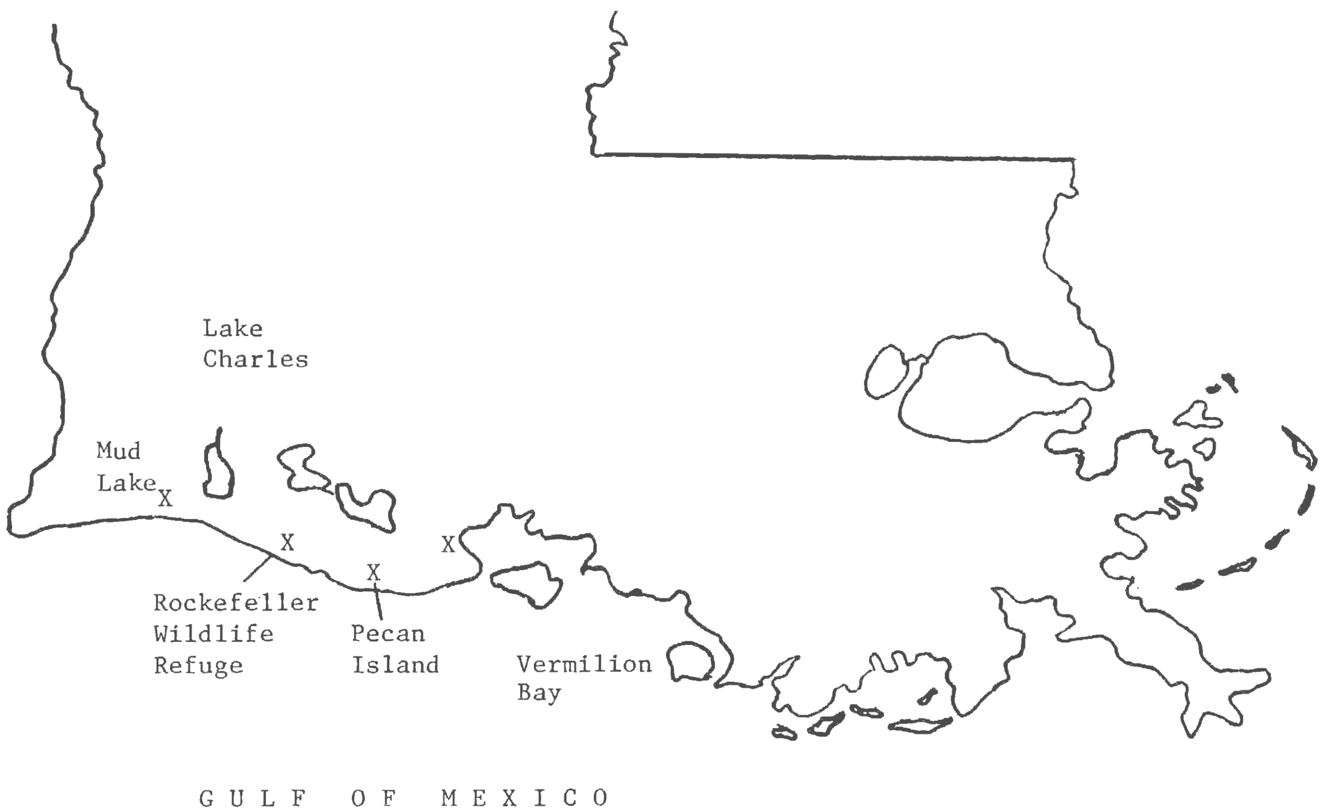

Figure 2. Locations (marked by an "X") where crabs eaten by patients with cholera were obtained along the Louisiana Gulf coast.

By the end of September, 11 cases of cholera in Louisiana had been reported to the CDC. Eight of the 11 became ill, and 3 were asymptomatic. Prior to becoming ill, all had eaten either steamed or boiled crabs. Those individuals with symptoms had eaten crabs within 5 days prior to the onset of illness while the asymptomatic-infected persons had eaten crabs within 9 days before culture (Center for Disease Control 1978d). Table 1 summarizes information on each patient as it relates to the cholera outbreak.

In early October, the FDA recommended to health officials in Louisiana that a broad area in coastal southwestern Louisiana be closed to commercial and private crabbing. The failure to do so, said the FDA, could result in seizure of crabs caught in those areas if they were introduced into interstate commerce. Louisiana health officials refused to follow the recommendations stating there was insufficient evidence of live crabs being contaminated with *V. cholerae.* In addition, all water samples were negative for *V. cholerae.* Newspaper and radio reports indicated that on Friday, October 6, 1978, a shipment of Louisiana crabs was intercepted in Baltimore, Maryland, and destroyed at the urging of the FDA as a precaution against the spread of cholera.

TABLE 1.

List of Patients (from Dr. Don Allegra, Center for Disease Control, New Orleans, LA).

Case No.	Age	Sex	Location	Hospitalized	Onset of Illness	Area Fished	Preparation and Handling
1	44	M	Abbeville	Yes	8/10/78	Rockefeller Wildlife Refuge	Crabs boiled 20 minutes and then put back into storage chest cleaned with soap and water.
2	52	F	Abbeville	Yes	9/19/78	Dewitt and Louisiana Fur Canal	Steamed crabs 30 to 35 minutes.
3	15	F	Abbeville	No	No Illness	Dewitt and Louisiana Fur Canal	Steamed crabs 30 to 35 minutes.
4	69	M	Kaplan	Yes	9/14/78	Mud Lake (west of Cameron)	Boiled crabs 10 minutes.
5	19	F	Intracoastal City	Yes	9/18/78	Vermilion Bay	Steamed about 30 minutes with poor fitting lid and crabs put back into storage chest and eaten 4 hours later.
6	58	F	Lafayette	Yes	9/24/78	White Lake and Old Intracoastal Canal	Three groups: first and second, boiled 20 minutes and put back into same storage ice chest and eaten about 6 hours later. Third, boiled 7 minutes and eaten 1 to 2 hours later.
7	62	M	Lafayette	No	9/24/78	Same as above	Same as above
8	56	M	Lafayette	No	9/24/78	Same as above	Same as above
9	12	M	Lafayette	No	9/27/78	Same as above	Same as above
10	47	M	Pecan Island	No	No Illness	Same as above	Same as above
11	42	F	Pecan Island	No	No Illness	Same as above	Same as above

Shortly thereafter, a water sample taken from the Old Intracoastal Waterway, between the Schooner Bayou central structure and White Lake, was confirmed as having cholera bacteria. Consequently, state health officials closed this specific area to commercial and private crabbing. Because of the uncertainty of further closing of crabbing waters and the posting of FDA inspectors at airports in Baton Rouge and New Orleans to examine and/or sample interstate shipments of crabs, the industry representing the affected area petitioned the Louisiana Cooperative Extensive Service for guidance.

Shortly after it was determined that the first few illnesses were not isolated cases, appropriate federal, state, and local agencies began an intensive sampling program. As of March 8, 1979, 491 live crab samples, involving approximately 2,455 crabs, failed to yield any positive results; from 109 shrimp samples involving approximately 1,448 shrimp, one sample was positive; 75 raw oyster samples involving approximately 923 oysters failed to yield any positive samples; 187 samples of commercially produced crabmeat did not yield any positive samples. From the 150 crab-plant drains examined, none were positive; from the 316 estuarine water samples taken, only one was positive. Since this reporting period, however, another positive water sample was taken in early April from St. Bernard Parish. In addition to the above sampling, ice houses were examined. All 20 ice samples were negative. Results of the sampling program as of March 8, 1979, are shown in Table 2.

Even though evidence showed that the problem was with mishandling practices of recreationally caught, home prepared and consumed crabs, Louisiana commercial crab and seafood processors and dealers indicated their sales were being affected. Retailers and restaurants were especially affected. As the problem developed, obvious confusion and gross misunderstanding existed. For example, daily accounts of the situation in many Louisiana newspapers, television and radio broadcasts contributed toward an emotionally involved public. The fact that the disease was not associated with commercially processed products did not surface in the numerous media reportings. Consumers were not aware of exactly how the disease was transmitted or how it could be controlled, except that some people who had eaten crabs had become ill from cholera. Consumers often associate cholera with diseases such as the plague. In addition, federal and state health officials did not agree on methods of controlling the problem. The crabbing industry was not informed of developments, and there was no mechanism to do so.

THE VIBRIOS

Vibrio cholerae is a gram negative, actively motile rod that causes the intestinal disease cholera. This disease is highly specific to man. Worldwide, there are two major biotypes,

TABLE 2.

Summary of specimens examined in cholera investigation sampling program, Louisiana 1978 (as of March 8, 1979).

	Live Crabs		Fresh Shrimp		Raw Oysters		Crab Meat		Sewage Swabs		Septic Tanks		Crab Plant Drains		Estuarine Water		Ice		People*	
Parish	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive	Total	Positive
Acadia							12		22		7									
Ascension									12											
Assumption	48						56		11				5							
Calcasieu	3		4		4				87		12				4		3		114	
Cameron	49		23		10		2		16		4				41		2			
East Baton Rouge									20											
Iberia					7				34		6				3		4		75	
Iberville									12											
Jefferson	62		8		4		25		87				37						201	
Jefferson Davis									64	3	8									
Lafayette	1								87	1	5						3		556	11
Lafourche	24						25		16				14						318	
Livingston																				
Orleans	57		3		7		7		33				11						702	
Plaquemines	2				4															
St. Bernard	42		3		16		11		15				18							
St. Charles	12						3		5				5							
St. John	3								7											
St. Martin	22						17		22		8		15				1			
St. Mary	43		2		2		15		200	6			27				7		23	
St. Tammany	5				1				23		5								181	
Tangipahoa	8				4		2						3							
Terrebonne	18		1		5		11		20				15						88	
Vermilion	91		65	1	11		1		341	11	21	4			268	1			210	
West Baton Rouge									4											
Total	491		109	1	75		187		1,138	21	76	4**	150		316	1	20		2,468	11

*Recorded by location of laboratory processing specimens, not by parish residence of patient.

**All four septic tank swabs, which were positive, were those directly attributable to patients.

NB: Estimated number tested: crabs, 2,455; shrimp, 1,448; oysters, 923 (these numbers are probably somewhat lower than what was actually tested because some samples were not submitted with the total number of specimens mentioned in each sample and were treated as being one or two in number).

(Information from Dr. Don Allegra, Center for Disease Control, Epidemiology Unit, New Orleans, LA.)

the Classical and the El Tor. The disease resulting from ingestion is the same regardless of the biotype. Three serotypes, Ogawa, Hikojima, and Inaba are known.

Traditionally, the organisms are transmitted to man through water. In the case of the Louisiana outbreak, the organisms were transmitted to man from blue crabs, a water-dwelling species. The incubation period is about 48 hours. Individuals who become ill usually experience diarrhea. In some cases, severe dehydration may result. Patients who receive the proper medical attention will excrete organisms for a few days while untreated patients may excrete organisms for several weeks. Not all individuals consuming the organisms become sick. One study (Bart and Gangarosa (1971) has shown that 75% of the individuals infected with El Tor biotype were asymptomatic.

Previously, it was thought that *V. cholerae* did not survive well in the environment, however, recent evidence indicates that it may. *Vibrio cholerae* does not have to be ingested to produce illness. In 1979, a man from Jefferson Parish, Louisiana, had *V. cholerae* 0-1 isolated from a leg ulcer.

Nonagglutanatable *V. cholerae* (often referred to as NAGS) are indistinguishable from *V. cholerae* except they will not agglutanate 0-1 serum (Hughes et al. 1978). Although these organisms do not produce the disease cholera, they may produce a cholera-like illness. NAGS can be isolated from coastal waters and seafood of the Gulf of Mexico. There were several NAGS infections identified in Louisiana in 1979. Like *V. cholerae*, NAGS can also produce wound infections.

Vibrio parahaemolyticus has been associated with gastroentiritis in humans as a result of ingesting crabmeat (Molenda et al. 1972).

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PROTOZOAN SYMBIONTS AND RELATED DISEASES OF THE BLUE CRAB, *CALLINECTES SAPIDUS* RATHBUN FROM THE ATLANTIC AND GULF COASTS OF THE UNITED STATES

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ABSTRACT The blue crab (*Callinectes sapidus* Rathbun, 1896) supports valuable fisheries along the mid-Atlantic and Gulf coasts of the United States. Because the crab is an estuarine species, capable of ranging widely within its habitat, it is subject to the rigors of the euryhaline environment, as well as to the stresses caused by human activity along coastlines. It has been demonstrated that captive-crab populations are particularly susceptible to parasites and commensals, and to their associated disease and debilities. Within wild populations, extensive mortalities due to these factors are difficult to monitor, but do cause fluctuating losses to the crab fishery. This paper reviews existing knowledge on the more common protozoan symbionts and diseases of the blue crab found on the eastern and Gulf coasts. Available information on recognition and diagnosis of disease, site of infection, and pathogenicity is included. Data are presented on taxonomy, morphology, and life cycles of associated protozoan parasites and commensals of *Callinectes sapidus*.

INTRODUCTION

The blue crab (*Callinectes sapidus* Rathbun, 1896) supports valuable seasonal fisheries in regions of the middle Atlantic coast, and the Gulf of Mexico coast of the United States. Estuaries provide the euryhaline conditions necessary for blue crab reproduction and maturation. The blue crab is a swimming crab (Portunidae) and is not restricted to localized areas, but may range widely within a given estuary. Therefore, this species is subject to the influence of diverse environmental factors during its life cycle. These factors, in conjunction with the biological properties of the blue crab, determine relative annual abundance of the species in any given estuary.

Some of the more important environmental-biological factors affecting the blue crab throughout its range are natural, infectious, and noninfectious diseases. The blue crab, like other estuarine species, must also contend with the effects of human activity, and anthropogenic-related disease (pollution).

There is ample literature on the biology of the blue crab (see bibliography by Tagatz and Hall 1971), but most of the detailed, informative papers concerned with symbionts* and disease are scattered in various journals.

In recent years several important reviews have been published that include information on specific protozoan diseases and symbionts of the blue crab. Sindermann and Rosenfield (1967) and Sindermann (1970) generally reviewed the principal diseases of the blue crab and other commercially important Crustacea. Sprague (1970a) reviewed the protozoan parasites of the blue crab, and Sprague and Couch (1971) presented an annotated taxonomic and nomenclatural list of the described protozoa found as parasites and commensals in the blue crab and other decapod Crustacea. None of these reviews, however, contained detailed diagnostic, pathological, or epizootiological descriptions of the protozoan diseases and symbionts of the blue crab.

The purpose of the present paper is to give a review of the better known protozoan symbionts and diseases of the blue crab found on the east and Gulf coasts of the United States. Included is information, if available, on the recognition and diagnosis of specific diseases, data on taxonomy, morphology, and life cycle of parasites and commensals, as well as histopathology and epizootiology associated with parasites and commensals.

Studies reported herein were begun in 1966 at the U.S. Bureau of Commercial Fisheries Laboratory, Oxford, Maryland. From 1966 to 1968, numerous seasonal samples of blue crabs from Maryland, Virginia, North and South Carolina, Georgia, and Florida were examined for symbionts and disease conditions. These studies, though not part of a systematic investigation, revealed new species of symbionts, and supplied new insights and data on several diseases of the blue crab.

In January 1969, a systematic study on the protozoan symbionts and diseases of blue crabs from Chesapeake Bay, and from the Atlantic coast of Maryland and Virginia was begun. During 1969, a minimum of 30 blue crabs per month were collected from York Spit Light in lower Chesapeake Bay (Virginia), and a minimum of 30 per month from Chincoteague Bay, on the Atlantic coast of Maryland and Virginia. The sex, molt condition, size, and gross appearance of these crabs were recorded. Over 3,000 blue crabs were collected and examined during 1969. The following tissues were examined histologically: gills, muscle, heart, hemolymph, hepatopancreas, and gonads. These tissues were fixed in Davidson's fixative (Shaw and Battle 1957), Bouin's (aqueous) fixative, or neutral, buffered 10% formalin. Paraffin sections (3 to 7 μm) of the tissues were stained with a variety of methods, including Harris hematoxylin

*The term symbiont may refer to a parasite, commensal, mutualistic associate, or pathogen in this paper.

and eosin, PAS (periodic acid Schiff technique [with and without diastase digestion]), mercury bromophenol blue, alcian blue, protargol silver, and Lillies' silver oxide. The resulting slides of tissues were examined for bacteria, fungi, protozoa, metazoan parasites or commensals, and lesions indicative of disease.

During the period 1969–1972, several samples of blue crabs from the Gulf coast of the United States were examined with the same methods as those collected from Virginia and Maryland during 1969.

The authors' observations and studies have been supplemented with numerous references to the existing literature on blue crab symbionts and diseases.

PROTOZOAN TAXA AND RELATED BLUE CRAB DISEASES

Amoeboid Protozoa

Species of amoeboid organisms are symbionts of crabs (Sprague and Couch 1971). At least one species of amoeba has been associated with disease conditions in blue crabs (*Callinectes sapidus*).

Paramoeba Disease

Paramoeba disease of the blue crab (*Callinectes sapidus*) is caused by *Paramoeba perniciosa* (Sprague et al. 1969). Found in the blood and in mainly nonepithelial tissues of the blue crab, this amoeba is highly pathogenic, and is the agent of "gray crab" disease. More data are available on this pathogen than for most other symbionts or disease agents of the blue crab.

Paramoeba perniciosa was first detected in blue crabs by Sprague and Beckett (1966, 1968), who were examining crabs from Chincoteague Bay, Virginia, that had the signs of gray crab disease. This disease has long been noted by fishermen in Maryland and Virginia, who have reported that some crabs develop gray sterna and gray ventral carapaces concomitant with lethargy during the months of May and June. When handled, gray crabs die quickly. Reports of heavy blue crab mortalities in June 1967, in Georgia, and in the Carolinas, led to an investigation by Couch and Tubiash (1967), who found crabs with signs of gray crab disease. Histological and blood preparations from those crabs showed the presence of *Paramoeba perniciosa* at high concentration. Since 1967, blue crab mortalities of greater or lesser magnitude have occurred during May and June along the eastern coast of the United States from Maryland to Florida (Newman and Ward 1973). The majority of those May and June mortalities, which have been investigated, have involved gray crab disease. Many mortalities of blue crabs held in commercial shedding tanks have been related to infections by *Paramoeba perniciosa*, particularly during early summer.

The amoebae, in blood smears, range from 3 to 35 µm, and are round to elongate; usually each contains a well-defined nucleus with a large central endosome. In advanced infections, there are usually two size classes of the amoeba: small (3 to 12 µm), and large (15 to 35 µm) (Figure 1). The major diagnostic characteristic of *Paramoeba perniciosa* is the presence of a secondary nucleus, amphosome or "nebenkörper" in the cytoplasm. This body is usually 1 to 4 µm, elongate, possesses a Feulgen-positive middle bar, and has two opposing basophilic polar caps. The secondary nucleus positively identifies the amoeba in tissues or hemolymph from blue crabs (Figure 2). Perkins and Castagna (1971) described the ultrastructure of the secondary nucleus of *Paramoeba perniciosa*, and raised the possibility that the body was a discrete organism parasitizing the amoeba.

Paramoeba perniciosa does not form cysts, and extensive pseudopodal formation is rare; the amoeba usually has a round or subspherical form, but may be very elongated (Figure 1).

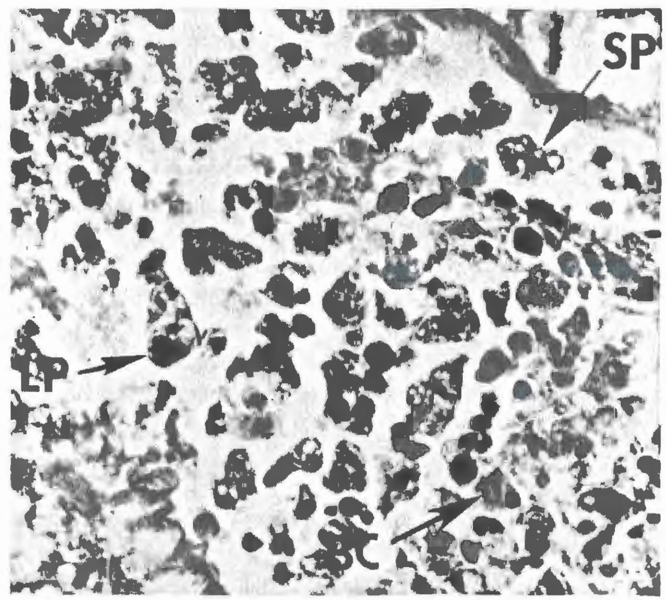

Figure 1. Advanced infection of *P. perniciosa* in blue crab hemocoel. Microscopic field contains large *Paramoeba* (LP), small *Paramoeba* (SP), and a few remaining blood cells (BC) of host.

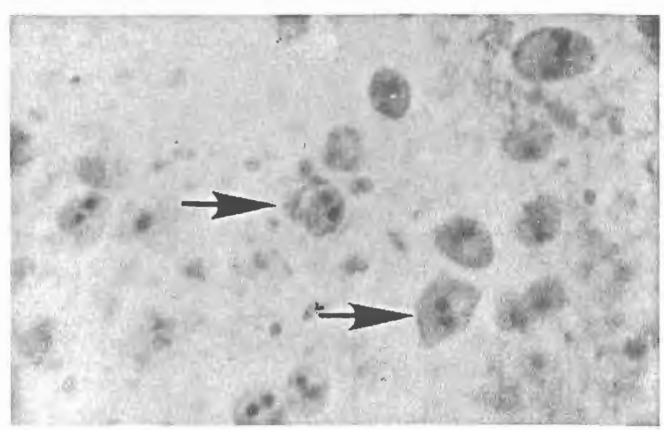

Figure 2. Blood smear of *Paramoeba*-infected blue crab; note both nucleus and secondary body in amoeba (arrows).

Paramoeba disease in blue crabs drastically alters certain tissues of heavily infected crabs and is systemic. In advanced infections, most blood cells are replaced by the amoeba in the blood sinuses throughout the circulatory system (Figure 3). In lightly infected crabs, one may have to search diligently for the amoeba. Not all infected crabs possess the gray signs grossly characteristic of the disease. However, the great majority of crabs which do have external gray signs and which are lethargic are infected, usually heavily.

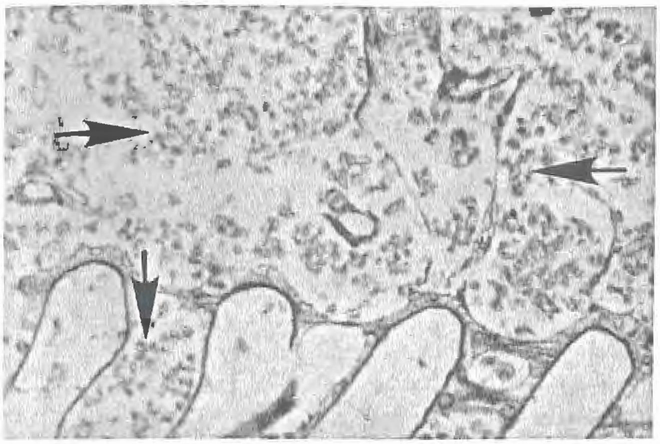

Figure 3. Section through gill branchium of heavily infected blue crab; arrows indicate masses of amoebae that have totally replaced blood cells of host.

In advanced infections, the hepatopancreas, gonad, muscle, gills, and blood become filled with *Paramoeba perniciosa* to the extent that normal connective tissue of the crab is replaced. In those crabs, however, the peripheral epithelial tissues of the gut, hepatopancreas, hypodermis, and gonad are not invaded. The amoeba is not an intracellular parasite, but often in sections, large halos surround individuals, suggesting lysis of host tissue or shrinkage artifact in the immediate area of the parasite.

Crab blood cells attempt to phagocytize the amoeba and occasional attempts at encapsulation of amoebae are found in early and intermediate infections.

The direct causes of death in *Paramoeba*-infected crabs are unknown. The remarkable extent to which the amoebae replace blood cells in heavily infected crabs suggests that loss of vital tissues, such as blood cells and muscle, may lead to loss of vital functions. Gill blood sinuses may become congested in severe infections and impairment of respiratory function may occur. Pauley et al (1975) observed a significant reduction in glucose levels in blood of infected crabs when compared to that of noninfected crabs. This was attributed to competition of *Paramoeba perniciosa* with the tissues of the blue crab for glucose. They also reported a substantial decline in serum proteins in infected crabs and considered this to be the major cause of the weakened or lethargic condition.

Blue crabs held in closed-system aquaria at oceanic and estuarine salinities were fed muscle and viscera of blue crabs heavily infected with a variety of stages of *Paramoeba perniciosa* (5 to 24 μm). In addition, blood from heavily infected blue crabs was injected into nondiseased blue crabs. Artificial sea salts and tapwater were used to prepare sea water for these aquaria. Neither method was successful in transmitting the amoeba or gray crab disease signs to healthy blue crabs. Johnson (1977), however, was able to transmit the small form of *Paramoeba perniciosa* to two of four blue crabs inoculated with amoeba-laden blood from infected crabs. Two crabs died with heavy amoebic infections 34 to 39 days after inoculation. *Paramoeba perniciosa* has not been successfully cultured *in vitro*.

Seasonality, prevalence, infectivity, distribution, and *Paramoeba*-associated mortality were studied by Couch (1966–1970) in Chincoteague Bay, Maryland, and in lower Chesapeake Bay, Virginia, and by Newman and Ward (1973) in Chincoteague Bay, Virginia, and Atlantic coasts of the southern United States. Johnson (1977) also reported patterns of mortality and disease prevalence. To date, *Paramoeba* has not been reported from crabs of the Gulf of Mexico.

Samples of blue crabs (30 crabs per month) from Chincoteague Bay, Maryland, and from near York Spit Light in lower Chesapeake Bay were examined for prevalence of *Paramoeba perniciosa* in 1969. High prevalences (up to 20% of crabs infected) of *Paramoeba perniciosa* in Chincoteague Bay were found in May and June, and in October through February. The June epizootic agrees in timing with epizootics that occurred in blue crab populations from Maryland to Georgia, as reported in one earlier and several subsequent studies (Couch and Tubiash 1967, Newman and Ward 1973, Sprague and Beckett 1968). The high prevalence (16–17% of crabs infected) in June was associated with gray crab signs and high mortality of crab pots, shedding floats, and free in water. The October through February epizootic of *Paramoeba perniciosa* in blue crabs dredged from hibernation represented a new seasonal occurrence (Couch, unpublished observations [1968, 1969]), and probably represents a winter impact of the disease.

Sporadic winter mortalities of blue crabs have often been reported from Chincoteague Bay (George Ward, personal communication), discovered as a result of winter dredge fishing. The cause(s) of these mortalities are not known, but often have been attributed to extremely low water temperatures. Up to 20% of crabs examined in January, February, October, and December 1969, were infected (Couch, unpublished observation). *Paramoeba perniciosa* could be a major factor contributing to winter mortality of crabs.

Crabs from the York Spit Light collecting site in lower Chesapeake Bay had relatively low prevalence of *Paramoeba* during 1969 (0 to 13% crabs infected). Only February (3%), July (3%), and December (13%) samples revealed infected crabs, and none of those samples had high amoeba prevalences in comparison to seasonally similar samples from Chincoteague Bay.

Although *Paramoeba perniciosa* occurs in lower Chesapeake Bay, there have been no reports of blue crab mass mortalities attributable to *Paramoeba* disease in the Bay. The lower bay area may be a marginal zone for the pathogen particularly if salinity determines distribution of susceptibility. Chincoteague Bay and other smaller coastal bays from Maryland to southeastern Georgia, the sites of *Paramoeba* disease epizootics, are fundamentally different in many aspects from a major estuary such as Chesapeake Bay, particularly in such characteristics as salinity gradients, biota, flushing, tidal behavior, and sediments. *Paramoeba perniciosa* probably is an opportunistic parasite/pathogen of blue crabs and other Crustacea. The pattern of seasonal infections, correlated with the summer molting periods of blue crabs, suggests that the free-living amoeba stage may enter soft or hard crabs through lesions prevalent in their cuticles (Figure 4). The fact that other species of *Paramoeba* are free living (Schaudinn 1896, Page 1970) strongly suggests that a normally free-living amoeba could, under the right circumstances, invade and survive or even thrive in the blood of a marine invertebrate. Sawyer and Maclean (1978) recently identified *Paramoeba perniciosa* as a parasite of the rock crab *Cancer irroratus*, and the lobster *Homarus americanus*.

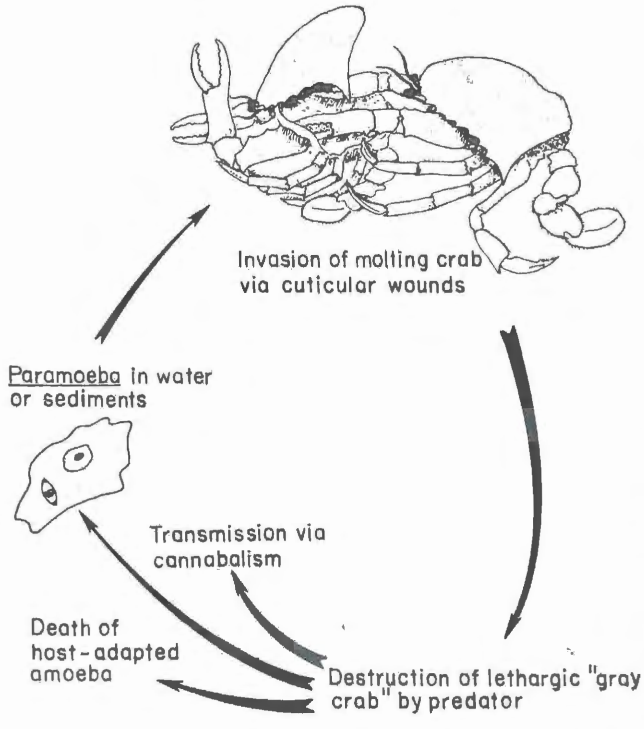

Figure 4. Diagram of possible mode of infection of blue crabs by *Paramoeba*. Note that the molt cycle of the crab, according to this scheme, plays an important role in the relationship between the blue crab and *Paramoeba* as an invasive, destructive pathogen.

Although mass mortalities of blue crabs attributable to *Paramoeba perniciosa* are not detected every year, the blue crab fishery can expect periodic losses of crabs to *Paramoeba* disease. Even in years where mass mortalities are not evident, there is chronic low-level loss to *Paramoeba perniciosa* in May-June and October-February periods. The shedding industry suffers periodic losses in the May-June period to "gray crab" disease, particularly in areas of high salinity such as seaside estuaries of the middle Atlantic states.

Dinoflagellate Disease

Chatton (1910) gave the first detailed summary of dinoflagellates as parasites of Crustacea, and later (Chatton 1920) monographed the peridinian dinoflagellate parasites of aquatic animals. Chatton and Poisson (1930) reported *Hematodinium perezi* as a pathogen in portunid crabs from France. Newman and Johnson (1975) reported the first cases of *Hematodinium* in blue crabs from the east coast of the United States. Subsequently, several blue crabs were found to be infected with a similar, probably identical, *Hematodinium* sp. from near Pensacola, Florida (Couch, unpublished). *Hematodinium* spp. in crabs cause a debilitating, fatal disease with no external signs except lethargy or weakness.

Stages of *Hematodinium* in blue crabs from the Gulf of Mexico were uninucleate, round cells averaging 5.8 μm in diameter, and having nuclear diameters ranging from 2.0 to 4.4 μm. Binucleate cells (7.3 μm diameter) and plasmodia (8.0 to 64 μm in length or diameter) also were found in Gulf blue crabs. The nuclei are large in proportion to cytoplasm and contain chromosomes in either condensed or diffused states (Figure 5). The dinokaryon nucleus is the major characteristic revealing the dinoflagellate identity of the parasite in the blue crab. No flagellated stages have been found in any crab hosts. The uninucleate and plasmodial stages are found in all vascularized tissue of the crab. Though primarily a parasite of the hemolymph or blood, *Hematodium* sp. may be found in and between muscle fibrils, in

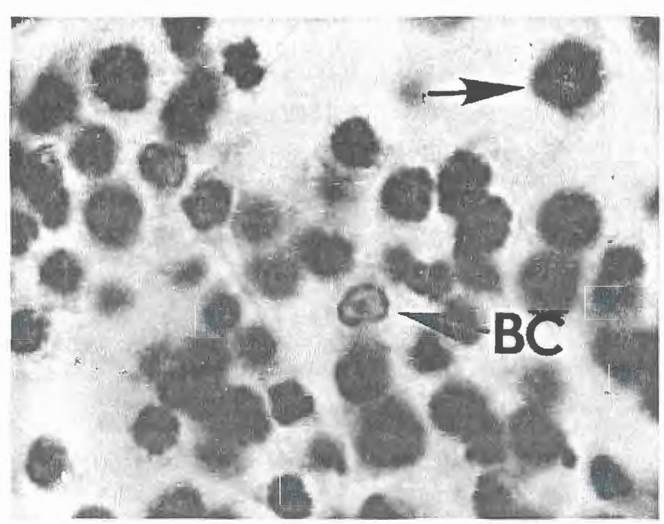

Figure 5. *Hematodinium* sp. from hemolymph specimen of heavily infected blue crab; arrows point to typical uninucleate stages of the dinoflagellate. A single normal blood cell is denoted by BC.

gonads, and in the hepatopancreas of most heavily infected crabs. In advanced infections, total lysis of hepatopancreatic tubules, and partial destruction of muscle fibers occurs. The drawn blood of infected crabs is milky or opaque.

The disease has been found in blue crabs only from salinities above 11 ppt (Newman and Johnson 1975), even though hosts have been examined for the parasite from lower salinities. Its known range in America presently is from Maryland to Florida, including the northeastern Gulf of Mexico.

Chatton and Poisson (1930) found only 3 of 3,500 portunid and shore crabs infected with *Hematodinium perezi* on the coast of France; Newman and Johnson (1975) found numerous blue crabs infected in all seasons except late winter and early spring along the Atlantic coast. Couch found crabs infected in May-June on the Gulf coast in 1974. Portions of the life cycle outside the crab are unknown. This parasite is lethal to blue crabs because of its ability to proliferate extensively, fill the vascular system, and replace most tissues.

Haplosporidia

Haplosporidians are an enigmatic protozoan group, only a few species of which have been described as pathogens of Crustacea (Sprague and Couch 1971, Newman et al. 1976). Haplosporidians have been of considerable interest in the last 20 years because of their roles as oyster pathogens worldwide (Sprague 1970b, 1978; Couch et al. 1966; Couch 1967b). They are characterized by relatively simple spores, and sporulative and schizogonic stages in the known portion of their life cycles. Modes of haplosporidian transmission from host to host are unknown.

Presently only five or six species in two genera are known to occur in Crustacea. The two genera in Crustacea are *Haplosporidium* and *Urosporidium.* Sprague (1978) recently returned several species of *Minchinia* to the genus *Haplosporidium. Haplosporidium louisiana* (Sprague 1978) in the mud crab *Panopeus herbstii* from Louisiana, *Haplosporidium* sp. (=*Minchinia* sp.) from the mud crab *Eurypanopeus depressus* in Virginia (Rosenfield et al. 1969), *Haplosporidium* (=*Minchinia*) from another mud crab *Panopeus herbistii*, and a *Haplosporidium*-like organism from the blue crab of Virginia and North Carolina (Newman et al. 1976) occur as histozoic, intercellular parasites of their respective crab hosts. *Urosporidium crescens* DeTurk, 1940 occurs in the blue crab as a hyperparasite, parasitic in microphallid trematode metacercaria encysted in the crab (Figure 6a, b).

Newman et al. (1976) found blue crabs heavily infected with a *Haplosporidium*-like organism to be moribund, with opaque, white hemolymph, and all their vascular spaces filled with uninucleate and plasmodial stages of the parasite. No spore stages were found, but ultrastructural studies of plasmodia revealed haplosporidian cytological characteristics including haplosporosomes (Perkins 1968). This organism is apparently lethal to its crab host, but only five blue crabs have been found infected from Chincoteague Bay, Virginia, and coastal North Carolina. Therefore, little is known of its effects on blue crab populations.

The hyperparasitic *Urosporidium* spp. have no known direct, pathologic effects on their crustacean hosts, but *Urosporidium crescens* causes the condition known to fishermen as "pepper crabs" (Couch 1974). The infected trematodes are black and highly visible in the tissues of crabs. These crabs are not marketable because of the unappetizing presence of the enlarged, blackened parasite. Therefore, *Urosporidium* has a vicarious, negative effect on the blue crab fishery.

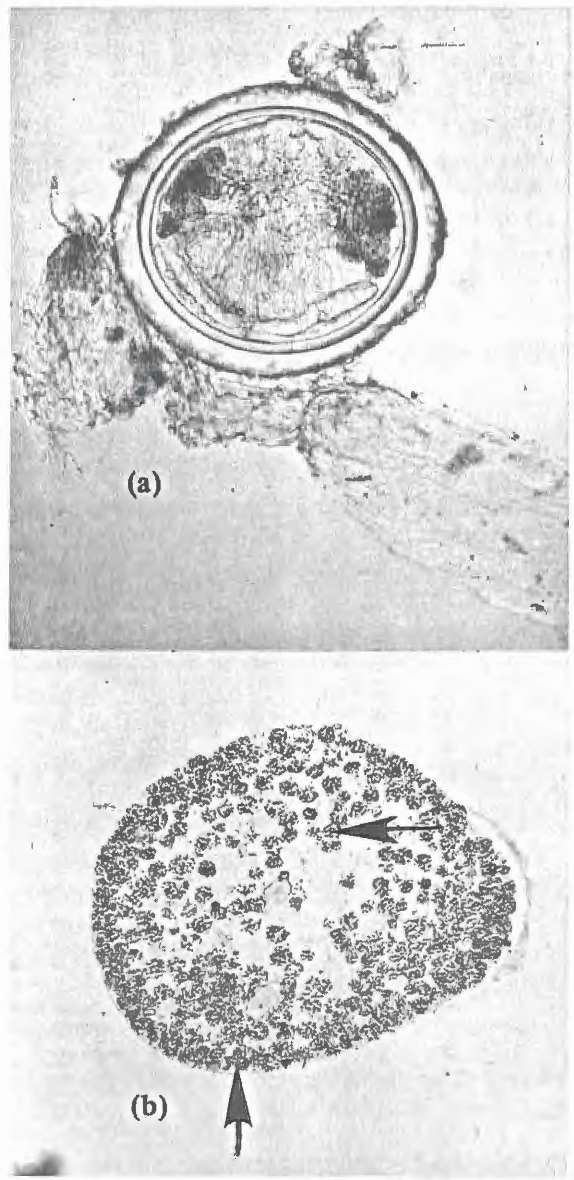

Figure 6. (a) Uninfected microphallid metacercaria from tissues of blue crab; note normal cyst walls and structures within metacercaria. (b) Microphallid metacercaria heavily infected with hyperparasite *Urosporidium crescens*; note that sporocysts of *Urosporidium* have completely filled the tissues of the trematode (arrows).

Microspora

Microsporidian protozoa, spore-producing protozoa, are very destructive pathogens in individual blue crabs. Two genera, *Ameson* and *Pleistophora,* which infect the host's musculature, are worthy of mention here as blue crab parasites.

Found in the muscle of the blue crab, *Ameson michaelis* (Sprague 1970a) has ovoid spores 2.2 μm by 1.7 μm. The life cycle of *Ameson* is direct (Figure 7); i.e., blue crabs feed on other infected blue crabs and ingest infectious spores which germinate and produce infective sporoplasms (Overstreet 1978).

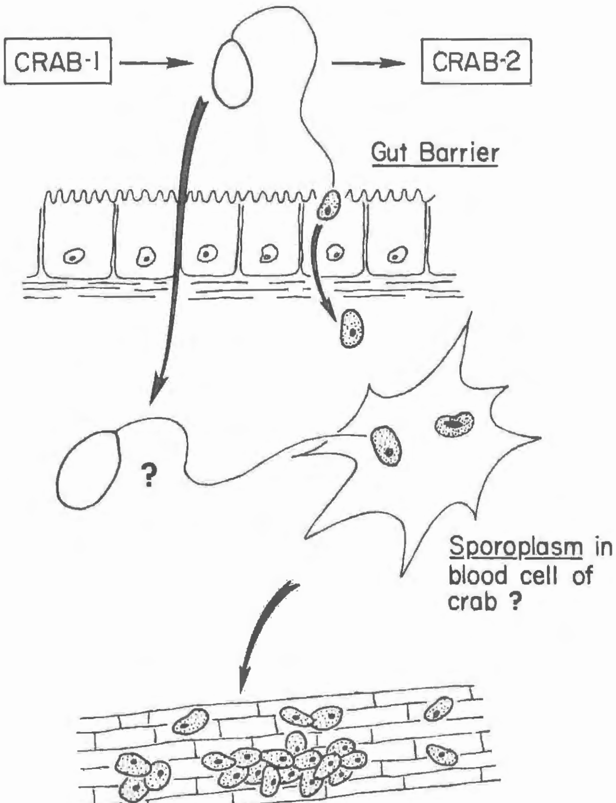

Figure 7. Conceptual scheme of possible mode of infection and transport of *Ameson michaelis* in tissues of blue crab host. Life cycle is direct and spores are transmitted most probably by blue crabs feeding on infected blue crabs.

Ameson michaelis is thought to cause lysis of musculature because infected crabs have white, degenerate muscles. Vernick and Sprague (1970) experimentally demonstrated that extracts of infected muscle caused *in vitro* lysis of non-infected muscle. Theirs was the first experimental demonstration of a tissue effect by a microsporidian in Crustacea. Overstreet and Weidner (1974) report that *Ameson michaelis* has more direct contact with crab tissue because it lacks pansporoblast membranes that ordinarily would "trap potentially harmful metabolites." The harmful substances leading to lysis of crab muscle by *A. michaelis* may be enzymes released to solubilize host tissues for nutrition of the parasite.

Sprague (1977) reports that *Ameson michaelis* is common and widely distributed in the blue crab on the Atlantic and Gulf coasts of the United States, although high prevalences have not been reported.

Ameson sapidi also causes extensive destruction of host muscle tissue, leading to white and opaque muscles. Spores are oval, and larger than *A. michaelis,* being approximately 3.5 μm by 2.13 μm. When fresh, the spores show no internal structure. Following staining, however, anterior and posterior vacuoles separated by a dark band may be detected (Sprague 1970a).

Sprague (1977) lists at least ten species of *Pleistophora* from the following crustacean orders: Decapoda, Copepoda, Cladocera, and Anostraca. *Pleistophora cargoi* (Sprague 1966) occurs in blue crabs (Sprague 1970a). The sporont is characterized by its development into more than 16 spores, which, when fresh are ellipsoidal and measure 5.1 μm by 3.3 μm. *Pleistophora cargoi* has been found in the skeletal and cardiac muscle of one host specimen from the Patuxent River in Maryland (Sprague 1970a). Little is known of its effects in populations of blue crabs.

Many other species of microsporidians that infect other Crustacea also cause either local or extensive changes in muscle opacity or color (Sprague 1977). Johnson et al. (1978) discussed at length the relationship between certain microsporidian species and host musculature, particularly in regard to kinds of lesions produced in Crustacea.

Ciliate Protozoa

The Genus *Lagenophrys* (Peritrichida: Lagenophryidae) contains 52 described species (Couch 1971). These peritrichous ciliates are sessile and spend all but a short dispersive phase of their lives in transparent, secreted loricae attached only to the cuticle of crustacean hosts. Species of *Lagenophrys* occur as ectocommensals on hosts from six orders of Crustacea.

Lagenophrys callinectes (Couch 1967a) is an ectocommensal found on the flat surfaces of the gill lamellae of the blue crab from the Atlantic Coast of the United states, and from the Gulf of Mexico. It lives in a colorless, transparent, semi-hemispherical lorica which is 48 μm to 59 μm long by 45 μm to 57 μm wide (Figure 8). The form and relative sizes of the lip elements comprise the single most important group of morphometric features available for identification of *L. callinectes* (Couch 1971, 1973).

Willis (1942), Shomay (1955), and Couch (1973) have examined the physical relationship of the lorica and trophont of *Lagenophrys* spp. to the tissues of their hosts but did not find evidence of significant alteration of the host's gill tissues.

Heavy infestation of a cuticle-covering ectocommensal protozoan might interfere with proper respiratory or excretory function of host gill tissues (Couch 1967a, 1978; Overstreet 1973).

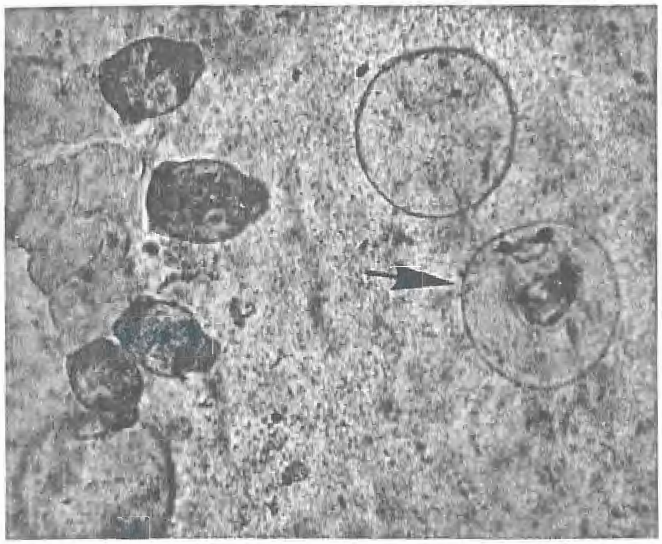

Figure 8. *Lagenophrys callinectes* within lorica on gill surface of blue crab (arrow); several empty loricae visible nearby; also note large, colonial stalked peritrich attached to gill. In heavy infestations, all surface area of the gill lamella may be occupied by *Lagenophrys* and other peritrichs.

With the exception of Shomay (1955), Couch (1971), and Overstreet (1973), epizootics of commensal peritrichs on natural populations of Crustacea have not been reported in detail. An earlier study afforded the authors an opportunity to examine the blue crab/*L. callinectes* relationship in Chincoteague Bay, Maryland, with respect to two factors: (1) seasonal prevalence of the ciliate in a natural population of hosts, and (2) seasonal intensity of infestation of individual hosts; both in relation to seasonal behavior of the host.

Lagenophrys callinectes was least prevalent from December through April, the period when blue crabs of Chincoteague Bay are in hibernation or in winter dormancy. During that time the crabs are largely buried in the mud or sand bottom. It may be presumed that their metabolic rates are low (compared to summer crabs), and that their filtering of water over gills for respiration is at a minimum. Histologic sections of gills taken from crabs from December through early April revealed great amounts of debris in the gill chamber and between gill lamellae. The intensity of infestation per crab was lowest in January coinciding with the reduced respiratory function and obstructed gill condition of the crabs, as well as with the depressed winter water temperatures.

From April through July, the prevalence of *L. callinectes* gradually increased, coinciding with the increase in water temperature, metabolic activity of the crab after it came out of hibernation, cleaning of the crab's gill chambers by increased flow of water through the chambers, and the resumption of normal feeding and mating of the crab. All these factors peaked during the month of August. In August, the prevalence and intensity of infestation reached their maximum.

During December, prevalence of infestation fell sharply and intensity of infestation in individual crabs also declined. Concurrent with this drop in prevalence and intensity of infestation, as well as a return to low winter water temperature levels, there occurred significant changes in the histologic conditions of the gills of crabs. The histologic changes were of two major kinds: (1) a swelling or edematous change in individual lamellae, and (2) a weakening, sloughing, and thinning of the actual lamellar cuticle. Organic debris and particulate matter also had accumulated in the gill chambers of most of the crabs in December.

During May and June 1969, the intensity of infestation was low compared to July through November. This low level of infestation is most reasonably explained by the fact that May, June, and July are the months of greatest initial molting and growth in the blue crab population of Chincoteague Bay. A high proportion of the crabs making up the May and June samples would have recently undergone a molt, thus freeing themselves of any attached populations of ectocommensals, including *Lagenophrys.*

If heavy infestation of *Lagenophrys callinectes* on the gills of blue crabs does play a debilitating role in preventing proper gas exchange between water and gill tissue, or in excretion, then this peritrich may be a seasonal factor affecting the survival of blue crabs, particularly in times of stress due to borderline oxygen tension in water.

Two general inferences can be made. The data strongly suggest that the yearly population patterns of *L. callinectes* are dependent upon the seasonal cycles of behavior of populations of the blue crab host. Further, there appears to be a direct relationship between high prevalence of *L. callinectes* in summer months (i.e., high reproductive rate) and high intensity of individual crab infestations of *L. callinectes.*

High prevalence and intensity of infestation of *L. callinectes* on the gills of blue crabs crowded in floats, shedding tanks, or crab traps have been correlated with high mortality of captured crabs (Couch 1966). With the added stress of other parasitic infections (i.e., *Paramoeba* and microsporidians), the ciliate load may become physiologically unbearable for the crab.

DISCUSSION

Blue crabs held in captivity such as in floats, traps, tanks, ponds, or in laboratories are particularly susceptible to a variety of protozoa that may fall heir to a captive, rich substrate and high-density host population. Protozoa that utilize the blue crab as hosts may range from normally harmless commensals (*Lagenophrys*) to lethal pathogens (*Paramoeba* or *Hematodinium*). The possibility exists that certain situations may turn normally harmless commensals into deadly adjuncts to physiological stress, the sum total of which causes mortality, particularly in captive crabs.

Protozoan symbionts may play important roles in the periodic fluctuations in the abundance of blue crabs along our coasts. It is much more difficult to try to assess the impact of Protozoa in wild populations than in captive groups of crabs. Protozoan disease control in blue crabs may be feasible in mariculture, but cannot be practiced, of course, in wild populations. A better knowledge of the roles of Protozoa in the overall ecology of blue crabs will permit more accurate predictions of fishery successes, losses, and total yields of blue crab populations over time.

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DISCUSSION

Q. (Unidentified): I have a question concerning dinoflagellates in the lipo-hepatic tissue. Did you ever come up with a connection with the flavor–maybe it is bitter tasting fat–because it has dinoflagellates in the fat?

A. John Couch: No, we have never done that kind of a study. Actually the dinoflagellate occurred rarely in the crabs, we only found it a couple of times. Once, I think, in April and once in June.

Q. (Unidentified)- With the few samples that you had, were the crabs bitter tasting?

A. Couch: I imagine that after steaming or boiling a crab that was heavily infected with dinoflagellates, you would not want to eat it anyway; it would be soup essentially. You could see some of the internal organs, but if anything, it would be soupy; we have not done that type of study.

Comment–Willard Van Engel: Because we know the blue crab is found anywhere from fresh water to ocean salinities, obviously these parasites (protozoa) are not expected to tolerate all ranges of salinity. You pointed out some differences in temperature and some problems with regard to oxygen. I am particularly interested in *Paramoeba perniciosa*; the places where you found it to be a problem, and how you found salinity regimes in these instances.

Comment–Couch: I am sorry I did not mention that, Van. That is a good point. I went through it rather hurriedly because I had several different protozoans to present. I should have concentrated more on *Paramoeba* because it is the prime protozoan pathogen of blue crabs in this country along the eastern seaboard. I think it plays a considerable role, much more than it has been given credit for, in causing fluctuations in abundance of adult crabs along the east coast. Now, in relation to salinity, *Paramoeba* is found usually in crabs that occur in salinities above about 18 to 20 ppt. We have found it, thanks to Van's help, in crabs from the lower Chesapeake Bay area, but again the salinities were up to 20 parts per thousand or above. I did a comparative study of the distribution of *Paramoeba* in crabs from the highly saline Chincoteague Bay area, which is an Atlantic coastal estuary and the mouth of the Chesapeake Bay, the York Spit Light area, from where a man was sending us crabs. I found *Paramoeba* in crabs from the lower Chesapeake Bay, but not on a predictable basis; the appearance was sporadic whereas in the Chincoteague Bay area, with a salinity of about 30 ppt or better consistently (usually year around), we found them on a predictable basis in May and June, and also in winter crabs. I forgot to mention that we first observed crabs that had died in the winter dredge fishery from Chincoteague Bay along the Atlantic coast. They harbored very heavy infections of *Paramoeba*; no one had suspected that before. People suspected these dead crabs, which had been dredged up, had died from temperature stress alone, you know extremely cold water temperature. But we looked at these crabs and found *Paramoeba* in their tissues from October through January; perhaps a combination of cold temperatures and parasitic stress resulted in mortality.

Comment–Van Engel: In the mid-1960's, mortalities of crabs in the South Carolina area were very evident and production was very low. At that time, there was a research program mounted in that area. I believe you or people you know were associated with that. It has never been clear to me how much you found *Paramoeba* implicated, although I do know it was mentioned as one of the things you found. I would like you, if possible, if you can recall back that far, to tell us the role you think *Paramoeba* played in those mortalities at that time.

Comment–Couch: We first went from Maryland to Georgia to investigate crab kills in 1966 or 67. Sapelo Island was one of the places we visited and studied. The crab kills had occurred and there had been massive windrows of dead crabs washing up on the beaches, in the estuaries, and so forth. By the time we arrived from Maryland, we had only a few crabs to look at that people had collected. We found *Paramoeba* in a fairly low percentage of those crabs, but we did find it there for the first time. No one had really looked or known it was there. Many of them were gray crabs, but there were crabs that appeared to be normal (with white carapace) dying also. One thing we found out later was that in

Paramoeba-infected crabs, when you find an extremely gray crab on the Atlantic coast, it almost invariably does have *Paramoeba*. You can have crabs that are still white in appearance which also have fairly heavy infections of the amoeba; the crabs have not undergone the graying of the carapace yet. In following years, in subsequent studies related to mortality, other people from the Oxford Laboratory and from the University of North Carolina, looked into these kills. They found seasonal occurrences of the amoeba in May and June at levels of 15 to 18% of the crabs examined. I believe, at least I believe intuitively, that *Paramoeba* played a significant role in those mortalities. That is my personal opinion. At that time, people were looking at Mirex, which was being used along the coasts of North and South Carolina, as a possible cause of death for these crabs. There were no Mirex residues of significance found in crabs when they were taken during those periods, therefore, I believe *Paramoeba* probably played a greater role in those crab mortalities than pesticides.

Comment–Van Engel: It seems to me that we have a possible problem here in interpretation of the cause of mortalities, extensive amounts of mortalities, in different geographic areas. I have the impression from the literature, which has been very casually handling the report that came out of that cooperative study in the Carolinas and Georgia, that *Paramoeba* was the primary agent. I disagree entirely with the conclusion reached. Maybe intuitively you feel it that way, I don't. I think that what has happened is that many scientists have casually said well that is the reason–we won't look any further for any evidences of mortality. Admittedly Mirex, DDT, and its derivatives were found to be at very low quantities. I think the possible problem here is that other people have been discouraged or perhaps accepted this as a total explanation of those mortalities during those mid-1960's, and have said we will not look any further. I think that is the danger in this particular instance. That is why I asked John if he would talk to us about *Paramoeba,* but I cannot accept his intuitive answer.

Comment–Couch: I had just the opposite impression. Usually parasitologists and pathologists are rarely called upon to look into mortalities in marine animals until the ecologists, fisheries biologists, and a whole host of other people have had their go at it. My impression from reading the published cooperative report, I think in the little blue book, was that *Paramoeba* was alluded to as a possible cause of the mortalities of the crabs, but still there was a great implication that pesticides may have been involved in the deaths. I did not get that same impression. Another thing, Van, I think what you are referring to, and perhaps you would phrase it differently than I would, is that I would not have said people were discouraged from looking for causes of mortalities of these crabs. Perhaps funding agencies used it as an excuse for not putting more money into the investigation of the mortality, but I think a lot of people would like to follow it up. As a matter of fact, Charlie Johnson at the Oxford Laboratory, followed up on *Paramoeba* as a pathologic agent for several years and is still working on it at Oxford. I think if scientific opinion is misinterpreted like that, it is not the fault of the scientists. Often the scientists have to help the fishery people, and so forth, to look at the right direction for what kind of studies should be done because, in absence of numerical data, I think the intuitive opinion of the experts is all you have. It should not be taken as a point at which to stop because that appears to be the obvious cause. I had a slightly different impression of that. I thought the pesticide people were pushing pretty hard to make it a pesticide-related mortality myself.

Comment–Van Engel: You are correct, and I was in error. The blue book cooperative report, as I recall as you stated correctly, did not state that *Paramoeba* was very heavily implicated. It did mention other things, pesticides, etc. I like your other further explanation.

Comment–Couch: I think when 13 or 15% of the natural population of any animal species, whether it is an aquatic species, terrestrial species, or a human population, is infected with a pathogen which is causing death, we ought to be alarmed. For example, 11 people with *Vibrio,* 11 people out of how many million in Louisiana? Rather, 11 people out of how many thousands that ate blue crabs. That caused quite a significant stir. Eleven people, that's not even part of a percent hardly, and we are talking about 13 or 14% of the blue crab population, for example, with this infection. Thank you.

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METAZOAN SYMBIONTS OF THE BLUE CRAB

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INTRODUCTION

Several metazoans have developed associations with the blue crab, *Callinectes sapidus* Rathbun, and common ones will be discussed below. Because these multicellular animals can be seen, usually without the aid of a microscope, many have received more attention than their smaller protozoan and microbial counterparts. Still, biological aspects of the relationships justify considerably more investigation than already pursued. Additional poorly understood symbionts seldom or never reported also associate with the blue crab, and, when encountered, these deserve attention. The term "symbiont" as used here designates an organism living in a special association with a host. The degree of benefit or harm involving either partner has no bearing on the term. For readers wishing more information, an extensive review (Overstreet, in press) covers metazoans of crustaceans including the blue crab, and a booklet (Overstreet 1978) treats a greater variety of parasites and diseases of the blue crab in a form more suitable for laymen or those unfamiliar with concepts of symbiosis.

SYMBIONTS

Digeneans (Flukes)

All known digeneans infecting the blue crab are microphallids, and most are microscopic. Most prevalent, *Microphallus basodactylophallus* (Bridgman) infects thoracic muscles, hepatopancreas, and ventral ganglion of *C. sapidus* from at least the Chesapeake Bay region to Texas (Figure 1). Of all the flukes, it attracts the most attention from fishermen, consumers, seafood dealers, and biologists because the ascetosporan *Urosporidium crescens* DeTurk occasionally hyperparasitizes it (Figures 1 and 2). When hyperparasitism occurs, pigmented spores deluge the much enlarged, but greatly debilitated, easily visible worm. Consequently, the relatively large brownish-black metacercariae support the common names "pepper-spot" and "buckshot." *Microphallus nicolli* (Cable and Hunninen), *Levinseniella capitanea* Overstreet and Perry, *Megalophallus diodontis* Siddiqi and Cable, a species identified as *Microphallus pygmaeus* (Levinsen) by Hutton (1964), and at least two other undescribed species also infect *C. sapidus* and, in some cases, infect additional species of *Callinectes* Stimpson and other decapods as well. They infect a variety of crab tissues and occur as adults in different mammals, birds, and fishes. With the exception of *M. nicolli*, Richard Heard (personal communication) and his co-workers are studying the biology of all of them.

Cestodes (Tapeworms)

Callinectes sapidus does not commonly harbor cestode stages, but apparently other blue crabs do. *Callinectes similis* Williams in Mississippi hosts a small metacestode (Figure 3) that occurs in large numbers and migrates throughout the thoracic tissues (Overstreet 1978). What may be the same or a similar species was reported from *C. ornatus* Ordway in North Carolina (DeTurk 1940). In addition to a tetrarhynch that occurred in the body cavity of the crab in North Carolina (DeTurk 1940), other cestodes in *C. sapidus* also have been observed, but infrequently (Overstreet 1978). All these worms probably mature only when appropriate elasmobranchs eat infected hosts.

Nemerteans (Ribbon worms)

The nemertean *Carcinonemertes carcinophila* (Kölliker) infests (a term delineating an external relationship, or infestation, as opposed to an internal one called an infection) gills (Figure 4) and egg masses of the blue crab. It also infests other crabs, but *C. sapidus* from high-salinity habitats can be especially vulnerable to heavy infestations by this worm. Its life cycle ensues when an adult female crab deposits her eggs and the worm leaves its mucus capsule that cements two gill lamellae together. Subsequently, the worm migrates to the host's egg mass. There, it secretes a sheath; feeds on the crab eggs; matures, if a juvenile; and mates. The female lays her eggs in the sheath, which later collapses to form a tube in which ciliated larvae develop. Adult individuals return to the crab's gills about the time their food supply hatches. In regions like the northern Gulf of Mexico, few male crabs accompany females to high-salinity water where females normally spawn. Consequently, few males in those regions have infestations.

Nematodes (Round worms)

The blue crab in the northern Gulf of Mexico does not commonly host nematode larvae as do penaeid shrimp and a few other decapods. Occasionally an individual will host the larval ascaridoid *Hysterothylacium* MA (of Norris and Overstreet 1976) (T. Deardorff, personal communication; personal observations), as do a large number of marine animals. Also, DeTurk (1940) mentioned the rare occurrence of an unidentified larva in North Carolina.

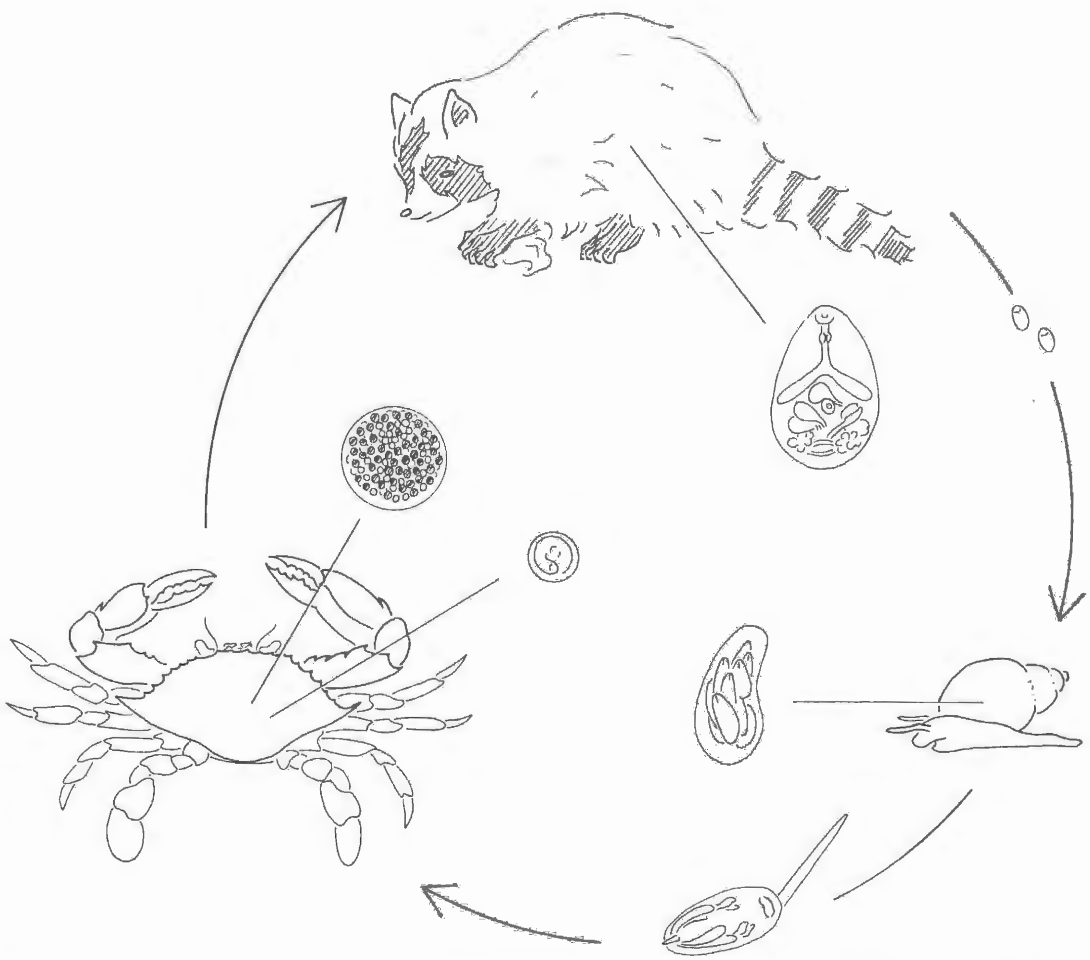

Figure 1. Life cycle of the microphallid digenean *Microphallus basodactylophallus.* The adult worm in the intestine of the raccoon discharges eggs in the host-feces which are eaten by any of several snails. From the enclosed larva are ultimately produced numerous asexually formed swimming cercariae. These penetrate the blue crab and encyst as spherical metacercariae about the diameter of the following period. When hyperparasitized, the encysted worm enlarges to an easily visible size. Nonhyperparasitized worms develop to adults if eaten by the proper final host (from Overstreet 1978).

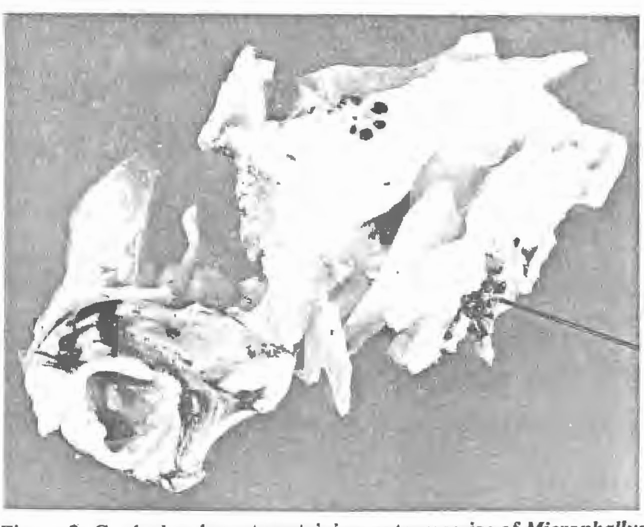

Figure 2. Cooked crabmeat containing metacercariae of *Microphallus basodactylophallus* or buckshot and pepper spots, hyperparasitized by the ascetosporan *Urosporidium crescens* (from Overstreet 1978).

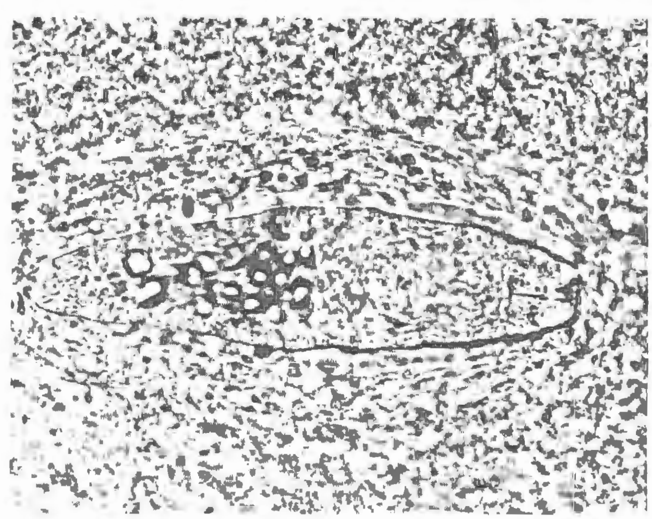

Figure 3. Metacestode of a tapeworm in musculature of lesser blue crab (from Overstreet 1978).

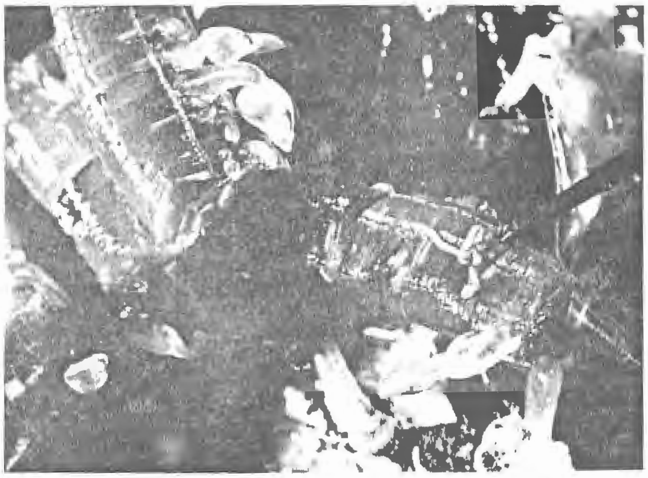

Figure 4. The ribbonworm *Carcinonemertes carcinophila* removed from between gill lamellae. Several specimens of the gooseneck barnacle (*Octolasmis muelleri*) attached to the lamellae (from Overstreet 1978).

Annelids (Leeches and related worms)

Of the three symbiotic annelids seen on *C. sapidus*, all are from low-salinity habitats and two are leeches (Sawyer et al. 1975): *Myzobdella lugubris* Leidy and *Calliobdella vivida* (Verrill). Of these, only *M. lugubris* is abundant on the blue crab, and it utilizes the crab in its life cycle (Figure 5).

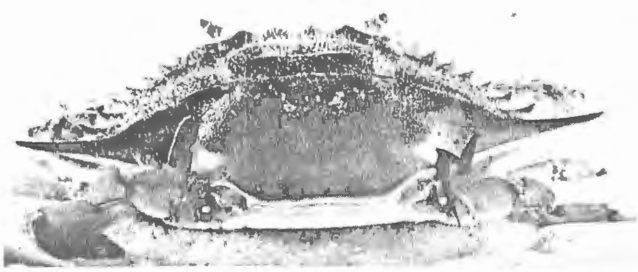

Figure 5. A few individuals of the leech *Myzobdella lugubris* attached to the crab's carapace on which they deposit cocoons.

The young leech feeds on blood from any of a variety of fishes, the most important of which is often different in various localities along the Gulf of Mexico and the Atlantic seaboard. The engorged leech attaches to vegetation, blue crabs, or grass shrimp. When on a blue crab, it deposits numerous cocoons, usually near the posterior margin of the carapace. Many individuals often infest the same individual crab or shrimp. In Mississippi, the male rather than female crab is the usual host, in contrast to the nemertean infestation. Males remain in low-salinity habitats that are optimal for the leech and molt infrequently. The single young leech hatched from each cocoon swims to a fish to repeat the life cycle.

The branchiobdellid *Cambarincola vitreus* Ellis, a worm intermediate between a leech and an oligochaete, also infests crabs when in fresh or nearly fresh water of the northern Gulf of Mexico (Holt 1973). Infestations of this small worm on the gills and carapace reach high numbers when environmental conditions are appropriate. The relationship between this symbiont, which does not feed on the crab, and the crab's health has not been established.

Cirripeds (Barnacles)

Barnacles on *C. sapidus* range from a fouling organism to a true parasite. *Balanus venustus niveus* Darwin and related species usually establish themselves on nonliving hard substrata, but will infest a crab. On the other hand, *Chelonibia patula* (Ranzani) infests a few specific crabs over a wide geographic range (Figure 6). Encrustation on a blue crab in high-salinity water in the northern Gulf occasionally reaches a degree in which the barnacles weigh as much as the crab. The gooseneck barnacle *Octolasmis muelleri* (Coker), perhaps a junior synonym of the widespread *O. lowei* (Darwin) (see Newman 1967), attaches to the gill lamellae (Figures 7 and 8). Over a thousand of these can infest the gills and associated gill chamber of a single crab occurring in high-salinity habitats. Often, the gills have to be lifted to see the barnacles because few occur on the outer surfaces (Walker 1974).

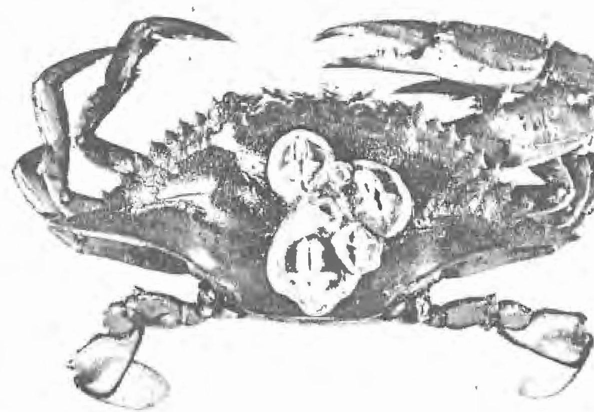

Figure 6. Encrusting *Chelonibia patula* of presumed different ages on the carapace. Less host-specific acorn barnacles also infest the blue crab, often involving appendages.

The truly parasitic *Loxothylacus texanus* Boschma apparently infects only *C. ornatus* and *C. marginatus* (Milne-Edwards) in addition to *C. sapidus*. This extremely important internal parasite (Figures 9 and 10) inhibits growth, terminates reproduction, and removes infected individuals from the fishery. Once the parasite enters the crab, it develops root-like branches that penetrate through muscle of its host. When approaching maturity, the parasite's external sac, or externa, penetrates externally under the abdomen when the crab molts. It ultimately accommodates both male and female reproductive tissues and serves as a brood sac for the nauplii larvae. Typically an infected crab has one

Figure 7. A moderately intense infestation of medium- and small-sized *Octolasmis muelleri*. Whereas most infestations are typically restricted to the "innerside" of the gills, several individuals were seen on the figured specimen upon removal of the carapace.

Figure 8. A histological section through a crab's gill showing the barnacle *Octolasmis muelleri* on the tips of gill lamellae and the ribbonworm *Carcinonemertes carcinophila* between them (from Overstreet, in press).

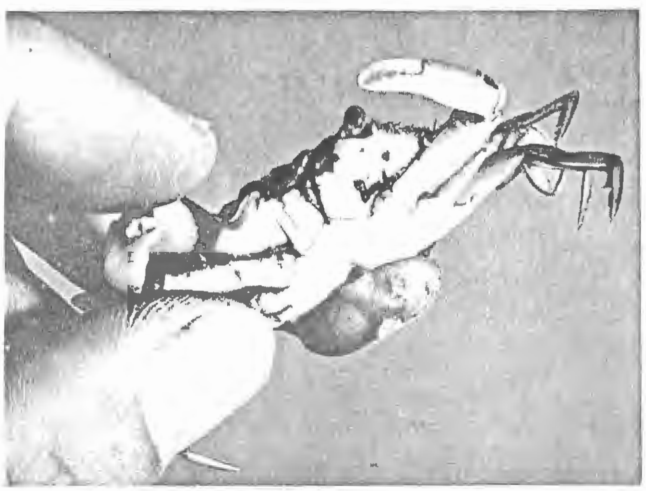

Figure 9. The sacculinid barnacle *Loxothylacus texanus* with its externa protruding under the crab's apron. Infected crabs develop secondary female characteristics of mature individuals. Note the apron appears like that of a mature female.

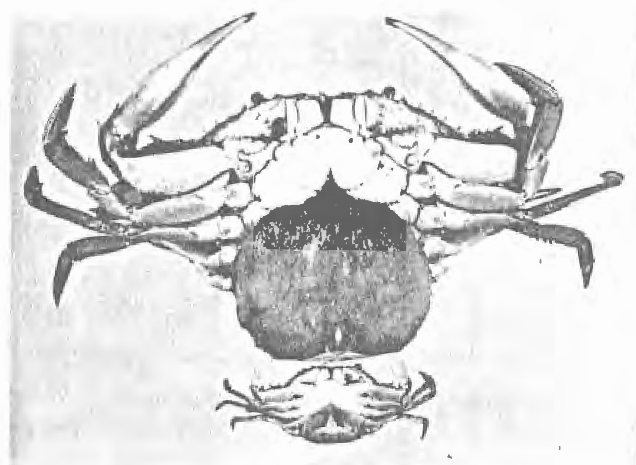

Figure 10. A berried female and a crab with *Loxothylacus texanus* to show the difference in crab size and the difference between an egg mass and externa (from Overstreet, in press).

externa, but can have as many as eight. Crabs infected with the mature rhizocephalan usually range between 3 and 10 cm wide, and male crabs acquire secondary sexual characteristics of a mature female. Ragan and Matherne (1974) reported infections from three Louisiana localities.

Miscellaneous

Isopod parasites often infect specific decapods and may have a substantial effect on their hosts' populations. To my knowledge, however, no blue crabs have been reported as hosts of isopods.

Many animals, such as the barnacle *Balanus venustus*, that attach to a variety of substrata other than the blue crab (most of which are nonliving) can be considered fouling organisms rather than symbionts. On the other hand, because the barnacle *Chelonibia patula* is restricted to certain crabs, it can be considered a symbiont. The ctenostomate ectoproct *Triticella elongata* (Osburn) also fits the classification of a symbiont (Maturo 1957). It also infests other crabs such as *Pinnixa chaetopterana* Stimpson which usually accommodates much heavier infestations than the blue crab. Heavy infestations of this bryozoan often extend from the branchial chamber to bases of legs. It occurs rather commonly along the Atlantic seaboard in high-salinity habitats.

Organisms on the blue crab like the American oyster attaching under the crab's abdomen and hydroids (e.g., *Obelia bidentata* Clarke and *Bougainvillia* sp.) which can attach to any of a variety of hard substrata should be considered fouling organisms. These plus polychaetes, mussels, sponges, bryozoans, algae, and other organisms also foul crabs, but usually do so when the host is in high-salinity water.

MANAGEMENT

Some metazoan symbionts of the blue crab either detrimentally affect the host or reflect the host's actions and, therefore, should be considered when discussing management of that crab. Some symbionts are also potential human pathogens.

Of the several metazoan symbionts that harm the blue crab, *Loxothylacus texanus* probably influences crab stocks most. Infections of this rhizocephalan barnacle apparently occur regularly in Louisiana, but epizootics in Mississippi and many other regions are periodic. Overstreet and Perry have been investigating both the disease and infected crabs from Mississippi during the last few years. Because the parasite inhibits host growth, infected crabs do not usually reach commercial size. We have seen samples with over half the crabs infected, and crabbers have complained about the high proportion of small "button crabs" comprising their catches during specific periods. These small crabs may be infected individuals lacking externae. In Moreton Bay, Australia, an estimated monetary loss equivalent to 10 to 15% of the crab catch was attributed to infections by a related rhizocephalan (Lester 1978).

Most parasites have evolved a relationship with their crab host that assures the well being of both partners. Consequently, the digeneans, cestodes, and nematodes seldom harm their hosts. A few species related to those on the blue crab affect their hosts in a manner that makes the crustacean host especially vulnerable to predation by the appropriate final host of the respective parasite (e.g., see Overstreet 1978); none of the helminths infecting the blue crab has been reported to alter the host's behavior in its natural environment. However, when infected with many individual larvae experimentally, and presumably when naturally in confined spaces, the blue crab can be detrimentally affected and even killed.

Symbionts are occasionally falsely accused of harming the blue crab. In some cases when visible organisms occur on dying crabs, they are accused of causing the mortalities. More than likely, the diseased crabs have a microbial infection or are physiologically stressed. Recent abundance of fresh water released by the Bonnet Carré Spillway into Lake Pontchartrain and ultimately Mississippi Sound has helped promote an abundance of otherwise relatively scarce or periodic infestations of the branchiobdellid *Cambarincola vitreus*, commonly called a "mullet bug" in some localities. Some crabbers blame the worms for poor condition, inhibited molting, loss of appendages, and even death of crabs. Probably excessive fresh water or an altered diet is more responsible for the debilitating conditions than the easily observed worms. The leech *Myzobdella lugubris* also has been blamed, probably falsely, for mortalities of crabs in low-salinity habitats.

The effect of external symbionts and fouling organisms on the blue crab is quite another matter. In the northern Gulf of Mexico, female crabs that have already spawned at least once are affected most. There is no estimate of the potential increase in stocks that would result if females did not get fouled.

In crabs offshore from the barrier islands off Mississippi, encrusting *Chelonibia patula* occasionally accounts for a high proportion of a crab's total weight. This burden probably makes infested individuals vulnerable to predators. Also, a respiratory burden probably is placed on crabs having the barnacle *Octolasmis muelleri* which cements itself to the tips of many lamellae or the ribbonworm *Carcinonemertes carcinophila* which adheres lamellae together. Once either of these organisms infests a host, that host begins to lose its ability to clean its own gills of debris. Ultimately, the symbionts plus the degradation of entrapped organic material and associated microorganisms all increase and compete with the host for available oxygen. Such stressed hosts are vulnerable to predators, pathogenic viruses, bacterial infections, and probably an early natural death. They typically appear more sluggish than their non-fouled counterparts. Dead spent female crabs with encrusting symbionts occasionally occur along barrier island beaches in the northern Gulf of Mexico (Perry 1975), but whether the symbionts cause, aid, or accelerate death should be established.

Norse (1978), who has examined numerous individuals of several different portunid crabs, noted that most species which inhabit a wide salinity regime were more susceptible to fouling when in high rather than low-salinity habitats. In contrast, related crabs which restrict their range to high-salinity water had a low susceptibility to fouling in that habitat.

Some of the same organisms that can harm a crab can also aid persons involved in management of the host stocks. As one example, if specimens of *Carcinonemertes carcinophila* on the gills are orange in color, that indicates the worm has fed on the host's egg mass. That, in turn, shows the observer that the crab has spawned at least once (Hopkins 1947). As another example, the presence of *Chelonibia patula* (and several other ectosymbionts) in the northern Gulf of Mexico indicates that the crab probably has been offshore because the cyprid larva requires high-salinity water (Lang 1976). Also, the size of barnacles indicates for how long the crab had been in those conditions.

A final matter that should be contemplated when considering the blue crab as a seafood product is the potential danger of impairing the health of consumers and crabbers. All microphallids should be considered potential parasites of man, if he eats the host raw. Most of these digeneans will infect a variety of mammals, but seldom harm them. On the other hand, eggs of *Microphallus breviceca* (Africa and Garcia), a close relative of *M. basodactylophallus*, have been found in lesions in the heart, brain, and spinal cord of persons dying in the Philippines from acute cardiac disease (refs. in Faust et al. 1970). The most prevalent microphallid and helminth in muscle tissue of *C. sapidus* throughout much of its range is *M. basodactylophallus*!

Some ascaridoid nematodes have been implicated in anisakiasis, a human disease which can cause severe abdominal or intestinal pain and even death. The single species identified from the blue crab has not been shown to penetrate the alimentary tract of mammals, as has a close relative found in several penaeid shrimps, other invertebrates, and fishes. Presumably that worm can infect the crab also, but infrequently.

A few of the microbial agents infecting blue crabs that also cause disease in man will be treated separately in this colloquium.

When consumers cook the blue crab, heat kills the parasites and other harmful organisms. However, some gourmet chefs, especially oriental ones, suggest eating crab and its juices uncooked for enhancement of flavor. The blue crab should be cooked.

ACKNOWLEDGMENTS

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NOTE ADDED IN PROOF:

In regard to fouling organisms, Pearse (1947. *J. Parasitol.* 33[6]:453–458) reported invertebrates in addition to *Carcinonemertes carcinophila* and *Octolasmis muelleri* from the blue crab in North Carolina. These were a stony coral (*Astrangia danae* Agassiz), a soft coral (*Leptogorgia vingulata* Lamark), a zoanthid (*Epizoanthus americanus* Verrill), a bryozoan (*Alcyonidium polyoum* [Hassall] as *A. mytili* Dalyell), an amphipod, and a tunicate (*Molgula manhattensis* [DeKay]). All those species do not occur on the blue crab in the northern Gulf of Mexico. Generally, the organisms attached to the blue crab in any particular region are the corresponding, common, sessile, high-salinity species and associated organisms of that area. Richard Heard (personal communication), who has examined heavily fouled, postspawning females in both Georgia and the northern Gulf of Mexico, recollects at least 30 fouling species on encrusted, postspawning females in Mississippi. These include bryozoans, caprellid amphipods, and at least five hydroids. Large male crabs occasionally host the bryozoans *Membranipora tenuis* Desor and *Conopeum tenuissium* (Canu), the latter which when in low-salinity water has some altered morphological features and can be mistaken for *M. tenuis.* Rather than being attached to the crab's carapace, the high-salinity sessile forms usually attach to the barnacles *Chelonibia patula* and *Balanus venustus niveus.*

DISCUSSION

Q. What are the depth ranges of the two species of barnacles?

A. Robin Overstreet: I don't know what the relationship is with depth. I know that both of these have particular feeding habits. If you feed them a variety of algal sources, the different ones will feed on different algae. If you take something like *Balanus*, *Balanus* will feed on anything that you give it. If you take *Chelonibia*, it will only feed on particular ones. I think much more important than depth, other than maybe the sunlight and where the naupliar or the cyprid larvae are, is temperature. There is a delimiting point of about 15 degrees, and below that you do not get your infections. This temperature is such that cyprids no longer will invade crab tissues, and, also, it will stop feeding activity of the barnacles.

Q. Willard Van Engel: I might have a comment to make concerning this. Are you thinking of the *Octolasmis* and *Chelonibia* barnacles? Is this what you are referring to?

A. Overstreet: Right, *Octolasmis muelleri* can be included.

Comment–Van Engel: In Chesapeake Bay, we commonly find a combination of parasites (commensals) on female blue crabs. Very commonly you get, *Carcinonemertes*, the nemertean on the gills, red or orange in color, indicating that the female crab has spawned. You get *Chelonibia patula* on the carapace, indicating that the animal has been in a high-salinity environment. You get *Octolasmis lowei (muelleri* might be the correct species name) on the gills. You get *Triticella*, the ectoproct, in the gill chamber. So you get all four, perhaps all of them being present, but certainly maybe one of the four, two or three, or all four of them on adult females that we find in the southern end of the Chesapeake Bay in the high-salinity waters–and they often move up into the mouths of the two tributaries of the lower part of the Bay–so I do not believe that we find these with any reference to depth.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 89–92.

BLUE CRAB MORTALITIES ASSOCIATED WITH PESTICIDES, HERBICIDES, TEMPERATURE, SALINITY, AND DISSOLVED OXYGEN*

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Commercial fisheries landings of the blue crab in the Chesapeake Bay have fluctuated widely since the late 1920s (Figure 1). Records of annual landings prior to 1929 are sparse and permit little more than a guess of trends, although a discontinuous series of catch records from 1907 to 1926 from individual watermen, on file at the Virginia Institute of Marine Science (VIMS), may provide sufficient baseline data for interpretations or estimates of trends in the early period.

Fluctuations in landings result primarily from variations in crab year-class strength and the distribution of the stock, both of which are largely determined by density-independent factors of the environment. Spawning stocks are believed to produce numbers of larvae in excess of what is needed to maintain the adult population at a high level. The effect of environmental variables on year-class strength cannot clearly be determined when annual landings are used as the measure of fishing success. Annual landings in the Chesapeake are derived predominantly from two separate year classes of crabs, while a third year class may contribute about 5% of the catch. Retabulation of the data into 12-month biological-year landings from September of one year through the following August, feasible only since 1960 when monthly landings data were first published by the National Marine Fisheries Service (NMFS), permits the identification of single year classes, with an approximate 2-month overlap of adjacent year classes in mid-summer.

Although the exact mechanisms through which environmental variables affect year-class strength are unknown, it is expected that they occur at critical times in the life cycle of the blue crab. We have identified four major stages in the life cycle: (1) egg extrusion (spawning), hatching, and growth of larvae, (2) larval and early post-larval (megalopal) distribution, (3) the juvenile stage distribution, and (4) adult

*Based on a talk given at the Blue Crab Colloquium, sponsored by the Gulf States Marine Fisheries Commission, October 18, 1979, Biloxi, Mississippi.

VIMS Contribution Number 1016.

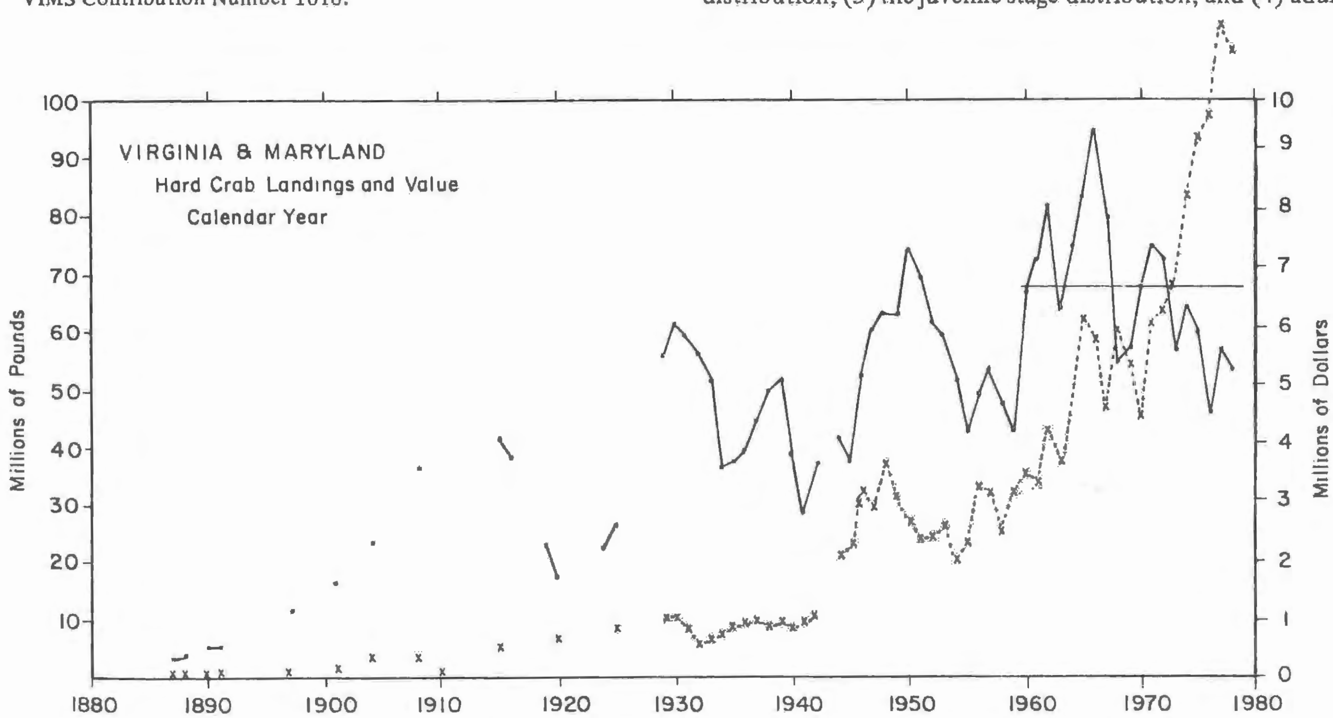

Figure 1. Commercial blue crab landings in the Chesapeake Bay area.

distribution. If managerial decisions are to be made to protect the blue crab resource, then both qualitative and quantitative information regarding the resource must be better described, including its relationship to chemical, physical, and biological factors of the aquatic ecosystem, as well as its economic value. There is a growing awareness of the effects of specific factors on aquatic life. Temperature, salinity, and substrate are the primary factors affecting growth, survival, and distribution of the blue crab. That these factors are optimal in the Chesapeake Bay is suggested by the fact that hard-shell crab landings by Virginia and Maryland watermen account for 45% of the total of east and Gulf coast landings (of those that are reported).

Surface water temperature in the bay normally ranges from 30 to 80°F, with lower and higher values being recorded. Salinities where crabs have been found range from fresh water to 34 ppt. Male crabs and juveniles of both sexes adjust to low salinities at low temperatures during winter when crabs are in the tributaries of the bay. Adult female crabs cannot adjust to these conditions in winter. Their migration each fall to the deeper waters of the southern end of the Chesapeake Bay, where salinities are greater than 15 ppt and temperatures are greater than 38°F, removes them from the stress in most winters. Watermen relate extreme winter cold to large dredge catches of dead female crabs in winter and a subsequent scarcity of crabs in their catch the following spring. After the extreme cold spells in the Chesapeake region in January 1977 and in February 1978, dead crabs were found in the dredge catch through March, varying from 20% of the catch in the southern, more saline portion of the bay, to 100% at the Virginia-Maryland border, where the salinity averages 15 ppt. Landings of crabs from January through May 1977 were only 29% of the 5-month average catch for the prior 18 years, and landings from February through May 1978 were 50% of the 4-month average landings of the last 18 years.

Eelgrass (*Zostera*) beds and tidal marshes are nursery grounds for juvenile blue crabs. The decimation of eelgrass, beginning in 1973 in the Chesapeake Bay and continuing to the present, coincides with a gradual decline in blue crab landings. In 1972, the Chesapeake Bay blue crab catch was 72 million pounds. The catch declined to 45 million pounds in 1976, a decrease of 37%. A striking parallel exists between the recent decrease in landings and the reduction in landings between 1930 and 1934. The commercial catch of 60.5 million pounds in 1930 declined to 36 million pounds in 1934, a decrease of 40% over 5 years. Explanations are varied for the die-off of the eelgrass in these two periods, separated by over 40 years. Warmer than normal winter and summer water temperatures occurred in the bay since 1972; these variations would discourage regrowth in winter and encourage massive defoliation of eelgrass in summer. Cownose rays, which cause destruction of eelgrass beds by digging for bivalves for food, are not believed to have been numerous enough to cause more than isolated instances of the disappearance of eelgrass. Herbicides are a potential pollutant and would be delivered to the rivers and the bay along with other chemicals in agricultural runoff. Their affects on eelgrass are now being studied. The original demise of eelgrass in the early 1930s in the Chesapeake Bay has frequently been ascribed to a mycetozoan called *Labyrinthula.*

Alternative evidence has been given that *Labyrinthula* does not kill *Zostera* but invades already destroyed plants. Also, it has been suggested that the 1930 *Zostera* die-off could have been caused by abnormal winter temperatures.

That commercial crab landings did not disappear during these two episodes suggests that the eelgrass beds are not the sole nursery grounds for blue crabs in the Chesapeake Bay. The value of tidal marshland as a nursery ground should be investigated.

Low pressure centers accompanied by high winds over the southern end of Chesapeake Bay occur frequently in winter. Winds blowing onshore or offshore for long periods of time produce large magnitude water currents, called wind tides. When the wind is blowing onshore, there will be a strong onshore surface current and a strong offshore subsurface current. The strength of these currents will be enhanced in relatively shallow water, such as in the Chesapeake Bay and on the Virginia coast, and when there is a large atmospheric pressure difference occurring in the passage of a storm center.

Apparently, crabs on the bay bottom can be helplessly swept along by these currents, and their shells abraded by the rough, sandy bottom. On February 16, 1964, thousands of dead female blue crabs were washed ashore at Virginia Beach, on the ocean side of Virginia, south of the mouth of the bay. These females had matured and mated the previous fall and could have spawned in about 4 months. They were not old, not reproductively exhausted females such as are seen dead along the southern shore of the bay each fall. Their top shells were smoothly abraded, superficially exposing a chalky layer, but often the shell was worn through. On March 6, 1969, the day after a storm had moved through the southern end of the Chesapeake Bay, over 40% of the crabs caught by crab dredgers had abraded shells; one half of them were dead. The abrasions were distinctly different from the marks of dredges. About 14% of the crabs were crushed, or had dredge tooth marks through the carapace or were missing the carapace. Atmospheric pressure at the center of the low was 972 mb at its passage through the southern end of Chesapeake Bay on March 5. The position of the low at 0700 EST on March 7 is shown in Figure 2.

Variations in the chemical, physical, and biological factors may be man made. Some have been described as being stresses on water quality and act upon physiological processes or ecological relationships or both. Pollution crises have become more common in news headlines, not because more of them are occurring now than there were

FRIDAY, MARCH 7, 1969

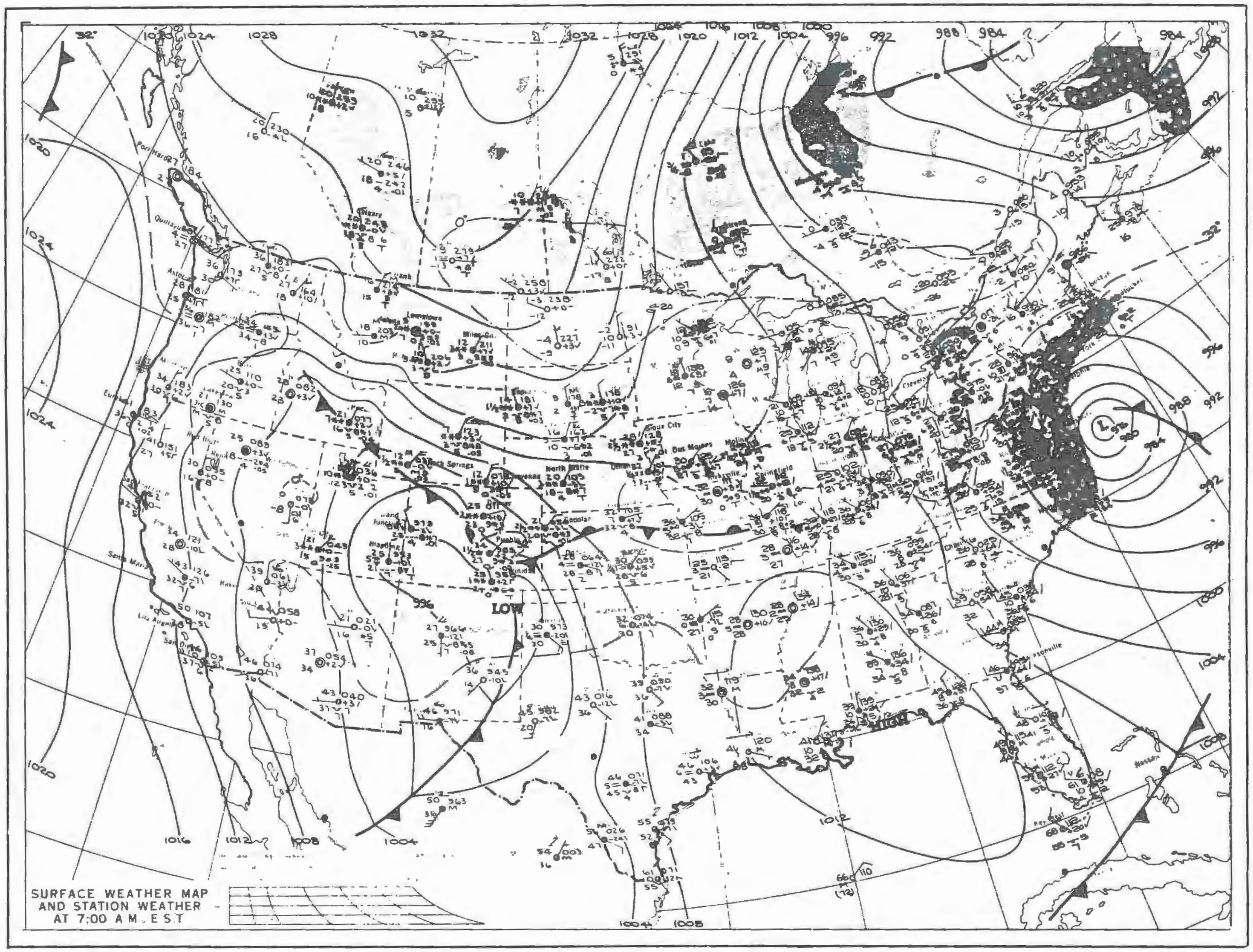

Figure 2. Weather map for Friday, March 7, 1969, showing position of low pressure at 0700 EST at the southern end of Chesapeake Bay.

25 or 50 years ago, but because we have developed more sensitive types of analytic instruments, devised better field sampling techniques and performed more numerous and more accurate, acute and chronic bioassays of potential pollutants on marine and estuarine organisms.

Awareness of chemical pollutants grows larger every year. Dichloro-diphenyl-trichloroethane (DDT), which had the most widespread use of all pesticides in the Chesapeake region from the end of World War II until the early 1970s, produced a characteristic paralysis and, ultimately, the death of blue crabs that were directly exposed or had consumed contaminated carcasses of other animals. The annual mortality from this pesticide remains unknown. The chlorinated hydrocarbon pesticide Kepone, released into the James River from the late 1950s to late 1975, was more restricted geographically in the Bay than was DDT. Mortality and lower rates of molting of crabs can be caused by the accumulation of the insecticide through consumption of contaminated live or dead animals which had accumulated Kepone. Commercial landings and juvenile crab abundance estimates have been lower in the James River than in the adjacent York and Rappahannock rivers for the past 15 years. However, the contribution of Kepone-related mortality to total deaths is unknown. There are numerous other potential sources of mortality in the James River. Between the James, York, and Rappahannock rivers, stresses on water quality are greatest in the James which has the heaviest industrial and municipal uses.

Sediment is the most significant pollutant from agriculture affecting water quality, although little is known of the full nature of its effects except for physical alteration of the substrate and reduction of light penetration. Pesticides, herbicides, fertilizers, and animal wastes, which are carried off the land, are potential aquatic pollutants dissolved in the water or adsorbed on sediment particles. Soft-shell crab shedding losses dramatically increase following each heavy rainfall in summer in the Chesapeake region, especially when the water is colored with suspended sediments.

Isolated instances of crab and fish mortalities occur in small tributaries following excessive freshwater runoff. Rapid decomposition of organic matter washed from the land, and decomposition of animals and plants killed by fresh water deplete the oxygen from the upper reaches of the tributary. The oxygen-depleted water mass then moves downstream with an ebb tide and a wave of mortalities ensues. After heavy rains in Norfolk, Virginia, in August 1949, refuse from a city sewage outfall overflowed into the Lafayette River. Decomposition and the resulting depletion of oxygen killed thousands of fish and crabs. Dissolved oxygen ranged from 0.2 to 1.4 ppm.

Low levels of dissolved oxygen are barriers to the migration of juvenile crabs from high salinity waters at the southern end of the bay to the brackish waters of the tributaries, and barriers to foraging by all sizes of crabs in the deeper channels of the rivers. Oxygen depletion in the deeper waters of Chesapeake Bay and in the Rappahannock, York, and James rivers occurs frequently in middle and late summer. Over the past 30 years, commercial crab-pot fishermen have frequently reported dead blue crabs in pots set in summer in deep waters in the mouth of the Rappahannock River and along the western shore of the Bay from the Patuxent River, Maryland, to New Point Comfort, Virginia.

During juvenile blue crab abundance surveys in the Potomac River in 1979, the only year we have trawled in that river, we found dissolved oxygen levels in the deeper waters to be as low or lower than those in other rivers we surveyed.

In summary, I have described probable important causes of mortality among blue crabs in the Chesapeake Bay. Intuitively and through circumstantial and some direct evidence, I believe that 10 to 50% of the crab population may die at any one time from one or a combination of physical and chemical factors.

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THE BLUE CRAB FISHERY OF THE GULF OF MEXICO

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ABSTRACT The blue crab fishery in the Gulf of Mexico has increased in reported landings and dollar value while other fisheries have decreased in total volume or have remained stable. Approximately 40 million pounds of live crabs are reported annually with Louisiana providing over one third of the production. Little has changed in harvesting technology since the introduction of the crab pot. The biggest impact on the $10 million industry has been the incorporation into east coast markets.

INTRODUCTION

Callinectes sapidus Rathbun is an equal opportunity employer utilizing an estimated 2,500 fishermen to catch a reported 40 million pounds of live product from the warm and fertile waters of the Gulf of Mexico.

There are stories to be told between the predawn excursions from darkened docks to the candle-lit dining rooms of expensive seafood restaurants and the blue crab is the protagonist. Caught by a kid with a chicken neck on a string or jerked up in a crab pot to become part of a 1,200-pound per day haul, this tasty crustacean provides recreation, employment, and good eating for any who will try or buy.

To discover the total economic impact of the industry, economists apply a type II multiplier of 3.12 to landing values which delivers a $31 million pie (Grubb 1973). That pie is sliced up between fishermen, fish houses, processors, pickers, dock jockeys, truckers, ice plants, container manufacturers, retailers, restaurants, air lines, and bait dealers; wire for traps, buoys, ropes, gloves, gas and diesel, parts, maintenance, boats, trailers, and motors, slickers and boots, all paid for out of the income from one aggressive, prolific, little animal whose main role in the economy of life is to clean up the waters around it, an effective, tireless garbage man.

Unlike the elitist swordfish or the secretive, migratory shrimp, the crab is seafood for the common man. No need for ocean-going vessels and expensive electronics or gear. The crab can be captured from jetty or bayou; off the bank or in an open skiff. Crabbing is the least-expensive fishery to enter, requiring minimal capital outlay even though crab meat is among the most expensive proteins on the market. Presidents dine on crab au gratin while "common" folks crack boiled crab taken from the bay at no expense and easily prepared on an open fire.

For all the egalitarian benefits and despite the significant economic factors, the blue crab fishery remains the best kept secret in the Gulf. The resource is subject to minimal regulation and even more nonchalant enforcement. "All other crabs (except egg-bearing females) may be taken in any number at any time and by any method . . . *A Guide to 1980-1981 Texas Hunting & Sports Fishing Regulations.*" Such rigid restrictions are ameliorated by the fact that the fisherman doesn't even need a license unless he intends to go commercial.

If regulations and enforcement are lax, the reporting system could qualify as creative writing. The reporting effort has serious problems recording accurately the daily commercial landings (Jaworski 1972). Recreational catch is an estimation (Walter Tatum, personal communication). Bootlegging, trucking, and roadside selling are almost untraceable. There is no doubt that Louisiana produces the most crabs. It has the most estuaries and wetlands. But, does Louisiana harvest 16 million pounds live weight or 60? As a resource manager, where would one set an optimum or maximum sustainable yield? There is no doubt that 1973 and 1977 were excellent crop years, and there is no doubt that the summer months and early fall are the most productive. But, if the harvest of crabs is determined not by available resource stocks, but is determined by the number of pounds of crabmeat sold and the production capacity of a processor, where does the manager draw the line to protect the breeding stock?

Any plan to effectively monitor the industry must consider the following to secure accurate data and to validate any conclusions drawn from that data.

Political Support

Voluntary reporting is not effective. Legislative mandates with built-in penalties and deadlines have proven a valid method for obtaining statistics. Without the mandate and certainly without penalty, the industry is left to its own morality to provide information accurate enough for decision making. Such legislation is the responsibility of sovereign states. Enforcement is the responsibility of the state regulatory agency. It is doubtful that political support for mandatory legislation can be achieved without an industry association calling for such legislation. Unfortunately, it does not appear that industry organizations are inclined to request their own policing. State agencies with resource management responsibilities may need to take the lead in requesting legislation. However, it is difficult for a state agency to influence the political structure. Without legislative mandates statistical analysis is crippled from the beginning.

Education of Processors

The bulk of the blue crab catch is purchased by crabmeat producers and live crab shippers. The necessity of producing a wholesome product has placed the processor under the regulatory authority of state health departments. However, the health department is interested in the quality of the product and not in the quantity. The processor is forced by economics to determine the number of pounds of live crab purchased and the number of pounds of crabmeat product processed. With the processor identified and the record keeping already established, it would appear that the bulk of the landings of blue crab could be determined if proper education of the processor was undertaken. The main deterrent here is a lack of faith in the confidentiality of the information and the ultimate use of the information. There must be some method to assure confidentiality and to ensure that the end use of the information is for resource management that will ultimately upgrade and benefit the industry. This is the responsibility of a convinced industry association.

Nonreported Use of the Resource

Bootleg activities are clandestine by necessity. Roadside vendors, recreational fishermen, direct-sale fish markets, all affect the landings. There is no problem that money cannot solve. Creel surveys, and investigation of roadside vendors have been successfully conducted. The problem of bootlegging is a difficult matter.

Licensing

It is generally agreed by those who are charged with the responsibility of regulation that it is necessary to license commercial and recreational crabbers. The purpose is not to gain financial benefit to the state, but rather to identify who is harvesting the resource. Without this information, regulation and data keeping are difficult.

Tagging Pots

The identification of the harvesting instrument is a key to managing the resource because it provides information concerning catch and effort. It is also helpful in preventing theft. There are no restrictions of the industry in the determination of how many units are involved in the harvesting of the resource.

With the preceding suggestions implemented, it is possible that an accurate statistical base could be developed and responsible management decisions made.

HISTORY OF EXPLOITATION

History does not record the name of the seafood hero and venturesome gourmet who first beheld the spidery clawed crustacean and began to think of dinner. Our hoary forefathers may have observed the ever-present gull dining on crab or perhaps in the stomach contents of a recently slain dinner of drum; he may have seen the partially digested remains of *Callinectes sapidus* and then reasoned that the animal was good to eat. Whoever is responsible for the first pursuit, capture, demise and devouring of that delectable delicacy, the Blue Crab, he or she did us all a favor. At the tomb of the unknown seafood gourmet, we lay our grateful wreath bearing the legend, "To Whom It may Concern."

In the light of cold statistics, the first Gulf states to record landings were Louisiana and Texas in the year 1880. It was 1927 before all five states reported landings. It was 1936 before any significant amount of crabs was reported. The statistical effort ceased during World War II, and resumed in the middle 1940's.

The first crab-picking plants were begun in 1924 in Berwick and Morgan City, Louisiana. In 1934, Westwego began the production of crab meat. Commercial picking plants were developed in 1958 in Texas.

The blue crab industry has not been subjected to the close scrutiny of dedicated historians. It is difficult to determine who has responsibility in this area.

However, following World War II, the industry developed rapidly. Many of those pioneer processors are still available and their fund of information could provide a fascinating picture of the second beginning of the blue crab industry in the Gulf states. It might be important that some agency begin to address this potential.

In the beginning, the crab fisherman utilized longlines or trotlines to gather his harvest. These were simple, inexpensive lengths of line, baited at intervals, and run as soon as they were set. Some lines extended for a mile or more. The crabs were taken from the bait by either a hand-held dip net or by a mechanism in which the line was passed over rollers and the crab dropped into a framed net which was emptied as it filled.

The development of the crab pot in the 1950's was the end of the longline because of the efficiency of the pot. In fact, with the exception of bush lines for peeler crabs, there is no other statistically significant method of taking crabs in the Gulf states.

There is industry resistance to trawl-caught crabs or dredged crabs even though the states have regulations concerning trawls and dredges. The primary factor in the discouragement of trawl-caught crabs is the superior quality of the pot-caught crab and the seasonality factor which brings trawl-caught crabs to the processor at a time when he is receiving ample pot-caught crabs. Trawling or dredging winter crabs concerns many processors, not only because of quality, but because of the lack of information concerning the effect on breeding stock, thus making the industry reluctant to consider these practices. Innovation in pot design consists of refining the basic trap developed in the 1950's and fully utilized in the 1960's.

The seasonal catch of crab is related to two factors in the Gulf. The first factor is water temperature. Crab activity is reduced during cold weather and the catch declines. The second factor is related to biology. High concentration of egg-bearing females, generally illegal to retain, and the lack of marketable large males commonly occur in the warm months. The question of seasonality is addressed by the 11-year chart with quarterly increments (Figure 1), and by the quarterly tables listed by state (Tables 1 through 5).

The question of geographic distribution or "hot spots" can be answered by consulting charts. Concentrations of blue crab are directly related to freshwater inflow. Those areas with the environmental benefits of estuaries and wetlands are blessed with large populations of crabs. Unusual environmental occurrances, such as hurricanes and flooding, have a dramatic effect upon the occurrance of crab populations. It is commonly held that an occasional hurricane, with the flushing out of the bay systems and the stirring up of the sediments (while disasterous to property owners), is beneficial to the ecology of the coastal zone.

Total yearly landings reported for the Gulf states for the 11-year period 1970–1980 are listed in Tables 6 through 10. A production comparison is found in Table 11. Historical catch statistics for the hard- and soft-shell crab fisheries are presented in Tables 12 and 13, respectively. Certain conclusions can be drawn from these tables even though they may represent a less-than-accurate quantitative analysis. Alabama and Mississippi have stabilized their production, fluctuating little from the 2 million pounds annual catch. For the past 3 years, Florida has produced 11 million pounds. Louisiana and Texas are providing the growth of the industry as the fishermen began to utilize more of the available resource which means that more Texas and Louisiana crabmeat products are being sold. Whether or not Louisiana and Texas have reached their full production capabilities is not known.

Table 14 outlines the suspected number of crab fishermen and the suspected number of gear units involved in the crab fishery for 1976.

A Texas blue crab is indistinguishable from a Florida blue crab and the environmental factors are the same whether the bay is called Vermillion or San Antonio or Mobile. But, the regulations concerning the capture of *C. sapidus* differ widely from county line to state boundary.

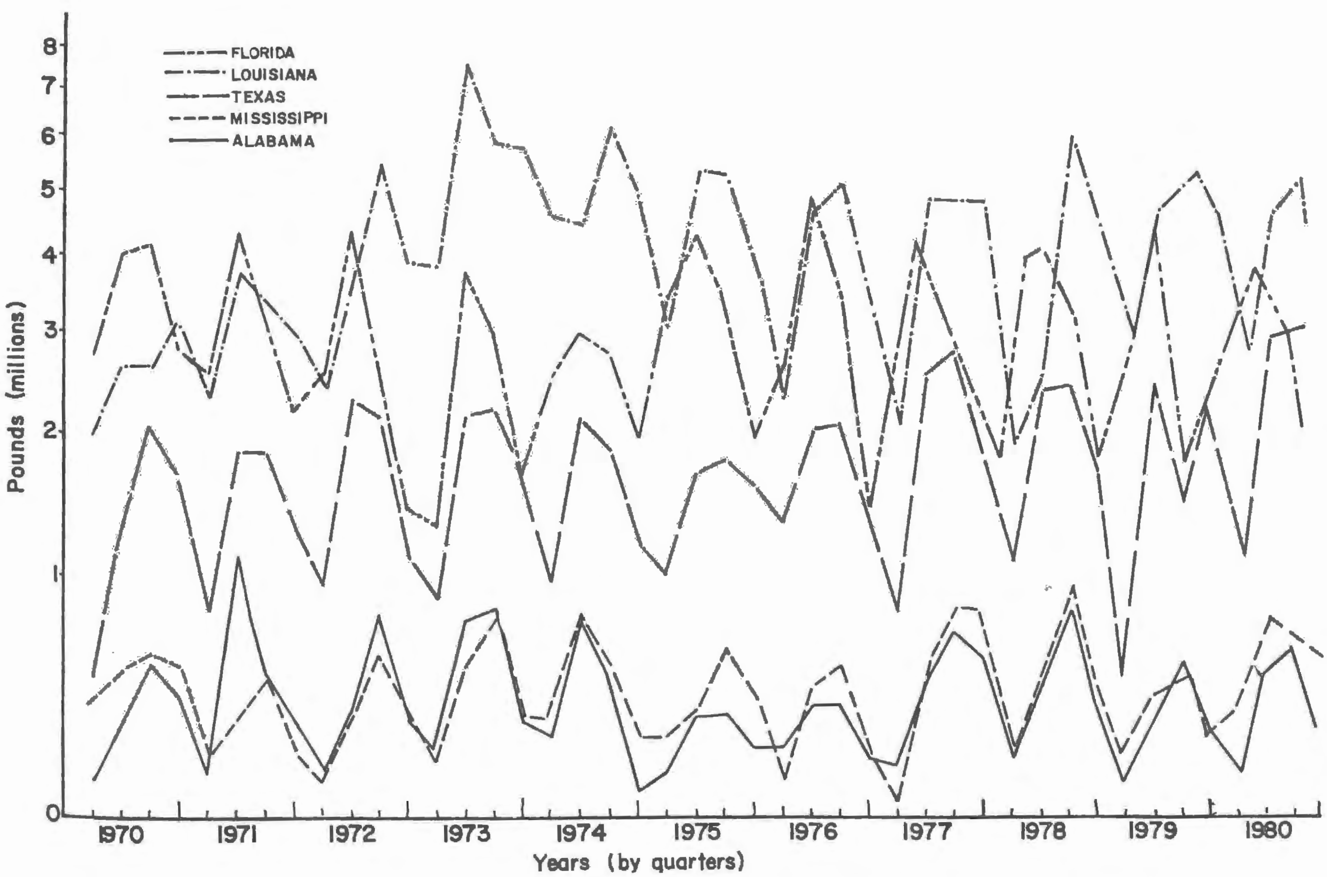

Figure 1. Gulf coast blue crab landing statistics.

TABLE 1.

Florida landings of blue crabs (in pounds).

Year	21% Jan–Mar	35% Apr–Jun	28% Jul–Sep	16% Oct–Dec
1970	2,747,091	3,974,435	4,140,573	2,813,681
1971	2,510,399	4,220,122	3,118,495	2,201,013
1972	2,555,845	4,137,630	2,576,197	1,403,595
1973	1,280,437	3,704,329	2,899,775	1,713,704
1974	2,452,056	2,999,287	2,727,046	1,955,448
1975	3,308,194	4,254,597	3,285,559	1,959,807
1976	2,506,501	4,671,447	3,385,927	1,484,569
1977*	2,499,000	4,165,000	3,332,000	1,904,000
1978*	2,415,000	4,025,000	3,220,000	1,840,000
1979*	2,407,650	4,012,750	3,210,200	1,834,400
1980*	2,365,230	3,942,050	3,153,640	1,802,080

*Extrapolated from annual reported landings.

TABLE 2.

Alabama landings of blue crabs (in pounds).

Year	9% Jan–Mar	31% Apr–Jun	38% Jul–Sep	22% Oct–Dec
1970	118,370	319,296	556,479	413,103
1971	138,257	1,003,951	527,657	327,425
1972	154,590	356,154	773,408	328,254
1973	209,287	756,079	828,693	304,412
1974	250,635	760,567	560,432	254,074
1975	260,330	363,056	616,712	426,386
1976	104,839	440,873	547,321	205,620
1977	49,564	521,160	805,344	798,074
1978	224,576	453,711	862,878	467,761
1979*	118,260	407,340	499,320	289,080
1980*	140,130	482,670	591,660	342,540

*Extrapolated from annual reported landings.

TABLE 3.

Mississippi landings of blue crabs (in pounds).

Year	14% Jan–Mar	29% Apr–Jun	27% Jul–Sep	20% Oct–Dec
1970	399,800	518,240	580,800	528,590
1971	214,660	347,800	478,100	218,450
1972	101,000	306,700	583,000	364,900
1973	179,300	547,850	741,000	346,300
1974	310,920	759,200	473,900	123,000
1975	195,100	329,500	398,700	213,300
1976	214,900	422,000	441,000	192,000
1977	154,000	452,600	713,000	567,000
1978	191,500	532,900	832,500	383,200
1979*	183,540	380,190	485,070	262,200
1980*	384,720	796,920	741,960	549,600

*Extrapolated from annual reported landings.

TABLE 4.

Louisiana landings of blue crabs (in pounds).

Year	17% Jan–Mar	27% Apr–Jun	30% Jul–Sep	26% Oct–Dec
1970	1,948,298	2,635,329	2,604,567	3,066,006
1971	2,374,034	3,518,210	3,393,391	3,026,792
1972	2,428,873	3,420,556	5,418,159	3,917,052
1973	3,838,910	7,757,453	5,877,938	5,725,331
1974	4,588,166	5,386,398	6,039,156	4,721,277
1975	3,007,022	5,257,365	5,207,359	3,782,303
1976	2,373,455	4,498,686	4,994,029	3,433,078
1977	2,109,782	4,771,727	4,751,098	4,764,285
1978	1,858,478	2,512,073	6,036,413	4,497,283
1979*	2,952,900	4,689,900	5,211,000	4,516,200
1980*	2,778,140	4,412,340	4,902,600	4,248,920

*Extrapolated from annual reported landings.

TABLE 5.

Texas landings of Blue crabs (in pounds).

Year	13% Jan–Mar	31% Apr–Jun	32% Jul–Sep	24% Oct–Dec
1970	499,800	1,328,300	2,065,600	1,631,700
1971	777,800	1,887,600	1,858,100	1,286,100
1972	958,800	2,261,400	2,138,900	1,105,300
1973	854,100	2,137,100	2,242,900	1,647,000
1974	953,200	2,084,100	1,863,000	1,187,300
1975	978,300	1,667,600	1,769,000	1,576,600
1976	1,320,200	2,005,700	2,064,300	1,278,200
1977	808,800	2,508,500	2,786,900	2,144,400
1978	1,070,400	2,379,000	2,382,500	1,637,600
1979	546,000	2,425,000	1,617,600	2,150,720
1980*	1,190,280	2,838,360	2,929,920	2,197,440

*Extrapolated from annual reported landings.

Even though crab buyers seldom willingly buy undersize crabs, Texas and Louisiana legislate a 5-inch minimum-size legal crab. Alabama permits a 4-inch minimum. Louisiana, Florida, and Mississippi require licenses. Louisiana and Florida tag and/or color code traps and limit the number to 300 pots maximum per crabber. Most Gulf states prohibit the taking of egg-bearing females. Rules and regulations are presented in Appendix 1.

CONCLUSION

In conclusion, one topic needs to be considered. In the increasing demand for energy and the expanding marine resource-user based, the crab fishery can scarcely compete dollarwise for an equitable share of the already extended environment. It is estimated that 20% of our wetlands have been lost to production. Our nurseries are vital to a continued healthy industry. The really big confrontation is yet to come. Who gets to use what and what can they do

TABLE 6.

Blue crab landings for Florida west coast, 1970–1980.

Year	Pounds
1970	14,786,000
1971	12,279,000
1972	10,673,000
1973	9,599,000
1974	10,134,000
1975	12,807,000
1976	12,048,000
1977	15,832,000
1978	11,679,000
1979	11,198,000
1980	11,263,000

Source: E. Snell, personal communication.

TABLE 7.

Blue crab landings for Alabama, 1970–1980.

Year	Pounds
1970	1,407,000
1971	1,997,000
1972	1,612,000
1973	2,098,000
1974	1,826,000
1975	1,639,000
1976	1,229,000
1977	2,174,000
1978	2,009,000
1979	1,314,000
1980	1,557,000

Source: Orville Allen, personal communication.

TABLE 8.

Blue crab landings for Mississippi, 1970–1980.

Year	Pounds
1970	2,027,000
1971	1,259,000
1972	1,362,000
1973	1,814,000
1974	1,667,000
1975	1,137,000
1976	1,334,000
1977	1,919,000
1978	1,940,000
1979	1,311,000
1980	2,748,000

Source: Orville Allen, personal communication.

TABLE 9.

Blue crab landings for Louisiana, 1970–1980.

Year	Pounds
1970	10,254,000
1971	12,186,000
1972	15,083,000
1973	23,080,000
1974	20,639,000
1975	17,144,000
1976	15,211,000
1977	16,514,000
1978	15,074,000
1979	17,370,000
1980	16,342,000

Source: Orville Allen, personal communication.

TABLE 10.

Blue crab landings for the Gulf and Texas bays (in pounds), 1970–1980.

Year	Gulf	Texas Bays
1970	21,900	5,503,500
1971	61,200	5,748,400
1972	14,400	6,450,000
1973	167,900	6,713,200
1974	39,900	6,047,700
1975	39,700	5,951,800
1976	20,300	6,648,100
1977	11,100	8,237,500
1978	1,700	7,468,000
1979	500	8,311,000
1980	3,600	8,949,400

Source: Jim Morgan, personal communication.

TABLE 11.

Production Comparison.*

State	1970	1977	1980
Louisiana	10,254,000	16,514,000	16,342,000
Mississippi	2,027,000	1,919,000	2,748,000
Alabama	1,407,000	2,174,000	1,557,000
Florida	14,786,000	15,382,000	11,263,000
Texas	5,503,500	8,237,500	8,949,400
Total	33,977,500	44,226,500	40,859,400

*Indicating increased landings over a 10-year period, including peak production year, 1977, for the decade.

to it? The future of the crab industry may not be so much harvesting and processing. The future may depend upon legislation and coastal zone management. These are not areas of high expertise among the crab fishermen. But, the fisherman cannot afford to lose many, if any, more productive wetlands.

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These people deserve all the credit and none of the blame for the information in this paper. Some have moved to other jobs, but at the time, they were helping where listed. Thanks for the help.

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Orville Allen

Others

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TABLE 12.

Historical hard-shell blue crab landing statistics, 1880–1980.
(thousands of pounds; thousands of dollars)

	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1880	–	–	–	–	–	–	288	7	36	1	324	8
1887	(2)	(2)	(2)	(2)	38	1	837	13	111	4	(2)	(2)
1888	3	(1)	96	6	16	(1)	851	13	115	4	1,081	23
1889	–	–	–	–	48	1	842	14	189	5	1,079	20
1890	–	–	–	–	33	1	851	13	191	5	1,075	19
1891	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1892	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1895	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1897	6	(1)	24	1	132	3	1,459	13	138	4	759	21
1898	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1899	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1901	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1902	1	(1)	75	2	235	5	312	16	43	2	1,666	25
1904	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1905	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1908	2	(1)	246	6	380	10	244	8	199	5	1,071	29
1915	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1918	–	–	96	3	216	6	282	10	193	11	787	30
1919	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1920	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1921	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1922	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1923	–	–	84	3	435	11	312	8	109	9	940	31
1924	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1925	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1926	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1927	12	1	32	1	2,426	62	1,091	51	121	9	3,682	124
1928	7	1	102	4	1,518	40	2,320	78	300	12	4,247	135
1929	2	(1)	103	3	1,247	33	2,675	78	163	11	4,190	125
1930	4	(1)	80	1	673	11	4,186	63	29	1	4,972	76
1931	4	(1)	78	1	454	7	4,985	53	49	1	5,570	62
1932	4	(1)	70	1	320	5	5,878	57	45	1	6,317	64
1933	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1934	49	1	257	4	603	7	11,676	164	258	13	12,843	189
1935	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1936	821	12	997	14	2,011	30	12,576	168	320	8	16,725	232
1937	775	12	756	11	1,435	25	14,717	195	922	24	18,605	267
1938	1,104	16	511	8	1,016	17	10,533	106	971	24	14,135	171
1939	722	11	558	8	1,469	25	11,228	129	406	8	14,383	181
1940	1,170	16	1,381	28	1,488	26	14,062	172	252	6	18,353	248
1941	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1942	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1943	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1944	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1945	1,092	54	2,207	110	5,639	282	31,280	1,418	339	39	40,557	1,903
1946	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1947	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1948	(2)	(2)	2,373	119	5,503	275	21,110	608	526	34	(2)	(2)
1949	2,056	91	2,128	106	4,163	208	17,874	555	374	22	26,595	982
1950	684	27	599	26	4,040	202	13,106	599	387	30	18,816	884
1951	2,076	83	1,109	46	1,623	82	8,710	461	280	24	13,798	696
1952	1,984	89	655	39	1,726	86	7,334	314	338	24	12,037	552
1953	3,153	126	1,087	54	1,412	71	8,131	333	432	39	14,215	623
1954	2,903	145	972	49	1,256	68	7,085	294	379	26	12,595	582
1955	4,954	248	1,613	81	1,763	88	10,811	449	356	29	19,497	895
1956	3,728	180	725	36	1,979	99	9,402	433	195	20	16,029	768

TABLE 12 (Continued).

Historical hard-shell blue crab landing statistics, 1880–1980.
(thousands of pounds; thousands of dollars)

	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1957	5,302	318	1,462	73	2,400	144	8,559	419	201	11	17,924	965
1958	8,693	461	1,182	56	2,124	123	9,336	402	570	51	21,905	1,083
1959	13,895	681	1,093	57	3,003	165	9,570	461	1,192	75	28,753	1,439
1960	18,648	895	499	26	2,812	169	10,050	497	2,867	177	34,876	1,764
1961	17,130	736	838	46	2,505	143	11,910	514	2,875	178	35,258	1,617
1962	10,356	487	634	35	907	55	9,523	463	4,473	289	25,893	1,329
1963	13,148	644	1,297	75	1,112	64	7,982	447	2,980	199	26,519	1,429
1964	14,068	843	1,762	110	1,286	82	5,692	379	2,484	175	25,292	1,589
1965	20,598	1,185	1,812	153	1,692	131	9,284	635	3,622	286	37,008	2,390
1966	16,547	912	2,183	182	1,457	105	7,986	537	2,778	228	30,951	1,964
1967	13,976	817	2,353	188	1,015	79	7,559	520	2,625	222	27,528	1,826
1968	9,008	674	1,980	159	1,136	108	9,551	807	4,084	329	25,759	2,077
1969	11,584	1,074	1,920	223	1,740	177	11,602	1,072	6,343	599	33,189	3,145
1970	14,786	1,076	1,407	144	2,027	193	10,254	928	5,525	509	33,999	2,850
1971	12,279	952	1,997	212	1,259	126	12,186	1,256	5,810	567	33,531	3,113
1972	10,673	959	1,613	195	1,362	169	15,083	1,777	6,464	653	35,195	3,753
1973	9,599	1,147	2,098	294	1,815	231	23,080	2,811	6,881	830	43,473	5,313
1974	10,134	1,280	1,826	284	1,667	227	20,640	2,701	6,088	832	40,355	5,324
1975	12,807	1,585	1,640	283	1,137	177	17,144	2,510	5,992	948	38,720	5,503
1976	12,048	1,966	1,299	281	1,335	268	15,211	3,061	6,668	1,179	36,561	6,755
1977	15,832	3,119	2,174	548	1,919	473	16,379	3,765	8,249	1,947	44,553	9,852
1978	11,679	2,235	2,009	458	1,940	423	15,207	3,189	7,470	2,004	38,305	8,309
1979	11,198	2,235	1,314	383	1,311	316	17,370	3,885	8,312	2,146	39,505	8,965
1980*	11,263	2,392	1,557	464	2,748	690	16,342	3,874	8,953	2,456	40,863	9,876

(1) – less than 500 pounds or $500.00.
(2) – data not available.
*Preliminary–added in proof.

TABLE 13.

Historical soft-shell blue crab landing statistics, 1880–1980.
(thousands of pounds; thousands of dollars)

	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1880	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1887	(2)	(2)	(2)	(2)	15	1	133	7	–	–	(2)	(2)
1888	–	–	–	–	40	1	143	7	–	–	183	8
1889	–	–	–	–	19	1	147	8	–	–	166	9
1890	–	–	–	–	15	1	130	7	–	–	145	8
1891	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1892	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1895	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1897	–	–	–	–	21	2	–	–	–	–	21	2
1898	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1899	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1901	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1902	(1)	(1)	–	–	30	3	–	–	–	–	30	3
1904	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1905	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1908	–	–	–	–	47	6	78	21	1	(1)	126	27
1915	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1918	–	–	–	–	9	2	–	–	1	(1)	10	2
1919	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1920	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1921	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1922	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1923	–	–	–	–	9	2	3	1	–	–	12	3
1924	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1925	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1926	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1927	–	–	–	–	8	2	137	48	–	–	145	50
1928	–	–	3	1	67	12	183	52	–	–	253	65
1929	–	–	4	1	12	4	81	25	–	–	97	30
1930	–	–	1	(1)	6	2	146	58	–	–	153	60
1931	–	–	1	(1)	5	1	121	45	–	–	127	46
1932	–	–	1	(1)	4	1	99	25	–	–	104	26
1933	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1934	–	–	2	(1)	4	1	651	86	–	–	657	87
1935	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1936	–	–	1	(1)	3	1	365	53	–	–	369	54
1937	2	(1)	–	–	2	(1)	329	51	–	–	333	51
1938	–	–	–	–	–	–	248	37	–	–	248	37
1939	–	–	–	–	–	–	215	33	–	–	215	33
1940	–	–	–	–	(1)	(1)	252	40	–	–	252	40
1941	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1942	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1943	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1944	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1945	–	–	–	–	–	–	2,370	1,706	–	–	2,370	1,706
1946	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1947	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
1948	(2)	(2)	–	–	–	–	881	440	–	–	(2)	(2)
1949	–	–	–	–	–	–	455	192	–	–	455	192
1950	(1)	(1)	(1)	(1)	–	–	364	165	–	–	364	165
1951	4	1	(1)	(1)	6	2	350	188	–	–	360	191
1952	15	2	–	–	15	4	448	215	–	–	478	221
1953	3	(1)	–	–	(1)	(1)	488	203	–	–	491	203
1954	(1)	(1)	–	–	–	–	455	215	–	–	455	215
1955	1	(1)	–	–	7	3	581	290	–	–	589	293
1956	1	1	–	–	6	1	600	250	–	–	607	252

TABLE 13 (Continued).

Historical soft-shell blue crab landing statistics, 1880–1980.
(thousands of pounds; thousands of dollars)

	Florida West Coast		Alabama		Mississippi		Louisiana		Texas		Total	
Year	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1957	10	5	–	–	17	3	551	192	–	–	578	200
1958	1	(1)	–	–	20	2	577	298	–	–	598	300
1959	3	2	–	–	11	1	605	302	–	–	619	305
1960	4	2	–	–	5	1	514	256	2	(1)	525	259
1961	5	3	–	–	7	1	620	310	2	1	634	315
1962	(1)	(1)	–	–	2	(1)	344	172	6	1	352	173
1963	4	2	–	–	3	1	329	164	2	(1)	338	167
1964	13	7	–	–	2	(1)	200	127	(1)	(1)	215	134
1965	12	9	–	–	1	(1)	204	141	–	–	217	150
1966	1	(1)	–	–	1	(1)	128	85	–	–	130	85
1967	7	4	–	–	1	(1)	146	121	–	–	154	125
1968	–	–	–	–	1	(1)	284	207	–	–	285	207
1969	(1)	(1)	–	–	(1)	(1)	197	161	–	–	197	161
1970	(1)	(1)	–	–	–	–	90	79	–	–	90	79
1971	–	–	–	–	–	–	127	126	–	–	127	126
1972	(1)	(1)	–	–	–	–	102	109	–	–	102	109
1973	–	–	–	–	–	–	119	132	–	–	119	132
1974	(1)	(1)	–	–	–	–	96	127	–	–	96	127
1975	2	1	–	–	–	–	110	155	–	–	112	156
1976	–	–	–	–	(1)	(1)	88	145	–	–	88	145
1977	–	–	–	–	–	–	224	570	–	–	224	570
1978	22	27	–	–	2	1	133	276	–	–	157	304
1979	9	5	–	–	–	–	119	272	–	–	128	277
1980*	16	12	–	–	–	–	79	182	–	–	95	194

(1) – less than 500 pounds or $500.00.
(2) – data not available.
*Preliminary–added in proof.

TABLE 14.

Estimated number of fishermen and gear units for 1976.

State	Number of Full-time Fishermen	Number of Pots
Florida	171	38,930
Alabama	57	10,650
Mississippi	20	2,950
Louisiana	789	144,014
Texas	173	23,375

REFERENCES CITED

Grubb, H. W. 1973. *The Structure of the Texas Economy.* Office of the Governor, Office of Information Services, Austin, Texas. Volume 1. 202 pp.

Jaworski, Eugene. 1972. *The Blue Crab Fishery, Barataria Estuary.* Center for Wetland Resources, Louisiana State University, Baton Rouge, LA. Publ. No. LSU–SG–72–01. 112 pp.

APPENDIX 1.

STATE REGULATIONS – 1981
(added in proof)

FLORIDA

Administrative Organization

Florida Department of Natural Resources, Division of Marine Resources.

License and Taxes

Commercial fishermen – alien or nonresident: $25.00

Processor or dealer – resident wholesale, $100.00; non-resisent wholesale, $150.00; residetn retail, $10.00; nonresident retail, $25.00

Crab pot – permit required.

Laws and Regulations

1. **General Statutes**

Minimum size limits – Except when authorized by special permit for the soft-shelled crab or bait trade, it is unlawful for any person to possess for sale blue crabs measuring less than 5 inches, point to point of shell, in an amount greater than 10% of the total number of blue crabs in that person's possession.

Protection of female crabs – unlawful to sell or offer for sale, any egg-bearing blue crabs.

Restrictions on fishing methods, gear, etc.

(a) Crab pots – no person, firm or corporation shall transport on the waters, fish with, or cause to be fished with, set, or place any trap designed for taking blue crabs, unless such trap has current state permit number permanently attached to the buoy. The permit number shall be affixed in legible figures at least one inch high on each buoy used. The blue crab permit shall be on board the boat, and both the permit and crabs shall be subject to inspection at all times. Only one permit shall be issued for each boat by the Department upon receipt of an application on forms prescribed by it. This subsection shall not apply to any individual fishing with no more than five traps.

A buoy or a time release buoy shall be attached to each trap, or at each end of a weighted trotline, and shall be of sufficient strength and buoyancy to float and of such color, hue and brilliancy to be easily distinguished, seen or located. Such color and permit number shall also be permanently and conspicuously displayed on the boat used for setting and collecting said traps and buoys, in the manner described by the Division of Law Enforcement, so as to be readily identifiable from the air and water. This subsection shall not apply to an individual fishing with no more than five traps.

It is unlawful for any person willfully to molest any traps, lines or buoys, as defined herein, belonging to another without permission of the permit holder.

Traps may be worked during daylight hours only, and the pulling of traps from one hour after official sunset until one hour before official sunrise is prohibited.

2. **Departmental Regulations**

Vessel and crab pot buoy identification

(a) Any vessel engaged in blue crab fishing pursuant to the provisions of Chapter 370.135, Florida Statutes, shall at all times while engaged in blue crab activities have the buoy design of its permitted buoy painted on a flat piece of permanent material permanently affixed to the uppermost structural portion of the vessel and displayed horizontally with the painted design up. If the vessel is of open design (example: skiff boat), one seat shall be painted with buoy assigned color with permit numbers painted thereon in contrasting color. Numbers are to be 10 inches in height.

(b) The buoy design placard shall be reproduced on a 20-inch in diameter circle outlined in a contrasting color on the above-mentioned flat piece of permanent material, together with the permit numbers permanently affixed under the 20-inch circle in numerals of not less than 10 inches in height.

(c) Nothing shall be placed on or above-said placard as it is displayed on the vessel.

(d) Any person, firm or corporation violating this rule shall be punished as provided by law.

ALABAMA

Administrative Organization

Alabama Department of Conservation and Natural Resources, Marine Resources Division.

Licenses and Taxes

Seafood packer, canner or processor – $50.00.

Laws and Regulations

1. **General Statute** – none, except above license.

2. **Departmental Regulations**

(a) *Minimum size of blue crab* – Blue crabs sold for commercial purposes shall measure not less than four inches from widest points of upper shell, and the sale of crabs smaller in size is prohibited. Provided, however, this regulation does not apply to soft shell crabs nor crabs sold for use as bait.

MISSISSIPPI

Administrative Organization

Department of Wildlife Conservation, Bureau of Marine Resources.

License and Taxes

Crab vessel, $2.00; wholesale dealer, $100.00

Laws and Regulations

1. **General Statutes** – none, except above licenses.

2. **Departmental Regulations**

Fishing for sponge crabs is prohibited in an area described as follows:

"South of the Intracoastal Waterway, commencing at the Alabama-Mississippi boundary, and running west to the Gulfport-Ship Island Channel." Any persons taking said sponge crabs by net, trap or other means shall immediately return same to the water.

All crabs caught in trawls regardless of the location shall be immediately returned to the water unless the boat operating the said trawl shall have a valid license as provided in Section 49-15-29(d) of the Mississippi Code of 1972.

Any person fishing for crabs by means of crab traps or crab pots shall mark each said trap or pot with the corresponding license number set out on the pot or trap in such a manner to be clearly visible to an inspecting officer.

LOUISIANA

Administrative Organization

Louisiana Department of Fish and Wildlife.

Licenses and Taxes

Commercial crab pots – no limit; Resident, $25.00; nonresident, $500.00.

Laws and Regulations

1. **General Statutes**

Minimum size of blue crabs – five inches in width as measured from point to point of the upper shell (soft shell crabs, 4½ inches). Crabs used to produce soft shells can be less than five inches in width.

Protection of female crabs – no person shall keep or sell adult female crabs in the berry stage, and such crabs shall be returned immediately to the water.

Restriction on gear and fishing methods

(a) Crab trawls – illegal.

(b) Crab pots – each crab trap must be marked with a numbered tag issued by the Commission.

A recreational crab fisherman may use up to five traps without obtaining a license, and may use a maximum of ten traps provided that he first obtains a recreational license and tags, therefore, at a cost of $2.00.

Use of untagged traps shall be unlawful. Each trap shall be attached to a visible float of at least six inches minimum diameter, or one-half gallon volume size and in Lake Pontchartrain the crab fisherman's license number shall be printed on the float in indelible ink. Floats shall be attached to the traps by a nonfloating line.

Crab traps which are no longer serviceable or in use shall be removed from the water by the owner thereof. No person shall intentionally damage or destroy tagged crab traps or the floats or lines attached thereto, or remove the contents thereof, other than the licensee or his agent.

No crab traps shall be set in navigable channels or entrances to streams.

Commercial dealers, distributors or processors shall not purchase crabs from anyone not licensed.

TEXAS

Administrative Organization

Texas Parks and Wildlife Department, Coastal Fisheries Division.

Licenses and Taxes

Commercial fisherman, $10.00; wholesale fish dealer (business), $250.00; wholesale fish dealer (truck), $125.00; fish boat, $6.00; seine net, $1.00.

Laws and Regulations

Minimum size of blue crab – crab size limits shall be as follows:

(1) No hard-shell blue crabs less than five inches, soft-shell blue crabs less than four and one-half inches, or peeler blue crabs less than four inches in carapace width, measured from tip of spine, may be possessed, except for bait. Crabs shall be separated by the catcher at the time taken, and all crabs less than the minimum size shall be returned to the waters from which taken or placed in a separate container for possession of bait only. A tolerance of not more than five percent (5%) by number of undersized crabs may be possessed for purposes other than bait.

(2) In Galveston, Chambers, Harris, and Victoria counties, no person may possess or may catch and retain a blue crab smaller than five inches across the shell from tip to tip except during the period from March 1 to April 30, when a person may catch and retain blue crabs of any size for use as bait if bait blue crabs are kept alive in a container separate from nonbait blue crabs. The holder of a commercial fishing license may catch and retain a number of blue crabs smaller than five inches that equals or is less than five percent (5%) of

the total number of blue crabs possessed by the licensee, excluding bait blue crabs.

Protection of female crabs – unlawful to take egg-bearing female crabs and in Chambers, Galveston, Harris, and Victoria counties it is unlawful to buy or sell a female crab that has its abdominal apron detached and was taken from coastal waters.

Restrictions on fishing methods, gears, etc.

(a) In Aransas, Brazoria, Cameron, Jackson, Jefferson, Kennedy, Kleberg, San Patricio, Matagorda, Nueces, Orange, Refugio, and Willacy counties, crabs may be taken in any number and at any time by dip net, set line, hand line, gig, trotline, crab pot, and 20-foot seine. Crabs taken during legal shrimping operations may be retained. Crab traps must be marked with the owner's name, address and license number imprinted on material as durable as the trap. All crab traps shall be marked with a floating visible buoy not less than 10 inches above the water and 10 inches in width, or with plastic bottles of not less than one gallon size. Crab trawls with a webbing size of not less than 5 inches stretched mesh are permitted in coastal waters as defined in Section 77.001, Texas Parks and Wildlife Code.

(b) Crabs may be taken only by crab lines, hooks or lines, trotlines and no more than three (3) crab pots per person in Burnett Bay, Scott Bay, Crystal Bay, and Black Duck Bay in Harris County.

(c) No crab traps may be placed within 200 feet of a marked navigable channel or in a net-free zone in Aransas County.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 105–109.

FLORIDA'S COLOR CODE SYSTEM FOR CRAB POT IDENTIFICATION

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Florida began to realize problems several years ago in its trap fishery. These were basically the need to identify traps and buoys that were blocking navigation in the waterway channels and also the need to prevent the theft of traps, buoys, and lines and/or the product inside these traps or pots.

To do this a permit/license requirement for trappers was mandated by the legislature and the Florida Department of Natural Resources initiated rules to better implement the trap and product identification. The rules basically require that each permit/license holder be assigned a number and color code by the Department, and that these numbers and color code be displayed on each trap, buoy, and boat engaged in working the traps. The trappers are checked for compliance by the state's patrol boats and patrol airplanes. Traps may not be worked, transported, or molested by other than the permit/license holder and may be worked during daylight hours only. Pots found in channels can be identified and the owners ordered to remove them or face state charges for the blocking of navigation. Florida now has approximately 131,500 permitted blue crab traps, 651,700 stone crab traps, and 700,000 lobster traps. This combined figure of 1,483,200 pots, each capable of blocking navigation to the one-half million registered state boaters, is a potential deterrent to boating safety. If systematically robbed, the value lost of the products contained therein could also cripple a large segment of the commercial industry.

To better aid the enforcement officer in catching and getting convictions of trap robbers, the legislature has made it legally possible for the occupants of a patrol plane or boat to relay the information via radio relating to a witnessed theft and have other officers make the apprehension and arrest. Techniques have been developed which assist in the identification of stolen products or the proving of pot molestation. One method is to mark the crabs in a trap line with some method of flipper notching, thread tagging, etc., by which a stolen product can be identified. A technique used to identify trap molesters incorporated the use of ultraviolet powder, black lights and petroleum jelly. The transparent ultraviolet powder is mixed in warm petroleum jelly and smeared in the upper extremity of the buoy rope where it is normally grabbed by the fisherman. During handling a small amount of the clear petroleum jelly containing the powder, which is transparent in normal light, adheres to the fisherman's hands and gloves, and in the cases of stone crab and lobster pots, to the snatch block or windlass as well. When a cover is thown over these items and the black (ultraviolet) flashlight is applied, the petroleum jelly smeared surfaces will shine with the appropriate color. A different colored powder should be used on each individual rope and buoy to prove, in a court of law, that the arrested subject molested many pots. If a single color is used throughout one trap line, the defense can claim that the subject was only removing a rope that accidentally caught in the propeller. Some arrested subjects have been found with the tell-tale petroleum jelly and ultraviolet traces on their ears, hands, gloves, boots, trousers, and the subject snatch blocks and pulleys have been removed by the officers for use as evidence in court. Florida's blue crab law and the department rule implementing it follow, as well as the law giving extended authority through the relaying of incriminating evidence by other law enforcement witnesses.

STATE OF FLORIDA
DEPARTMENT OF NATURAL RESOURCES

Division of Marine Resources

BLUE CRAB REGULATION

Summary of Chapter 370.135, Florida Statutes – Blue Crab Regulations.

(1) No person, firm or corporation shall transport on the waters, fish with, or cause to be fished with, set or place any trap designed for taking blue crabs, unless such trap has current state permit number permanently attached to the buoy. The permit number shall be affixed in legible figures at least one inch high on each buoy used. The blue crab permit shall be on board the boat and both the permit and the crabs shall be subject to inspection at all times. Only one permit

shall be issued for each boat by the Department upon receipt of an application on forms prescribed by it. This subsection shall not apply to an individual fishing with no more than five traps.

(2) A buoy or a time release buoy shall be attached to each trap or at each end of a weighted trot line and shall be of sufficient strength and buoyance to float and of such color, hue and brilliancy to be easily distinguished, seen and located. Such color and permit number shall also be permanently and conspicuously displayed on the boat used for setting and collecting said traps and buoys, in the manner prescribed by the Division of Marine Resources, so as to be readily identifiable from the air and water. This subsection shall not apply to an individual fishing with no more than five traps.

(3) It is unlawful for any person to willfully molest any traps, lines or buoys, as defined herein, belonging to another without permission of the permit holder or to sell or offer for sale any egg-bearing blue crabs. Except when authorized by special permit issued by the Department for the soft-shelled crab or bait trade, it is unlawful for any person to possess for sale blue crabs measuring less than 5 inches from point to point across the carapace in an amount greater than 10 percent of the total number of blue crabs in such person's possession. Traps may be worked during daylight hours only and the pulling of traps from 1 hour after official sunset until 1 hour before official sunrise is prohibited.

(4) Upon the arrest and conviction for violation of any of the blue crab regulations or laws, the permit holder shall show just cause why his permit should not be suspended or revoked. This subsection shall not apply to an individual fishing with no more than five traps.

(5) Any person violating the provisions of this section is guilty of a misdemeanor of the second degree punishable as provided in Florida Statutes Sections 775.082 and 775.083.

Chapter 16B-19.01
BLUE CRAB BUOY AND PERMIT NUMBER

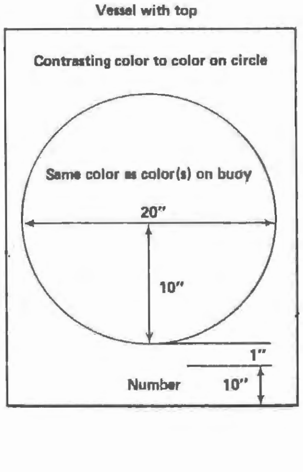
16B-19.01

(1) Any vessel engaged in blue crab fishing pursuant to the provisions of Chapter 370.135, Florida Statutes, shall at all times while engaged in blue crab activities have the buoy design of its permitted buoy painted on a flat piece of permanent material permanently affixed to the uppermost structural portion of the vessel and displayed horizontally with the painted design up. If the vessel is of open design (example: skiff boat), one seat shall be painted with buoy assigned color with permit numbers painted thereon in contrasting color. Numbers are to be 10 inches in height.

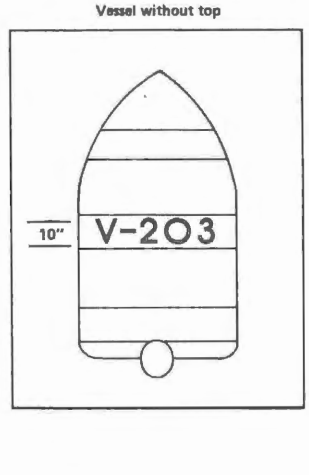
(2) The buoy design placard will be reproduced on a 20-inch diameter circle outlined in a contrasting color on the above-mentioned flat piece of permanent material, together with the permit numbers permanently affixed under the 20-inch circle in numerals of not less than 10 inches in height.

(3) For the purpose of this rule, the diagrams reproduced below will suffice.

Vessel with top



Vessel without top



(4) Nothing shall be placed on or above said placard as it is displayed on the vessel.

(5) Any person, firm or corporation violating this rule shall be punished as provided by law.

Chapter 79–217
HOUSE BILL NO. 1102

An act relating to the Department of Natural Resources and the Game and Fresh Water Fish Commission; amending s. 372.071, Florida Statutes, authorizing arrest by certified law enforcement officers of the Department of Natural Resources or the Game and Fresh Water Fish Commission under certain circumstances involving violations of chapters 370, 371, or 372, Florida Statutes; creating s. 372.085, Florida Statutes; creating the Endangered and Threatened Species Reward Trust Fund within the commission; authorizing the use of the fund for rewards to persons responsible for providing information leading to the conviction of persons violating laws protecting endangered and threatened species; authorizing certain expenditures; amending s. 372.72, Florida Statutes; providing for the disposition of fines, penalties, or forfeitures of bail of persons convicted of violations relating to endangered species, into the reward trust fund; providing an appropriation; providing an effective date.

Be It Enacted by the Legislature of the State of Florida:

Section 1. Section 372.071, Florida Statutes, is amended to read:

372.071 Power of arrest by agents of the Department of Natural Resources or the Game and Fresh Water Fish Commission.––Any certified law enforcement officer of the Department of Natural Resources or the Game and Fresh Water Fish Commission, upon receiving information, relayed to him from any law enforcement officer stationed on the ground, on the water, or in the air, that a driver, operator or occupant of any vehicle, boat, or airboat has violated any section of chapters 370, 371, or 372, may arrest the driver, operator, or occupant for violation of said laws when reasonable and proper identification of the vehicle, boat, or airboat and reasonable and probable grounds to believe that the driver, operator, or occupant has committed or is committing any such offense have been communicated to the arresting officer by the other officer stationed on the ground, on the water, or in the air.

Section 2. Section 372.085, Florida Statutes, is created to read:

372.085 Endangered and Threatened Species Reward Trust Fund.––

(1) There is hereby established within the Game and Fresh Water Fish Commission the Endangered and Threatened Species Reward Trust Fund to be used exclusively for the purposes of this section. The fund shall be for the primary purpose of posting rewards to persons responsible for providing information leading to the arrest and conviction of persons illegally killing, wounding, or wrongfully possessing any of the endangered and threatened species listed on the official Florida list of such species maintained by the commission or of persons who violate s. 372.667 or s. 372.671. The fund shall be credited with money collected pursuant to s. 372.72(2). Additional funds may be provided by donations from interested individuals and organizations and from legislative appropriations. The reward program is to be administered by the commission under the advisement of the Florida Endangered and Threatened Species Advisory Council. The commission shall establish a schedule of rewards after considering any recommendations of the council.

(2) Proceeds from the fund shall be expended only for the following purposes:

(a) The payment of rewards to persons, other than law enforcement officers, commission personnel, and members of their immediate families, for information as specified in subsection (1); or

(b) The promotion of public recognition and awareness of the endangered and threatened species reward program.

Section 3. Section 372.72, Florida Statutes, is amended to read:

372.72 Disposition of Fines, Penalties, and Forfeitures.––

(1) All moneys collected from fines, penalties, or forfeitures of bail of persons convicted under this chapter shall be deposited in the fine and forfeiture fund of the county where such convictions are had, except for the disposition of moneys as provided in subsection (2).

(2) All moneys collected from fines, penalties, or forfeitures of bail of persons convicted of violations of rules, regulations, or orders of the Game and Fresh Water Fish Commission concerning endangered or threatened species, or for violation of ss. 372.662, 372.663, 372.6645, 372.671, or 372.667, shall be deposited in the Endangered and Threatened Species Reward Trust Fund.

Section 4. The sum of $10,000 is appropriated from the General Revenue Fund to the Game and Fresh Water Fish Commission for the purposes of establishing the Endangered and Threatened Species Reward Trust Fund.

Section 5. This act shall take effect October 1, 1979.

Approved by the Governor June 28, 1979.

Filed in Office Secretary of State June 29, 1979.

FLORIDA DEPARTMENT OF NATURAL RESOURCES
202 BLOUNT STREET
CROWN BUILDING
TALLAHASSEE, FLORIDA 32301

APPLICATION FOR PERMIT TO TRAP BLUE CRABS

I hereby make application for permit as indicated herein and do declare the following to be true and correct.

NAME AND ADDRESS

This space for address correction or use if label is missing.

PLEASE PRINT YOUR NAME

ADDRESS

CITY OR TOWN

STATE ZIP CODE

COUNTY

Blue crab trap permit number last year:
V__________

Maximum number of traps fished:__________

Do you fish full-time for blue crabs? That is, is this your only occupation?
YES ☐ NO ☐

Telephone Number:
_____ ________
(Area Code) (Number)

Boat Registration or Documentation number:
FL__________ DO__________

Colors on buoys and boat:

In whose name is boat registered?

Address __________

Counties where products are landed:__________

Do you sell small blue crabs (less than 5 inches wide) as:
Bait ☐
Soft Shell Crabs ☐
Neither ☐

I have read the appropriate laws accompanying this form, and understand that a violation of any regulations concerning blue crab trapping may be cause for revocation of the blue crab trapping permit, and that I am to have my permit whenever I am engaged in blue crab trapping.

________________ ________
Signature of Applicant Date

DNR 105 (16)
(Rev. 4/20/79)

DISCUSSION

Q. **(Unidentified)**: We have two basic problems in terms of commercial fishermen versus weekend fishermen. One is the taking of the crabs in the pot; the other is the actual stealing of the pots and/or cutting the buoy lines. Which type of situation tends to be dominant in the blue crab fishery in Florida?

A. **Cliff Willis**: I don't think we have many incidents of cutting of lines there, we do have a lot of robbing of traps. We had about a 125 cases last year, actual arrests, of robbing the traps. We have commercial fishermen robbing from another one, also the weekend boaters–I'm talking about the recreational fishermen–like to take a few home. Most of the commercial fishermen will not object to them taking a half of a dozen or a dozen, but combined with the many boaters out there, this really cuts into a man's livelihood. One of our major problems, and it does not deal with blue crabs as much although it does deal with some blue crab trappers, is the conflict between the shrimpers and the crabbers. The shrimpers going through an area at night just wipe-out a trapline and their pots. This is mainly a problem in the stone crab fishery but there are some blue crab cases like this, too. In cases like this, we have to run a water patrol to keep the two factions from fighting each other. There is no simple answer–it is just a conflict over the water space.

Q. **(Unidentified)**: How do you examine a fisherman's gloves and hands without violating his constitutional rights?

A. **Willis**: You establish probable cause first by viewing at a distance that the man is working the wrong trap lines.

Q. **(Unidentified)**: Do you think that this color coding has increased the visability of traps in the Bay to where recreational sport fishermen are able to zero in on traps better?

A. **Willis**: I really don't know. Most of them were white before and it is pretty hard to find anything more visible than white.

Q. **(Unidentified)**: I meant in terms of some people not marking the traps and placing them where they would not be subject to theft.

A. **Willis**: I don't think it has any real effect on theft. You see a crabber also allows for time-released floats. You can put traps on a trotline, put up to 25 on one line, and have a time released float. If you want to sink your trap for a day or two, you can do so.

Q. **(Unidentified)**: What are the penalities for conviction?

A. **Willis**: This is a misdemeanor; it can range from suspended sentence to a $500 fine. It generally runs–it depends on who does it–you get a county judge and you got someone from outside the county who comes in there, the judge is protecting local people, he might throw the book at you. We have had convictions of up to $500, then again, we have had suspended sentences, too. The average fine is about $50.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 111–127.

BLUE CRAB FISHERIES OF THE ATLANTIC COAST

TERRY M. SHOLAR
North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Washington, North Carolina 27889

ABSTRACT Blue crabs support sizable fisheries on the Atlantic coast from Delaware Bay to Florida. Since 1970, approximately 103 million pounds of blue crab have been landed annually, with a dollar value of $14 million. A wide variety of methods are employed in the fisheries such as pots, trot lines, dredges, and trawls. In recent years, the fishery has become dependent on blue crab pots as the major method of harvesting the crabs. Chesapeake Bay has been historically, and is currently, the major producer of blue crabs on the Atlantic coast.

INTRODUCTION

The blue crab supports one of the major commercial and recreational fisheries on the Atlantic coast. Since 1970, approximately 103 million pounds* of blue crab have been landed annually, worth about $14 million. Blue crab fisheries provide primary and supplemental incomes, as well as recreation for large numbers of people. From 1970 to 1975, an average of 14,000 people annually commerically fished with gear specifically designed for blue crabs. There are no accurate estimates of the number of recreational crabbers. Blue crabs are landed on the Atlantic coast from Connecticut to Florida, with the primary fisheries occurring from Delaware Bay southward.

This report describes the fisheries in various regions and states. In addition, statistical data will be used to make comparisons and analyze past trends. However, the use of statistical data can be misleading. Mere numbers may not present a true picture of actual landings or number of gear units used, but, the information does lend itself to determining trends over a period time. During the time period discussed, available data indicate that several trends are evident.

HARVESTING METHODS

Blue crabs are caught by a wide variety of gears, either directly or as incidental catches from other fisheries. Blue crabs are pursued primarily with pots, dredges, trawls, and trot lines. Van Engel (1962) gave a description and history of the use of pots, dredges, and trot lines in Chesapeake Bay. Blue crab pots used on the Atlantic coast generally are the same design developed for Chesapeake Bay with some minor local variations. Use of crab trawls on the Atlantic coast is limited to the south Atlantic states, in particular North Carolina. They are basically an otter trawl with stretched mesh size varying from 2 inches to 4½ inches. Trawls generally are used during the colder months when crabs are not very active, and the trawls are chained heavier on the bottom line. Otter boards are set to dig more into the bottom than conventional shrimp or fish trawls.

REGIONAL FISHERIES

New England Region

In the New England region, Connecticut is the only state reporting blue crab landings. During the 1950s, annual landings were approximately 3,000 pounds. Currently, it is only a few hundred pounds annually, if there are any reported.

Middle Atlantic Region

The middle Atlantic states of New York, New Jersey, and Delaware rank third in blue crab production behind the Chesapeake and south Atlantic regions.

New York crab landings are comparatively insignificant. Currently, landings are about 17,000 pounds per year. Figure 1 shows the annual landings of blue crabs in the middle Atlantic states. During the 1960s, crab landings dropped to a very low level in the mid-Atlantic region. After 1970, New Jersey and Delaware reported parallel increases in catches. Since 1976, however, drastic decreases occurred which may have been the result of unusually cold winters.

Delaware Bay is the principal fishing area in the mid-Atlantic. Blue crabs are caught primarily with pots and dredges in the mid-Atlantic. Since 1950, there has been an increase in the importance of pots as commercial gear (Figure 2). Trot lines, which once accounted for over 20% of the landings, no longer contribute to the fishery. Pots are fished primarily in Delaware Bay from May through November. Dredges operate in the Lower Delaware Bay and other coastal bays from December to March. Commercial gear is prohibited in the tributaries of Delaware Bay except in the Delaware River.

Table 1 shows the number of units for major gears, and the number of fishermen and boats fishing for blue crabs in the mid-Atlantic from 1950 to 1975. There was a significant increase in the number of pots used in the early 1970s. Along with the decrease in landings in the mid-to-late

*All statistical data presented are from *Fishery Statistics of the United States 1950–1975* and *Current Fishery Statistics*, published by the National Marine Fisheries Service, unless otherwise noted.

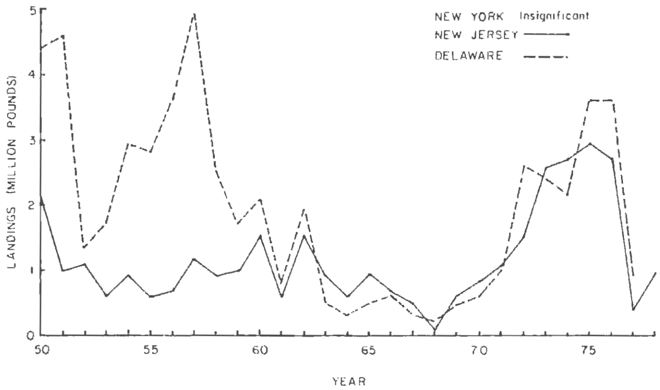


Figure 1. Total annual hard blue crab landings for the middle Atlantic states, 1950–1978.

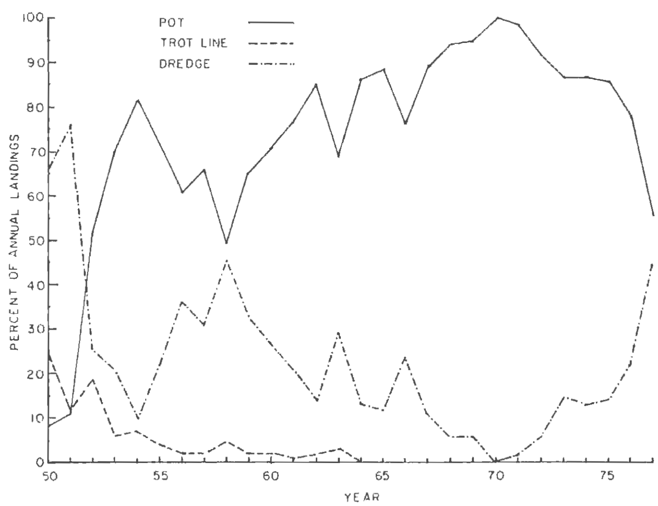


Figure 2. Annual percent contribution of the major gears to hard blue crab landings for the middle Atlantic states, 1950–1977.

1960s, there was an accompanying decrease in the number of fishermen and boats.

Recreational crabbing is very popular in the mid-Atlantic. During 1976, it was estimated that over 60,000 man-days were spent crabbing recreationally in Delaware (Richard W. Cole, personal communication). In both New Jersey and Delaware, crabs are caught recreationally with pots, hand lines, trot lines, and collapsible traps.

The soft and peeler crab industry is somewhat limited. Since 1970, Delaware and New Jersey reported landings on an average of 40,000 pounds per year. Peelers are caught almost exclusively with standard blue crab pots.

New Jersey and Delaware have regulations dealing with the time and method of fishing. Licenses are required, and Delaware has a limit on the number of pots that can be used per license.

Mid-Atlantic data are summarized in table form in the appendix.

CHESAPEAKE BAY REGION

Chesapeake Bay is the major blue crab production area with a long history and rich tradition associated with its fishery. It produces approximately 60 million pounds per year. Blue crab catches in the Chesapeake region since 1950 have been somewhat steady, although there have been yearly fluctuations in landings (Figure 3). Viginia generally leads Maryland in crab production.

TABLE 1.

Numbers of gear units, fishermen, and boats operating in the blue crab fisheries of the middle Atlantic states, 1950–1975.*

Year	Pots	Trot line baits	Dredges	Fishermen	Boats
1950	1,780	49,200	70	236	132
1951	2,490	29,800	64	223	124
1952	6,800	24,600	69	219	146
1953	7,360	13,250	55	195	139
1954	9,125	18,200	88	279	180
1955	8,065	29,200	64	297	159
1956	8,310	21,850	88	315	162
1957	7,950	16,600	112	346	161
1958	6,300	15,807	167	403	191
1959	5,444	10,750	110	290	141
1960	8,020	7,700	162	319	182
1961	5,580	5,400	64	154	92
1962	8,107	9,150	68	235	130
1963	5,450	8,700	57	171	103
1964	6,074	19,000	24	116	85
1965	6,132	1,350	39	124	102
1966	4,859	0	33	113	75
1967	5,197	0	21	93	69
1968	3,228	0	15	65	49
1969	4,438	0	12	92	68
1970	6,321	0	0	108	102
1971	6,240	0	5	90	86
1972	10,915	0	45	190	158
1973	14,214	0	69	307	248
1974	24,129	0	83	420	306
1975	26,387	0	93	464	362

*In this and subsequent tables the number of fishermen and boats are those reported to fish blue crab gear specifically.

As seen in Figure 4, the importance of pots for harvesting blue crab has been on the increase. This has been accompanied by a general decrease in importance of trot lines. Production by dredges has remained the same although fluctuating somewhat from year to year. In recent years, trot lines have contributed insignificantly to Virginia s crab landings, but in Maryland, they contributed about 30 to 40% of the catch annually. Dredging is done generally in the Virginia portion of lower Chesapeake Bay from December through March. Scrapes (small, lightweight dredges) are used primarily for catching peelers on the Eastern Shore. Pots are used throughout Chesapeake Bay from April to December. In addition, other gears such as peeler pots, bank traps, channel pounds, and fyke nets are used mainly on the Eastern Shore to catch peelers.

From 1950 to 1975, the number of pots used increased steadily in Chesapeake Bay (Table 2). The number of trot

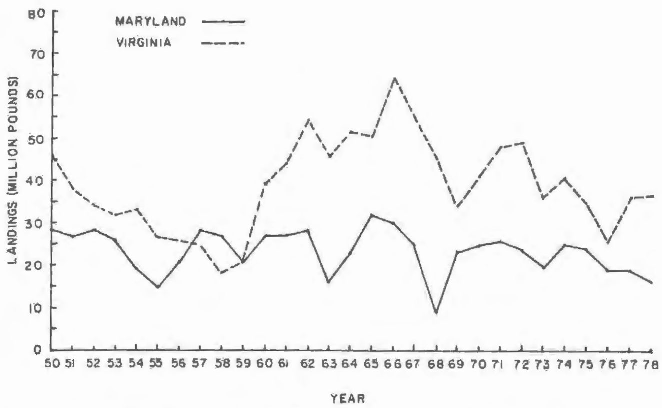


Figure 3. Total annual hard blue crab landings for the Chesapeake Bay states, 1950–1978.

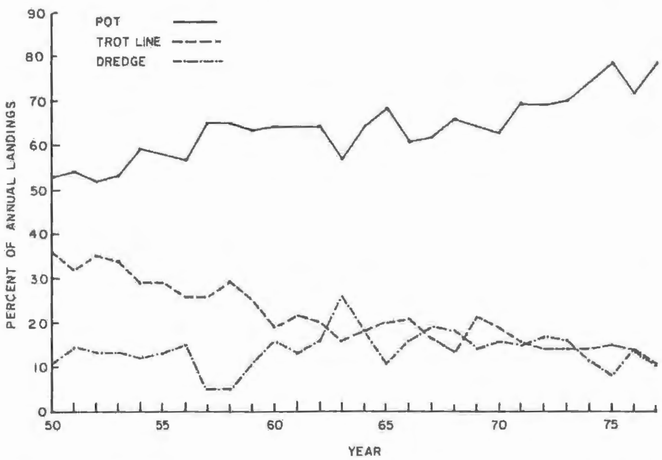


Figure 4. Annual percent contribution of the major gears to hard blue crab landings for the Chesapeake Bay states, 1950–1977.

lines has also increased, due to the rise in trot line use in Maryland. Virginia has reported a significant decrease in this gear. The number of fishermen operating in the Chesapeake Bay crab fishery has increased steadily.

The recreational blue crab fishery in Maryland and Virginia is very important. Although Virginia has no statistical data, Maryland reported that over 3 million pounds of crabs were caught for sport in 1976 (Speir et al. 1977). Recreational crabbers use pots, collapsible traps, trot lines, hand lines, and dip nets.

Chesapeake Bay supports a substantial soft and peeler crab fishery. In recent years, the landings of soft and peeler crabs have been on the decline (Figure 5). Maryland catches reached some high peaks during the late 1950s and early 1960s; however, Virginia landings have exhibited a general decline since the early 1950s. The principal fishing area for soft and peeler crabs is on the Eastern Shore with scrapes, peeler pots, hard crab pots, and crab pounds. Shedders use both floats and high ground systems, although in recent years the high ground systems are becoming more common.

Both Maryland and Virginia require licenses for commercial crab gear. Maryland limits the number of pots per license.

TABLE 2.

Numbers of gear units, fishermen, and boats operating in the blue crab fisheries of the Chesapeake Bay states, 1950–1975.

Year	Pots	Trot Lines	Dredges	Scrapes	Crab Pounds	Fishermen	Boats
1950	85,530	1,596	268	596	–	4,653	3,879
1951	87,200	1,455	332	733	–	5,044	4,209
1952	72,250	1,479	364	640	–	4,574	3,834
1953	82,500	1,527	328	750	–	5,005	4,089
1954	88,650	1,306	333	802	–	4,896	4,006
1955	94,650	2,494	437	747	–	6,319	5,289
1956	95,552	2,914	450	466	1,783	6,418	5,668
1957	133,935	2,608	416	720	2,182	5,845	5,148
1958	129,430	2,604	370	611	2,441	5,737	5,064
1959	169,545	2,491	320	586	2,535	5,658	5,025
1960	195,073	2,231	348	563	2,550	5,506	4,855
1961	175,270	2,542	704	615	2,787	5,813	5,004
1962	188,164	2,314	596	392	2,787	5,687	4,938
1963	192,083	2,305	407	614	2,805	5,708	4,920
1964	184,595	2,342	366	579	2,839	5,304	4,826
1965	217,376	2,735	325	414	2,687	6,306	5,469
1966	213,622	2,976	298	373	2,815	6,414	5,524
1967	203,488	3,139	283	322	2,798	6,189	5,396
1968	212,490	3,080	320	355	2,168	6,194	5,435
1969	229,995	3,263	300	348	2,331	6,743	5,813
1970	254,435	5,650	324	197	1,990	9,237	7,981
1971	227,480	7,982	285	428	1,476	11,576	9,417
1972	235,270	8,130	273	410	1,588	11,697	9,330
1973	221,200	7,993	320	410	1,181	10,582	8,547
1974	232,599	9,272	158	428	3,168	13,841	11,454
1975	264,536	9,964	173	371	2,338	14,437	11,710

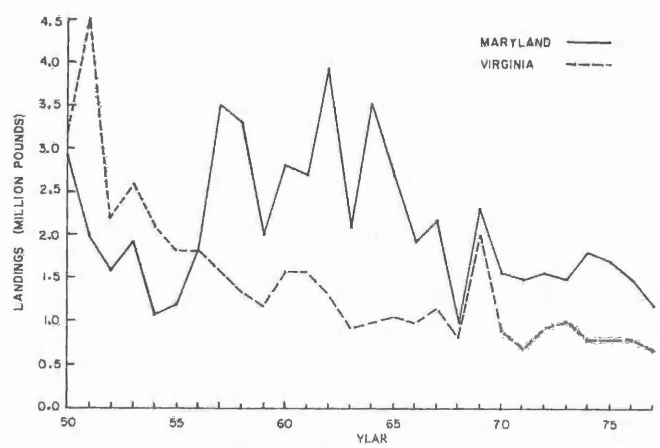


Figure 5. Annual landings of soft and peeler blue crabs for the Chesapeake Bay states, 1950–1977.

Pots are required to be marked for identification, and Maryland also regulates pot size, fishing depth, and fishing area. Both Maryland and Virginia have seasons for scrapes and dredges, and Maryland also has design restrictions. The length of hedging and top size of bank traps and channel pounds are regulated in Maryland. Nonlicensed crabbers may take up to one bushel per day, and the number of pots allowed for nonlicensed fishermen in both states is limited.

A 5-inch minimum size limit is enforced for hard crabs. Maryland has a 3-inch minimum size limit for soft and peeler crabs, while Virginia has no limit on peelers or adult females. Maryland prohibits the taking of sponge crabs, while Virginia has a spawning sanctuary. Bearden (1978) gave a more detailed account of regulations in Maryland and Virginia.

Chesapeake Bay data are summarized in table form in the appendix.

SOUTH ATLANTIC REGION

The blue crab fishery of the south Atlantic is second in importance only to the Chesapeake Bay region with landings of about 35 million pounds annually. From 1970 to 1976, there was a general decline in landings; however, in 1978, landings increased dramatically (Figure 6). North Carolina generally leads the south Atlantic in blue crab production, ranking third on the Atlantic coast. (In 1978, preliminary landings indicate North Carolina was second only to Virginia.) North Carolina's Pamlico Sound, which has yielded about 10 million pounds of crabs annually since 1970, is the major production area for the south Atlantic. In South Carolina, which currently lands about 7 million pounds a year, the greatest production area is the southern bay systems. Georgia lands about 8 million pounds annually, while the eastern coast of Florida produces about 5 million pounds. Florida's major production area is from the Indian River north.

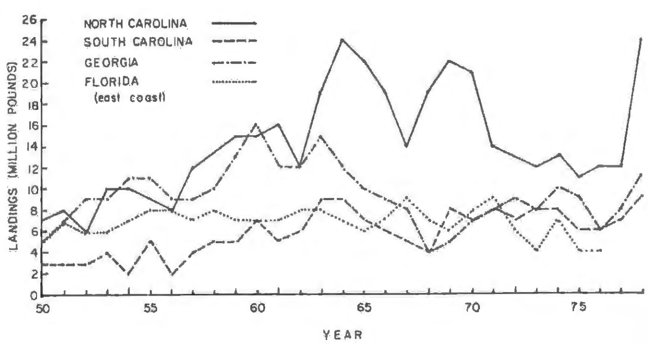


Figure 6. Total annual hard-shell blue crab landings for the South Atlantic states, 1950–1978.

In the south Atlantic, blue crabs are harvested primarily with pots, trawls, and trot lines. Figure 7 shows the relative importance of major gears. As was seen in the Chesapeake Bay region, the importance of pots has increased since 1950, accompanied by a decline in the contribution by trot lines. Trawls, which are a major gear in the south Atlantic region, showed a dramatic increase in contribution from 1963 to 1967, followed by an even sharper decline.

Pots are fished primarily from April to November, although some are fished year around. Crab trawls generally are used during the winter months, and the major fishery occurs in Pamlico Sound. In North Carolina, trawls contribute about 20% of the state's blue crab landings. South Carolina and Georgia allow some winter crab trawling in certain inside waters. In addition, crabs are sometimes taken incidental to shrimp trawling, depending on market conditions and abundance.

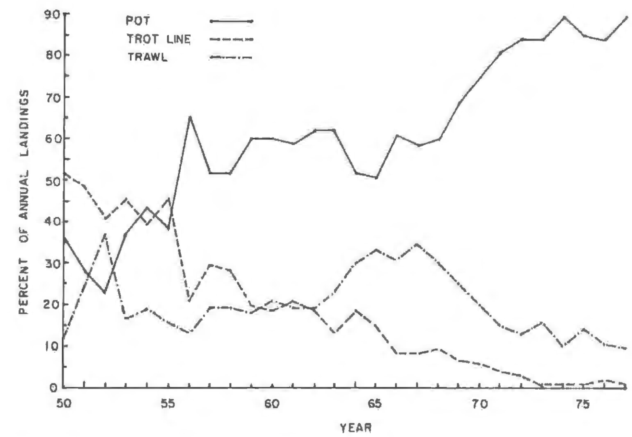


Figure 7. Annual percent contribution of major gears to the hard-shell blue crab landings, South Atlantic states, 1950–1977.

The number of pots used in south Atlantic states has increased steadily since 1950, and has been accompanied by a steady decline in the number of trot lines (Table 3). The number of crab trawls has increased somewhat since 1950. The reported number of fishermen and boats has remained relatively constant.

TABLE 3.

Numbers of gear units, fishermen, and boats operating in the blue crab fisheries of the south Atlantic states, 1950–1975.

Year	Pots	Trot Lines	Trawls	Fishermen	Boats
1950	11,030	793	184	1,728	1,124
1951	13,175	783	129	1,455	1,137
1952	9,975	631	127	1,268	988
1953	14,565	909	160	1,501	1,003
1954	22,179	905	169	1,380	1,131
1955	28,519	663	143	1,379	1,172
1956	29,030	545	158	1,318	1,123
1957	39,895	561	175	1,477	1,249
1958	37,305	636	218	1,595	1,330
1959	43,856	526	288	1,826	1,415
1960	40,900	528	263	1,762	1,396
1961	46,625	528	264	1,720	1,483
1962	50,545	508	296	1,765	1,495
1963	54,490	510	337	1,895	1,592
1964	63,530	393	432	1,991	1,659
1965	61,842	280	424	1,844	1,528
1966	65,125	168	560	1,762	1,463
1967	59,245	155	538	1,603	1,290
1968	65,315	159	493	1,550	1,192
1969	70,115	160	386	1,482	1,262
1970	70,515	118	449	1,479	1,191
1971	69,426	116	518	1,601	1,248
1972	61,770	112	473	1,608	1,205
1973	76,140	80	508	1,742	1,284
1974	75,697	79	433	1,652	1,176
1975	81,853	75	441	1,837	1,301

The recreational crab fishery is considered to be very large, although no surveys have been conducted in the southeastern states. The methods used include hand lines, collapsible traps, and one to five pots depending on the state. In addition, crabs are taken incidental to the recreational shrimp fisheries in some states.

The soft and peeler crab fishery in the south Atlantic is extremely limited or nonexistent, although most states are taking developmental measures. North Carolina is the only state that reports any significant soft and peeler crab fishery, and even there the fishery is on the decline. Since 1970, only about 30,000 pounds were landed annually compared to over 100,000 pounds per year prior to 1965. Peeler crabbing is done with pots and trawls. Peeler trawls can be no larger than 25 feet or have a mesh smaller than 2 inches stretched mesh in North Carolina.

There are numerous regulations pertaining to crab fishing in the various south Atlantic states. All states require licenses, and some even require licenses or permits for specific gears. All states, except Florida, have a 5-inch minimum size for hard crabs. (Florida requires this in one county.) Georgia is the only state with a 3-inch minimum size for soft or peeler crabs. All states prohibit the taking of sponge crabs, except North Carolina which prohibits crabbing in designated spawning sanctuaries. Most states regulate when and where different types of gear can be used as well as mesh sizes for trawls. Pots are required to be marked, with Florida having developed an elaborate color-coding system of pot identification. Bearden (1978) gave a more detailed summary of the licenses and regulations for the various south Atlantic states.

South Atlantic data are summarized in table form in the appendix.

ACKNOWLEDGMENTS

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APPENDIX – SUMMARY DATA OF BLUE CRAB FISHERIES

TABLE A1. Annual landings and percent contribution of hard blue crabs by gear, New York, 1950–1977.

Year	Pot	Percent	Pound Net	Percent	Dredge	Percent	Dip Net	Percent	Total
1950							8,300	100.0	8,300
1951							7,000	100.0	7,000
1952							56,900	100.0	56,900
1953							75,300	100.0	75,300
1954			29,800	66.8	14,800	33.2			44,600
1955			35,700	83.6	7,000	16.4			42,700
1956			9,200	100.0					9,200
1957			5,000	58.8	3,500	41.2			8,500
1958			14,600	79.8	3,700	20.2			18,300
1959					1,800	100.0			1,800
1960					1,100	100.0			1,100
1961					1,300	100.0			1,300
1962									
1963									
1964									
1965									
1966									
1967									
1968									
1969									
1970									
1971									
1972									
1973									
1974	3,200	100.0							3,200
1975	16,000	100.0							16,000
1976	52,000	99.4	300	0.6					52,300
1977	12,800	100.0							12,800

TABLE A2. Annual landings* and percent contribution of hard blue crabs by gear, New Jersey, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Dredge	Percent	Pound Net	Percent	Dip Net	Percent	Wier	Percent	Haul Seine	Percent	Trawl	Percent	Total
1950			1,318.4	61.9	735.0	34.5			4.2	0.2	70.0	3.3	3.8	0.2			2,131.4
1951			524.3	50.1	470.0	45.0			4.6	0.4	42.6	4.1	4.0	0.4			1,045.5
1952	292.8	27.5	420.4	39.4	321.7	30.2	3.6	0.3	8.4	0.8	16.0	1.5	3.7	0.3			1,066.6
1953	342.8	61.5	146.5	26.3	56.6	10.1	1.9	0.3	7.4	1.3	1.4	0.3	1.2	0.2			557.8
1954	549.2	63.1	271.6	31.2	17.8	2.0	2.8	0.3	17.4	2.0			11.9	1.4			870.7
1955	359.0	57.0	81.4	12.9	161.9	25.7	1.5	0.2	13.1	2.1	5.1	0.8	6.6	1.0	1.0	0.2	629.6
1956	376.4	54.4	59.0	8.5	232.8	33.6	3.5	0.5	13.3	1.9			6.5	0.9	0.9	0.1	692.4
1957	875.1	72.1	86.1	7.1	196.8	16.2	36.3	3.0	12.6	1.0			6.2	0.5	0.6	<0.1	1,213.7
1958	379.2	43.7	161.6	18.6	318.7	36.7	1.9	0.2	5.5	0.6			1.6	0.2			868.5
1959	586.8	59.7	51.2	5.2	342.5	34.8	0.5	0.1			1.8	0.2	0.5	0.1			983.3
1960	1,037.9	67.7	70.2	4.6	423.1	27.6					1.7	0.1					1,532.9
1961	459.1	71.0	18.2	2.8	161.4	25.0	0.7	0.1			2.0	0.3	4.1	0.6	0.9	0.1	646.4
1962	1,188.0	78.9	50.3	3.3	266.1	17.7	0.2	<0.1							0.5	<0.1	1,505.1
1963	694.2	80.6	36.2	4.2	130.4	15.1									0.2	<0.1	861.0
1964	494.6	86.8	0.7	0.1	74.2	13.0											569.5
1965	728.6	80.5	4.1	0.5	172.6	19.1											905.3
1966	571.3	83.5			112.7	16.5											684.0
1967	416.8	89.8			47.6	10.2											464.4
1968	113.5	84.0			21.6	16.0											135.1
1969	607.5	97.7			14.6	2.3											622.1
1970	750.9	99.9					0.4	0.1									751.3
1971	1,053.4	95.5			48.8	4.4	0.4	<0.1									1,102.6
1972	1,254.6	82.5			180.8	11.9	0.3	<0.1							1.2	0.1	1,520.7
1973	1,942.2	75.5			628.6	24.4	1.3	0.1									2,572.1
1974	2,345.6	88.1	0.2	< 0.1	314.1	11.8	1.3	<0.1									2,661.2
1975	2,331.7	81.2			535.9	18.7	2.4	0.1									2,870.0
1976	2,011.4	74.6			682.1	25.3	0.9	<0.1							1.6	0.1	2,696.0
1977	266.9	68.3			123.6	31.6	0.1	<0.1									390.6

*Landings in thousands of pounds.

TABLE A3. Annual landings* and percent contribution of hard blue crabs by gear, Delaware, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Dredge	Percent	Fyke Net	Percent	Dip Net	Percent	Haul Seine	Percent	Gill Net	Percent	Total
1950	536.9	12.2	223.0	5.1	3,651.7	82.8									4,411.6
1951	642.3	13.8	150.6	3.2	3,853.1	82.9									4,646.0
1952	950.0	76.0			300.0	24.0									1,250.0
1953	1,300.0	75.3			427.5	24.7									1,727.5
1954	2,572.5	88.4			338.4	11.6					0.4	<0.1	0.2	<0.1	2,911.5
1955	2,148.6	76.4	60.2	2.1	600.0	21.3			1.9	0.1					2,810.7
1956	2,221.2	62.1	35.7	1.0	1,320.8	36.9									3,577.7
1957	3,164.5	64.3	46.0	0.9	1,711.1	34.8	1.3	<0.1							4,922.9
1958	1,260.0	51.4	17.6	0.7	1,176.0	47.9									2,453.6
1959	1,113.7	67.5	3.7	0.2	532.6	32.3									1,650.0
1960	1,561.4	74.0	5.6	0.3	542.2	25.7									2,109.2
1961	628.5	82.8			130.9	17.2									759.4
1962	1,675.4	88.9			209.1	11.1									1,884.5
1963	256.1	49.0			266.2	51.0									522.3
1964	273.0	87.1			40.3	12.9									313.3
1965	545.6	100.0													545.6
1966	388.6	68.1			182.4	31.9									571.0
1967	253.6	88.1			34.3	11.9									287.9
1968	223.4	100.0													223.4
1969	462.0	90.6			47.7	9.4									509.7
1970	608.2	100.0													608.2
1971	1,013.8	100.0													1,013.8
1972	2,504.0	98.1			48.0	1.9									2,552.0
1973	2,334.0	98.3			39.4	1.7									2,373.4
1974	1,906.9	84.8			340.8	15.2									2,247.7
1975	3,186.0	89.7			364.8	10.3									3,550.8
1976	2,833.9	79.5			731.2	20.5									3,565.1
1977	426.4	49.5			435.8	50.5									862.2

*Landings in thousands of pounds.

TABLE A4. Annual landings* and percent contribution of hard blue crabs by gear, Maryland, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Dredge	Percent	Scrape	Percent	Pound Net	Percent	Dip Net	Percent	Total
1950	8,806.8	32.0	18,349.1	66.7	202.9	0.7	127.0	0.5			36.5	0.1	27,522.3
1951	12,026.4	44.3	14,899.3	54.8	138.4	0.5	77.8	0.3			34.5	0.1	27,176.4
1952	11,153.6	40.6	15,799.2	57.5	305.6	1.1	224.9	0.8			15.9	0.1	27,499.2
1953	11,664.8	44.2	14,303.5	54.2	256.0	1.0	130.2	0.5			13.4	0.1	26,367.9
1954	9,263.0	48.6	9,597.7	50.3	86.7	0.5	107.3	0.6			18.7	0.1	19,073.4
1955	7,278.3	47.8	7,771.5	51.0	72.5	0.5	90.7	0.6			18.5	0.1	15,231.5
1956	11,911.1	56.2	8,415.3	39.7	75.2	0.4	775.2	3.7			31.0	0.1	21,207.8
1957	15,924.7	56.1	10,747.7	37.9	98.5	0.3	1,513.9	5.3			83.2	0.3	28,369.0
1958	15,661.3	57.8	11,070.1	40.9	104.0	0.4	220.3	0.8			39.7	0.1	27,095.4
1959	11,887.4	56.1	9,062.9	42.8	57.7	0.3	160.6	0.8			18.5	0.1	21,187.1
1960	15,446.4	57.1	11,222.1	41.5	192.9	0.7	183.7	0.7			22.9	0.1	27,068.0
1961	13,854.0	52.0	12,597.2	47.3	12.3	<0.1	167.9	0.6			26.9	0.1	26,658.3
1962	14,883.4	53.8	12,573.3	45.5	10.1	<0.1	176.0	0.6			18.3	0.1	27,661.1
1963	8,481.0	50.1	8,320.8	49.1	30.1	0.2	97.4	0.6			4.6	<0.1	16,933.9
1964	12,060.5	53.5	10,361.6	46.0	24.6	0.1	87.8	0.4			5.7	<0.1	22,540.2
1965	17,592.4	55.0	14,253.9	44.5	5.2	<0.1	82.1	0.3	57.8	0.2	6.6	<0.1	31,998.0
1966	16,187.7	53.3	14,051.3	46.3			86.7	0.3	40.7	0.1	6.4	<0.1	30.372.8
1967	12,833.6	52.2	11,634.2	47.3			72.6	0.3	35.6	0.1	11.9	<0.1	24,587.9
1968	5,003.3	53.5	4,264.4	45.6			71.9	0.8			5.4	0.1	9,345.0
1969	13,053.2	56.7	9,812.8	42.6			129.9	0.6	5.9	<0.1	12.1	0.1	23,013.9
1970	14,283.2	57.3	10,496.2	42.1			133.5	0.5	6.4	<0.1	16.1	0.1	24,935.4
1971	15,394.1	59.0	10,549.1	40.5			107.2	0.4	4.7	<0.1	19.9	0.1	26,075.0
1972	13,725.4	58.5	9,639.8	41.1			91.1	0.4	8.8	<0.1	16.6	0.1	23.481.7
1973	11,476.4	58.7	7,943.7	40.7			95.6	0.5	8.1	<0.1	14.8	0.1	19,538.6
1974	15,448.7	62.6	9,091.0	36.9			97.4	0.4	7.7	<0.1	15.5	0.1	24,660.3
1975	15,649.1	64.5	8,499.0	35.0			93.0	0.4	7.5	<0.1	15.4	0.1	24,264.0
1976	12,918.4	66.5	6,424.7	33.1			68.5	0.4	7.0	<0.1	10.9	0.1	19,429.5
1977	12,713.9	66.1	6,440.6	33.5			70.0	0.4	9.0	<0.1	9.9	0.1	19,243.4

*Landings in thousands of pounds.

TABLE A5. Annual landings* and percent contribution of hard blue crabs by gear, Virginia, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Dredge	Percent	Scrape	Percent	Pound Net	Percent	Fyke Net	Percent	Dip Net	Percent	Haul Seine	Percent	Other	Percent	Total
1950	30,156.8	65.0	8,254.4	17.8	7,682.2	16.6		0.1	169.2	0.4	87.0	0.2	8.5	<0.1	4.0	<0.1	11.0	<0.1	46,373.1
1951	22,947.1	61.1	5,835.4	15.5	8,671.5	23.1	19.4	0.1	65.2	0.2	34.9	0.1	7.3	<0.1					37,580.8
1952	20,533.3	61.2	5,309.9	15.8	7,618.3	22.7	23.7	0.1	13.6	<0.1	38.1	0.1	5.3	<0.1					33,542.2
1953	19,683.2	60.9	5,466.4	16.9	7,098.1	22.0	19.1	0.1	17.0	0.1	38.9	0.1	6.3	<0.1					32,329.0
1954	20,925.0	64.4	5,226.8	16.1	6,237.6	19.2	18.4	0.1	18.7	0.1	32.5	0.1	6.2	<0.1	5.2	<0.1			32,470.4
1955	17,242.2	64.1	4,350.0	16.2	5,171.5	19.2	23.0	0.1	13.9	0.1	46.4	0.2	8.0	<0.1	31.8	0.1			26,886.8
1956	14,899.5	57.9	3,583.3	13.9	7,177.2	27.9	36.2	0.1	32.6	0.1	1.7	<0.1	13.3	0.1	1.8	<0.1			25,745.6
1957	18,852.2	75.8	3,161.2	12.7	2,801.3	11.3	22.4		31.8	0.1			9.1	<0.1	1.8	<0.1			24,879.8
1958	13,392.5	75.4	1,869.4	10.5	2,270.8	12.8			213.3	1.2			6.6	<0.1	0.9	<0.1			17,753.5
1959	14,653.1	69.3	1,700.3	8.0	4,644.2	22.0			141.9	0.7			8.8	<0.1					21,148.3
1960	26,948.8	68.6	1,650.1	4.2	10,545.1	26.9			118.9	0.3			7.1	<0.1					39,270.0
1961	31,605.4	71.8	3,065.4	7.0	9,082.5	20.6	55.0	0.1	130.5	0.3			37.4	0.1			33.0	0.1	44,009.2
1962	36,855.2	68.7	3,564.1	6.6	13,032.8	24.3			192.0	0.4			26.9	0.1					53,671.0
1963	27,470.6	59.5	1,959.3	4.2	16,525.4	35.8			154.5	0.3			28.7	0.1					46,138.5
1964	35,579.9	69.0	2,587.5	5.0	13,138.5	25.5	1.8	<0.1	225.1	0.4			39.2	0.1					51,572.0
1965	38,863.5	76.9	1,893.7	3.7	9,439.2	18.7	3.0	<0.1	335.1	0.7			28.1	0.1					50,562.6
1966	41,063.2	64.4	5,387.0	8.5	15,246.0	23.9	10.4	<0.1	1,886.0	3.0			138.6	0.2					63,731.2
1967	36,079.3	65.8	1,839.9	3.4	14,977.8	27.3	57.1	0.1	1,717.5	3.1			151.7	0.3					54,823.3
1968	30,975.8	69.1	2,568.9	5.7	9,873.3	22.0	115.0	0.3	1,260.2	2.8			47.7	0.1					44,840.9
1969	22,929.0	68.2	2,014.4	6.0	7,694.9	22.9			966.3	2.9			35.3	0.1					33,639.9
1970	28,120.2	66.3	2,535.7	6.0	10,558.5	24.9			1,157.9	2.7			44.0	0.1					42,416.3
1971	35,250.2	73.7	1,124.1	2.4	10,961.6	22.9			460.8	1.0			10.9	<0.1					47,807.6
1972	36,011.7	74.2	154.7	0.3	12,348.7	25.4			39.0	0.1									48,554.1
1973	27,717.5	75.4	17.5	0.1	8,998.7	24.5			12.3	<0.1									36,746.0
1974	32,713.1	80.1			8,136.4	19.9													40,849.5
1975	30,225.6	86.8	53.4	0.2	4,483.1	12.9	55.6	0.2	1.3	<0.1									34,819.0
1976	19,669.6	76.4			6,091.0	23.6			0.5	<0.1									25,761.1
1977	31,004.3	83.4	0.2	0.1	6,124.0	16.5			49.2	0.1									37,177.7

*Landings in thousands of pounds.

TABLE A6. Annual landings* and percent contribution of hard blue crabs by gear, North Carolina, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Trawl	Percent	Dredge	Percent	Dip Net	Percent	Haul Seine	Percent	Bag Net	Percent	Total
1950			4,414.5	66.1	2,265.7	33.9					0.3	<0.1			6,680.5
1951			4,709.2	60.2	3,113.0	39.8									7,822.2
1952			4,700.2	76.3	1,461.5	23.7									6,161.7
1953	185.7	1.8	8,524.3	81.3	1,776.9	16.9									10,486.9
1954	350.0	3.6	7,675.3	78.9	1,701.9	17.5									9,727.2
1955	1,800.0	19.0	6,781.9	71.5	898.2	9.5									9,480.1
1956	4,471.2	54.2	3,263.9	39.6	509.9	6.2									8,245.0
1957	3,530.2	30.5	6,184.0	53.4	1,857.4	16.1									11,571.6
1958	3,749.1	29.9	7,061.5	56.4	1,712.9	13.7									12,523.5
1959	6,736.8	45.7	5,866.9	39.8	1,755.0	11.9	380.2	2.6							14,738.9
1960	6,072.9	40.7	5,744.0	38.5	3,044.8	20.4	75.0	0.5							14,936.7
1961	6,030.1	37.9	6,479.8	40.8	3,370.2	21.2			11.0	0.1					15,891.1
1962	4,964.3	40.6	4,957.0	40.6	2,300.0	18.8									12,221.3
1963	11,755.3	62.4	3,555.1	18.9	3,525.0	18.7									18,835.4
1964	13,296.5	55.2	4,745.0	19.7	6,050.0	25.1									24,091.5
1965	8,935.2	40.0	5,434.9	24.3	7,963.6	35.7									22,333.7
1966	7,966.4	42.1	2,920.3	15.4	8,027.4	42.4									18,914.1
1967	4,071.8	28.5	2,740.0	19.2	7,440.6	52.1	2.2	<0.1					17.7	0.1	14,272.3
1968	7,820.5	40.8	2,965.1	15.5	8,358.2	43.6							27.4	0.1	19,171.2
1969	11,612.3	52.4	2,716.4	12.3	7,830.6	35.3									22,159.3
1970	13,148.8	63.0	2,263.1	10.8	5,468.3	26.2									20,880.2
1971	10,893.0	75.3	1,412.8	9.8	2,169.7	15.0									14,475.5
1972	10,924.8	81.0	1,119.3	8.3	1,435.3	10.6									13,479.4
1973	9,436.3	78.9	241.5	2.0	2,275.4	19.0	9.9	0.1							11,963.1
1974	11,173.5	84.9	435.4	3.3	1,554.7	11.8									13,163.6
1975	7,879.2	71.2	374.4	3.4	2,818.5	25.5									11,072.1
1976	8,005.1	68.2	572.3	4.9	2,426.7	20.7					727.5	6.2			11,731.6
1977	9,528.1	78.0	387.7	3.2	2,304.9	18.9									12,220.7

*Landings in thousands of pounds.

TABLE A7. Annual landings* and percent contribution of hard blue crabs by gear, South Carolina, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Trawl	Percent	Total
1950			2,791.0	97.3	78.1	2.7	2,869.1
1951			2,496.2	98.0	52.0	2.0	2,548.2
1952			2,169.7	83.3	435.0	16.7	2,604.7
1953			2,901.5	77.0	864.5	23.0	3,766.0
1954			1,478.9	59.4	1,008.9	40.6	2,487.8
1955	12.5	0.3	4,032.2	86.8	599.4	12.9	4,644.1
1956	25.0	1.3	1,402.5	73.7	474.3	24.9	1,901.8
1957			2,149.4	60.0	1,434.8	40.0	3,584.2
1958	935.0	19.3	2,423.4	50.1	1,481.0	30.6	4,839.4
1959	1,839.7	38.5	1,737.2	36.4	1,195.5	25.1	4,772.4
1960	3,682.0	51.7	2,129.1	29.9	1,309.7	18.4	7,120.8
1961	2,586.4	55.4	1,693.0	36.2	392.7	8.4	4,672.1
1962	3,790.1	59.8	1,756.5	27.7	791.0	12.5	6,337.6
1963	6,333.1	71.6	1,507.3	17.1	998.8	11.3	8,839.2
1964	4,352.7	46.1	4,430.3	47.0	653.1	6.9	9,436.1
1965	5,770.7	77.8	1,481.0	20.0	168.3	2.3	7,420.0
1966	5,516.2	96.4	208.3	3.6			5,724.5
1967	4,363.0	83.1	202.0	3.8	682.2	13.0	5,247.2
1968	3,556.8	92.1	161.7	4.2	143.7	3.7	3,862.2
1969	7,489.4	90.8	262.7	3.2	497.8	6.0	8,249.9
1970	6,815.8	98.1	130.5	1.9	3.2	$<$ 0.1	6,949.5
1971	6,712.4	89.4	162.1	2.2	633.5	8.4	7,508.0
1972	6,968.9	93.9	38.7	0.5	414.5	5.6	7,422.1
1973	7,746.4	97.4	37.1	0.5	168.3	2.1	7,951.8
1974	7,235.2	95.9			312.3	4.1	7,547.5
1975	6,379.2	100.0			1.1	$<$ 0.1	6,380.3
1976	5,734.7	99.9	0.1	$<$ 0.1	5.3	0.1	5,740.1
1977	7,323.8	99.8	6.5	0.1	3.0	$<$ 0.1	7,336.1

*Landings in thousands of pounds.

TABLE A8. Annual landings* and percent contribution of hard blue crabs by gear, Georgia, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Trawl	Percent	Dip Net	Percent	Total
1950	1,320.0	26.3	2,662.6	53.0	1,045.0	20.8			5,027.6
1951	1,055.0	16.2	3,936.4	60.3	1,535.0	23.5			6,526.4
1952	1,987.7	21.0	3,060.1	32.4	4,410.4	46.6			9,458.2
1953	5,962.8	62.9	1,538.0	16.2	1,985.0	20.9			9,485.8
1954	6,289.0	59.1	2,091.5	19.7	2,259.4	21.2			10,639.9
1955	4,767.8	44.4	3,965.0	36.9	2,012.5	18.7			10,745.3
1956	5,293.7	62.0	875.7	10.3	2,140.8	25.1	232.1	2.7	8,542.3
1957	6,088.8	67.9	659.5	7.4	2,067.7	23.1	151.8	1.7	8,967.8
1958	5,655.5	55.5	598.8	5.9	3,658.3	35.9	272.3	2.7	10,184.9
1959	7,908.2	62.4	283.5	2.2	4,192.6	33.1	298.2	2.4	12,682.5
1960	10,111.7	64.1	174.2	1.1	5,107.4	32.4	372.7	2.4	15,766.0
1961	7,653.8	62.2	148.6	1.2	3,965.3	32.2	544.5	4.4	12,312.2
1962	7,517.9	61.1	110.0	0.9	4,095.3	33.3	580.0	4.7	12,303.2
1963	8,022.3	55.3	221.3	1.5	4,286.0	36.5	970.4	6.7	14,500.0
1964	2,859.4	24.8	100.8	0.9	8,484.5	73.6	87.2	0.8	11,531.9
1965	2,964.7	28.9	73.3	0.7	7,089.7	69.1	131.3	1.3	10,259.0
1966	4,102.3	47.9			4,409.3	51.5	44.1	0.5	8,555.7
1967	4,140.4	48.7			4,356.1	51.3			8,496.5
1968	2,229.1	60.8			1,439.8	39.2			3,668.9
1969	3,469.9	67.4			1,647.2	32.0	29.7	0.6	5,146.8
1970	4,386.5	61.8			2,705.7	38.2			7,092.2
1971	5,224.1	61.9			3,211.4	38.1			8,435.5
1972	6,145.7	67.8			2,913.9	32.2			9,058.6
1973	5,515.6	69.1			2,468.6	30.9			7,984.2
1974	8,087.4	79.8			2,043.6	20.2			10,131.0
1975	7,398.4	83.5			1,466.8	16.5			8,865.2
1976	5,289.0	90.1			583.6	9.9			5,872.6
1977	7,390.3	95.7			331.2	4.3			7,721.5

*Landings in thousands of pounds.

TABLE A9. Annual landings* and percent contribution of hard blue crabs by gear, Florida–East Coast, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Trawl	Percent	Dip Net	Percent	Total
1950	5,479.9	100.0	2.5	< 0.1					5,482.4
1951	5,500.0	82.9	187.8	2.8	950.2	14.3			6,638.0
1952	3,492.0	56.8	150.0	2.4	2,507.2	40.8			6,149.2
1953	4,992.7	78.9	720.0	11.4	614.0	9.7			6,326.7
1954	6,031.7	87.1	318.5	4.6	577.1	8.3			6,927.3
1955	5,838.1	76.0	20.3	0.3	1,824.5	23.7			7,682.9
1956	7,496.1	93.1	124.0	1.5	429.1	5.3			8,049.2
1957	6,154.7	94.2	1.0	< 0.1	377.0	5.8			6,532.7
1958	7,985.6	99.9	8.7	0.1			2.2	<0.1	7,996.5
1959	6,602.7	99.9	9.7	0.1			0.2	<0.1	6,612.6
1960	6,945.8	99.8	6.5	0.1	9.0	0.1	0.8	<0.1	6,962.1
1961	7,398.5	98.8			87.1	1.2			7,485.6
1962	7,755.5	98.6	32.4	0.4	80.7	1.0			7,868.6
1963	7,726.6	89.9	340.0	4.0	528.6	6.1			8,595.2
1964	6,564.6	94.4	175.3	2.5	210.9	3.0			6,950.8
1965	5,806.3	97.4			156.9	2.6			5,963.2
1966	7,153.3	97.7			170.0	2.3			7,323.0
1967	9,169.4	98.4			150.0	1.6			9,320.0
1968	6,413.3	96.9	12.0	0.2	190.0	2.9			6,615.3
1969	5,574.1	97.4			150.0	2.6			5,724.1
1970	7,633.5	98.1			145.0	1.9			7,778.5
1971	9,081.7	99.4			50.5	0.6			9,132.2
1972	6,237.5	99.2			50.0	0.8			6,287.5
1973	3,869.7	98.9			44.0	1.1			3,913.7
1974	7,431.7	99.5			40.0	0.5			7,471.7
1975	4,156.3	99.3			29.5	0.7			4,185.8
1976	3,990.5	99.2			33.5	0.8			4,024.0
1977	Data not available								

*Landings in thousands of pounds.

TABLE A10. Annual landings* and percent contribution of soft and peeler blue crabs by gear, Maryland, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Scrape	Percent	Pound Net	Percent	Dip Net	Percent	Total
1950	168.7	5.8	214.9	7.4	2,342.7	80.8			171.8	5.9	2,898.1
1951	94.4	4.7	130.8	6.5	1,667.9	82.5			128.5	6.4	2,021.6
1952	97.6	6.1	135.5	8.5	1,253.5	79.0			101.0	6.4	1,587.6
1953	101.0	5.3	120.3	6.3	1,586.3	83.2			98.3	5.2	1,905.9
1954	85.9	7.7	81.7	7.4	845.7	76.3			95.5	8.6	1,108.8
1955	90.3	7.5	83.8	7.0	938.4	78.1			88.5	7.4	1,201.0
1956	85.0	4.6	72.1	3.9	1,582.6	86.5			89.2	4.9	1,828.9
1957	935.4	27.0	195.9	5.6	2,226.2	64.2			111.5	3.2	3,469.2
1958	685.8	21.0	163.4	5.0	2,318.4	71.0			97.7	3.0	3,265.3
1959	232.0	11.8	79.8	4.0	1,623.3	82.3			37.9	1.9	1,973.0
1960	328.6	11.8	94.2	3.4	2,324.0	83.4			41.1	1.5	2,787.9
1961	257.1	9.6	94.4	3.5	2,302.6	85.5			37.9	1.4	2,692.0
1962	333.8	8.6	117.9	3.0	3,397.9	87.3			42.4	1.1	3,892.0
1963	198.2	9.4	121.6	5.8	1,782.7	84.6			5.6	0.3	2,108.1
1964	264.6	7.6	153.8	4.4	3,067.0	87.7			12.5	0.4	3,497.9
1965	337.5	12.5	137.2	5.1	1,993.7	74.0	212.1	7.9	13.6	0.5	2,694.1
1966	189.6	10.1	134.8	7.2	1,358.5	72.1	189.4	10.1	11.8	0.6	1,884.1
1967	254.7	11.6	163.7	7.5	1,558.6	71.3	190.0	8.7	19.3	0.9	2,186.3
1968	123.2	12.3	99.7	10.0	723.7	72.3	50.0	5.0	5.0	0.5	1,001.6
1969	161.9	7.2	110.0	4.9	1,740.8	77.3	202.7	9.0	35.2	1.6	2,250.7
1970	103.4	10.2	63.6	4.0	1,212.2	76.7	167.3	10.6	33.3	2.1	1,579.8
1971	156.3	10.2	60.9	4.0	1,170.8	76.5	106.7	7.0	35.4	2.3	1,530.1
1972	107.3	6.8	52.7	3.3	1,274.8	80.9	112.7	7.2	27.3	1.7	1,574.8
1973	126.8	8.4	41.7	2.8	1,193.8	78.9	125.5	8.3	25.7	1.7	1,513.5
1974	101.2	5.6	58.3	3.2	1,438.3	79.0	194.5	10.7	29.3	1.6	1,821.6
1975	153.8	9.3	47.8	2.9	1,231.6	74.5	200.0	12.1	20.7	1.3	1,653.9
1976	156.6	10.6	52.1	3.5	1,073.5	72.8	175.0	11.9	16.5	1.1	1,473.7
1977	70.1	6.1	45.6	4.0	873.3	75.8	150.4	13.1	12.7	1.1	1,152.1

*Landings in thousands of pounds.

TABLE A11. **Annual landings* and percent contribution of soft and peeler blue crabs by gear, Virginia, 1950–1977.**

Year	Pot	Percent	Trot Line	Percent	Scrape	Percent	Fyke Net	Percent	Pound Net	Percent	Dip Net	Percent	Hand	Percent	Other	Percent	Total
1950	368.4	11.4	87.4	2.7	1,337.4	41.4	1,133.1	35.1			115.0	3.6	185.1	5.7	3.9	0.1	3,230.3
1951	251.6	5.6	63.6	1.4	2,579.7	57.4	959.0	21.4			94.7	2.1	26.0	0.6	516.9	11.5	4,491.5
1952	164.8	7.5	53.1	2.4	1,035.4	46.9	861.7	39.0			79.7	3.6	12.3	0.6	0.4	< 0.1	2,207.4
1953	164.6	6.4	43.6	1.7	1,411.0	54.7	892.3	34.6			63.3	2.5	5.9	0.2	0.8	< 0.1	2,581.5
1954	173.9	8.3	48.1	2.3	940.0	45.0	850.7	40.7			63.8	3.1	14.3	0.7			2,090.8
1955	182.2	10.1	42.9	2.4	580.7	32.1	905.4	50.1			68.1	3.8	29.0	1.6			1,808.3
1956	93.3	5.1	25.9	1.4	423.1	23.3			1,034.3	56.9	175.5	9.7	61.4	3.4	3.0	0.2	1,816.5
1957	132.2	8.1	26.7	1.6	406.0	24.9			964.6	59.1	65.6	4.0	32.8	2.0	5.4	0.3	1,633.3
1958	174.1	12.9	17.4	1.3	213.2	15.8			853.9	63.4	46.7	3.5	39.2	2.9	3.1	0.2	1,347.6
1959	284.9	23.0	20.0	1.6	173.7	14.0			701.2	56.5	36.8	3.0	24.0	1.9			1,240.6
1960	493.6	31.0	31.5	2.0	200.0	12.6			789.2	49.6	37.8	2.4	38.1	2.4			1,590.2
1961	360.9	23.0	20.9	1.3	177.9	11.3			878.1	56.0	97.4	6.2	33.0	2.1			1,568.2
1962	271.6	20.2	28.6	2.1	204.3	15.2			777.1	57.7	36.9	2.7	28.8	2.1			1,347.3
1963	238.8	25.2	19.2	2.0	106.5	11.2			499.6	52.7	63.1	6.7	21.6	2.3			948.8
1964	369.0	37.0	20.9	2.1	139.7	14.0			374.9	37.6	73.0	7.3	20.2	2.0			997.7
1965	419.6	38.9	13.4	1.2	39.0	3.6			560.5	51.9	44.9	4.2	2.0	0.2			1,079.4
1966	365.3	35.5	27.2	2.6	156.3	15.2			418.6	40.7	60.6	5.9					1,028.0
1967	288.0	23.7	12.1	1.0	211.4	17.4			661.1	54.3	29.0	2.4	15.6	1.3			1,217.2
1968	318.6	39.5	33.7	4.2	150.5	18.7			273.5	33.9	15.4	1.9	14.0	1.7			805.7
1969	1,074.2	54.5	58.9	3.0	500.0	25.4			367.0	13.5	49.5	2.5	21.2	1.1			1,970.8
1970	393.8	43.3	34.7	3.8	316.4	34.8			132.2	14.5	23.2	2.6	9.4	1.0			909.7
1971	369.1	53.3			100.0	14.4			221.6	32.0			2.0	0.3			692.7
1972	390.8	45.6			246.7	28.8			213.7	24.9			6.6	0.8			857.8
1973	615.1	62.6			195.9	19.9			172.0	17.5							983.0
1974	552.7	67.9			80.4	9.9			172.7	21.2			8.0	1.0			813.8
1975	405.3	53.7			100.3	13.3			248.7	33.0							754.3
1976	345.0	45.3			54.5	7.2			361.4	47.5							760.9
1977	475.6	68.4			15.6	2.2			204.1	29.4							695.3

*Landings in thousands of pounds.

TABLE A12. Annual landings* and percent contribution of soft and peeler blue crabs by gear, North Carolina, 1950–1977.

Year	Pot	Percent	Trot Line	Percent	Trawl	Percent	Dip Net	Percent	Haul Seine	Percent	Total
1950					178.1	85.3			30.7	14.7	208.8
1951					134.5	80.5	4.0	2.4	28.5	17.1	167.0
1952					98.5	79.3	12.0	9.7	13.7	11.0	124.2
1953					125.4	74.7	12.8	7.6	29.6	17.6	167.8
1954					85.6	90.0	9.5	10.0			95.1
1955					22.3	86.4	3.5	13.6			25.8
1956					67.1	94.5	3.9	5.5			71.0
1957					58.1	91.4	5.5	8.6			63.6
1958					60.9	80.6	14.7	19.4			75.6
1959					119.9	96.4	4.5	3.6			124.4
1960					81.9	90.1	9.0	9.9			90.9
1961					89.8	89.1	11.0	10.9			100.8
1962					90.2	92.3	7.5	7.7			97.7
1963					77.9	93.4	5.5	6.6			83.4
1964					63.6	91.2	6.1	8.8			69.7
1965					150.8	63.6	86.2	36.4			237.0
1966	37.6	29.9	20.8	16.6	67.2	53.5					125.6
1967	21.5	25.0	22.0	25.6	42.0	48.8	0.6	0.7			86.1
1968					83.4	99.9	0.1	0.1			83.5
1969	18.9	20.2			71.2	76.2	3.3	3.5			93.4
1970	9.6	16.1			44.2	73.9	6.0	10.0			59.8
1971	1.7	3.5	0.2	0.4	37.7	77.1	9.3	19.0			48.9
1972	11.8	23.6			35.2	70.4	3.0	6.0			50.0
1973	25.7	57.0			19.4	43.0					45.1
1974	8.7	26.1			24.6	73.9					33.3
1975	8.2	40.8			11.9	59.2					20.1
1976	16.0	80.0			4.0	20.0					20.0
1977	9.9	61.9			6.1	38.1					16.0

*Landings in thousands of pounds.

DISCUSSION

Q. **May Usannaz**: Since you have a trawl and dredge fishery for crabs on the east coast, do you have complaints from processors about sand or trash in the crabs, and do they die faster using these methods of capture? Processors in the Gulf do not like to buy trawl or dredge crabs.

A. **Terry Sholar**: I have never heard that comment about having trouble with sand or trash in trawl-caught crabs. There is a small dredge fishery in North Carolina, but it is done primarily in conjunction with oyster dredging in the winter. Basically, they use oyster dredges and they keep all of the crabs they catch. I have never heard any comments about them having problems with trash or anything like that.

Comment–Usannaz: From our own observations crabs seem to die faster.

Comment–(Unidentified): There are a couple of factors to consider here. One is that most of your trawl-caught crabs are females; most processors would rather not deal with female crabs if they can get male crabs. Two, processors will buy trawl-caught crabs if they cannot get pot-caught crabs.

Comment–Sholar: In North Carolina, in the spring and fall, the trawlers are working on jimmies, too. Basically, the reason they do that is because the crabs are so inactive that they don't pot well. Shrimpers are not shrimping at that particular time, therefore, they put the crab trawls on and go crabbing; it is a tradeoff.

Comment–(Unidentified): In Louisiana, I think the trawl crab is objectionable. My husband is a shrimper with a big boat. He makes 3-hour drags which kills quite a few crabs. The trawlers will not hold the crabs because they stay out anywhere from 5 to 8 days. No one wants to hold crabs when they come in; they do not want to take up the space with crabs instead of shrimp. Now the smaller boats may only drag an hour at a time, so the crabs are in better condition. I am a crab buyer and if the crabs are in good condition, I will buy them.

Comment–Sholar: Again, the crab trawl fishery in Pamlico Sound, NC, is a day-trip operation. The crabbers are based right there on the Sound; they go out in the morning and come in that same day. They land the fish on the same day. Its primarily a small boat fishery, 40- or 50-foot boats; you very rarely see a large shrimp boat.

Q. **(Unidentified)**: Earlier you mentioned that Maryland had run a survey on their sports fisheries, do you have any information on how the survey was conducted?

A. **Sholar**: I am not really sure.

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REVIEW OF THE SOFT–SHELL CRAB FISHERY IN THE UNITED STATES[1]

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INTRODUCTION

Soft-shell crab fisheries in the United States began around the Chesapeake Bay. Credit for initiation of the fishery belongs to some anonymous, brave soul who dreamed of the challenging consumption of a dangling mass of post-molted, whole-fried blue crab legs protruding from two pieces of bread. Although his concoction was not a picture of delight, the rewarding, succulent flavor of the soft-shell crab was a delightful experience which defied attempts to protect the secret recipe. Thus, a taste for soft-shell crabs grew in popularity throughout the Chesapeake Bay region. In time, the demand for soft-shell crabs increased along the entire Atlantic seaboard, extending into specific southern regions, in particular, New Orleans.

This review outlines the response of the blue crab industry to this growing demand for soft-shell crabs. The trends in production and market value suggest that the demand for soft-shell crabs has always exceeded supply. Currently, soft-shell crabs are so popular, they demand some of the highest prices paid for any seafood on the market today. This situation has prompted the recent recommendation for introduction of blue crab shedding operations where they are presently underutilized and show potential (Rhodes and Van Engle 1978).

SHEDDING OPERATIONS

In response to a growing demand for soft-shell crabs, attempts to mass produce soft-shell blue crabs began in the mid-1800's. Warner (1976) gives a brief, entertaining account of early attempts to shed crabs. Controlled shedding began in the 1950's with wire enclosures (crab pounds) staked in tidal zones. Initially there was no specific sorting of the hard-shell crabs prior to placement in the pens. These wire pens were filled with hard-shell crabs which were fed and watched very closely for molting. This method was difficult to manage and numerous crabs were lost to cannibalism and mortality due to variations in water quality.

Later, the crab pounds were equipped with floating boxes to house and protect those crabs nearer to molting. Experienced producers had learned to examine hard-shell crabs for unique signs which indicated a premolt condition. These floating boxes were successful and were continually modified to suit specific requirements of individual producers. The boxes were built from pine, cedar, and/or cyprus depending on available wood. Some box modifications include tapered designs to prevent resistance to tidal flow, and solid flooring (without slots) to prevent predation from fish (eels). Box size, depth, and location varied with preference.

In time, producers used more floating boxes or cars and became less dependent on crab pounds which required extra care and feeding. Production become more dependent on a selective harvest of peelers; hard-shell crabs displaying premolt signs. Dealers who learned the "fine art" of shedding, began to separate the peelers into a series of floating boxes according to the progressive signs of premolting.

Little change occurred until the 1950's, when bank floats or shore floats were developed. Shore floats were simply troughs or shallow-built shedding tables used to hold running water pumped from an adjacent natural water supply. The open systems were easier to manage, and they soon evolved into enclosed shedding tables which were housed to provide shade and protection from rain and predators. To prevent cannibalism, some dealers would nick the crab claws. Nicking simply broke the moveable finger of the claw, but if done incorrectly, could promote diseases and hinder the molting process. Some researchers (Overstreet and Cook 1972) have suggested that removing the eye stalks from crabs would enhance shedding because the eyes contain cells with a molt-inhibitory hormone (Knowles and Carlisle 1956). Removing these hormones would accelerate the shedding process. Unfortunately, experience has shown that this method is not reliable and could promote diseases, death, or hinder shedding. Proper sorting according to premolt signs remains the better method to control cannibalism and shedding.

Today, floating boxes are still used, but enclosed shedding tables are more popular. These open systems depend on the quality of the water pumped from the natural water supplies and on the selective harvest of premolt blue crabs. Researchers (Haefner and Garten 1974, Epifanio et al. 1973, Winget et al. 1973) have tried to develop elaborate closed systems that control water temperature, salinity, oxygen, etc., to eliminate the water quality problems. Theoretically these systems could enhance molting and/or prolong the molting season. Overstreet and Cook (1972) described an early attempt at closed-system shedding in Mississippi. The first successful and practical closed system

[1]This review has been extracted from portions of the final report on Florida Sea Grant Immediate Response Project, "Development of a Soft Crab Fishery in Florida," funded from October–December 1978.

of troughs has recently opened in Mississippi (Anon. 1979, Perry et al. 1982). This large closed system claims to produce 60 to 90 dozen soft-shell crabs per day during the peak season for peelers. Currently, Louisiana and Maryland crabbers are trying to develop practical closed systems for use near shore and inland. Thus the present trend in soft-shell crab production is toward closed systems, but production from these systems still depends on a source of premolt crabs or peelers.

PEELER HARVEST

Regardless of the shedding system used, all methods gradually became more dependent on the selective harvest of premolt blue crabs or peelers. Initially, peelers were collected at random. Folk tales recommended soft-shell crab hunting was best during the light of a full moon when peelers were more visible. Some producers argued that more crabs molt on the dark moon when darkness provided protection from predators. The influence of the moon phase on blue crab molting has not been studied, but the commercial soft-shell crab "experts" agree it is a definite part of the soft-shell crab "art."

Crabbers who had learned the signs for the premolt condition would sort for peelers caught in their traps or on their trotlines. Crabs caught in traditional crab traps or pots were more difficult to examine and subject to damage which would adversely affect the shedding process. Crabs caught on trotlines (continuous lines of special baits tied at measured intervals) could be individually examined and were in better postharvest condition. Trotlines were productive and yielded the preferred peeler, but were more labor demanding than traditional pots.

"Jimmie" potting was the first, simple attempt at selective harvesting of premolting blue crabs. The principle of the system was to use 1 to 3 large male crabs (jimmies) as a live "bait" to attract female peelers. Female blue crabs, during their last (terminal) molt, will mate with a mature male crab. One large jimmie can attract many female peelers. The males are placed in a closed compartment to prevent cannibalism. The jimmie pot is built of 1-inch mesh wiring as opposed to the 1.5-inch mesh used in common crab pots. The effectiveness of the jimmie pot would depend on the availability of free male crabs. A region and/or season with a high female-to-male crab ratio is best for jimmie potting.

Some crabbers have used empty, unbaited pots (bare potting) to attract peelers of both sexes. These bare pots are constructed of 1-inch mesh wiring. A recent modification of this pot, using shading material to enclose the pot as an "artificial habitat," has been demonstrated as a potential method to harvest peelers in South Carolina (Bishop et al. 1982).

In 1870, a patented crab scrape was invented for towing through shallow grassbeds often inhabited by blue crabs in premolt conditions (Warner 1976). The scrape consisted of a rectangular metal frame (approximately 1 X 4 square feet) weighing about 40 pounds and was equipped with cotton netting to bag the catch and a bridle for towing from a small skiff. The frame would scrape through the grass, cutting well above the root line and capture peelers seeking grassy protection. Some hand-operated push scrapes have been equipped with rollers to facilitate the flow through the grass.

Bush lines and peeler pounds have also been used to catch peelers from specific habitats. Bush lines are artificial habitats created by bush cuttings strung in waters 3 to 6 feet deep (Horst 1979). One bush line can consist of over 100 bushes tied in one long row between permanent posts. After the peelers seek the bushes for protection, the line is periodically lifted for harvest. Bush lines made with cuttings from wax myrtles are most popularly used in Louisiana. Peeler pounds are modeled after the traditional Chesapeake Bay fish pounds (Van Engle 1979). A wire mesh (1 square inch) lead is built perpendicular from the shore, running into the "heart" which channels the crabs into the head section (wire mesh, 1 square inch). The head (approximately 3 X 4 X 5 cubic feet) is situated such that the high tide line does not cover the entire trap. The crabber can harvest the peelers directly from the top of the trap. The selectivity of the peeler pound for premolt crabs is not well understood, but location of the pound is critical. Location depends on availability of peelers, but should avoid destructive tidal flow.

Presently, peelers are harvested by all methods previously discussed, but each method is area specific. The crab scrapes and peeler pounds used in the Chesapeake Bay are not suited for use in more southern regions which lack broad, shallow grassbeds and gentle tidal flows. The traditional wax myrtle bush line has not been used outside of Louisiana. Hopefully, jimmie potting and the recently introduced artificial habitats (Bishop et al. 1982) will have more universal application. Overall the common crab trap remains the most popular source of peeler crabs. Despite damage caused during harvesting and sorting, crab traps are more practical and offer additional income from hard-shell crabs. Peeler production from crab traps depends on the location fished and the ability of the crabber to select true peelers.

Thus, the development of the soft-shell crab industry has been an evolution of methods designed for convenient mass shedding; and the shedding methods used have always depended on a source of premolt crabs. Use of peelers minimizes the holding time in the shedding facility and assures a higher percent shedding. Use of green crabs (non-peelers) would require feeding and monitoring of water quality. Despite the extra care, experience indicates that the extra labor is no assurance that green crabs would survive and shed. Successful soft-shell crab shedding operations are designed to minimize the work required for this labor-intense art.

PRODUCTION AND VALUE

Average annual production (and/or landings—terms used synonymously in this report) of soft-shell crabs in the United States since 1970 slightly exceeds 2.6 million pounds (Table 1 and Figure 1). This average production represents less than 2% of the respective hard-shell blue crab harvest, but the soft-shell crab dollar value averaged greater than 9% of the total hard-shell crab value. Present production of soft-shell crabs in the 1970's is at least 38% less than averaged in previous decades, but present production is more consistent. (Standard deviation for production since 1970 is ± 181 as compared to ± 1,123 and ± 1,091 for the 1950's and the 1960's, respectively.) Despite fluctuations in production, the dollar value per pound for soft-shell crabs has continuously increased. From 1950 to 1970, the value increased at an annual rate slightly greater than 1% per year, but since 1970, the average annual value has accelerated from $0.42 to $1.04 per pound in 1977.

It is apparent that an inverse relationship has existed between hard- and soft-shell blue crab landings between 1950 and 1978 (Figure 1). Generally, the overall trend in hard-shell blue crab landings is positive during this period while that of soft-shell blue crab landings is negative. At the same time, soft-shell blue crab prices or values have increased

TABLE 1.

Total United States landings and value of blue crabs, 1950–1978.

	Market Form					
	Hard-Shell Crabs		Soft-Shell Crabs			
Year	Thousands of pounds	Cents per pound[1]	Thousands of pounds	Cents per pound[1]	Soft-shell crab landings (as % of hard-shell crab landings[2])	Soft-shell crab landed value (as % of hard-shell crab landed value)
1950	119,346	0.04	6,727	0.16	5.6	22.9
1951	107,807	0.04	6,566	0.21	6.1	31.9
1952	99,837	0.04	4,411	0.20	4.4	19.7
1953	105,384	0.05	5,155	0.18	4.9	19.9
1954	97,750	0.04	3,761	0.21	3.8	18.2
1956	94,003	0.06	4,334	0.21	4.6	16.1
1957	107,978	0.06	5,750	0.22	5.3	20.0
1958	105,641	0.05	5,293	0.22	5.0	20.2
1959	112,531	0.06	3,957	0.28	3.5	15.9
10-year average	104,793	0.05	4,960	0.21	4.7	20.0
1960	149,646	0.05	5,051	0.27	3.4	17.5
1961	147,652	0.05	5,106	0.28	3.5	20.9
1962	149,347	0.05	5,871	0.25	3.9	19.3
1963	141,743	0.05	3,514	0.37	2.5	16.8
1964	152,297	0.06	4,795	0.39	3.1	20.4
1965	166,996	0.07	4,273	0.38	2.8	14.3
1966	166,827	0.06	3,172	0.39	1.9	12.5
1967	145,027	0.06	3,649	0.40	2.5	16.8
1968	113,619	0.10	2,178	0.47	1.9	9.1
1969	132,255	0.09	4,524	0.41	3.4	14.8
10-year average	146,541	0.06	4,213	0.36	2.9	16.2
1970	146,410	0.07	2,675	0.42	1.8	10.8
1971	149,081	0.09	2,421	0.50	1.6	9.4
1972	147,468	0.10	2,610	0.50	1.8	8.9
1973	136,516	0.13	2,701	0.54	2.0	8.2
1974	149,176	0.13	2,964	0.57	2.0	8.8
1975	130,816	0.14	2,622	0.75	2.0	10.4
1976	113,152	0.20	2,533	0.76	2.2	8.0
1977	128,860	0.21	2,453	1.04	1.9	9.3
1978	138,230	0.20	na	na	na	na
9-year average	137,643	0.14	2,710	0.64	1.7	9.7
Total average	129,381		4,021		2.3	5.6

[1]Value computed from reported total value data.

[2]Indicates the total soft-shell crab and peelers landed relative to the total crabs landed. Thus a state that only reports hard-shell crab landings can use this figure to estimate potential soft-shell crab landings.

na – data not available.

Source: Recorded and derived from Fishery Statistics of the U.S. and *Annual Landings Reports* of the various regions, 1950–1978. U.S. National Marine Fisheries Service.

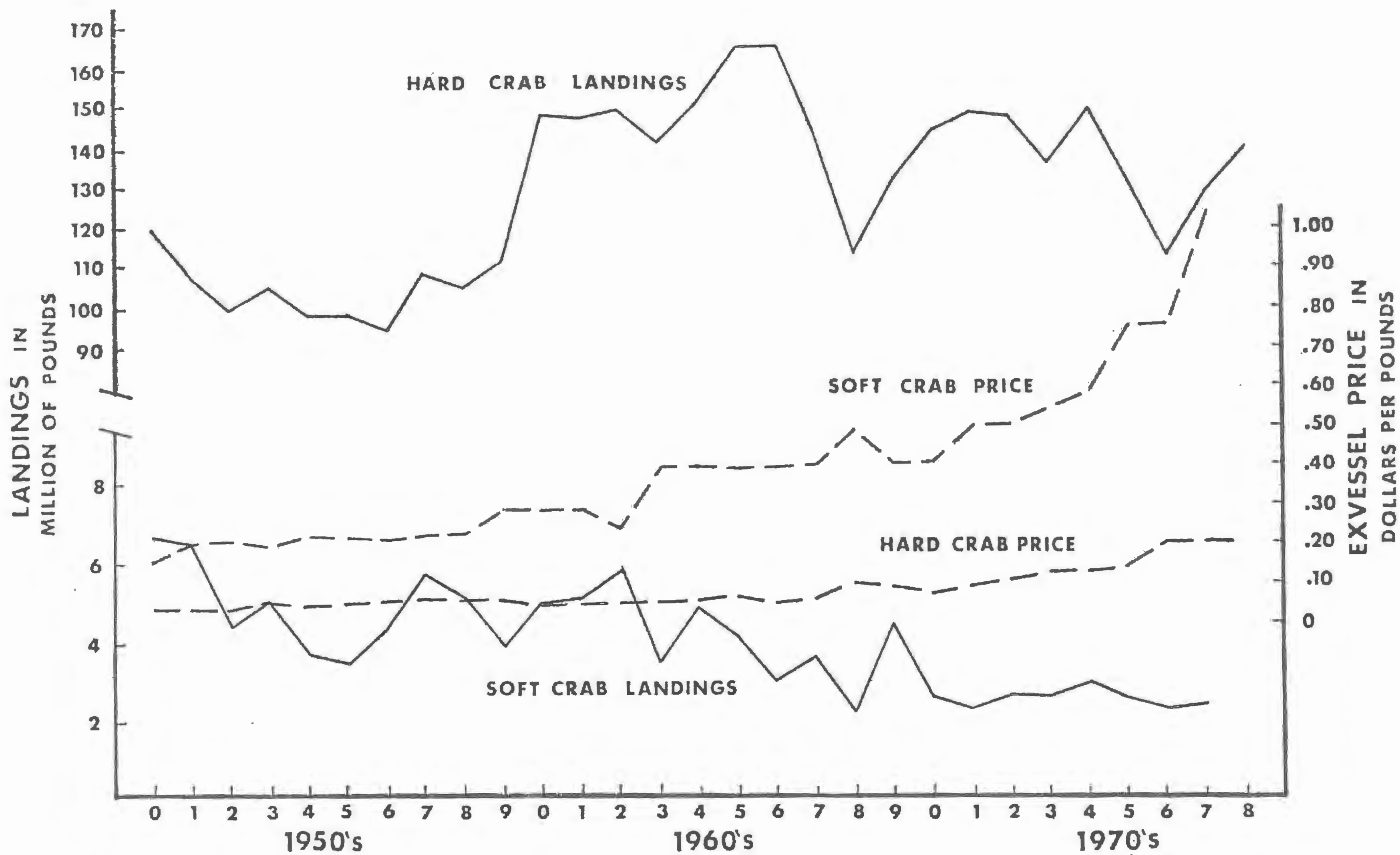

Figure 1. Landings and ex-vessel prices of soft- and hard-shell blue crabs in the United States, 1950–1978.

at a much more rapid rate as discussed earlier. The effect of this decline in soft-shell crab landings is probably reflected through the price increases. Even with stable demand, decline in the supply of soft-shell crabs would result in higher prices in the marketplace. Normally, higher prices would encourage the expansion of soft-shell crab supplies or landings, and/or a diversion of hard-shell crabs into the soft-shell crab market. One possible explanation why this has not happened is that soft-shell crab fishing and shedding are a labor intensive art and those with the adequate knowledge and desire to practice this labor intensive occupation are declining in number.

The use of poundage to express the dollar value of soft-shell crabs is inconsistent with commercial practice and complicates the interpretation of production data. Soft-shell crabs are usually sold by the dozen and, in most regions, are graded by size (width). The value of a graded size can vary in a season (Table 2). Fishery statisticians record soft-shell crab sales in dollars per pound using 2.5 pounds per dozen for conversion to the commercial scale (Statistical Branch, NMFS, Easton, MD, personal communication, 1979). Recorded sales are considered transactions at the dock or direct return to the producer. Recorded sales include peelers and soft-shell crabs. These records cannot account for variations in price/grade of a dozen, specific price per dozen by region, differences in price and weight of peelers versus equal size soft-shell crabs, etc. Understandably, the small volume of the soft-shell crab industry does not warrant more specific identification, thus, more specific interpretation of the records is limited to overall trends and speculation.

TABLE 2.

Northern Chesapeake Bay region wholesale soft-shell crab prices by common market category, 1978.

Grades	Size[2] (inches)	Color Code	Wholesale Value[1] (dollars per dozen) June	July	August
Whales (slabs)	>5.5		10.00	9.50	7.50
Jumbos	5.0–5.5	Red	9.00	8.50	6.50
Primes	4.5–5.0	Orange	7.00	6.50	4.00
Hotel primes	4.0–4.5	Yellow	5.00	4.00	3.00
Mediums	[4]3.5–4.0	Green	3.00	2.00	1.50

[1]Wholesale value is direct-sales price paid by the handler to the primary producer or operator of the shedding facility. Handlers would normally add from $2.00 to $3.00 for packing and shipping.
[2]Distance measured between lateral spine tips of carapace.
[3]Box color codes used to indicate grade.
[4]The minimum legal size width for marketing soft-shell crabs in Maryland.
Source: Personal communication, University of Maryland Seafood Laboratory in Crisfield, MD.

Only six states (New Jersey, Delaware, Maryland, Virginia, North Carolina, and Louisiana) record any substantial (greater than 1,000 pounds per year) soft-shell crab production (Table 3). Annual production per state suggests the Chesapeake Bay has always been the major productive region for soft-shell crabs. In the 1970's, Virginia and Maryland accounted for over 90% of the total soft-shell crabs produced. Larger volumes of hard-shell crabs were harvested in Virginia, but Maryland produced a larger volume of soft-shell crabs. This may be due to the origin of soft-shell crabbing in Maryland and the higher yield of peelers in the abundant grassy shoals of the northern Chesapeake Bay.

Traditionally the southern states have produced the more valuable soft-shell crabs (Table 3 and Figure 2). Louisiana produces the most valuable soft-shell crabs (1977, $2.53 per pound). Speculative reasons for the higher value for Louisiana soft-shell crabs suggest a larger crab size (Lee and Stanford 1962), excessive demand in New Orleans, and a common practice of direct sales to retailers (Horst 1979). Most Louisiana producers are not dependent on established northern markets and they sell directly to local restaurants. The normal middleman's margin or share of the profit would, in this case, be recorded in the dollar value to the producer.

All current indications suggest the value of soft-shell crabs is continuing to increase. Some new dealers in the southeast have indicated they are selling nongraded soft-shell crabs at $10.00 to $15.00 per dozen (personal communications, 1979). This commercial value, converted to the statisticians scale ($4.00 to $6.00 per pound), is inconsistent with previously recorded values and may reflect the high demand for early spring production and/or the inaccuracy of the statistical data.

Despite the limitations of the recorded data, soft-shell crabbing appears to remain a profitable business. Supply of soft-shell crabs has decreased to a steady state production just above 2.6 million pounds per year, but price has continued to increase. Thus, expansion of soft-shell crab fisheries warrants further investigations.

SUMMARY

The soft-shell crab industry originated during the late 1800's in the Chesapeake Bay region and slowly spread to neighboring states. Today only six states (New Jersey, Delaware, Maryland, Virginia, North Carolina, and Louisiana) record a substantial soft-shell crab production, and the Chesapeake Bay region remains the dominant production area. Since 1970, the average annual production of soft-shell crabs in the United States exceeds 2.6 million pounds. Increasing per pound value for soft-shell crabs indicates demand exceeds the current supply.

Production methods for soft-shell crabs have evolved through a series of open culture systems which house the crabs during their natural molting process. Thus, soft-shell crab production has always depended on a source of pre-molting crabs or peelers which require less residence time in

TABLE 3.

Total annual landings and value of hard- and soft-shell blue crabs in states that record a substantial soft-shell crab fishery.

	Market Form					
	Hard-Shell Crabs		Soft-Shell Crabs			
Year	Thousands of pounds	Cents per pound[1]	Thousands of pounds	Cents per pound[1]	Soft-shell crab landings (as % of hard-shell crab landings[2])	Soft-shell crab landed value (as % of hard-shell crab landed value)
			NEW JERSEY			
1970	538	0.15	18	0.24	3.3	5.4
1971	1,153	0.16	15	0.33	1.3	2.8
1972	1,437	0.22	15	0.30	1.0	1.4
1973	2,572	0.26	23	0.67	0.9	2.3
1974	2,745	0.24	126	0.42	4.6	7.9
1975	2,870	0.22	39	0.41	1.3	2.5
1976	2,696	0.31	90	0.44	3.3	4.8
1977	390	0.38	5	0.53	1.3	1.7
Average	1,800		41		2.1	3.6
			DELAWARE			
1970	na	na	na	na	na	na
1971	1,014	0.20	9	0.56	0.9	2.5
1972	2,552	0.26	10	0.80	0.4	1.2
1973	2,373	0.26	18	0.72	0.8	2.0
1974	2,248	0.18	73	0.71	3.2	13.0
1975	3,551	0.22	34	0.71	1.0	3.1
1976	3,565	0.30	na	na	na	na
1977	862	0.35	na	na	na	na
Average	2,309		29		1.3	4.4
			MARYLAND			
1970	24,935	0.08	1,579	0.42	6.3	32.1
1971	23,935	0.09	1,530	0.48	5.9	29.6
1972	23,482	0.10	1,575	0.48	6.7	31.8
1973	19,539	0.14	1,513	0.50	7.7	27.4
1974	24,660	0.16	1,822	0.57	7.4	25.4
1975	24,264	0.18	1,654	0.53	6.8	20.3
1976	19,429	0.24	1,474	0.73	7.6	23.4
1977	19,243	0.24	1,512	0.92	7.9	29.9
Average	22,703		1,582		7.0	27.5
			VIRGINIA			
1970	42,416	0.06	909	0.37	2.1	14.2
1971	47,807	0.08	693	0.46	1.4	8.7
1972	48,554	0.08	858	0.48	1.8	10.4
1973	36,746	0.11	983	0.41	2.7	12.2
1974	40,850	0.10	814	0.49	2.0	9.5
1975	34,819	0.14	754	0.51	2.2	7.7
1976	25,761	0.20	761	0.72	3.0	10.8
1977	37,160	0.18	695	0.84	1.9	8.7
Average	39,264		808		2.1	10.3
			NORTH CAROLINA			
1970	20,880	0.06	59	0.39	0.3	1.9
1971	14,476	0.08	49	0.51	0.3	2.2
1972	13,479	0.10	50	0.58	0.4	2.2
1973	11,963	0.13	45	0.62	0.4	1.8
1974	13,164	0.10	33	0.70	0.3	1.7
1975	11,072	0.13	20	0.85	0.2	1.2
1976	11,732	0.20	20	1.32	0.2	1.1
1977	12,221	0.18	16	1.06	0.1	0.8
Average	13,573		37		0.3	1.6

TABLE 3 (Continued).

Total annual landings and value of hard- and soft-shell blue crabs in states that record a substantial soft-shell crab fishery.

	Market Form					
	Hard-Shell Crabs		Soft-Shell Crabs			
Year	Thousands of pounds	Cents per pound[1]	Thousands of pounds	Cents per pound[1]	Soft-shell crab landings (as % of hard-shell crab landings[2])	Soft-shell crab landed value (as % of hard-shell crab landed value)
			LOUISIANA			
1970	10,254	0.09	89	0.90	0.9	8.6
1971	12,186	0.10	127	0.99	1.0	10.0
1972	15,083	0.12	102	1.07	0.7	6.1
1973	23,080	0.12	119	1.11	0.5	4.7
1974	20,640	0.13	96	1.32	0.5	4.7
1975	17,144	0.15	119	1.30	0.7	6.2
1976	15,211	0.20	88	1.65	0.6	4.7
1977	16,154	0.23	225	2.53	1.4	15.1
Average	16,219		121		0.8	7.5

[1]Value computed from reported total value data.

[2]Indicates the total soft-shell crab and peelers landed relative to the total crabs landed. Thus a state that only reports hard-shell crab landings can use this figure to estimate potential soft-shell crab landings.

na – data not available.

Source: Recorded and derived from *Fishery Statistics of the U.S.* and *Annual Landings Reports* of the various regions, 1950–1978. U.S. National Marine Fisheries Service.

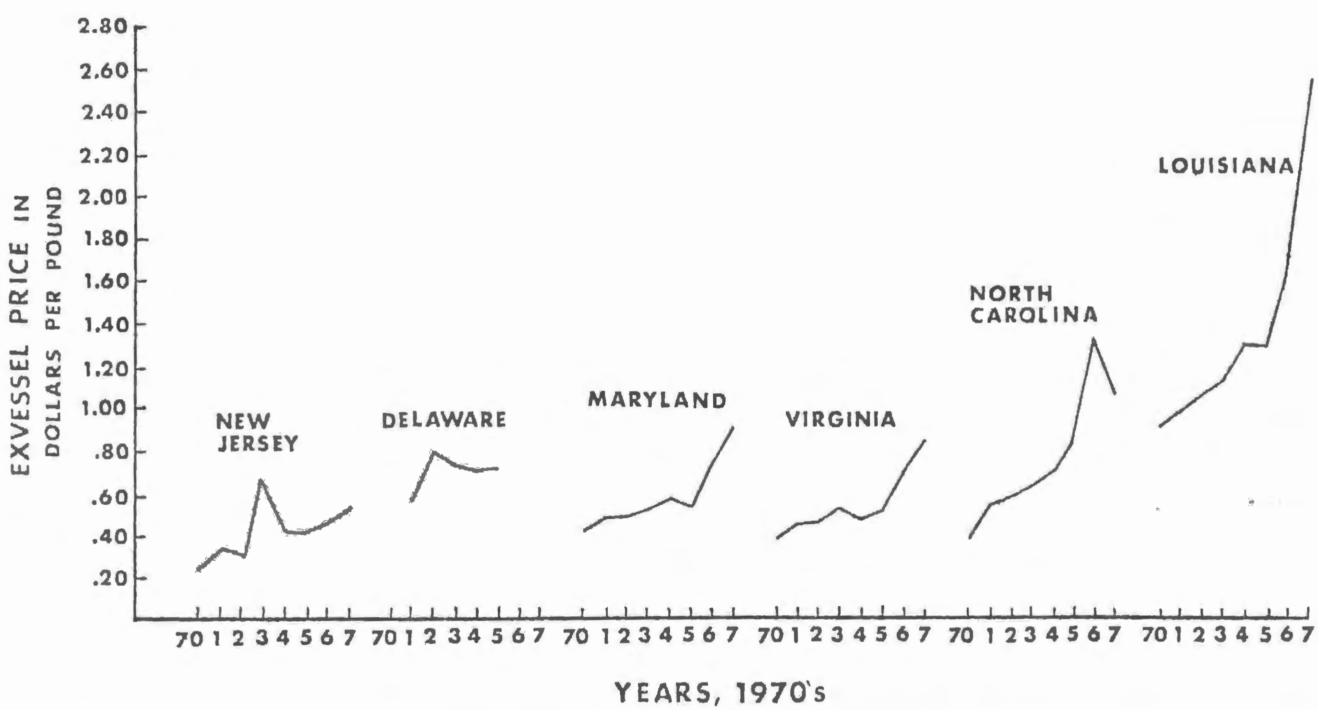

Figure 2. Ex-vessel price in dollars per pound of soft-shell crabs in New Jersey, Delaware, Maryland, Virginia, North Carolina, and Lousiana, 1970–1977.

the culture system. Prolonged residence in the system would be more labor demanding and expensive. Currently new closed culture systems designed to control water quality are being developed. Theoretically these systems could use green crabs (nonpeelers), but they presently still remain dependent on a source of true peelers. Today, successful soft-shell crab shedding operations are designed to minimize the work and expense of this labor intensive art.

Expansion of soft-shell crab fisheries into regions presently underutilized and which show potential for production warrant further investigations. Initial investigations should determine the availability of peelers. Production methods should include both open and closed systems. Marketing promotions would be required to introduce soft-shell crabs into underutilized areas. The overall result could be the development of a fishery which offers promise for the small-scale fishermen, who normally are not able, to take advantage of expansion into more capital-intensive fisheries.

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THE FISHERY FOR SOFT CRABS WITH EMPHASIS ON THE DEVELOPMENT OF A CLOSED RECIRCULATING SEAWATER SYSTEM FOR SHEDDING CRABS

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ABSTRACT This paper reviews methods for recognizing, harvesting, and shedding peeler crabs. The theory of operation and designs for constructing a closed recirculating seawater system are presented.

INTRODUCTION

The origins for consumption of soft-shell crabs (hereinafter referred to as soft crabs) are lost in antiquity; however, records of the fishery date back to the mid-1800's (Warner 1976). Historically, the Chesapeake Bay states of Maryland and Virginia have produced the highest percentage of this country's soft crab catch. These states sustained an annual yield of 4 to 4.5 million pounds* in the 1960's, with the catch falling to half of that figure in the 1970's. Louisiana is the major supplier of soft crabs to the southern states. Soft crab landings in that state have fluctuated widely, declining from a record 2,370,000 pounds in 1945 to 119,000 pounds in 1979. Soft crab production in the other Gulf states has been limited to a few small operations, usually associated with live bait dealers. The drastic decline in soft crab landings along the Gulf and Atlantic coasts of the United States has been attributed to a general lowering of water quality, loss of natural habitats, and disease.

Despite the decline in production, the value for soft crabs has continued to increase in all states harvesting the resource. Prices paid for soft crabs in the Gulf states have traditionally exceeded the prices paid for soft crabs in the Chesapeake and south Atlantic states. Current 1979 data indicate the value of the resource in the Atlantic to be in excess of $2 million with a price per pound of $1.05. Landings of 128,000 pounds, recorded from the Gulf states in 1979, were worth $277,000 with a price per pound of $2.16. When compared to the average price per pound for hard-shell crabs (hereinafter referred to as hard crabs) ($0.22 Atlantic, $0.18 Gulf) in 1979, the prices paid for soft crabs should encourage rapid expansion of the industry. However, there has been little growth of the fishery because of the continuing decline in the quality of estuarine waters, and the lack of a reliable source of supply of peeler crabs. The use of closed, recirculating seawater systems to hold and shed peeler crabs should allow for growth of the industry regardless of coastal water quality, thus leaving the problem of source of supply still to be resolved.

*All statistical data are from *Current Fishery Statistics, Monthly Landings*, published by the U.S. National Marine Fisheries Service.

THE MOLTING PROCESS

Because they possess a hard outer shell (exoskeleton or cuticle), blue crab growth is discontinuous. Increase in size is accomplished by casting off the rigid shell in a process called molting, ecdysis, or shedding. Molting involves the softening or dissolution of the inner layer of the old exoskeleton, the formation of a new elastic cuticle, and the casting off of the old shell. Once ecdysis has been initiated, calcium is removed from the old exoskeleton and stored in the blood of the crab. Specific resorption (removal of calcium) occurs in certain areas (suture lines) where the exoskeleton will split. The hepatopancreas begins to store food reserves which are used while the crab is fasting prior to and during molting. Water is absorbed through the lining of the digestive tract and the crab begins to swell. The exoskeleton then splits along predetermined suture lines (Figure 1). When shedding is completed, more water is absorbed to stretch the new, soft exoskeleton. Increase in size (approximately 25%) results from this intake of water. After stretching, the new cuticle begins to harden.

Ecdysis is under the control of the central nervous system and is dependent on the activation and secretion of a molting hormone, crustacean ecdysone. The eyestalk of the crab contains a group of neurosecretory cells known as the x-organ, whose axons terminate in a sinus gland. These secretory cells produce a molt-inhibiting hormone. Near each eye socket of the crab is found a gland called the y-organ, which produces a molt-inducing hormone. Most of the time the molt-inhibiting hormones are in control. During premolt, however, the y-organs (molting glands) are released from this control. The initiation of a molt may be blocked by removing the y-organs which produce the molting hormone. The removal of the eyestalks, which produce the molt-inhibiting hormone, may quicken the initiation of the premolt process.

Although data are lacking on the commercial application of hormonally induced molting, the use of molt-stimulating hormones has been attempted in the laboratory with conflicting success. Until recently, the cost of

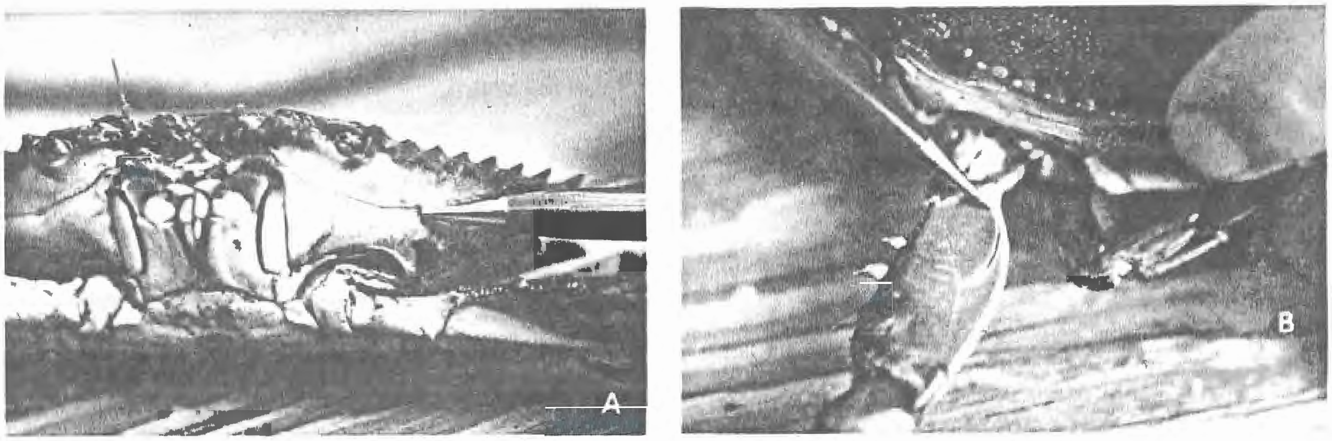


Figure 1. Suture lines on blue crab prior to molting; (A) epimeral line, and (B) merus of chela (photographs courtesy of Steve Otwell).

hormonally stimulating ecdysis was prohibitive. The increase in the price paid for soft shelled crabs, coupled with the isolation of a molt-inducing hormone from plants, should encourage controlled scientific research into the commercial feasibility of using hormones to bring about molting.

Removal of the eyestalks to induce molting has been used in the laboratory with some success; however, it is doubtful that this technique would be suitable to a large commercial shedding operation. The labor required, together with the trauma of removing the eystalks and the possibility of infection, negate its usefulness in a commercial venture.

RECOGNIZING PREMOLT CRABS

Premolt crabs or peelers show definite signs of shedding and can be recognized from intermolt-stage blue crabs (hard crabs). Most of the molting signs involve coloration changes. The most common method of separation is to check the last two segments of the swimming paddle where the newly formed shell is easily visible. As the crab approaches the molt, a white line appears just inside the edge of the paddle (Figure 2). White-line crabs usually shed within 7 to 14 days. Crabs within 3 to 6 days of shedding have a pink line in the area where the white line appeared (Figure 3), and crabs with a red line will shed in 1 to 3 days (Figure 4). Other signs of imminent shedding include changes in the color of the immature female abdomen or apron (from creamy white to reddish-purple, Figure 5), or the possession of well-developed limb buds (Figure 6). Based on these coloration changes, crabs may be classified as either green (white line) or ripe/rank (pink or red line). In some areas, the term "green crab" refers to those crabs that show no molting signs and are, thus, between molts or in the intermolt stage. Crabs with similar molting signs are normally placed together. It is especially important that white-line crabs be separated from pink and red line individuals. White-line crabs can be graded (checked for changes in molting signs) every 2 to 3 days, while those showing more advanced signs of molting should be graded more often (red line– daily, busters–every 3 to 4 hours).

When a split occurs under the lateral spines and across the back, the crab is called a "buster" or "cracked crab" (Figure 7). Once the crab shell has split across the back, it may be 2 to 3 hours before the entire shell has been cast off. When the crab has completed the molt, expansion to full size usually occurs within an hour; however, the length of time between white and red line stages, as well as the molting time, is dependent upon the size of the crab and water temperature. Crabs should be removed from the water when they have expanded to full size and placed under refrigeration to keep the new shell from getting hard. Papershells are newly molted crabs whose shells have already begun to harden. While papershells are marketable in some areas, soft crabs bring top prices.

Crabs are usually individually wrapped in plastic and marketed as a frozen product. Depending upon the preference of the buyer, the crabs are either sold dressed (gills, face and apron removed) or whole. In the Gulf states area, most soft crabs are sold directly to restaurants. At present no standardized grading system exists for sizing the marketed crabs.

HARVESTING AND HANDLING

Recent improvements in methods of holding and shedding peelers have emphasized the need for the selective harvest of premolt crabs. Directed fisheries for peelers are found in very few states. Crab scrapes, peeler pounds, and jimmy or peeler pots are used in Chesapeake Bay to take shedding crabs. Bush trotlines (fishing method in use in the Barataria Bay estuary of south Louisiana) are also effective in the selective capture of premolt crabs. In areas where there is no directed fishery for peelers, a variety of hard crab gear types are employed, although the capture of premolt crabs is, in most instances, an incidental catch. Harvesting methods for peelers are illustrated and explained in Figures 8 through 12.

The type of handling a peeler receives in the field will greatly affect the percentage of crabs that successfully complete the molt. Peeler crabs should be culled in the field, placed in shallow boxes, and covered with moist burlap. The

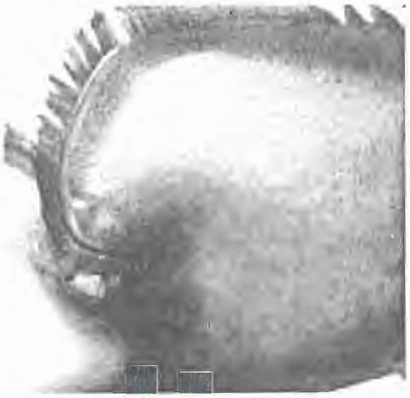


Figure 2. White line stage.

Figure 3. Pink line stage.

Figure 4. Red line stage.

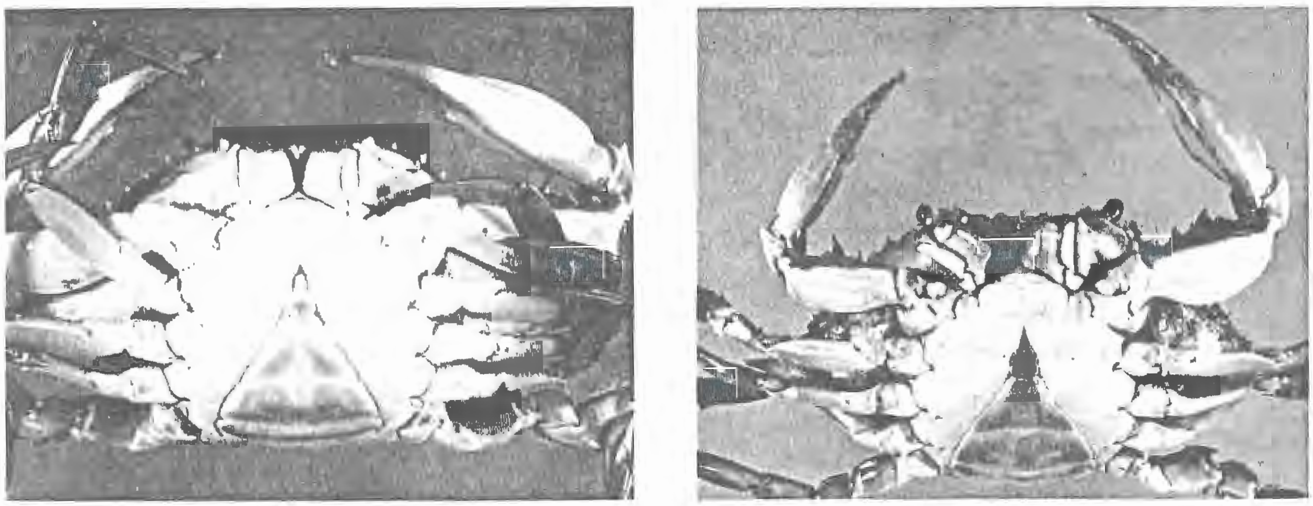


Figure 5. Immature female abdomen: intermolt (left) and ripe (right).

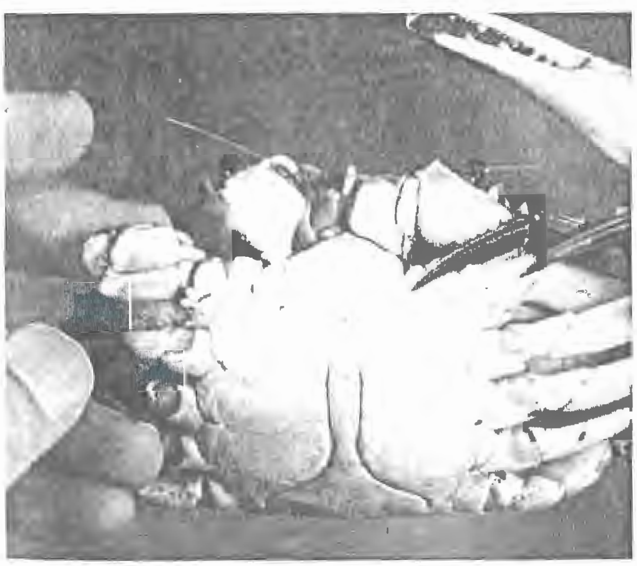


Figure 6. Male crab with well developed limb bud.

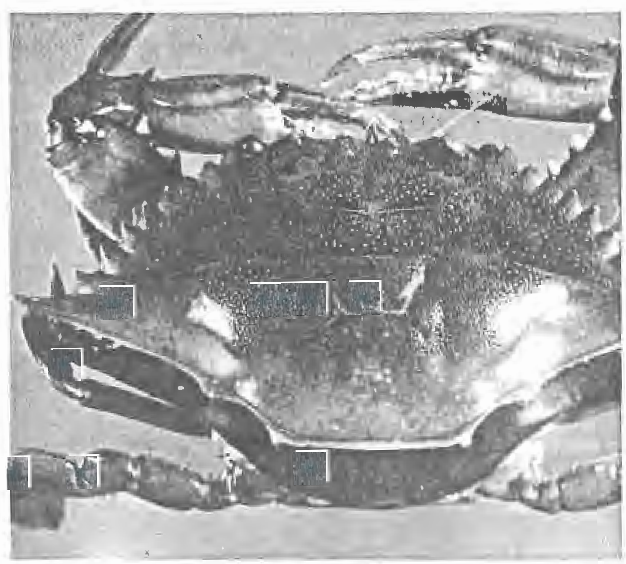
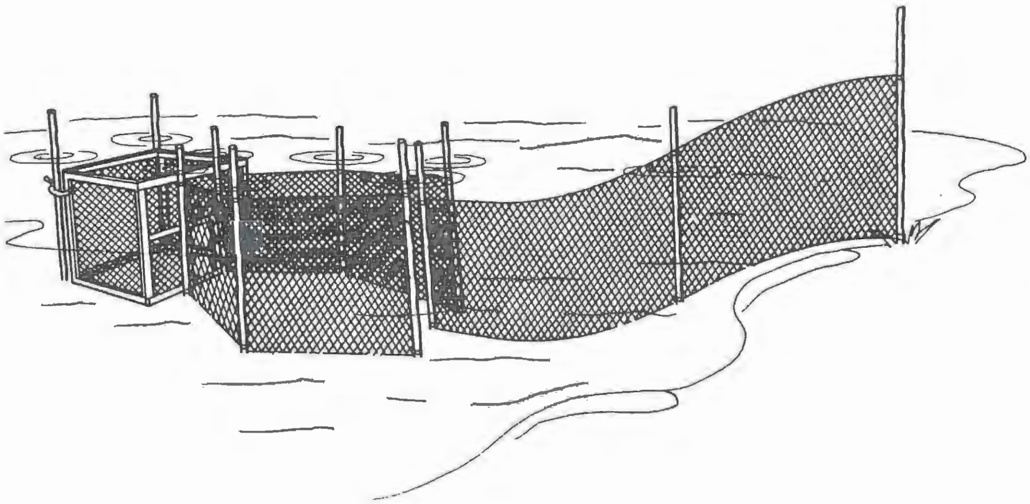


Figure 7. "Buster."



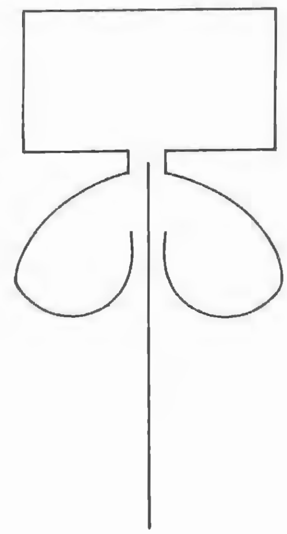


Figure 8. Peeler pound or crab fyke–pound net made of chicken wire. The pot or trap is attached to a wooden frame that rises above the high tide mark so that crabs can be scooped from the top or it is fitted with a lid so that the trap can be lifted out of the water to remove the crabs. Chicken wire leads run from the shore to the trap with "hearts" that direct the crabs toward the funnel. Pounds are common in Virginia in quiet waters in areas where there are known concentrations of peelers (from Dumont and Sundstrom 1961).

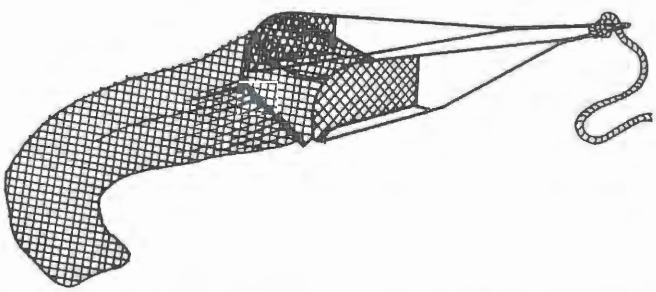
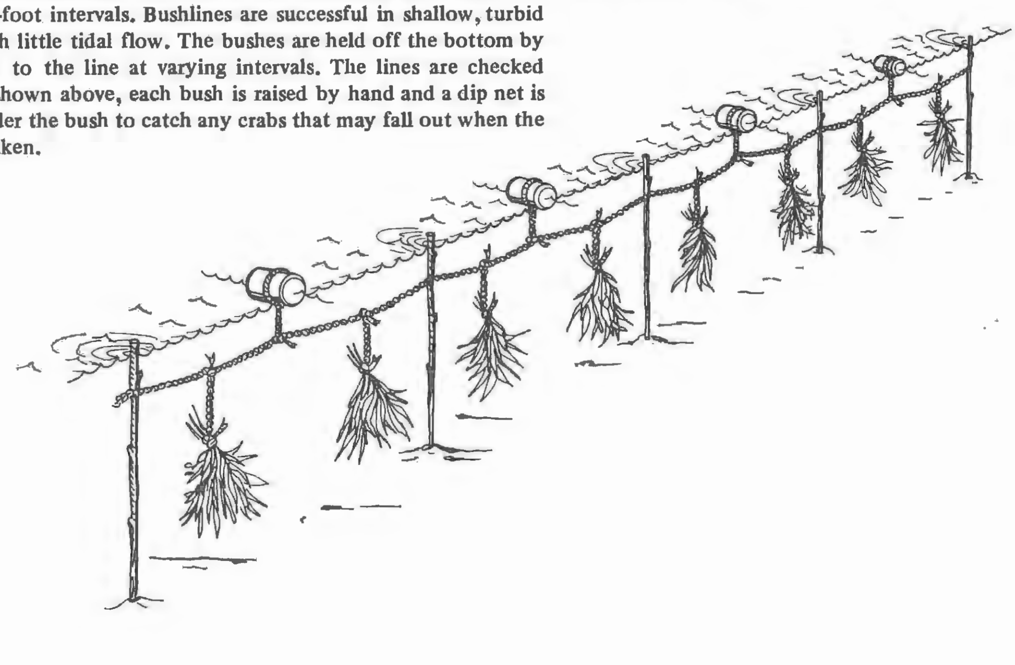


Figure 9. Crab scrape–retangular metal frame with an attached bag of webbing and a bridle for towing. There are no teeth on the scrape bar. In Chesapeake Bay, scrapes are pulled over submerged grasses where peelers congregate seeking protection (from Dumont and Sundstrom 1961).

Figure 10. Bush trotline (below)–branches of wax myrtle (*Myrica cerifera*) fashioned into bundles and tied to a stout line at approximately 15-foot intervals. Bushlines are successful in shallow, turbid waters with little tidal flow. The bushes are held off the bottom by floats tied to the line at varying intervals. The lines are checked daily. As shown above, each bush is raised by hand and a dip net is placed under the bush to catch any crabs that may fall out when the bush is shaken.



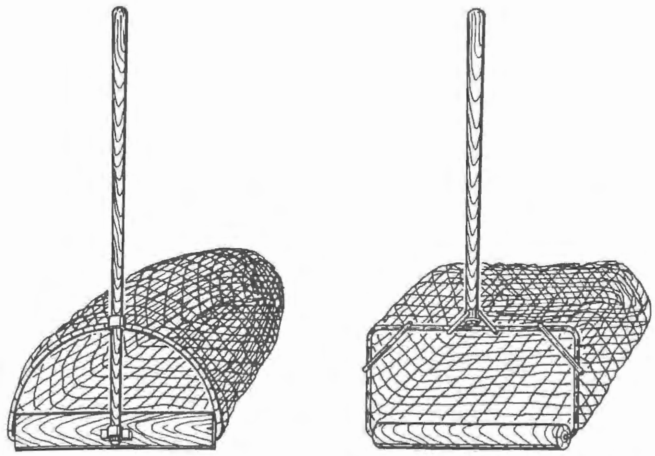


Figure 11. Push net–large-mouth net with a flat wooden blade or a metal roller attached to a 2-inch mesh bag. These nets are pushed over grass beds to "scare" peelers up into the bag. An adaptation of this gear is used on the north shore of Lake Pontchartrain (Louisiana) in the Lacombe area. A fiberglass blade attached to handles is pushed through the grass and "spooked" peelers are scooped up with a dip net (illustrations courtesy of Steve Otwell).

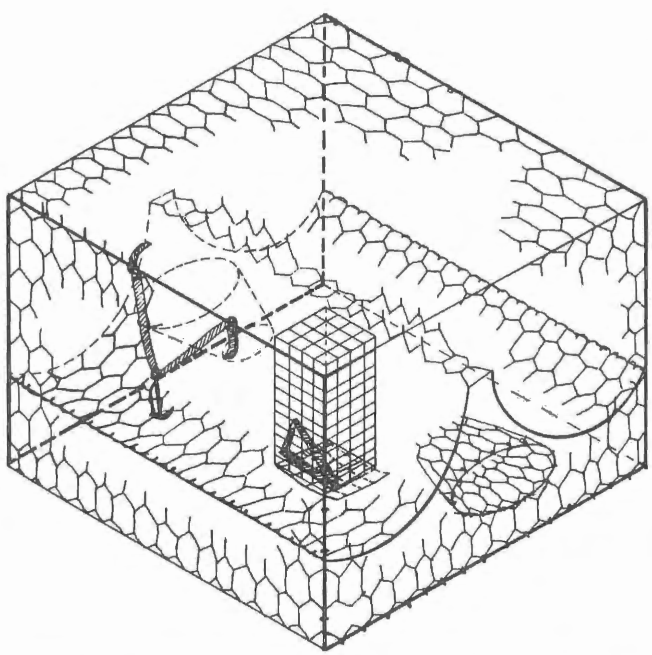


Figure 12. Peeler or "jimmy" pot–traditional crab pot using males as bait to attract females. The success of jimmy pots is dependent upon behavioral patterns exhibited by pubertal-molt females and upon the ability of fishermen to "fish out" or remove a sizable portion of the male crabs from a natural population. The removal of large numbers of male crabs from the natural environment makes the captive "jimmy" crab more attractive to pubertal-molt females seeking a mate. In areas where this gear is employed, it is seasonally effective with highest catches in the spring and early summer. A 1-inch wire mesh may be used in the construction of this pot, and the upper compartment of the pot may be modified to keep jimmies separated from the females. In some areas, shrubbery or frayed rope is put into traditional crab pots to attract peelers of both sexes seeking protection.

addition of vegetation (wax myrtle or water hyacinth, for example) to the boxes will cushion the crabs and also reduce aggressive behavior. Boxes should be kept out of direct sunlight and away from motor fumes.

METHODS OF SHEDDING

According to Warner (1976), enclosures to hold shedding crabs were used as early as the 1850's in Chesapeake Bay. From these crab pens evolved the floating boxes or cars which are still in use today.

Traditionally, Chesapeake Bay floats were constructed of pine, while in Louisiana cypress was used. The bottom of the float consisted of closely fitted boards with wooden slats spaced at narrow intervals to form the sides and ends. A wooden shelf or side wing was added to the outside of the float at mid-depth to give it buoyancy and stability. A lip on the inside of the box prevented the escape of the crabs. Because the box floated well above the water line, covers were not used. Modifications of this basic design (Figure 13) may be found in use today (Figures 14 through 17).

Although floats are the least expensive method of shedding crabs, they have several limitations. Successful float operations require good quality water in an area where there is some wave action or tidal flow. Crabs held in floats are confined to the upper few inches of water and are thus susceptible to the periodic rapid changes in water temperature and salinity that can occur in surface waters. Siltation and pollution may also present problems in some areas. Predation on soft crabs by gulls, eels, and catfish plague many float operators with the result that in some areas the floats are covered and the holes or spaces allowing for water circulation are much reduced in size. Another disadvantage of this type of facility is the inherent difficulty in tending a group of floating boxes. For these reasons and for convenience, many operators have turned to a shore-based facility where water is pumped from the bay or bayou through a series of tanks and returned overboard.

SHORE FACILITIES

At present, many crabs in Mississippi and Louisiana are shed in either a flow-through system (open) or in a recirculating seawater system (closed). In either system, crabs are held in tanks on shore with water pumped through the tanks as opposed to crabs held in floats in natural bodies of water. The type of system employed depends on many factors, including cost, available space, supply of crabs, accessibility of suitable water, and the desires of the individual setting up the operation.

The type of tanks used to hold crabs can vary as to size, type of construction and number. Tank dimensions of 4 X 8 feet and 3 X 6 feet are easily constructed. These tanks are generally stocked with 100 to 200 crabs. They should be at a height to allow easy accessibility to the crabs without excessive bending or stooping. The tanks should be shallow; water depths of 3 to 4 inches are sufficient to hold and

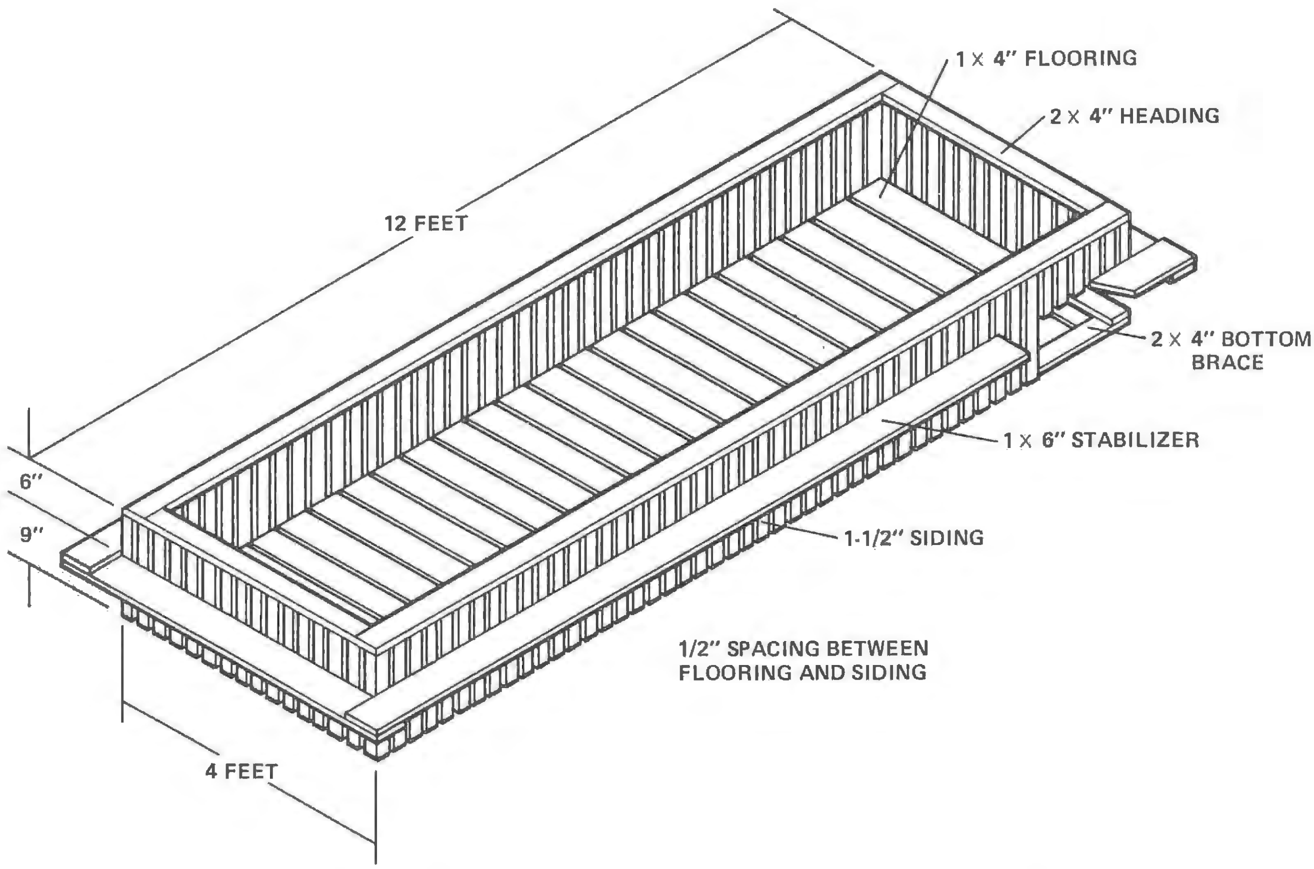


Figure 13. Float or box of wood slats used to hold blue crabs (illustration courtesy of Steve Otwell).

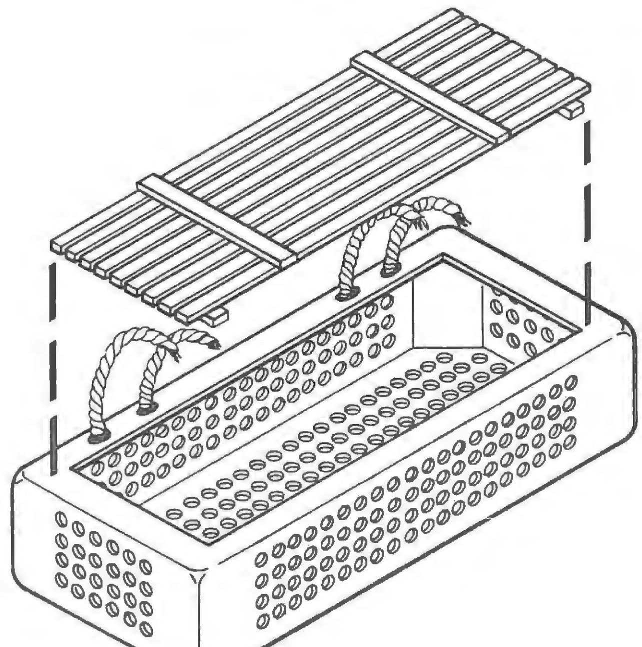


Figure 14. A modern crab float constructed of fiberglass. Air pockets formed into the corners afford floatation. The holes drilled into the box should not exceed ¼-inch to prevent predation on crab appendages. A slatted wooden lid covers the box. This type of float is used on the north shore of Lake Pontchartrain, Louisiana.

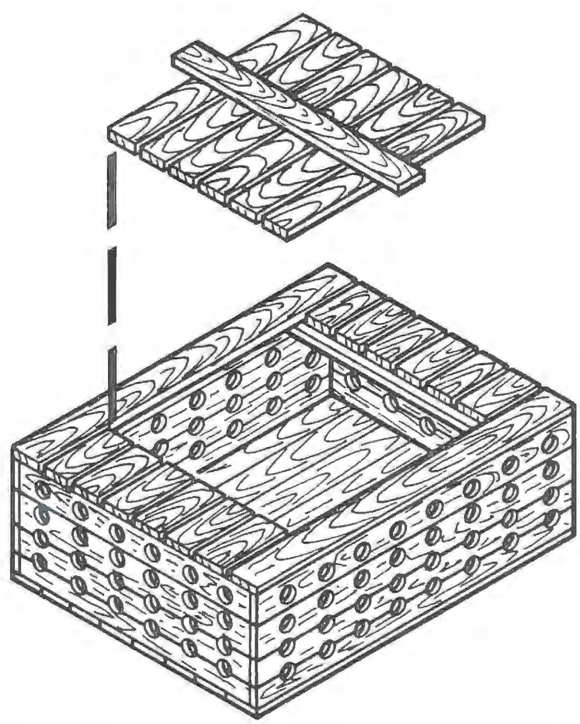


Figure 15. A traditional southern crab float constructed of cypress. The box is wider at one end, producing a taper that allows the box to face into the waves when anchored.

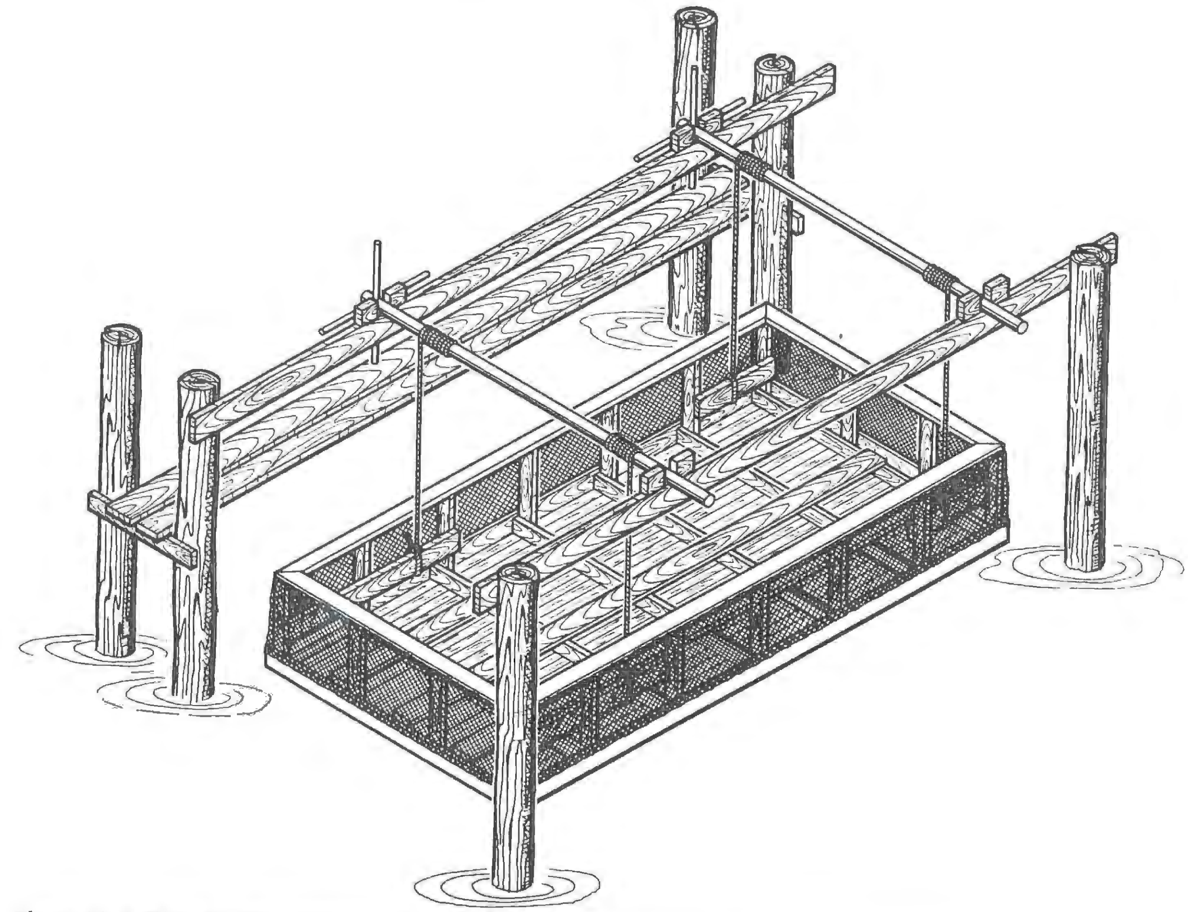


Figure 16. A "live car" with windlasses to raise and lower the structure. Live cars are constructed of wood framing covered with vinyl-coated hardware cloth. The bottom is slatted with ¼-inch spacings. The live car is usually 8 feet long, 4 feet wide, and 2 to 3 feet deep. Live cars are used in the Barataria Bay estuary in Louisiana.

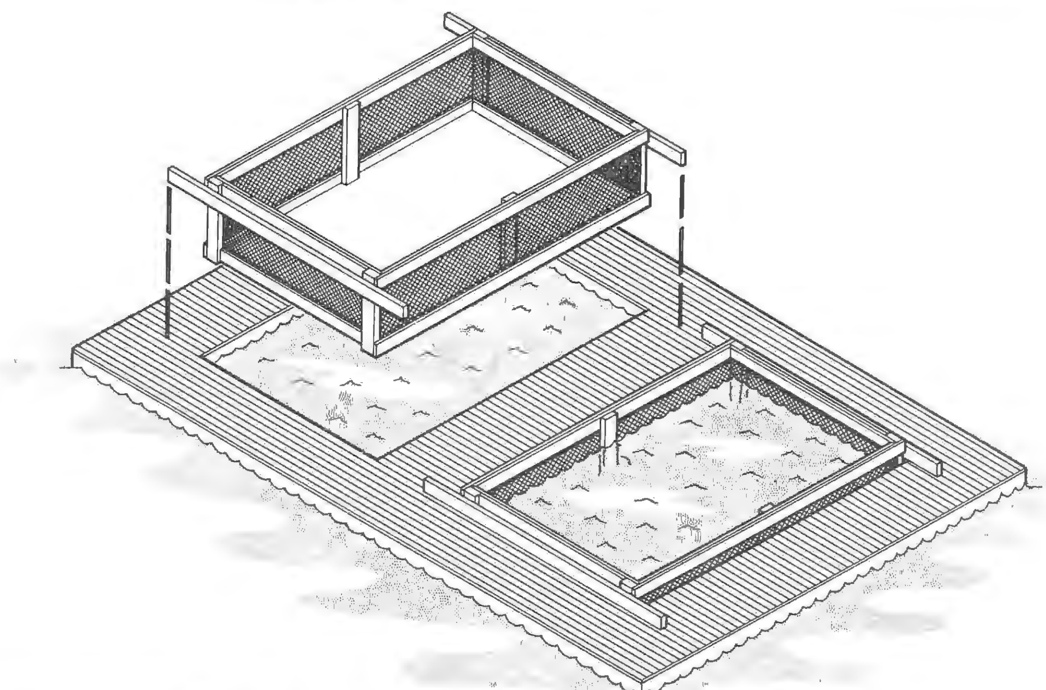


Figure 17. A crab raft floated with styrofoam or oil drums. The cage frames are covered with vinyl-coated wire and have a slatted bottom.

shed crabs. Materials used to construct the tanks may include wood, fiberglass, plastic, or concrete. Cedar and redwood should not be used. Tanks constructed of wood, concrete or cinder blocks should be sealed with a nontoxic epoxy paint (one without a heavy metal base), epoxy resin, or fiberglass. Before the tanks are put into operation, they should be filled with water and flushed two to three times to leach out any toxic materials or impurities.

Corners and obstructions in the tank collect debris and can be areas subject to low concentrations of dissolved oxygen. The incoming flow of water should be directed into the tank in such a manner as to achieve adequate circulation and eliminate dead areas. Rounding of corners aids in water circulation and may prevent crabs from "bunching."

Water can be sprayed into the tanks though a closed supply pipe with holes in the cap or through a series of holes in an overhead pipe. A venturi aspirator can also be used. Pumping water through holes in a pipe achieves aeration by breaking the surface tension and trapping air into the water. One problem encountered with this type of aeration is that the holes may clog and require periodic cleaning. A venturi functions by reducing air pressure as water velocity is increased when water is forced through a constriction. The resulting vacuum draws air through a connection or tee and thereby traps air in the water.

Commercial venturi aspirators are available from hot tub distributors. They can also be built from PVC fittings (Figure 18). A ¾- by ½-inch reducing bushing is sanded on the outside so that it can be placed backwards into a long arm of the tee. A ½-inch polypropylene adapter is then screwed into the bushing so it faces the inside of the tee. The insert is cut off so that it just fits the throat of the tee fitting. A 4-inch length of pipe is glued into the upright arm of the tee. It is sometimes possible to improve the efficiency by using a short length of pipe in the outflow arm of the fitting. The venturi can be used to direct currents in the tanks so that dirt and debris collect in the center of the tank. Other methods of aeration include air pumps and mechanical agitators. Air compressors and aquarium air pumps force air through diffusers. Agitators mechanically trap air from the atmosphere into the water.

The tanks can be drained by a hole in the sides or the bottom. Drains should be 1-¼ inches or larger and, if plumbed into the bottom of the tank, they should be flush with the floor to allow easy cleaning. The water level is controlled by the length of pipe fitting into the drain (a standpipe).

A self-flushing tank can be made by placing a notched pipe of larger diameter over a bottom standpipe (Figure 19). This causes water to be drawn from the bottom of the tank, pulling some debris with it.

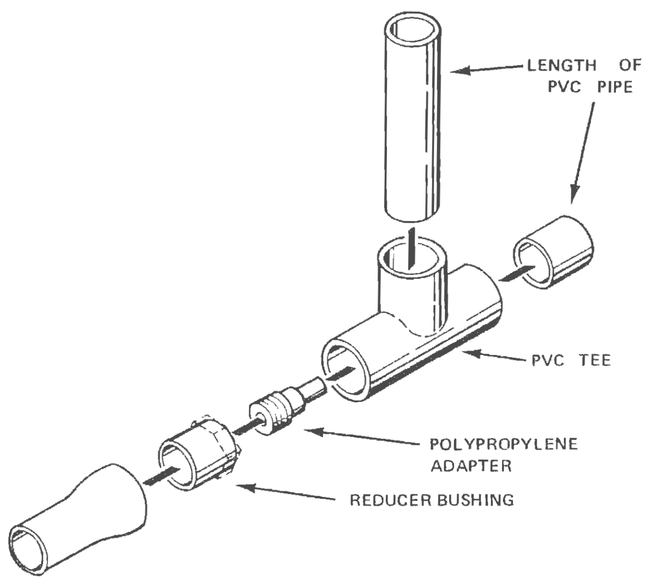


Figure 18. Venturi aspirator.

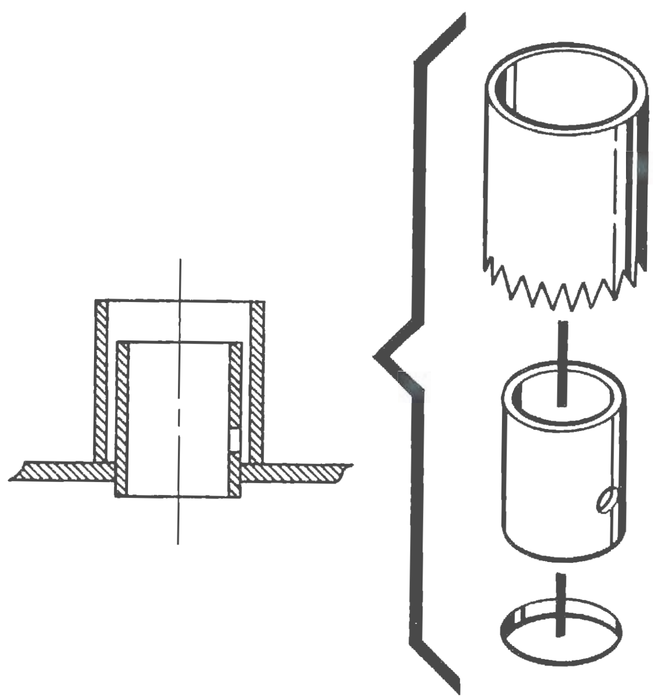


Figure 19. Detail of the drain showing a standpipe with a draw down hole and a venturi to cause the water to be drawn off the tank bottom.

Loss of power or a mechanical breakdown that shuts off water circulation can be detrimental if prolonged. Drilling a small hole (¼-inch) in the standpipe approximately ½-inch above the bottom of the tank will allow the system to drain (Figure 19), leaving enough water over the crabs to keep them alive. The crabs will actively aerate the gills with atmospheric oxygen by bubbling water. If the crabs are completely submerged, the oxygen in the water will be quickly used up, foul, and the crabs will die. In a closed recirculating system, the lowest tank in the system should be deep enough to hold the excess water from the draw down of the crab tanks when pump failure occurs.

All plumbing must be of plastic pipe to avoid exposing the crabs to toxic heavy meatals (copper, zinc or lead). The pump should have a plastic or stainless steel impeller.

Pump capacity will vary according to the size of the system. The input pipe from the pump to the tanks will depend on the diameter of the discharge opening of the pump.

If natural bay or bayou water is available and is suitable for shedding crabs, a flow-through system can be constructed (Figure 20). This is the least expensive of the two shore systems to build because filters are not required and artificial sea salt is unnecessary.

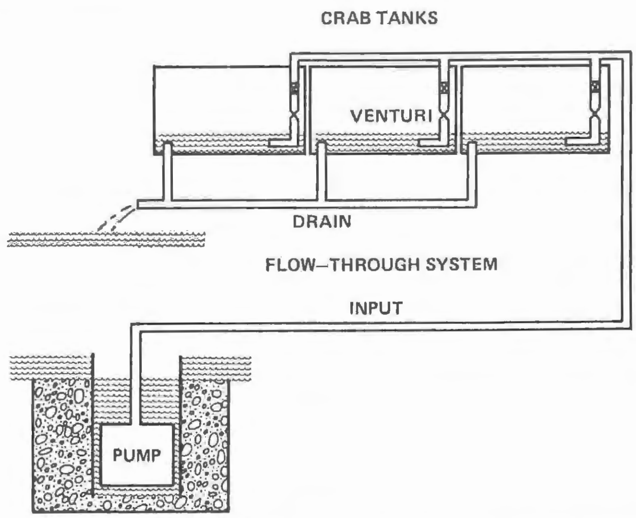


Figure 20. A land-based shedding system consisting of a pump in a mechanical filter box, plumbing, venturi aerators, crab tanks and drains.

Flow-through System

The open or flow-through system requires a good pump constructed of noncorrosive material and capable of exchanging the volume of water in the shedding tanks every 15 to 20 minutes. Major problems in a flow-through system are the presence of fouling organisms and silt. Sets of oysters and barnacles can severely restrict the flow of water through the pipes and, if they are not removed, the flow of water may be completely blocked. The occurrence of fouling organisms in natural waters is seasonal and is usually heaviest in the spring and summer. To remove these organisms, the system must be shut down and mechanically cleaned and/or back flushed with fresh water periodically. Rather than suspend operations, a dual system should be constructed. When one pump and set of lines are being cleaned, the other can be used. This system will also decrease the possibility of loss of crabs because of mechanical failures. The benefits of a dual system outweigh the major drawback, cost.

The intake pipe should be placed in deeper waters which are normally cooler and have a more constant salinity than waters near the surface. In dead-end canals, however, bottom waters should be avoided as they are often devoid of oxygen. An intake pipe at mid-water depth may be necessary. Water from the system itself should not be discharged in close proximity to the intake line. A removable screen covering the intake line is recommended to prevent debris from clogging the pump and line. This screen will collect debris, so it must be cleaned periodically. A mechanical filter box filled with clam shells, oyster shells or gravel will not only help to trap debris, but will also remove the suspended solids and prevent some fouling (Figure 21). This type of structure will require maintenance. Depending upon the distance from the intake to the crab tanks, either a submergible or a nonsubmergible pump may be used. Maintenance and corrosive wear are less and the electrical connection simpler on the land-based pump if the distance is short. A submergible pump is easier to plumb as it

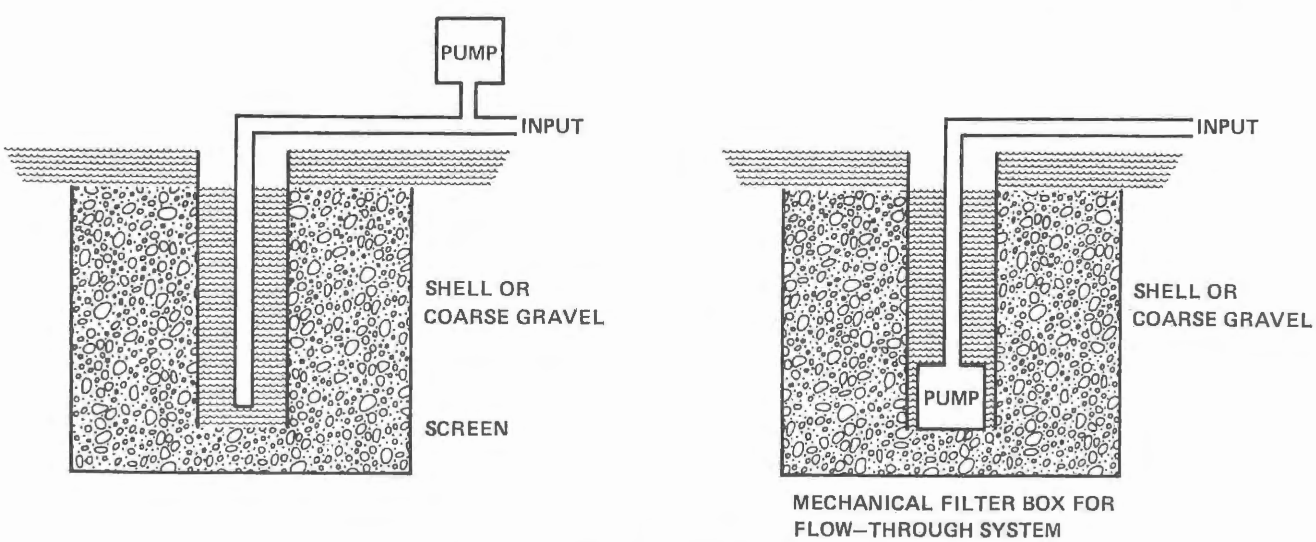


Figure 21. Alternate placement of pumps for flow-through system.

requires no intake pipe and can supply water from a distance if adequate power is available.

Closed System

The basic principles governing closed recirculating seawater systems are discussed in detail by Spotte (1979). Many of these principles have been incorporated in the following discussion.

A recirculating crab-shedding system consists of the same crab tanks, pump and plumbing as described for a flow-through system except that a biological filter and an algal filter have been added (Figure 22). This type of system is more involved and costly than the flow-through system; however, it allows greater control over the physical, chemical and biological variations characteristic of natural bay water (temperature, salinity, silt, plankton, pollutants). In a closed system, however, the water is recirculated and used indefinitely, and it will become fouled by the crabs. Results of water quality deterioration are increases in the levels of carbon dioxide, nitrogenous compounds, phosphates, and dissolved and particulate organic substances. The pH of the system declines. Accumulation of excretory substances (ammonia, nitrite, nitrate, urea, uric acid, proteins, amino acids), which are added by the crabs, may reach lethal levels.

Therefore, water treatment becomes necessary to stabilize the water quality of the system within the optimum range for crabs. Water treatment may be biological, mechanical, chemical, or physical in nature. Because crabs do not need to be fed prior to shedding, mechanical filtration of the water (e.g., using rapid sand filters, gravity sand filters, pressure sand filters, or diatomaceous earth filtration) is not neccessary. Although chemical treatment of the water (using ozonation) will help to reduce the number of free-floating microorganisms and will convert some oxidized compounds to other dissolved organics, it is not effective in removing or oxidizing ammonia to higher oxidation states. Thus, biological and physical water treatment procedures become the primary methods of removing nitrogenous wastes and other metabolic by-products.

Biological water treatment involves the mineralization (conversion of nitrogenous organic compounds to simple substances such as ammonia), nitrification (biological oxidation of ammonia to nitrites and then to nitrates), dissimilation (reduction of nitrates to free nitrogen) of nitrogenous compounds, and/or the conversion of nitrate to plant tissue. Mineralization and nitrification are accomplished by the culture of bacteria in a biological filter. The filter unit will contain bacteria that alter the nitrogenous compounds in the water. Some bacteria will convert nitrogenous organic compounds such as urea, amino acids, and proteins into ammonia.Other bacteria, known as nitrifiers, convert the ammonia into nitrites and nitrates. Although nitrate is much less toxic than ammonia, it too must be removed from the water. Some nitrogen is driven into the atmosphere through the process of dissimilation, but the oxidation of inorganic nitrogen during nitrification far exceeds the reduction of these compounds and nitrate accumulates in the system. A macroscopic alga, grown in a separate tank, provides an economic and reliable means of removing this inorganic nitrogen.

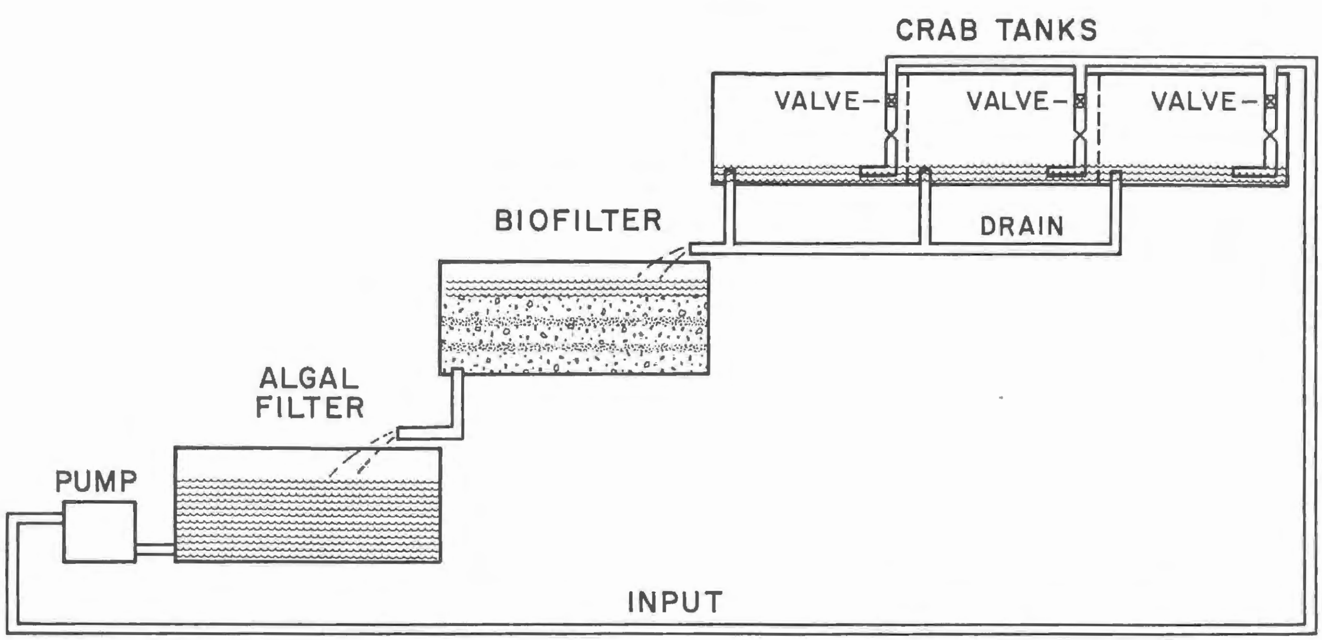


Figure 22. A recirculating system for holding shedding crabs. Water is supplied to the tanks through venturi aerators. Draw down drains siphon water off the tank bottoms where it passes into a multimedia biological filter and then into a tank in which macroscopic algae is grown. A pump coming off the algal filter recirculates water back to the crab tanks.

The biological filter consists of a box containing materials that provide surface area to which the bacteria attach. Water passing through the filter bed is acted upon by the bacteria growing on the surface area of the filter material. The filter may consist of a layer of granular, marine-activated carbon (available from marine aquaria supply houses), a layer of crushed oyster shell (pullet or chicken scratch) or dolomite, and a layer of coarse oyster or clam shell (Figure 23). The charcoal and shell material should be washed thoroughly before being placed in the filter box. The bottom layer of coarse shell rests on a perforated filter plate which suspends it above the floor of the tank providing an under drainage. This plate may be fabricated from egg-crate louvering (used to cover fluorescent lights) or corrugated fiberglass roofing. The edges of the filter plate should be sealed to the sides of the tank or fitted snugly to prevent the shell from working beneath the plate. The plate is covered with a synthetic, knotless trawl webbing and coarse shell is layered on top. A piece of nylon window screen is placed over the top of the coarse shell and dolomite or crushed shell is layered onto it. Although sand or gravel would also offer a large surface area for the growth of bacteria, crushed shell or dolomite is recommended because of their calcium content.

Because of the biological activity in closed systems, there is a tendency for a continuous decline in pH. The use of calcareous materials in the filter aids in buffering against sudden changes in hydrogen ion concentrations. An additional piece of screening is placed over the dolomite to hold the activated marine carbon. Granular activated carbon is a specially treated, porous charcoal with a very large surface area. The physical adsorption of dissolved organic carbon is accomplished within this layer. Activated marine-grade carbon must be used in the filter. Because this carbon is small, it is best to keep it contained or "sandwiched" between two layers of nylon screen. The webbing and netting are used to keep the layers separate which greatly facilitates their removal for cleaning.

The accumulation of some detritus or sediment in the filter bed is advantageous because it increases the mechanical efficiency of the filter. However, the filter needs cleaning when (1) mud mats form, (2) there is a heavy accumulation of detritus in the corners or along the walls of the filter, (3) there is a reduced flow rate with a subsequent reduction in the level of dissolved oxygen in the filtered water, or (4) channeling of the water through the filter bed occurs. All of the filter layers are reusable and should be rinsed thoroughly after the filter is broken down for cleaning. The carbon can be reactivated by baking. After rinsing, it should be drained, and thin (1 inch) layers placed on baking sheets in a preheated oven (500°F) for one hour. The carbon should not be allowed to dry out prior to baking.

The surface area of the filter bed should be as large as is practical. Experience with successful commercial, closed, recirculating seawater systems indicates that 25% of the total water area be devoted to the biological filter. Filter depth should not exceed 1 foot as microbial activity diminishes with increasing depth. The amount of water recirculated through the filter per unit of time must be sufficient to maintain the concentration (above 4.0 ppm) of dissolved oxygen at a level that supports adequate bacterial growth and, at the same time, avoids disturbances due to excess water movement. The turnover ratio should be 2 to 3 tank volumes per hour.

Changes in water temperature, salinity, pH, and dissolved oxygen may affect filtration efficiency. Temperature not

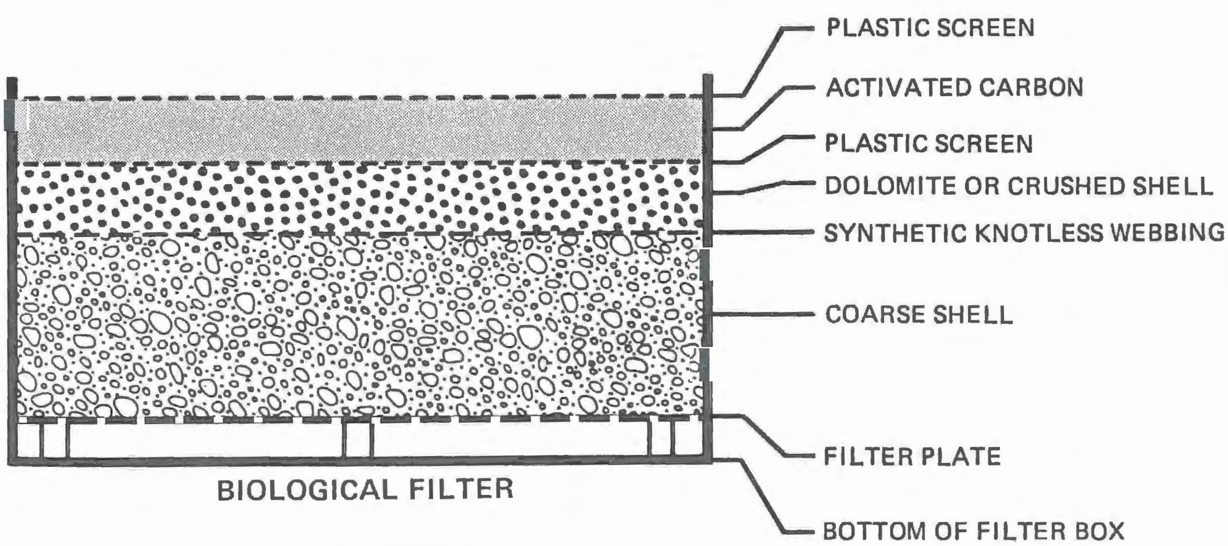


Figure 23. A multimedia biological filter packed with activated, marine carbon, dolomite or crushed shell, and coarse oyster or clam shells. The filtrant material rests on a plate of egg-crate type louvering suspended above the bottom of the filter box to provide under drainage. Water may be pumped into the bottom of the tank and the overflow removed from the top (updraft filter), or the water may be pumped into the top and drawn off the bottom of the tank (down draft filter).

only dictates the rate at which the crabs excrete and secrete their metabolic by-products, but also determines the microbial utilization of these by-products. Nitrification and mineralization are particularly affected by changes in temperature. When temperatures are lowered, a time lag may develop in the conversion of nitrogenous substances. In elevated temperatures, these conversions may take place at a more rapid rate. The sudden heating or cooling of the system may adversely affect its equilibrium.

Biological filters require a period of time to develop. In new systems it is advisable to allow at least 1 month for conditioning of the filter. Filtrant bacteria can be introduced into the system by the addition of natural bay water or marine organisms that normally carry various types of bacteria, by the addition of soil-nitrifying bacteria, or by inoculation from an established filter bed. The latter two methods are suggested to decrease the time period required for the filter to develop. To obtain nitrifying bacteria from soil, Paparella (1979) advises that well-cultivated garden soil be put into a jar and the jar filled three-quarter full of fresh water. After shaking vigorously, the soil should be allowed to settle out and the overlying liquid can then be gently added to the system. Individuals having access to established recirculating seawater systems (home aquaria, mariculture facilities) may simply introduce some of the filtrant material and water from these systems into their own filter bed. Once the bacteria are introduced into the system, steps must be taken to supply the nutrients necessary for their growth and proliferation. The addition of marine catfish or hard crabs prior to the introduction of shedding crabs is recommended. Catfish or hard crabs will supply the metablic by-products necessary for bacterial growth and, at the same time, are resistant to ammonia toxicity. Once the system has been conditioned, it is ready to receive premolt crabs. An effective filter is one in which the microbial population of the filter bed is in equilibrium with the normal input of waste from the crabs. A balance has been reached when the nitrogen compounds processed by the filtrant bacteria are equal to those produced by the crabs. Factors that upset this balance adversely affect the ability of filtrant bacteria to assimilate the metabolic waste products of the crabs under culture. Although filtrant bacteria can accommodate gradual changes in the number of crabs added to the system, a sudden, drastic increase in the load may result in measurable increases in the levels of ammonia and nitrate. If the filter beds are overloaded, permanent rises in the levels of ammonia and nitrate will exist. The addition of such a super-rich organic load can have the same effect on the filtrant bacteria and algae that overfertilization has on a garden. Conversely, during periods when the system contains few or no shedding crabs, a few fish or hard crabs should be kept in the system to maintain the filters.

Secondary water treatment is an essential part of the biological filtration system and is accomplished by the culture of marine macroscopic algae. The species selected for culture should be a filamentous or leafy variety, and must be tolerant of the salinity in the system. In most instances, the algae used to inoculate the tank can be collected locally from natural waters. Shallow tanks with large surface areas are more conducive to the culture of algae than are deep tanks. The algal tank must be provided with light, either natural or artificial, for the plants to conduct their photosynthetic processes. Care should be taken to ensure that the algae remain confined in its tank and do not grow throughout the system. Growth and spread of the algae are controlled by light. Keeping the biological filter and crab tanks in dim light will help to prevent the spread of algae through the system.

As with the microbial population of the biological filter, the growth and viability of the algae under culture will depend upon the supply of available nutrients. Again, a balance or equilibrium is established between the crab wastes processed by the bacteria and the subsequent uptake of nutrients by the algae. A reduction in animal load will, in turn, reduce the microbial population which may cause a loss of some of the algae. An increase in animal load (providing it does not exceed the carrying capacity of the system) may have the opposite effect.

To fill the system initially, saline water can be transported from natural waters or fresh water can be mixed with artificial sea salts to obtain the proper salinity. The salinity of the crab shedding system will depend upon the salinity of the water from which the peeler crabs are to be harvested. Municipal tap water should be aerated for a period of 3 days to remove any chlorine in the water. The salinity of the system should be checked periodically. As the water in the system evaporates, the salinity will increase and fresh water must be added to bring it to its original level. An easy and inexpensive method of measuring salinity is to use a hydrometer. These may be purchased in a pet store, but it is best to have a direct-reading hydrometer with an expanded scale (available from Kahl Scientific Instrument Corporation, P.O. Box 1166, El Cajon, CA 92022, catalog number 110WA130). Pet store hydrometers are normally designed to read full seawater (36.0 ppt) and are not accurate at the salinities found in most crab-shedding systems (2.0 to 10.0 ppt).

Any shedding facility should be under a roof to afford a more constant environment for the crabs. Covering the facility will eliminate problems from rainfall and keep debris out of the tanks. It will also aid in temperature control. If natural light is desired for the algae tank, it can be placed outside of the shed or building, but it must be covered with a transparent material such as plastic, fiberglass panels, or glass.

It is important to remember that any substance added to a closed system will remain indefinitely, and care should be taken to avoid the introduction of nonmetabolic contaminents such as hand lotions, tobacco, and insect sprays.

Successful, commercial shedding facilities have been constructed using the principles discussed in this section. Two such commercial-scale shedding facilities are operational at the present time, one in Mississippi, and one in Louisiana. A diagram of one of these facilities is illustrated in Figure 24. As long as the basic principles governing closed recirculating systems are kept in mind, various sized tanks may be arranged linearly or vertically to meet the particular space requirements of the individual.

The system in Figure 24 was designed around a set of existing fiberglass tanks with modifications to house the biological filters and algae. The corners of the tank were blocked to prevent "bunching," and to aid in water circulation. The tank depth is 12 inches. A centrifugal one-third horsepower pump supplies water through a 1-¼-inch overhead pipe. Four tees and valves divide the water into seven supply pipes which spray the water into the tanks through ¼-inch holes drilled into caps on the pipe. One half of the drain water from the tanks flows into the biological filters. This half of the water is divided between the two filters and enters a head chamber occupying the first foot of filter length; the other half is diverted directly to the algal filter. The head chamber is formed by a baffle extending to within 1 inch of the filter bottom. Water passes under the baffle to the area beneath the filter plate. The filter material is held off the bottom of the tank by pieces of egg-crate louvering supported on lengths of 1 inch pipe. A single piece of knotless, synthetic trawl liner (¼-inch webbing) has been placed on top of the filter plate. The liner should be large enough to extend up the sides of the filter box. Layered on top of the webbing are 3 inches of washed, whole clam or oyster shells. The shells should be packed against the sides of the filter box to prevent water from bypassing the filter media, and to keep the shells from working beneath the filter plate. A layer of fiberglass window screen is placed on top of the shells to hold 1-½ inches of dolomite or crushed oyster shell. Again, the shell should be pushed tightly around the tank sides. Another layer of screen covers the shell or dolomite, and holds 1 inch of activated marine carbon. The screen used to support the carbon should be long enough to fold over the top of this final layer to prevent it from washing out of the tank. Drains of 2-inch pipe, placed near the top of the filter tanks, carry the filtered water down a ½-inch slope to the algal filter. This filter box has alternating fiberglass baffles placed across the tank forcing the water to travel a serpentine path through the box. The last baffle compartment is connected by a 1-¼-inch pipe to the pump. The biological filters are covered with plywood, and the algal filter is illuminated using two double 4-foot fluorescent fixtures containing gro-lux bulbs. The entire system is located within a warehouse.

Although this system design has proven itself over the past few years, it is not necessarily the only approach possible. Paparella (1979) uses a different method of filtration in designing systems for the Chesapeake Bay area. In his systems, the algal filter and marine-activated carbon are eliminated and a protein skimmer is added (Figure 25). A protein skimmer operates by producing a foam which adsorbs dissolved organic material at the bubble surface.

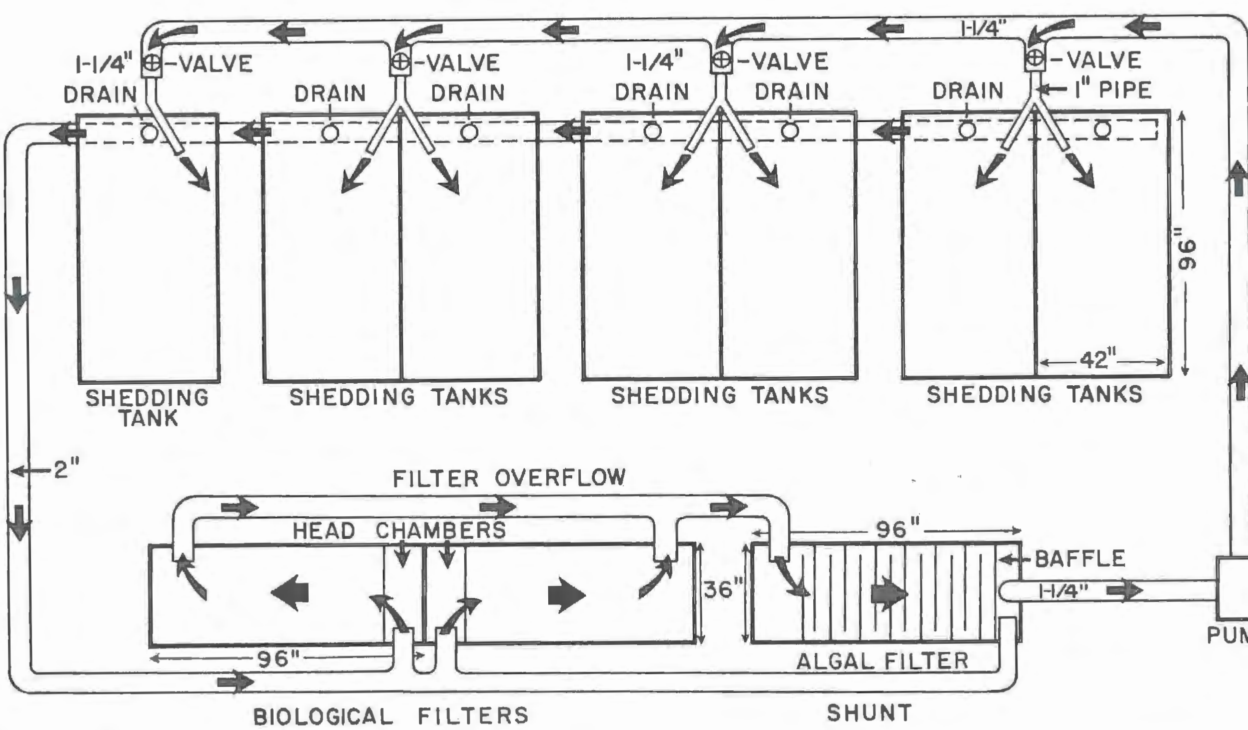


Figure 24. Diagram of an operational commercial shedding system using recirculating seawater (illustration courtesy of Cultus Pearson).

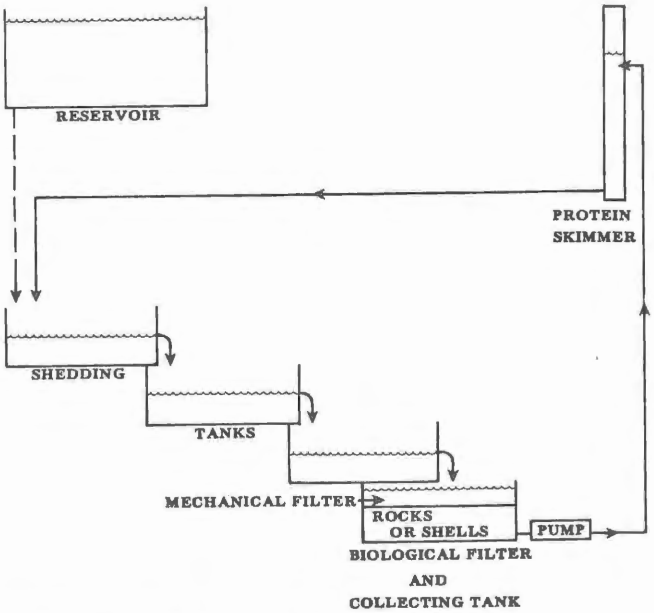


Figure 25. Closed recirculating seawater system using protein skimmer (illustration courtesy of Mike Paparella).

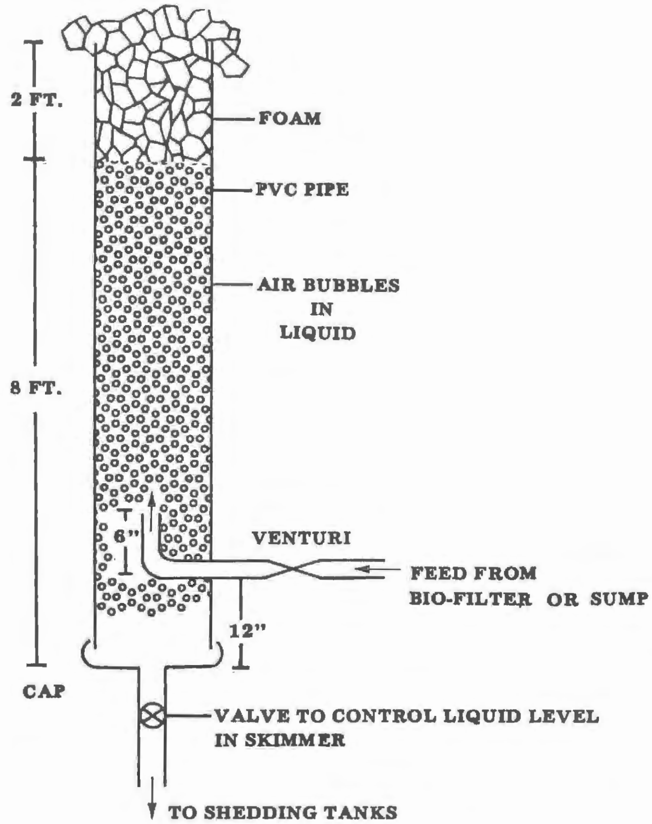


Figure 26. Protein skimmer (illustration courtesy of Mike Paparella).

The skimmer illustrated in Figure 26 is fabricated of a 10-foot length of 6-inch diameter PVC pipe. A 1 horse-power pump is required to force water through the venturi and maintain the water at a height of 8 feet. Paparella's system requires that one fourth of the water volume be changed every 2 to 3 weeks to reduce the level of nitrate. He also recommends a separate reservoir of water equal to the total volume of the system be made available for emergency water replacement. The systems in use on the Gulf coast use smaller pumps and require no water change. In fact, the system illustrated in Figure 24 operated for 2 years using the same water.

ACKNOWLEDGMENTS

Many people have provided information and assistance. Cultus Pearson and Lee Seymour, owners of commercial, closed recirculating seawater systems in Louisiana and Mississippi, respectively, worked closely with us in the adaptation, application, and refinement of basic "aquarium technology" to holding and shedding crabs. The authors are grateful to the following fishermen who shared their knowledge of blue crabs with us: Luke Dubaz, Marcel and Andrew Blondeau, Herman Adam, and Julian King. Jerald Horst, Louisiana Sea Grant Advisory Service, gave generously of his time on our many trips to Louisiana. We also acknowledge his review of this paper. We thank Don Watson and Linda Paulson for their illustrations. Steve Otwell, Florida Sea Grant Advisory Service, provided the photographs used in Figure 1, and the illustrations used in Figures 11 and 13. Special thanks to Mike Paparella of the University of Maryland, Seafood Products Laboratory, for his review of the manuscript. He also provided us with the illustrations used in Figures 25 and 26.

Appreciation is also extended to Drs. David Cook, Adrian Lawler and Thomas McIllwain, and Gerald Corcoran of the Gulf Coast Research Laboratory (GCRL), and to Ron Herring and Tommy VanDevender (formerly of the GCRL) for their technical assistance during the "early years" of this undertaking.

Finally, we thank Dr. Harold Howse, director of the Gulf Coast Research Laboratory, for his support and encouragement over the many years we have been involved in the development of a closed mariculture system for holding and shedding crabs.

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DISCUSSION

Q. Mr. Pearson, would you describe the gear used to "scare" up peelers in the Lake?

A. Cultus Pearson: I'm a crab fisherman who likes to improvise things to try to catch those crabs, and also try to shed them. I developed a thing I call a "pusher;" its got handles on it similar to those on a lawnmower. It has a blade on the bottom about 5 inches wide and 5 feet long. The first one of these things I made–I made it out of ½-inch pipe. I put "tickler" chains all along the bottom. The only trouble with that was that you needed to put a mule in front of it to pull it. The next one I built out of fiberglass with this blade. It works good in the grass beds along the north shore of Lake Pontchartrain. I got this idea from watching fishermen who pushed a scoop net through the water to "spook" the crabs up. They covered about 15 inches of area with these nets. They worked pretty well. I decided that if that worked, why not build one about 5 feet long and you could "spook" out a lot more; you also help keep your scoop net clear from algae. This stuff will cover your net so completely when you push it through the grass that its like dragging a bucket through the water.

I designed a special peeler pot. I noticed that there was a direct correlation between catching peeler crabs and catching hard crabs. When the hard crabs don't bite, you catch more peeler crabs. From that I figured the hard crabs were "spooking" them off. I also noticed that when a crab pot gets this grassy stuff growing on it, you catch more peeler crabs.

I also designed a fiberglass box to hold crabs in the Lake. There are airtight compartments in it to give you floatation. The box is drilled with ¼-inch holes for water circulation. We have problems with these boxes. The soft crabs in these boxes, if they stick a leg through a hole, there is going to be a hard head catfish just waiting for it–to suck the leg off. We also have problems with the green crabs–this just developed last year–I guess we have an over abundance of sheepshead. Even the green crabs, when they stick a leg through those holes, the sheepshead are there to snap it off. When this occurs you get some funny looking crabs. They might have two big pincers, not one flipper, and not one leg because the sheepsheads have taken them off. Another thing about the north shore of Lake Pontchartrain is that this type of box works well because you have good water movement. You have to have good circulation or cut down on the number of crabs. This floating box, if you have wave action, you can see how it would force the water in and out these small holes which gives you ample circulation. This type of box would hold 600 to 700 crabs; the dimensions are 42 inches wide, 12 inches high, and 8 feet long. You have to have good wave action though to hold that many crabs. You slide these boxes up on a ramp so you can "class them out." We nip our green crabs because we handle them every 2 days in warm weather. We pick out 3-day shedders and put them in another box. Before we had fiberglass boxes, we used cypress, redwood, or western red cedar boxes.

Q. Willard Van Engel: I've seen a lot of floats in Maryland and Virginia, but I've never seen any like the wooden boxes used in Lake Pontchartrain. There is a publication out, dated 1918, and they never showed any floats of that style. I think, possibly, those boxes with the covers may have originated in the Gulf.

A. Pearson: When I was a child, about 6 or 7 years old–I'm 54 years old now–they had some men on Lake Pontchartrain that used those wood-type boxes you saw earlier. They were using those covered boxes when I was a child about 6 or 7 years old, in about 1932 or 1933.

Q. Harriet Perry: I would like to ask Mr. Lee Seymour to say a few words. Lee, would you describe your closed system for us? Also, what volume of crabs can you handle?

A. Lee Seymour: My closed recirculating system is not a large one; I am able to produce 50 to 70 dozen soft-shelled crabs a night when I am able to get the crabs. That is one of my biggest problems. Catching the peelers is one of the basic problems in the whole soft shell industry. It does not matter how elaborate your system is, its useless without the crabs. However, that is not the only problem. Eventually a system is going to have to be developed to hold what I call a green crab. That would be any crab that you would have to feed. We have to develop this system as well as looking at ways to catch peelers in the wild. We need to get laws on the books that will allow fishermen to use this different gear to catch peeler crabs. We need stiff fines and penalties for people that tamper with or destroy this gear.

I know you asked me to describe my system. Basically, I have a series of shedding tanks, a filter system, and an algae tank. I shed about 97% of all the crabs I put into the tank. I only put crabs into the tanks that do not have to be fed. My main source of shedders is from crabbers. You know the old story about the elephant dying grounds–I am convinced that there are shedding grounds. I maintain my system at 5 to 8 ppt salinity and have found that a 77 to 78° temperature is ideal.

Comment–Cultus Pearson: I would like to bring out one other problem. Soft crabs are sold by the dozen. You can go to the grocery store and buy eggs by the dozen–they come small, medium, large, and extra large. You know about what size egg you are going to get. It was brought out earlier that we sell crabs in Louisiana by the dozen. I think some type of common terminology should be adopted. We need to establish some standards, either weight or some other means, so we are talking in the same terms.

Comment–Eugene Jaworski: I would suggest standardization by weight, perhaps calling 7-ounce crabs or larger, jumbos; 4- to 7-ounce crabs, mediums; and under 4 ounces, small crabs.

Comment–May Usannaz: I would like to comment on an earlier topic. If you put a crab in a box and hold him too long, he will get box burn and will turn back and not shed.

Comment–Willard Van Engel: I think it is a good practice to discard any crab that does not shed within 10 days. This is a Chesapeake [Bay region] practice. You are wasting your space and your time by holding a crab which has gone backward or is not going forward. To have to cull it over and over again is a good waste of time. Get rid of crabs that have box burn or ones that have picked up a lot of "moss." Getting back to a green crab system, it is important to remember that a green male crab will stop going through the molting process if there are females in the tank with it. He will double with them and want to wait until that female sheds to mate with her. He will stay away from shedding day after day as long as he is in a tank with females that are close to molting. If you are going to hold green crabs, you might want to hold the sexes separately.

Comment–(unidentified): We have had some obvious white sign crabs in our tanks revert back.

Q. Lee Seymour: Van, did you say that they discard crabs further than 10 days away from shedding to keep from culling them over and over again?

A. Van Engel: What I said was that it is traditional in the Chesapeake systems to separate the crabs into busters, red signs and pink signs, and then white signs and hair signs, although they don't like to hold white signs and hair signs. The pink and red signs are checked every 4 hours. The white signs and hair signs are checked every three days. If these crabs have not progressed by the third culling, they are discarded. That is common practice in the Chesapeake.

Comment–Lee Seymour: I've found that I can keep white lines in with the pink and red lines and I don't have any white lines turning back–male or female.

Comment–Van Engel: This is what is done in Maryland and Virginia. It may be that the warmer temperatures you have down here or the different quality of water may make a difference. From the point of view of economics, if you can buy busters and pink and red signs only, and hold them you turn the whole quantity of crabs over in your system every 3 days. You are making more money with less effort.

Comment–Seymour: For every pink line or red line crab brought in by a crabber, there are 100 to 150 white line or hair signs. You can shed more crabs by accepting the earlier signs.

Comment–Van Engel: You have a real problem with a scarcity of peelers.

Comment–Seymour: Let me correct that–we don't have a scarcity of peelers–we have a scarcity of "catchers."

ERRATA

FIGURE 23, P. 147. SYNTHETIC, KNOTLESS WEBBING SHOULD READ PLASTIC SCREEN - WEBBING RESTS ON FILTER PLATE.
PAGE 149,SECOND PARAGRAPH. ONE-QUARTER INCH HOLES SHOULD READ TWO,ONE-EIGHTH INCH HOLES.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 153–157.

HISTORY AND STATUS OF LOUISIANA'S SOFT–SHELL BLUE CRAB FISHERY

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ABSTRACT Peak production of soft-shell blue crab in Louisiana occurred during World War II when over 2.3 million pounds were produced. Current production fluctuates from year to year, but averages only 150,000 pounds per year. Conversely, wholesale prices paid to fishermen have risen sharply since the 1960s, and now exceed $2 a pound. Problems identified by crab fishermen include inadequate supply of peeler crabs, unreliable water quality in shedding habitats, changes in distribution of crab populations, and insufficient knowledge of mechanized shedding facilities.

DEVELOPMENT OF THE FISHERY

One of the earliest blue crab fisheries in the United States developed near the city of New Orleans during the late 1800s (Rathbun 1884). The first record of commercial soft-shell production in Louisiana dates back to 1887 when 133,000 pounds, valued at $7,000, were harvested (Lyles 1969).

Because of the market demand generated by the city of New Orleans, the soft-shell crabbing industry initially developed along the northern shore of Lake Pontchartrain, and in the Pass Rigolettes region. Crab terminology and shedding techniques from Chesapeake Bay slowly diffused into those regions. Specifically, the art of grading shedding crabs, the use of holding cars, and the practice of clipping claws of green crabs appear to be derived from east coast fishermen. However, the wooden crab floats, with air wells and special lids, are local in origin.

In contrast, the fishery in Barataria Estuary, centering in the village of Lafitte, evolved from swamp-dweller settlements along the lakes and bayous. During the period 1890 to 1930, a number of extended-family settlements existed along Bayou Des Allemands, Lake Salvador, and Bayou Barataria (Jaworski 1972). Soft-shell crab production in this estuary increased when a fisherman from Lake Cataouatche discovered that peeler crabs were attracted to fresh willow branches placed in the estuarine lakes to catch river shrimp and eels (Frost 1938). Fishermen soon found that wax myrtle (*Myrica cerifera*) branches were even more effective than willow branches in attracting "doubles" and other shedding crabs.

HISTORICAL SOFT-SHELL CRAB LANDINGS

The commercial soft-crab fishery began during the late 1800s (Table 1). Production levels increased in 1934 as a result of the development of the bush line technique in Barataria Estuary. The highest historical landings occurred in 1945, when World War II food demands greatly accelerated crabbing effort. During the 1960s, soft-crab production began declining from an average of 500,000 pounds per year. Output of less than 100,000 pounds per year occurred in 1970, 1974, and in 1976. Although 1979 production may exceed 200,000 pounds, year-to-year fluctuations in abundance of peeler crabs characterize the modern soft-shell fishery of Louisiana.

It should be emphasized that the crab statistics in Table 1 represent estimates of actual production. Catch data are collected through monthly and, in places, yearly canvassing of fishermen, crab buyers, and seafood dealers. It is likely that commercial production of soft crabs is underestimated by 40 to 50% (de la Bretonne, personal communication).

TABLE 1.

Soft-shell blue crab production in Louisiana, 1887 to 1978.*

Year	Pounds	$ Value	Year	Pounds	$ Value
1887	133,000	7,000	1954	455,000	215,000
1888	143,000	7,000	1955	580,600	209,000
1889	147,000	8,000	1956	600,000	250,000
1890	130,000	7,000	1957	551,000	192,000
1908	78,000	21,000	1958	577,000	298,000
1923	3,000	1,000	1959	605,000	302,000
1927	137,000	48,000	1960	514,000	256,000
1928	183,000	52,000	1961	620,000	310,000
1929	81,000	25,000	1962	344,000	172,000
1930	146,000	58,000	1963	329,000	164,000
1931	121,000	45,000	1964	200,000	127,000
1932	99,000	25,000	1965	204,000	141,000
1934	651,000	86,000	1966	128,000	85,000
1936	365,000	53,000	1967	146,000	121,000
1937	329,000	51,000	1968	284,000	206,398
1938	248,000	37,000	1969	196,600	161,235
1939	215,000	33,000	1970	89,600	79,532
1940	252,000	40,000	1971	126,909	125,770
1945	2,370,000	1,706,000	1972	101,959	109,130
1948	881,000	440,000	1973	119,475	131,552
1949	455,000	192,000	1974	95,559	126,986
1950	364,000	165,000	1975	110,540	155,101
1951	350,000	188,000	1976	88,205	144,945
1952	448,000	215,000	1977	224,749	569,539
1953	488,000	203,000	1978	133,000	273,392

*Sources: Lyles (1969); National Marine Fisheries Service, *Landing Records*, 1968–1978.

As the average annual production declined slowly over the years, wholesale prices of soft crabs at the dock increased substantially. During the 1880s, soft crabs were valued at approximately $0.05 per pound. In 1971, the price reached $1.00 per pound, and jumbos or "counters" sold for $3 to $5 per dozen. (A "jumbo" soft crab weighs 7 ounces or more, but many soft crabs average 5.5 ounces.) By 1978, average price for soft crabs had escalated to $2.05 per pound. Several fishermen reported that during the summer of 1979, large soft crabs were marketed at the dock for $1.50 each.

A lack of standardization in soft-crab weights or sizes, and in selling prices frustrates many crab fishermen as they deal with inexperienced seafood buyers. Table 2 illustrates the variation in crab sizes and prices among Louisiana crab fishermen.

TABLE 2.

Sizes, weights, and selling prices for soft crabs, Lake Pontchartrain versus Barataria Estuary

Lake Pontchartrain	Barataria Estuary	Current Prices In Both Areas
Jumbo (7 oz or more)	Counter (over 5.5 in.)	$20 per dozen
Medium (4 to 7 oz)	Three-for-two	$15 per dozen
Small (less than 4 oz)	Two-for-one	$ 8 per dozen

MAJOR PRODUCTION AREAS

The two major soft-crab production areas in Louisiana are located along the northeastern shore of Lake Pontchartrain, and in the Lake Salvador region of Barataria Estuary (Figure 1). In general, crab-shedding habitats center in the upper and middle portions of estuaries where large numbers of juvenile blue crabs maturate (Jaworski 1972). In these oligohaline and mesohaline environments water salinities range from 0.5 to 18 ppt. Crab populations appear to be highest in areas of direct tidal exchange as well as where *Rangia* clam beds and sandy substrates prevail. Juvenile blue crabs particularly are abundant in beds of *Ruppia maritima* and *Vallisneria spiralis* which extend along the northern shore of Lake Pontchartrain from Bayou Liberty west to Pontchartrain Causeway.

Although the map in Figure 1 was prepared in 1970, distribution of shedding houses has not changed appreciably. However, shedding houses at Bayou Dularge and at Lake Maurepas have been discontinued, while one has been constructed along Bayou Petit Caillou.

Soft-shell crab production in Louisiana is restricted to the eastern portion of the Mississippi River delta (Table 3). Barataria Estuary (identified as the coastal region between Mississippi River and Bayou Lafourche in Table 3) historically has been an important production area. Although estuaries in the western portion of the deltaic plain support large populations of blue crab, fishermen in that region do not shed crabs. In 1978, soft-crab production in Lake Pontchartrain/Lake Borgne region may have been low due to the scarcity of peelers, but discussions with local fishermen also suggest that the area harvest was underestimated.

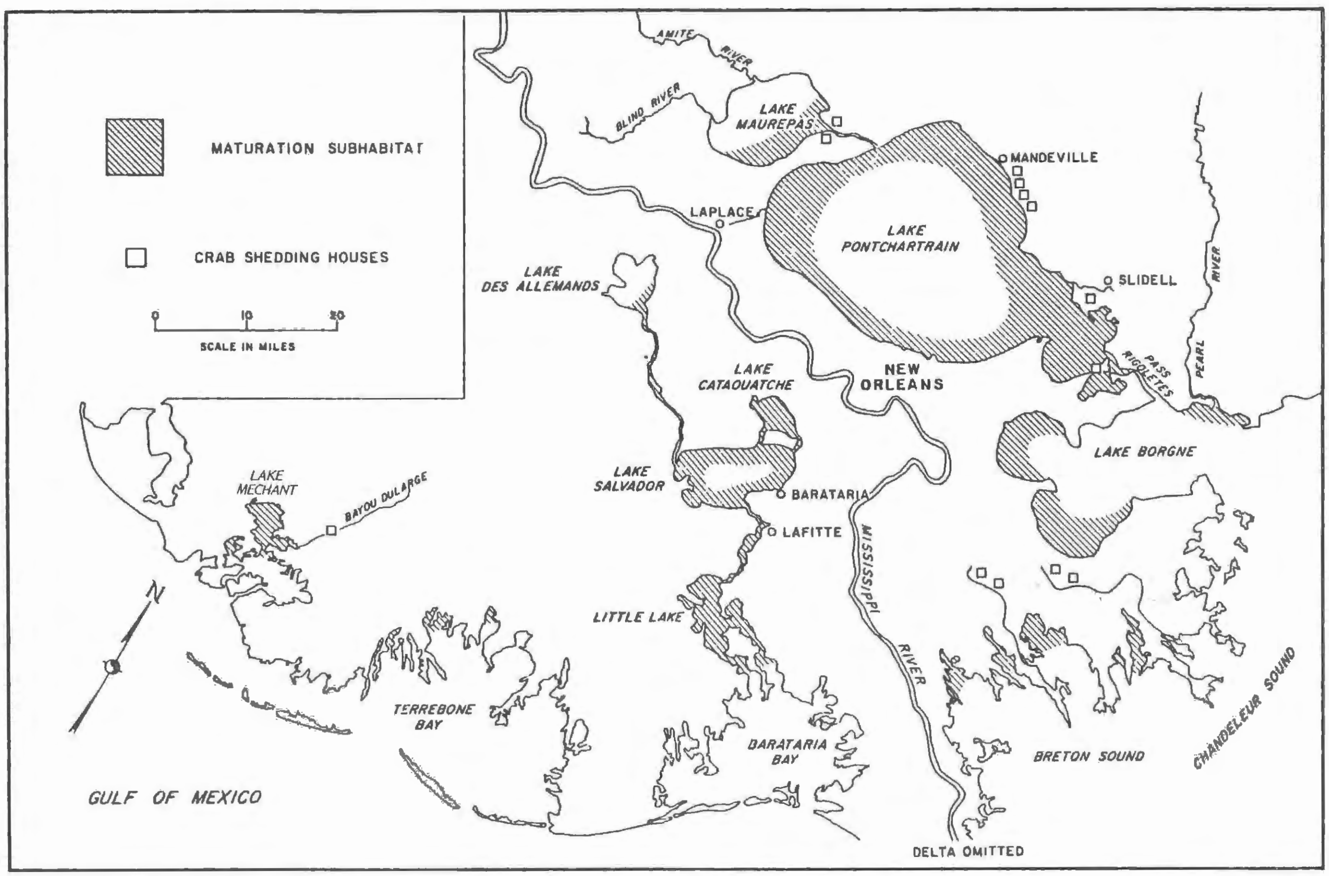

Figure 1. Location of crab shedding houses and distribution of the blue crab maturation subhabitat (shaded area) in coastal Louisiana (adapted from Jaworski 1971).

TABLE 3.

Soft-shell blue crab landings† in Louisiana by water body (in pounds) for 1955, 1970, and 1978

Water Body	1955	1970	1978
Lakes Maurepas, Borgne, and Pontchartrain	178,700	26,700	1,200
Breton and Chandeleur Sounds	77,600	25,400	1,800
Mississippi River to Bayou Lafourche*	324,300	37,100	129,000
Bayou Lafourche to Atchafalaya River	0	300	1,000
Atchafalaya River to Tiger Point	0	100	0
Tiger Point to Louisiana Point	0	0	0
Louisiana Point to Sabine River	0	0	0
Totals	580,000	89,600	133,000

†Source: National Marine Fisheries Service, *Landing Records*, 1955, 1970, and 1978.
*Also referred to as Barataria Estuary.

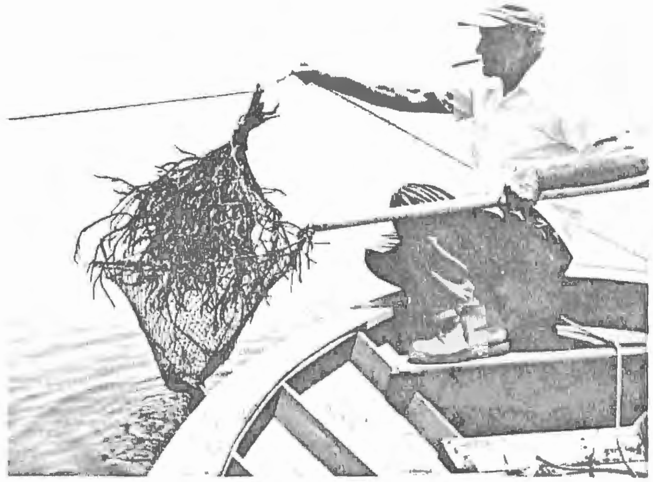

Figure 2. A crabber from Lafitte running his bushlines. A scoop net is placed under the bush to catch peelers.

SHEDDING TECHNIQUES

Most fishermen who shed crabs are also hard-crab fishermen who commonly trawl for shrimp and trap furbearers as well. Since crab pots now constitute the primary hard-crab gear type, peeler crabs are taken along with hard crabs. Some crabbers in Lake Pontchartrain/Lake Borgne area use drop nets, and youngsters usually crab for peelers with push nets along grassy shorelines. When soft crabs are scarce, soft-shell crabbers may pay as much as $2 to $3 a dozen for ripe crabs.

In Barataria Estuary, bushlines constructed from wax myrtle are utilized to catch ripe (green) crabs, busters, and doubles (Figure 2). In an attempt to seek cover from predators, as well as to wedge against something stationary during ecdysis, shedding crabs may move into beds of submerged aquatics, tree roots, or into a crabber's bushlines.

Fishermen commonly hold peelers in wooden floats that are tethered along the lake shore in the Lake Pontchartrain area. Floats usually are 8 feet long, 3.5 feet wide, and 1 foot deep. As many as 500 shedding crabs may be placed in a single car. The claws of green crabs are clipped, and these peelers are kept in floats separate from the more ripe crabs, including busters. Green crabs are graded every day or every second day; if any busters or "red line" peelers are found, they are removed and carefully placed into the ripe-crab floats.

In contrast, crabbers in Barataria Estuary utilize open live cars to hold peelers. Although construction varies, live cars are usually 8 feet long, 4 feet wide, and 2 to 3 feet deep. Windlasses are utilized to raise and lower the live cars during grading operations and crab feeding. Green-crab and buster-crab cars are maintained with each car holding 250 to 500 peelers. Crabs remain in the green-crab car for approximately 2 to 7 days, and in the buster-crab car from 12 to 36 hours.

Since the 1960s, several crabbers have abandoned passive shedding operations and have constructed crab-shedding houses. In 1970, there were 13 shedding houses in coastal Louisiana (Jaworski 1971). Each shedding facility is equipped with a water pump, and some feature a water reservoir and an internal water circulation system. To avoid polluted land drainage, water usually is withdrawn from the bottom of the bayou or lake. The shedding operation is completed in sloping concrete troughs, or in plastic tubs (Figure 3).

Figure 3. Inside view of a modern crab-shedding house along Pass Rigolettes near Lake Borgne. Crabs are being shed in plastic tubs into which a jet of water is sprayed constantly.

PROBLEMS AFFECTING THE FISHERY

A number of problems characterize the Louisiana soft-shell blue crab fishery, including the totally unwarranted concern over cholera in Vermillion Bay in September 1978, which caused the temporary closing of the industry. Based on discussions with fishermen, the four most frequent complaints are: (1) inadequate supply of peelers, (2) unreliable water quality in shedding habitats, (3) changes in distribution of the blue crab, and (4) insufficient knowledge of modern shedding techniques.

Perhaps the most significant factor regarding the decline of soft-shell crab production in Louisiana is the lack of peeler crabs. Blue crabs may undergo ecdysis during all months of the year, but commonly shed from February through October when estuarine water temperatures exceed 16°C or 60°F (Jaworski 1972). Shedding crabs are especially abundant when large numbers of juveniles are able to secure sufficient invertebrate and other preferred food items (Fischler 1965). In Barataria Estuary, soft-crab production is generally highest in April, and a secondary peak occurs in July–September following a mid-summer slack period.

Because of the popularity of submerged vegetation beds along Lake Pontchartrain for soft-shell crabbing, these habitats may be overfished by sport fishermen and youngsters using push nets. However, most crabbing gear, e.g., crab pots, employ baits to attract actively feeding crabs. Green crabs and doubles may be taken, but ripe crabs, particularly red line crabs and busters, are not harvested effectively by baited-gear types. In contrast, bush lines provide cover clues to shedding crabs and, therefore, may be an underutilized soft-crab gear type. Moreover, because ripe crabs are less mobile than hard crabs, it may be possible to seine for peelers along obstacle-free, shoreline environments.

A problem related to the supply of peeler crabs is the water quality of the upper estuarine environments where blue crabs shed and maturate. Water masses that are oxygen deficient and/or contain toxic substances may kill the less motile, shedding crabs, or may lengthen the process of ecdysis, particularly at the buster stage (Jaworski 1971). Adverse water quality also reduces populations of crustaceans and mollusks, including *Rangia cuneata,* which constitute the main food items of juvenile blue crabs (Darnell 1958). Increased runoff from terrestrial environments results in rapid fluctuations in salinity and water quality of upper estuarine water bodies. Drainage modifications, such as the Barataria Waterway, reduce the buffering capacity of the estuary and, as a result, sudden salinity changes may exceed the osmoregulatory ability of shedding crabs.

Another problem cited by crab fishermen is the changing distribution of the blue crab in relation to the overall ecology of the delta. It is widely known that part of the flow of the Mississippi River has been directed down the Atchafalaya River system. As delta extension is occurring at the mouth of the Atchafalaya River, subsidence and increasing salinity now characterize large tracts of the Mississippi River delta. Gagliano and van Beek (1970) have documented a land-loss rate of 16.5 square miles per year as a result of subsidence and wave erosion. Crabbers complain that spring salinities in Lake Pontchartrain are too low when the Bonnet Carré floodway is opened. Land development, e.g., Eden Isles subdivision along Lake Pontchartrain, is destroying valuable shoreline habitat for juvenile blue crabs (Adkins, personal communication).

There is little correlation between the main hard-crab fishing areas and the highest soft-crab production areas (Table 4). The soft-crab resource base of the western portion of the deltaic plain, particularly near the mouth of Atchafalaya River, may be underexploited. However, few crabbers west of Barataria Estuary are knowledgable of crab-shedding signs and shedding procedures.

Finally, many crabbers do not know the art of recognizing crab-shedding signs, and those fishermen with shedding houses could benefit from workshops on mechanized shedding facilities. Crab shedding is a labor-intensive activity that offers little incentive if the perceived risks of crab die-offs outweigh potential economic gain. Because of unreliable water quality in the upper estuaries, crabbers must either move their operations to larger water bodies, or develop at least partially closed shedding systems.

TABLE 4.

Hard- and soft-shell blue crab landings in Louisiana, by water body (in pounds).*

Water Body	1978 Hard-Crab Harvest	Recent Average Soft-shell Production
Lake Pontchartrain and Lake Borgne	1,419,000	75,000
Breton and Chandeleur Sounds	1,578,000	40,000
Mississippi River to Bayou Lafourche	3,017,000	120,000
Bayou Lafourche to Atchafalaya River	2,212,000	1,000
Atchafalaya River to Tiger Point	4,240,000	100
Tiger Point to Louisiana Point	2,141,000	0
Louisiana Point to Sabine River	124,000	0
Total	14,730,000	236,100

*U.S. National Marine Fisheries Service, *Landing Records,* 1970–1978.

PROSPECTIVES

Without public assistance, it is likely that the commercial soft-shell crab fishermen will continue to have difficulty supplying the market demand for soft-shell crabs. Public planning is needed to ensure that sufficient environmental quality is preserved for Louisiana's shellfish industries. Currently the U.S. Fish and Wildlife Service, in cooperation with the Bureau of Land Management, is sponsoring an ecological characterization study of the Mississippi deltaic plain.

State agencies and other public institutions may assist crabbers in adjusting to changes in water quality of the upper estuaries, and in the distribution of the blue crab. Specifically, underfished crab maturation environments should be identified, and new crab-fishing gear and shedding procedures should be developed experimentally. Because considerable capital investment may be required for a closed-system type of shedding facility, fishermen may wish to observe demonstration projects first-hand before making large private investments. If 5% of the total blue crab harvest in Louisiana consisted of soft-shell crabs, then the Pelican State would yield 3 million pounds of soft-shell crabs for a value of approximately $6.1 million.

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SOUTH CAROLINA'S SOFT–SHELL CRAB PROGRAM[1]

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ABSTRACT Bush lines, peeler pots, experimental habitat pots, crab fykes, and hard crab pots were comparatively fished at 9 stations in three areas (three stations/area) of the Ashley River, Charleston County, SC, to determine the most successful methods, locations, and seasons for capturing peeler crabs. Fishing efforts were initiated April 18, and continued through August 24; gear was fished daily Tuesday through Friday. Recorded data for each captured crab included station, gear type, salinity, temperature, lunar day, total width, sex, and molt sign. Success was based on the average catch per gear-day, i.e., one piece of gear fishing a 24-hour day. Crab fykes were vulnerable to local currents and tides, and were finally abandoned after becoming unrepairable. The remaining gear captured 9,048 crabs of which 751 were peelers (pink sign, red sign, and busters). Experimental habitat pots were the most consistent and successful gear tested, accounting for 0.64 peeler per gear-day while hard crab pots and bush lines were the least successful, catching 0.17 to 0.19 peeler per gear-day. Catch rates for all tested gears were highest in the mid-portion of the river where salinities averaged 12.4 ppt.

Another study was conducted to evaluate the effectiveness of selected mesh trawls at capturing peelers ≥ 76 mm (total width). Trawls with 1-7/8-inch stretch mesh were towed simultaneously with 2-1/2-, 3-, or 3-1/2-inch stretch mesh trawls and results compared. Trawls with 1-7/8-inch stretch mesh captured more peelers, but differences were not significant.

INTRODUCTION

Commercial production of soft-shell crabs has not been reported in South Carolina for the past 22 years. In 1936, production peaked at $>$ 9,000 pounds, and declined rather drastically thereafter (Figure 1). By 1957, the last year of recorded landings, production had decreased to $<$ 500 pounds. Reasons for the demise of soft-shell crab production in the state are unknown, but as long as trotlines were the principal means of capturing crabs, soft-shell crab landings were reported. There appears to be a relationship between the end of soft-shell crab production and the introduction of the crab pot as the primary method of harvesting hard-shell crabs.

Trotlines require relatively constant attention and are checked several times daily. Feedings crabs were dip netted from each baited snood, and this procedure allowed the crabber to "study" individual crabs at capture. Pubertal molt females doubled with feeding "jimmies" (males) could be easily recognized and set aside for shedding operations. Crabs captured by pots do not lend themselves to such close inspection.

Recently there has been considerable interest in reestablishing the local production of soft-shell crabs (Bearden et al. 1979). Reasons are, in part, economic, a crowded hard-shell crab fishery, and availability of the resource. No less than four pilot operations were shedding crabs in 1979 (Table 1), and more than 4,800 pounds of soft-shell crabs were reported (assuming 3 crabs per pound).

[1]Much of this information was presented at the Workshop on Soft-Shell Blue Crabs, 22 September 1979, Charleston, SC.

TABLE 1.

Known production of soft-shell crabs (dozens) in South Carolina in 1979.

Month	Shedding Facility			
	A	B	C	D
April	61	100	80	300
May	84	62	20	200
June	24	127		
July		60		
August		100		
Total	169	449	100	500

The success of any soft-shell crab operation depends on its ability to obtain a relatively constant and sufficient supply of peelers. Because essentially nothing was known about premolt crabs in South Carolina, a sampling program was designed that would provide information on their availability, distribution, and abundance.

MATERIALS AND METHODS

Three stations in each of three areas of the Ashley River, Charleston County, SC, were established to comparatively test five types of gear (Figure 2). Each gear type was deployed at every station establishing a 3 (area) $\times$ 5 (gear type) factorial arrangement with three replicates.

Tested gear consisted of bush lines (Jaworski 1972), peeler pots (Warner 1976), experimental habitat pots, crab fykes (Young 1955), and the hard crab pot with two entrances (Van Engel 1962). Two "bushes" were fished on

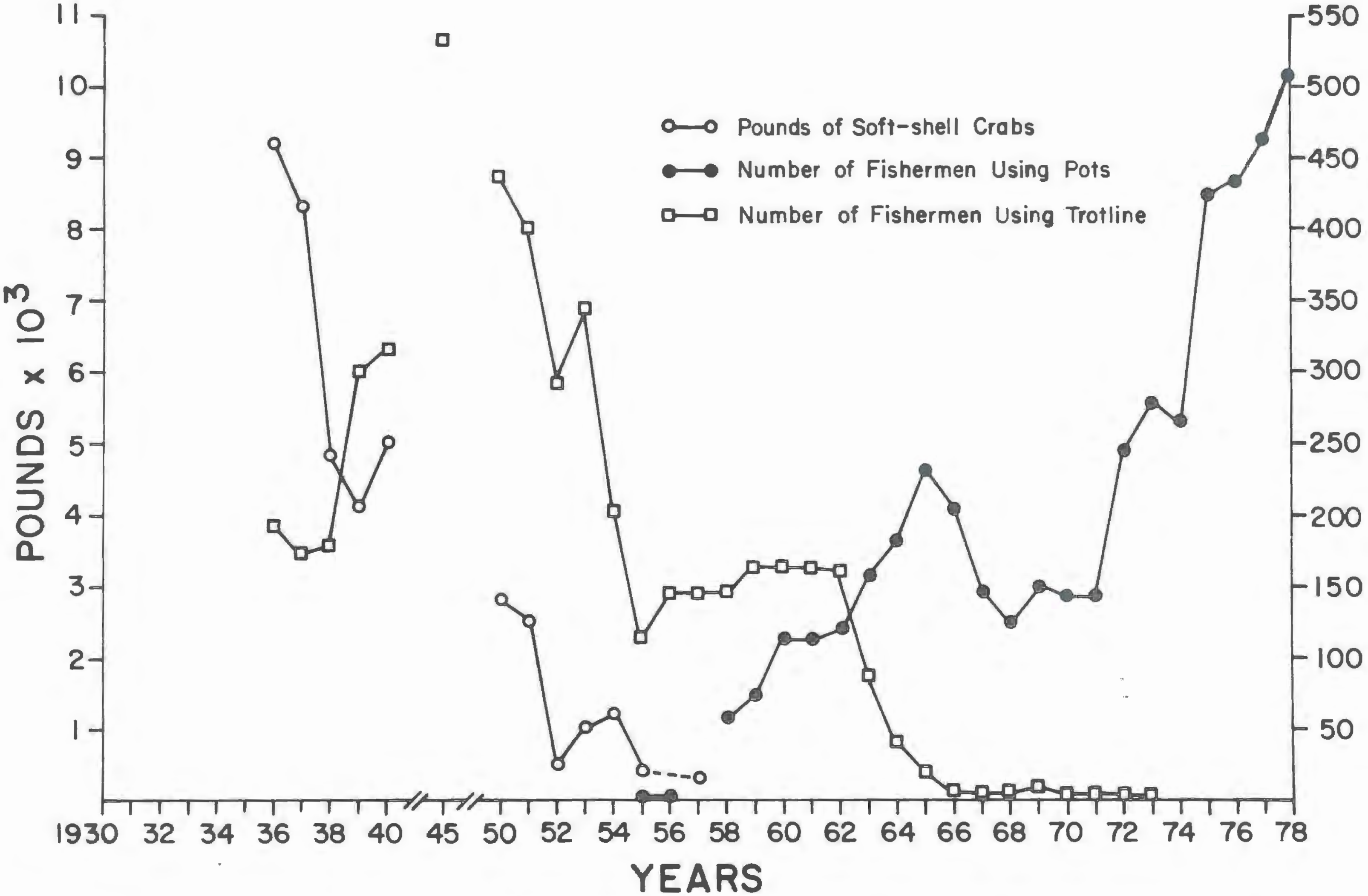

Figure 1. Annual production of soft-shell crabs and number of fishermen using baited trotlines or pots in South Carolina. Data from Fishery Industries of the U.S. 1931–1939, Bureau of Fisheries; Fishery Statistics of the U.S. 1939–1967, U.S. Dept. Interior; Fishery Statistics of the U.S. 1968–1975, National Marine Fisheries Service; and Fisheries Statistics Section, South Carolina Wildlife and Marine Resources Department.

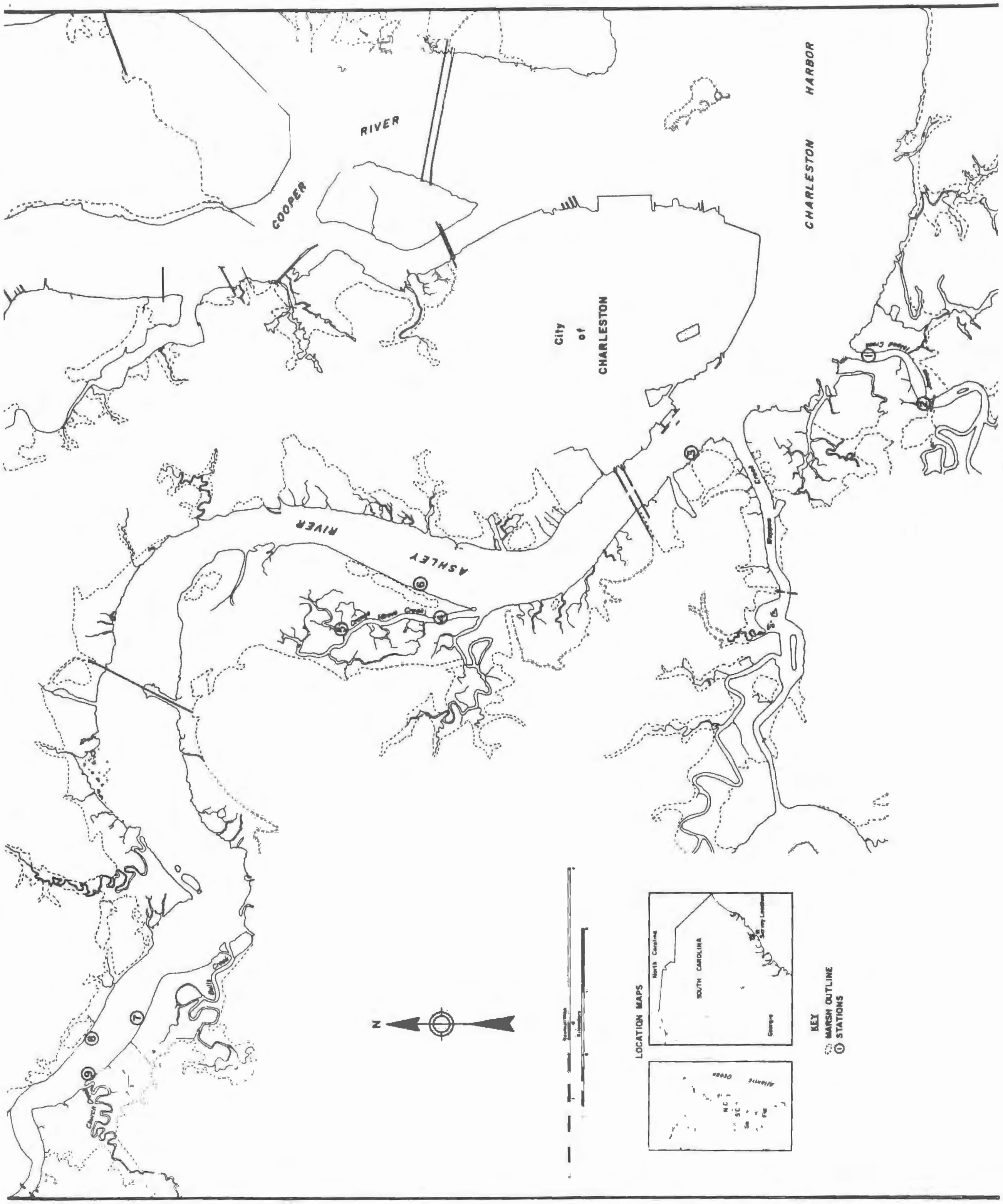

Figure 2. Peeler crab survey stations sampled in 1979.

each bush line. Peeler pots were constructed similar to the hard crab pot, but 1-inch mesh wire was substituted for 1.5-inch mesh. Experimental habitat pots consisted of peeler pots with 1-inch wide plastic flagging tape interwoven among the wire mesh on all sides except the bottom. Crab fyke hedgings, i.e., wire fence leads, were placed perpendicular to tidal current flow between the estuarine edge of the *Spartina* marsh and the low water line. Lengths varied from 40 to 90 feet depending on location. Width, depth, and height of the trap portion of the fyke were 4 feet × 3 feet × 4 feet, respectively. One-inch mesh wire was used for crab fyke construction. Crab fykes, bush lines, and experimental habitat pots were fished unbaited; peeler pots were "baited" with two marked jimmie crabs; and hard crab pots were baited with frozen whole menhaden.

All gear was reset each Monday and fished daily Tuesday through Friday. Jimmie crabs in the peeler pots were replaced as necessary, and the hard crab pots were baited daily Monday through Thursday. Bottom water temperature and refractive index (for salinity) were recorded at each station as crabs were collected. Crabs captured by each piece of gear were bagged, labeled, and returned to the laboratory for work-up. Recorded data for each crab included station, gear type, salinity, temperature, lunar day, total width, sex, and molt sign. Premolt sign categories follow those discussed by Van Engel (1958), and the term peeler is used to denote pink and red sign crabs and busters. Except for the crab fykes, fishing efforts began April 18, 1979, and data analyses for this report continued through August 24. On April 25, a storm damaged the fykes. Repairs were completed by May 31, and fishing initiated June 1. Gear-day is used as a measure of fishing effort, and one gear-day implies one unit of gear fishing one 24-hour day.

A separate experiment was conducted to evaluate the effectiveness of selected mesh trawls at capturing peelers. Twenty-foot otter trawls of 1-7/8-, 2-1/2-, 3-, and 3-1/2-inch stretch mesh were towed with the Department's R/V CAROLINA PRIDE, a double rigged 52-foot Thompson trawler. The 1-7/8-inch mesh trawl was used as a control and towed simultaneously with one of the other experimental nets. Nine comparative tows were made by each test net for a total of 27 tows. Trawl tows were conducted April 24 and 25, May 2, May 16 and 17, and June 27 and 28, and lasted 10, 15, or 20 minutes depending on crab abundance. All trawl tows were in the Charleston Harbor area, and all but three were made in the Ashley River near station 6 (Figure 2). Capture success was compared between the control and test nets. An Analysis of Variance (ANOVA) for a completely randomized design with equal replication (Steel and Torrie 1960) was computed for numbers of peelers $\geqslant 76$ mm. Significant differences were tested at $\alpha = 0.05$.

RESULTS

As of August 24, a total of 9,141 crabs was captured by all fishing methods exclusive of trawling. Crab fykes were fished a total of 30 times (fyke days) and captured 93 crabs of which 11 were peelers.

Of the remaining 9,048 crabs, 751 were determined to be peelers. Hard crab pots and bush lines captured the fewest peelers while experimental habitat pots accounted for almost half (Table 2). Males outnumbered females 2 to 1 in experimental habitat pots, but in hard crab pots, female peelers dominated males by almost 6 to 1 (Table 2). Mean total widths between sexes captured by each gear type were similar, and the smallest crabs (83 to 84 mm) were captured in bush lines and the largest (109 to 110 mm) in hard crab pots (Table 2).

TABLE 2.

Total number of peelers captured, by gear, from 18 April–24 August 1979. (mean width in mm)

	Bush Line	Habitat Pot	Peeler Pot	Hard Crab Pot
Number	109	359	175	108
Percent male/female	54/46	65/35	53/47	15/85
Mean width male/female	84/83	93/87	100/104	109/110

Peeler capture success was greatest (0.64 per pot-day) in experimental habitat pots and least (0.17 per bush-line day) in bush lines (Table 3). All gear types were most successful (0.21 to 0.81 peeler per gear-type per day) in the mid-portion of the river (stations 4–6), but experimental habitat pots were the most successful (0.51 to 0.81 peeler per pot-day) gear type in each of the three sampled areas (Table 4).

TABLE 3.

Daily catch by gear. One gear-day equals an individual gear-type fished one day.

	Gear Type			
	Bush Line	Habitat Pot	Peeler Pot	Hard Crab Pot
Total Peelers	109	359	175	108
Total Crabs	252	894	705	7,197
Gear-Days	624	561	589	578
Peelers/day	0.17	0.64	0.30	0.19
Crabs/day	0.40	1.59	1.20	12.45

Success of each gear type varied considerably from week to week (Figure 3). In general, catch success for peeler pots and hard crab pots followed similar patterns with greatest peaks occurring in April and May. Bush lines were the least successful during the spring and peaked the week of July 3–6 at an average of 0.44 crab per bush-line day. Experimental habitat pots captured peelers more successfully and consistently during every week except April 18–20. All gear showed a marked decrease in capture rates during the week of July 10–13 (Figure 3).

TABLE 4.

Peeler catch per day by gear and area.

	Gear Type				
Ashley River	Bush Line	Habitat Pot	Peeler Pot	Hard Crab Pot	Average
Lower	0.13	0.59	0.22	0.15	0.26
Mid	0.21	0.81	0.45	0.25	0.43
Upper	0.18	0.51	0.21	0.14	0.26
Average	0.17	0.64	0.30	0.19	

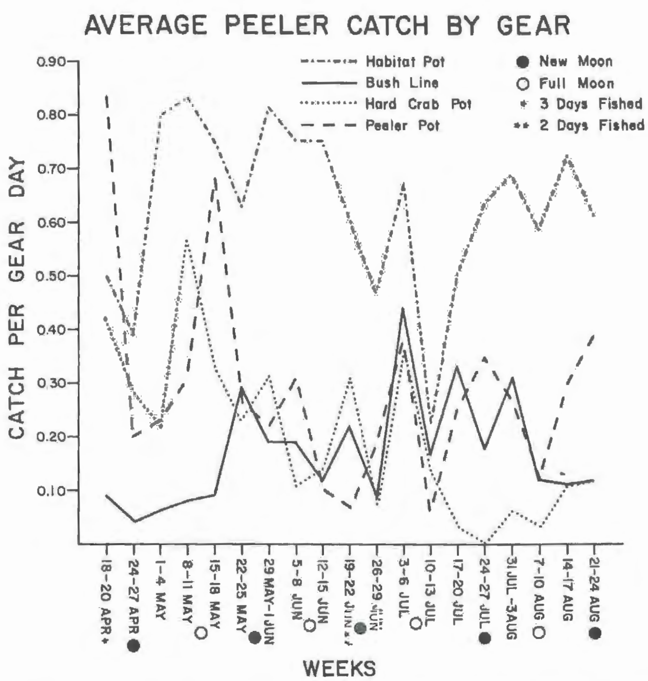

Figure 3. Average daily peeler catch by gear from April 18–August 24, 1979.

Salinity at the lower, mid, and upper river stations (± 1 standard deviation) averaged 12.8 ± 3.1, 12.4 ± 3.4, and 6.2 ± 4.4 ppt, respectively. Corresponding temperatures averaged 25.6 ± 2.8, 25.9 ± 2.9, and 26.1 ± 2.7°C.

The number of peelers ⩾ 76 mm total width captured by the 1-7/8-inch mesh trawl was greater than those captured by the 2-1/2-, 3-, and 3-1/2-inch mesh trawls (Table 5). In no instance was this difference significant, however (Table 6).

TABLE 6.

ANOVA (completely randomized design with equal replications) of selected mesh trawl catches of peeler crabs ⩾76 mm total width.

Source of Variation	df	SS	MS	F
Among trawls (1-7/8 inches versus 2-1/2 inches)	1	14.22	14.22	2.47*NS
Within trawls (1-7/8 inches versus 2-1/2 inches)	16	92.22	5.76	
Total	17	106.44		
Among trawls (1-7/8 inches versus 3 inches)	1	10.89	10.89	0.27 NS
Within trawls (1-7/8 inches versus 3 inches)	16	641.56	40.10	
Total	17	652.45		
Among trawls (1-7/8 inches versus 3-1/2 inches)	1	22.22	22.22	1.08 NS
Within trawls (1-7/8 inches versus 3-1/2 inches)	16	329.78	20.61	
Total	17	351.90		

*NS = not significant

DISCUSSION

Because most of the currently active crab fishermen began crabbing after soft-shell crabs were no longer produced commercially in South Carolina, most are not cognizant of peeler crab capture and shedding procedures.

TABLE 5.

Crabs captured by selected mesh 20-foot otter trawls.

Net Mesh (inches)	Number of Tows	Cumulative Tow Time (minutes)	Number of Crabs Captured	Number Crabs ⩾76 mm Total Width	Number Peelers ⩾76 mm Total Width
1-7/8	9	130	516	278	48
2-1/2	9	130	257	200	32
1-7/8	9	150	438	265	57
3	9	150	396	253	43
1-7/8	9	150	400	269	49
3-1/2	9	150	181	142	29

Consequently, there are no indigenous methods of capturing peelers and, except for Sandifer (1974), methods used in other states have not been tested in the estuaries of South Carolina which differ substantially from those where soft-shell crabs are currently produced. The estuaries of South Carolina are characterized by extensive intertidal marsh borders, mean tidal amplitude ⩾ 5 feet, and tidal currents > 1 knot. Also, broad mud flats are frequently exposed at low tide.

Techniques employed to capture peelers that appeared to be most promising included peeler pots and crab fykes used in the Chesapeake Bay, and bush lines used in Louisiana. Crab scrapes, also used in Chesapeake Bay, have been tested previously and were shown to be ineffective because of the absence of subtidal grass beds (Sandifer 1974). The concept of the experimental habitat pot was based on the success of bush lines, i.e., that crabs seek shelter in which to molt. It was believed that the experimental habitat pot would provide the shelter of a bush, but it would not require the precautions necessary to fish bush lines (Jaworski 1972). Hard crab pots were fished as controls because the hard-shell crab fishery is dependent on this gear; it is the ability of this pot to capture peelers that must be surpassed.

Comparing success of fishing procedures on a gear-day may not be representative of equal effort in each case. The decisions to use two bushes per bush line and equating a bush-line day to a pot-day were based on the time required to fish that piece of gear. In general, individual gear types took about equal time to fish; hard crab pots took slightly more time because they required baiting and, invariably, one or two crabs became entagled in the wire mesh. Also, peeler pots, experimental habitat pots, and crab fykes captured crabs that hard crab pots could not because smaller mesh wire was used in their construction.

Crab fykes were the least-adaptable gear tested because tidal currents damaged the wire fences (hedgings) and frequently dislocated the trap portion. The hedgings intercepted flotsam and marsh debris, and the resulting drag from tidal currents caused chronic states of disrepair (in spite of efforts to maintain them in fishing condition). To keep the trap portion of the fyke in place, reinforcement rods were attached vertically to each corner and anchored into the mud, 35 to 40 cm. Additional anchorage was provided by tying the trap to stakes placed at each corner. These procedures necessitated that crabs be removed by dip net at tide stages other than high. In time, however, the crab fykes became unrepairable and were abandoned for the remainder of the experiment. Because of the relatively few number of days that fykes were fished, their efficacy at capturing peelers cannot be judged fairly. Crab fykes may prove to be an effective piece of gear if they can be redesigned to cope with local tidal currents and amplitudes. Nearly 12% of the crabs captured by fykes were peelers.

The experimental habitat pot was the most successful gear tested. This pot was not only the most consistent producer over time (Figure 3), but it captured the most peelers in total numbers (Table 2) and per pot-day (Table 3). Forty percent of the crabs captured by experimental habitats were peelers, and it is believed that the average catch rate of 0.64 crab per pot-day could be substantially improved by fishing pots in selected areas. Whether this gear could sufficiently supply a shedding operation with peelers is unknown.

Peeler pots and hard crab pots showed moderate success during April and May, which coincided with the spring run of pubertal molt females. During the first 6 weeks of this study (April 18 to May 25), 78 and 66 peelers were captured by peeler pots and hard crab pots, respectively; females outnumbered males by 2 to 1 and 5 to 1, respectively. Although total numbers of peelers did not differ greatly, peelers accounted for 33% of the peeler pot catch and only 2.7% of the hard crab pot catch. Thus, time spent sorting peelers would be considerably less for peeler pots.

The overall success of bush lines was low (0.17 peeler per bush-line day), but when a crab was captured, the chance of it being a peeler was high. Forty-three percent of the crabs collected in bushes were peelers, the highest such percentage among the gears tested. The relatively poor success of bush lines probably resulted from tidal currents and presence of extensive *Spartina* marshes located nearby. During flood tide, peelers may relocate in marshes where cover is more extensive. Also, tidal currents cause bush lines to tangle, and stationary cover such as the stems of *Spartina* may be more attractive as long as they remain inundated.

The otter trawl study was initiated to investigate the effects of mesh size for capturing peelers, not to determine whether trawling is a viable method for their capture. Although no significant differences were found between catch rates, the 2-1/2- and 3-inch mesh nets captured substantially fewer small crabs (Table 5) and could probably be towed for longer periods. North Carolina, the only state that legally allows peelers to be captured by trawl, restricts net widths to ⩽ 25 feet (corkline length) and stretched net mesh to ⩾ 2 inches (Bearden 1978). Commercial soft-shell crab operators in North Carolina rely heavily on the trawl as a method of obtaining peelers after the spring run of pubertal molt females (Murray Bridges, September 22, 1979, personal communication). Trawling for peeler crabs in the inside waters of South Carolina is presently illegal and, if legalized, would certainly result in controversy because of conflicts with shrimp resources. Thus, in the foreseeable future, shedding operations will have to depend on other methods of peeler-crab capture.

Preliminary results of our field study indicate that there appears to be no single straightforward and highly successful method of capturing peelers in South Carolina. As in other states, shedding operations will have to pursue a multifarious approach to obtaining peelers if they are to maintain continuous operations throughout warm weather.

Pilot soft-shell crab operations in South Carolina relied exclusively on commercial hard-shell crab fishermen as a source of peelers in 1979. This proved to be unsatisfactory for several reasons: (1) it was necessary to convince crabbers that it would be worthwhile to sort peelers for shedding operations; (2) many crabbers did not know how to recognize peeler-crab signs readily; (3) peelers obtained from hard-shell crab fishermen were frequently injured by intermolt crabs prior to and during sorting; and (4) peelers captured consisted almost exclusively of pubertal molt females which were available in numbers only during the spring run. These limitations resulted in pilot operations obtaining an adequate supply of peelers for a relatively short period of time, and only one operated for more than 3 months (Table 1). If the efficiency of the best methods of capturing peelers can be improved and successfully transmitted to the commercial sector, then soft-shell crab production may become an important segment of the blue crab fishery of South Carolina.

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DISCUSSION

Q. (Unidentified): Jim, did you say that you tried a different mesh size in your experimental habitat pots than in your commercial pots?

A. Jim Bishop: Yes.

Q. (Unidentified): Did you try any experimental habitat pots with the same mesh size to see if the average size of the crab was different?

A. Bishop: No. Right now that is not part of the study design. We are currently just comparing gear to see what will catch crabs. I would imagine that you would get a smaller crab in the 1-inch mesh.

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EX–VESSEL PRICE TRENDS IN THE BLUE CRAB FISHERY OF THE UNITED STATES[1]

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ABSTRACT Factors influencing national and regional ex-vessel prices for hard-shell blue crabs in the United States were examined by regressing national and regional prices on total United States disposable income, quantities of crabs landed, Chesapeake Bay states region prices, and crab poundage. Historically, ex-vessel price trends suggested that fishermen have received lower prices for trawl-caught blue crabs than for pot- or trotline-caught crabs. Income coefficients were significant in all estimated price-response equations. Chesapeake Bay states regional crab poundage and ex-vessel prices were apparently important in predicting ex-vessel prices in the South Atlantic states region but were not significant in the Gulf states region. Future price analysis should examine influences of seasonality, marketing channels, and interdependencies between the blue crab fishery and other fisheries.

INTRODUCTION

A large number of factors affect commodity prices, and blue crab prices should not be an exception. Quantities landed, product shelflife, location of landings relative to the market, harvesting methods, and consumer tastes, preferences and incomes all may affect blue crab prices. Laws and policies of regulatory agencies affect prices directly or indirectly through their influence on the forces of supply and demand.

This paper attempts to identify only readily discernible factors which predict ex-vessel prices for hard-shell blue crabs in the United States. The discussion focuses on regional trends because research by Prochaska et al. (1982) suggested that regional factors, and not state-level variables (e.g., quantities landed in Florida), are generally significant in the prediction of state ex-vessel prices. In addition, the multiple regression (price response) equations in this paper are not intended to specify all critical independent variables, but to explore only the possible predictive influence of selected variables and to suggest associated market implications. These independent variables have been selected based upon data availability and potential relationship to the dependent variables.

The price analysis is of annual ex-vessel (dockside) prices since 1950, including the effects of major harvesting gear on ex-vessel prices. Hard-shell blue crab price trends have been selected because the aggregate ex-vessel value of hard-shell blue crab landings has constituted more than 80% of the aggregate blue crab ex-vessel value in the United States since 1952. This does not imply that the relative profitability of harvesting blue crabs for soft-shell shedding is less than that for hard-shell blue crab harvesting.

In addition, the regional analysis is restricted to the designations used by the National Marine Fisheries Service (NMFS), i.e., the Chesapeake Bay states region (Maryland and Virginia), the South Atlantic states (North Carolina, South Carolina, Georgia and the eastern coast of Florida), and the Gulf states (the western coast of Florida, and Alabama, Mississippi, Louisiana, and Texas), because blue crab landings in these regions are the major sources of blue crab landings in the United States (Table 1).

TABLE 1.

Hard-shell blue crab poundage by region[1] for selected years with percentage of U.S. poundage in parentheses.

	Pounds in thousands							
Year	Mid-Atlantic States		Chesapeake Bay States		South Atlantic States		Gulf States	
1975	6,437	(4.8)	59,083	(43.8)	30,502	(22.6)	38,720	(28.7)
1970	1,359	(0.9)	67,351	(46.3)	42,701	(29.4)	33,999	(23.4)
1965	1,451	(0.9)	82,561	(49.4)	45,976	(27.5)	37,008	(22.2)
1960	3,643	(2.4)	66,338	(44.3)	44,786	(29.9)	34,876	(23.3)
1955	3,484	(3.6)	42,119	(43.1)	32,552	(33.3)	19,427	(20.0)

[1]The pounds for the New England states were not included.
Source: *U.S. Natl. Mar. Fish. Serv. Stat. Dig.* series.

NATIONAL TRENDS

During the 1950 to 1978 period, hard-shell blue crab landings in the United States varied from a low of 94.0 million pounds in 1956, to a high of 167.0 million pounds in 1965 (Figure 1). The annual ex-vessel prices for hard-shell blue crab ranged from a low of 4.00 cents per pound in 1960, to a maximum in 1977 of 21.31 cents. During the 1950–67 period, annual prices displayed no conspicuous responsiveness to the quantity of hard-shell blue crabs landed. During that period, the highest price, 6.73 cents per pound, was recorded in 1965, the same year the maximum pounds were landed for the entire 1950–78 period (Figure 1).

[1]Contribution No. 110 from the South Carolina Marine Resources Department.

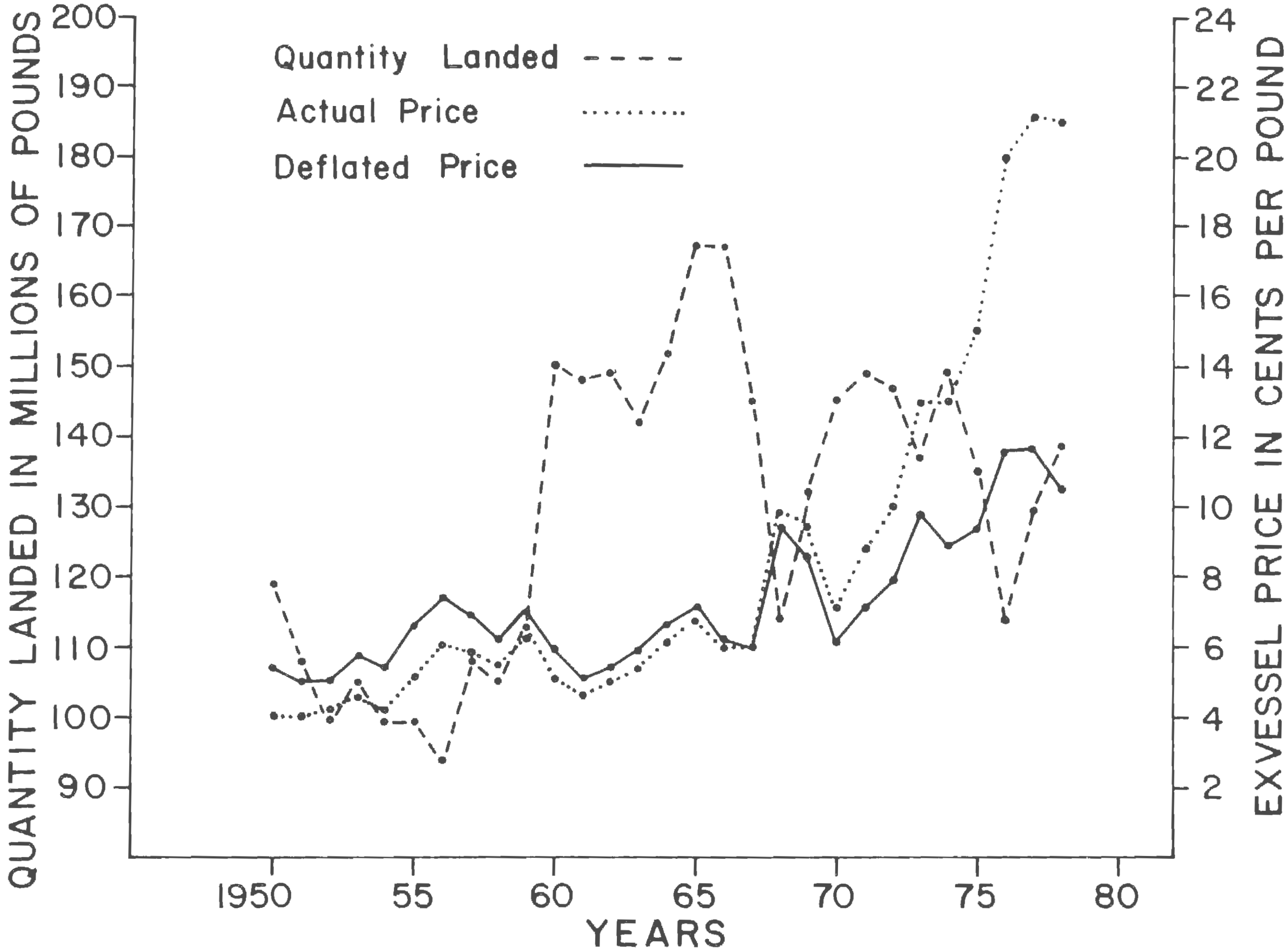

Figure 1. Annual ex-vessel blue crab prices (actual and deflated) and quantities landed in the United States, 1950–78.

A relatively lower price might have been expected for such large crab landings in 1965.

In the 1970's, the general price level in the United States underwent the sharpest inflation rates in peacetime history (Peterson 1978). These inflationary trends within the United States economy have probably affected blue crab price trends as well. In the 1970–78 period, the visual comparison of deflated prices with annual landings does display some responsiveness to quantities landed (Figure 1).

REGIONAL TRENDS

Annual prices in the major regions have increased through time (Figure 2) with the Chesapeake Bay states region generally higher than the Gulf and South Atlantic states regions prices before 1969. After 1969, the Gulf or Chesapeake Bay region prices have usually been the highest annual average ex-vessel price for hard-shell blue crabs. The mean annual prices were 8.64, 7.52, 9.13 cents per pound, respectively, for the Chesapeake Bay, South Atlantic, and Gulf states during the 1955–77 period.

The price differences between the Chesapeake Bay and the South Atlantic states may be indicative of buying practices by crab processors during the 1950's in the South Atlantic states. Some fishing communities in these states were apparently isolated from market information in the Chesapeake Bay states (H. F. Prytherch, personal communication). In recent years, interstate shipment of live crabs by both processors and other buyers has generally mitigated this problem. In addition, the contribution of lower iced trawl-caught crabs (see Harvesting Gear Effects section) to South Atlantic states prices may have also decreased the average annual price compared to the Chesapeake Bay states.

HARVESTING GEAR EFFECTS

Major harvesting gears used during the 1955–77 period were crab dredges and scrapes, otter trawls, pots, and trotlines (Table 2). Data for pots and trotline landings have been pooled. Since the 1950's, pots have replaced trotline gear as the major hard-shell blue crab harvesting gear in the United States. Ex-vessel price for trotline- and pot-caught crabs compared to dredge and scrape prices indicated no significant difference (Table 3).

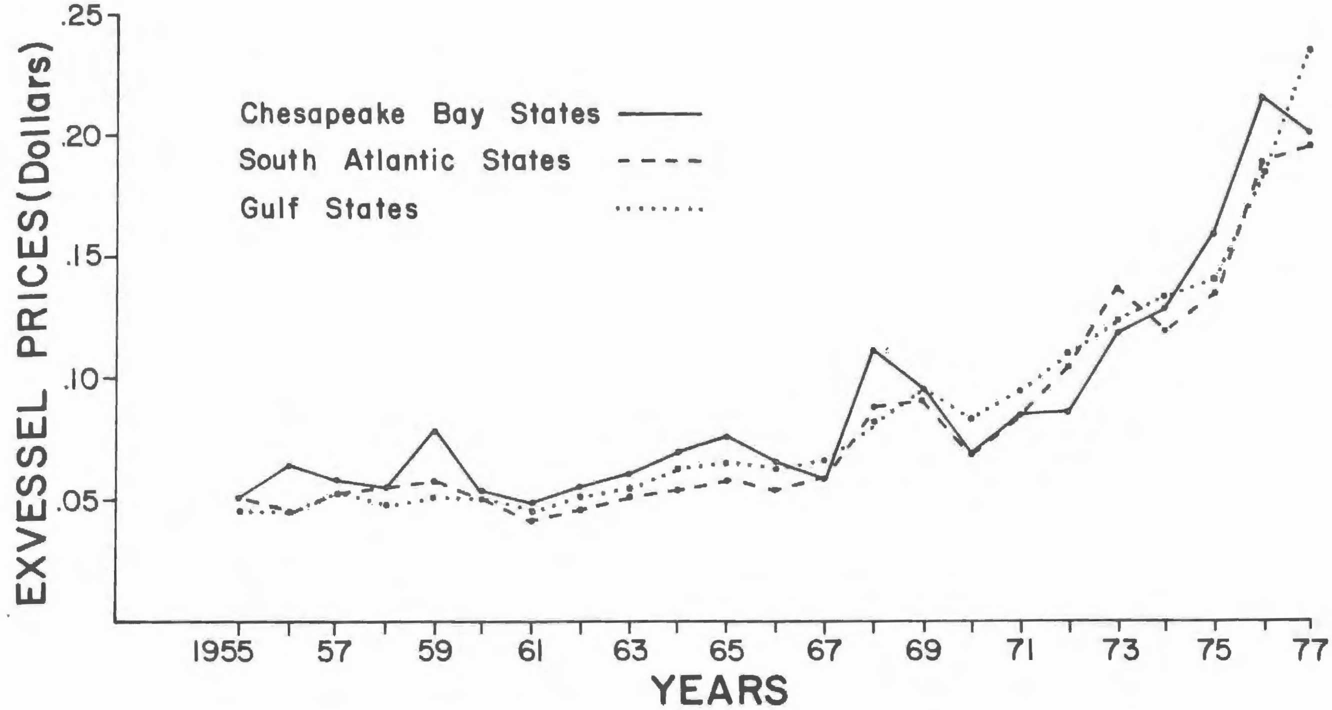

Figure 2. Annual regional ex-vessel prices for hard-shell blue crabs in the United States, 1955–77.

TABLE 2.

Average annual pounds (thousands) landed by major gear types for the 1955–1977 period with percentages of average (1955–77) total regional pounds in parentheses.

	Region		
Gear Type	Chesapeake Bay States	South Atlantic States	Gulf States
Dredges and scrapes	9,122 (14.5)	---	---
Pots and trotlines	53,135 (84.4)	29,578 (78.8)	28,364 (93.6)
Otter trawls	---	7,717 (20.6)	911 (3.0)

This historical price differential is probably associated with two factors: (1) meat yield of trawl-caught blue crabs, and (2) physical condition of trawl-caught blue crabs. In South Carolina (e.g., Eldridge and Waltz 1977) and other states, 80% or more of trawl catches of blue crabs were females. The processed meat yield of female crabs was usually less than the yield from pot and trotline catches which contained a higher percentage of males. Consequently, buyers will pay lower prices for trawl-caught crabs. In addition, the incidence of mud or sand contamination in trawl-caught crabs was apparently higher compared to catches by pots or trotlines, thereby decreasing their quality in the view of the buyers. The exception to this exists in the winter crab-dredge fishery in Virginia. This may represent a shift in buyer preferences because no other crab supply alternatives existed for buyers. The inconsistency and possible unpredictability of trawl-caught crab supplies have probably made some contribution to this price differential in the Gulf and South Atlantic states (G. Adkins, personal communication).

TABLE 3.

Average annual ex-vessel prices for hard-shell blue crab caught by dredges,[1] trotlines or pots, and otter trawls in the United States,[2] 1955–1977.

Gear Type	Average
Dredges	$0.091
Trotlines and/or pots	0.085
Otter trawls	0.075

t-test for Paired Comparisons

	n	t-statistic
Dredges versus trotlines or pots[3]	23	–1.3618
Trawls versus trotlines or pots[4]	46	5.3747*

[1]This includes crabs captured by scrapes.
[2]Only the major regions (see text).
[3]Only paired data for the Chesapeake Bay states were used because dredge and scrape observations were less than 3 in the other regions.
[4]The Chesapeake Bay states paired data were not used because trawl observations were less than 3.
*Significant at the 1% level.

PRICE–RESPONSE EQUATIONS

Estimated price-response equations for hard-shell blue crab in the United States, by regions and gear, are given in Tables 4 to 6. Regression coefficients provided predictive information concerning the possible effects of the quantity of crabs and income. It is recognized that these equations may be subject to simultaneous equation bias but given project objectives and cost, this problem was not investigated. In these equations, total disposable personal income in the United State may represent a linkage between prices and demand derived from higher population levels and higher disposable incomes. The income coefficients in all equations (Table 4 to 6) were significant. Previous analysis for the 1947–71 period has indicated that the estimated income elasticity for crab consumption in the United States was greater than one (NMFS 1973). Consequently, the annual increase in the blue crab ex-vessel price level may be linked to changes in aggregate money demand if not real aggregate demand for crab products in the United States.

The estimated United States price equation suggested that a 1 million-pound increase in hard-shell blue crab landings would only result in a 0.005 cent decrease in average ex-vessel prices in the United States fishery (Table 4) with the values of other variables affecting crab prices held constant.

TABLE 4.

Price response equation for annual ex-vessel hard-shell blue crab prices in the United States, 1950–1977.[1]

Dependent Variable[2]	Constant	Independent Variables[3]		R^2	Durbin-Watson Statistic
		Q_t	I_t		
P_t	0.05978	–0.00005 (5.39)	0.00015 (23.83)	0.96	1.15*

[1] Number of observations, 28; t-statistic in parentheses.
[2] Dependent variable is annual ex-vessel price of hard-shell blue crab in dollars per pound (live weight) in year t.
[3] Independent variables where Q_t = annual hard-shell blue crab pounds (millions) landed in year t in the United States, and I_t = U.S. total disposable income in billions of dollars in year t.
*There may be some serial correlation in this equation.

Total disposable income and quantity landed were both significant in predicting annual blue crab prices in the Chesapeake Bay region pot and trotline fisheries (Eq. 1, Table 5). Historically, a 1 million-pound increase in the quantity of hard-shell blue crab landed caused a 0.10 cent decline in prices. Because the Chesapeake Bay region has paid higher prices in the past, has landed a larger share of the total United States catch, and has been able to influence the total market (George Harrison, personal communication), the other regions may have paid prices based on the Chesapeake Bay region landings.

To examine this hypothesis, regressions were estimated using quantities landed and ex-vessel prices in the Chesapeake Bay region. The influence of Chesapeake Bay region landings on price was found to be (at the 1% level) only significant in the South Atlantic region (Eqs. 2 and 4, Table 5). A 1 million-pound increase in Virginia and Maryland landings resulted in a 0.08 cent per pound decrease of the South Atlantic region ex-vessel prices (Eq. 2, Table 5). A 1.00 cent increase in Chesapeake Bay region prices resulted in a 0.53 increase in the South Atlantic region ex-vessel prices. Landings of blue crabs in the South Atlantic states were not statistically important in predicting the ex-vessel price in the region.

The pounds landed and ex-vessel prices in the Chesapeake Bay region were not significant in the Gulf states region. Quantity landed in the Gulf states was significant in influencing the prices in the region, with a 1 million-pound increase apparently causing a 0.13 cent decrease in price. As might be expected, the influence of the Chesapeake Bay region on the Gulf states compared to the South Atlantic states was not readily apparent in these regressions. Marketing logistics and costs to the Virginia and Maryland areas have probably motivated crab wholesalers to seek out other markets. In contrast, it has been common for Carolina blue crab processors to purchase picked crab meat or live crabs from Virginia and Maryland. In recent years, the interstate shipment of live crabs for basket-crab markets in Virginia, Maryland, and Washington, D.C., has also increased (e.g., Rhodes and Bishop 1979).

Price response equations (Eqs. 1 and 2, Table 6) for otter trawl ex-vessel prices in the South Atlantic and Gulf states regions suggested that quantities landed by pots and trotlines or trawls were not statistically significant (at the 1% level) in influencing regional prices (Table 6). Chesapeake Bay region landings were historically important in influencing prices paid for trawl-caught crabs in the South Atlantic region (Eqs. 1 and 3, Table 6). This influence probably reflected the previously discussed market ties between the South Atlantic states and the Chesapeake Bay states.

PRICE–QUANTITY

If there is a relationship between quantities landed and ex-vessel prices as suggested by these regressions, then a calculation of price-quantity flexibilities may provide some insight relative to other fisheries. Price-quantity flexibilities display the percent change in price resulting from a 1% change in quantity given the influence of other variables affecting price remain constant. The assumed percentage effect of hard-shell blue crab quantities by region for pot and trotline catches on price are shown in Table 7. For example, a 1% increase in the quantity of blue crabs landed in the Chesapeake Bay region would result in a 0.591% decrease in price. Cato (1976) reported that a 1% increase in annual mullet landings caused a 1.251% decline in price. From an annual perspective, mullet buyers might be considered quite responsive to changes in the quantities of mullet landings since storage periods usually do not extend beyond

TABLE 5.

Pot and trotline price response equations for annual ex-vessel hard-shell blue crab prices in the Chesapeake Bay, the South Atlantic, and the Gulf states, 1955–1977.[1]

Equation	Region	Dependent Variable[2]	Constant	Independent Variables[3]			R^2	Durbin-Watson Statistic
				$Q_t^{Ches.}$	Q_t	I_t		
1	Chesapeake Bay	$P_t^{Ches.}$	0.05771	---	−0.00099 (3.32)	0.00014 (12.80)	0.90	1.26*
2	South Atlantic	$P_t^{S.Atl.}$	0.06338	−0.00077 (4.26)	−0.00081 (1.79)	0.00014 (21.22)	0.97	1.63
3	Gulf	P_t^{Gulf}	0.02812	−0.00022 (1.01)	−0.00133 (2.94)	0.00018 (17.31)	0.96	1.26*
				$P_t^{Ches.}$	Q_t	I_t		
4	South Atlantic	$P_t^{S.Atl.}$	0.00719	0.52664 (4.79)	−0.00039 (0.86)	0.00006 (4.07)	0.97	1.62
5	Gulf	P_t^{Gulf}	0.01087	0.28214 (2.38)	−0.00110 (2.67)	0.00013 (6.31)	0.97	1.58

[1]Number of observations, 23, except the South Atlantic and Gulf states do not include Florida landing data in 1977; t-statistic shown in parentheses.

[2]Dependent variable is annual ex-vessel price of hard-shell blue crab in dollars per pound (live weight) in each region in year t.

[3]Independent variables where $Q_t^{Ches.}$ = annual hard-shell blue crab pounds (millions) landed in year t in the Chesapeake Bay states region; Q_t = annual pounds landed in each region in year t; $P_t^{Ches.}$ = annual ex-vessel price for hard-shell blue crabs caught with pots or trotlines in year t in the Chesapeake Bay states region; and I_t = U.S. total disposable income in billions of dollars in year t.

*The Durbin-Watson statistic indicates there may be some serial correlation in these equations.

TABLE 6.

Otter trawl price response equations for annual ex-vessel hard-shell blue crab prices in the Chesapeake Bay, the South Atlantic, and the Gulf states, 1955–1977.[1]

Equation	Region	Dependent Variable[2]	Constant	Independent Variables[3]				R^2	Durbin-Watson Statistic
				$Q_t^{Ches.}$	Q_t^p	Q_t^o	I_t		
1	South Atlantic	$P_t^{S.Atl.}$	0.07011	−0.00109 (3.94)	−0.00143 (2.42)	0.00113 (1.20)	0.00016 (16.09)	0.96	2.13
2	Gulf	P_t^{Gulf}	0.03173	−0.00009 (0.30)	−0.00131 (2.08)	−0.03673 (0.59)	0.00015 (11.90)	0.92	1.39*
				$Q_t^{Ches.}$	Q_t		I_t		
3	South Atlantic	$P_t^{S.Atl.}$	0.05364	−0.00090 (3.18)	0.00061 (1.22)		0.00015 (14.85)	0.94	1.83
4	Gulf	P_t^{Gulf}	0.03754	−0.00016 (0.59)	−0.00133 (2.55)		0.00014 (12.60)	0.92	1.26*

[1]Number of observations, 23, except the South Atlantic and Gulf states do not include Florida landing data in 1977; t-statistic is shown in parentheses.

[2]Dependent variable is annual ex-vessel price of hard-shell blue crab in dollars per pound (live weight) in each region in year t.

[3]Independent variables where: $Q_t^{Ches.}$ = annual hard-shell blue crab pounds (millions) landed by pots or trotlines in year t in the Chesapeake Bay states region; Q_t^p = annual pounds landed by pots or trotlines in year t in each region; Q_t^o = annual pounds landed by otter trawls in each region in year t; Q_t = annual pounds landed in each region in year t; and I_t = U.S. total disposable income in billions of dollars in year t.

*The Durbin-Watson statistic indicates there may be some serial correlation in these equations.

4 months. From a comparative standpoint, the annual price-quantity flexibilities for blue crab should be less (i.e., absolute value) than mullet because the storage life of processed crabs is usually many months longer than that of mullet.

TABLE 7.

Price-quantity flexibilities for regional hard-shell blue crab ex-vessel prices based on pot or trotline.

Source[1]	Region	Price-quantity Flexibility[2]
Equation 1	Chesapeake Bay	–0.591
Equation 2	South Atlantic	–0.505
Equation 3	Gulf	–0.439

[1]The price response equations in Table 5 were used in computing price-quantity flexibility.
[2]Price-quantity flexibility was computed as

$$(\partial P_t/\partial Q_t)\ (\bar{Q}_t/\bar{P}_t)$$

where $(\partial P_t/\partial Q_t)$ = partial derivative of estimated hard-shell blue crab price response equations with respect to quantities given as independent variables; and $\bar{P}_t$, $\bar{Q}_t$ = means of crab prices and quantity variables used to estimate equations. In the South Atlantic states, Q_t = mean of Chesapeake Bay states region quantity variable in Equation 2, Table 5.

FUTURE RESEARCH CONSIDERATIONS

This report does not present an exhaustive analysis of variables affecting hard-shell blue crab prices. The influence of monthly and quarterly blue crab landing patterns needs to be investigated. Waugh and Norton (1969) have reported that hard-shell blue crab prices on the Fulton Market did display significant seasonal shifts in demand during the year. Several structural variables in the marketing channels still need to be evaluated when examining ex-vessel price-response relationship at the fishermens level. For example, the seasonality of hard-shell blue crab prices are probably affected by the wholesale market for "basket" crabs in coastal areas. Unfortunately, information on ex-vessel prices for basket crabs was not differentiated in the NMFS data collection except for three states.

Besides the effects of seasonality and marketing channels, an equally important consideration for future analysis is the economic interdependencies between the hard-shell blue crab fishery and other fisheries. The existence of significant economic interdependencies between fisheries involving different species has been hypothesized (e.g., Crutchfield 1973). With regard to the blue crab fishery, Strand and Matteucci (1977) have provided empirical evidence for the existence of short-term economic interrelations between the Virginia oyster and the blue crab fisheries. Historical interpretations of blue crab landing trends in Georgia and South Carolina have also implicated economic interrelations between the blue crab and the shrimp trawling efforts.

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*added in proof

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MARSHES AND THE ECONOMIC PRODUCTIVITY OF THE FLORIDA BLUE CRAB INDUSTRY

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ABSTRACT Society must decide how much marsh-estuarine area should be preserved. Information on the economic value of such marsh areas is crucial to this decision process. Only limited work has been completed in this area. Two economic-valuation approaches using aggregate data on the Florida west coast blue crab industry are developed. Economic value must be estimated as current marsh markets fail to reflect this value. The economic value of the salt marsh to the blue crab (for human food production) industry was estimated to range from $0.80 to $3.10 per acre, using a 10% capitalization rate. Further research work must be started to quantify the effect of marsh changes on fishery output.

INTRODUCTION

Salt marshes and estuarine areas provide unique natural environments that contribute various flows of goods and services to society. One of these flows relates to the food production, spawning, and habitat functions for various types of marine life. At the same time, society finds other uses for coastal resources which are also in demand and generally serve useful functions. As a result, conflicts in use arise with respect to resources in the coastal zone. Society is forced to decide how much salt marsh-estuarine area should be maintained in the face of economic development pressures.

The socio-political-economic process must decide how to allocate these marine-related resources to their "highest and best use." A necessary type of information to this allocation process is the value in alternative uses or combinations of uses. Unfortunately, there is little agreement, and even fewer empirical estimates, as to the value of salt marsh-estuarine areas. Some argue these areas have a very high (infinite) value, defended by the perspective that they cannot be replaced (Odum and Skjei 1973). It is questionable, however, that society would place an infinite value on this vital resource at the current time even if they fully understood all the functions these areas provide. Knowledge of such values is important to the decision-making process. Both the private and public sectors are making daily decisions affecting the future of all the wetland areas in the coastal zone with little value information.

It is the overall purpose of this paper to clarify some of the issues relating to the determination of the value of salt marsh-estuarine* areas to marine-production processes. More specifically, there are three purposes, namely: (1) to indicate the nature of "economic value" in the context of the marsh value question; (2) to illustrate two alternative approaches to economic valuation of salt marsh-estuarine areas for marine (food) production processes using generally available data; and (3) to suggest research efforts that need to be undertaken to improve models and actual empirical estimates of economic value.

PREVIOUS RESEARCH EFFORTS

Only minimal efforts have been made at the application of economic concepts and tools to the valuation of marsh-estuarine areas in fisheries (food) production. Generally, previous researchers have used one or more of the following approaches, some having no basis in the economic theory of value: (1) total value estimates; (2) energy value estimates; (3) net or residual value estimates; and (4) marginal value estimates. The applications that have been made of these various approaches are reviewed extensively elsewhere (Lynne et al. 1981). The remainder of this section is devoted to a summary of that review with only some key references included herein.

In the total value approach, the entire dollar value of the marine species in food markets is alloted to the marsh. Generally, this is not valid in the real world as the fisherman's labor, management, and capital also contribute to that dollar value. It would be appropriate if, and only if, these other inputs had zero opportunity costs. Energy values using gross national product/total energy used (Gosselink et al. 1973) conversions are equally invalid for similar reasons (Shabman and Batie 1978). The residuals value approach may be accurate under certain conditions (Lynne and Conroy 1978). The marginal value approach is the most desirable. Data requirements are the most stringent for this approach, requiring extensive biological data (Lynne and Conroy 1978) for accurate modeling. Aggregate production functions using available data sources may also be possible, however, as demonstrated in the study on which this paper is based (Lynne et al. 1981).

*"Marsh area" and "marsh-estuarine area" and "wetland area" are used interchangably throughout the remainder of this paper. Marsh area was defined to include small bays and estuaries up to 1.5 miles in width, river inlets to recognizable tree lines, and all lands where the water table was at or above the land surface for a significant part of the year (Lynne et al. 1981).

ECONOMIC VALUE–A DEFINITION

Given a certain, socially desired distribution of wealth and income, the economic value of a natural resource (or of any goods and/or services) is the exchange value in a perfectly functioning market. Under such conditions, the economic value would reflect the value people place on the marsh resource in all its uses, which may include esthetic viewing, value derived from food production, wildlife production, recreation, and value of the contribution of a species to the ecosystem, among others. Some individuals may gain satisfaction simply from knowing a certain natural resource (e.g., a certain species) exists; this value would also be captured in the value of the marsh in this perfect market. Also, this exchange value will likely be different from the value in use (use value),* and it will vary with the distribution of wealth and income.

The nature of the concept of "economic value" is depicted in Figure 1. The values held by society affect tastes and preferences for goods and services (such as recreation, preservation of species, and food production). Use value is affected either directly or indirectly. The indirect effect arises through the derived demand value, which simply means that some share of the use value of a good or service will affect the exchange value of that particular natural resource.

The use values generated by society are combined with a set of income and wealth distribution patterns to form the economists notion of economic demand. Ultimately, the supply and availability of the resource are balanced with these demands to yield the exchange (economic) value of the resource in the perfect market (Figure 1).

Within the confines of this pure model, conservation, preservation, ecological, aesthetic, food production, storm buffering, and other uses affecting "value" will all be balanced against available supplies. A market clearing price would surface, and would be the marginal value to society. When divided by the appropriate capitalization rate, this value would represent the value (at the margin) of the marsh to society. That is, given the socially desired distribution of income and wealth, the true social value will be reflected in the exchange (economic) value.

We were told in a recent coastal zone planning document of Florida that "because of their resource values–conservation areas require special precautions . . . " (Department of Environmental Regulation 1978, p. iii), and later in the same document, " . . . specific areas may be designated for the purpose of preserving or restoring them for conservation, recreational, ecological or aesthetic value . . . " (Department of Environmental Regulation 1978, p. 32). Why not for their economic value? In the above discussion, of course, it was noted that conservation, recreational, ecological, and aesthetic values would all be reflected in the economic value under the market conditions specified.

So, how does the "marsh market" fare? Is the observed market price the exchange value? Are the tastes and preferences of society conditioned by a sufficient amount of information regarding the value in use of marsh systems? The correctness of current wealth and income distribution patterns in the United States is left to the judgment of the reader. In terms of the perfection of the marsh market, however, we can be very definitive. The marsh market fares very poorly with the net result that observed prices for marsh acreage cannot be taken to represent an informed public perception of value in use. There has been "market failure" in the representation of the true economic value of the marsh resource. A major cause of this failure is the lack of knowledge by society-at-large of the true function and role of a marsh system within the larger ecosystem. Thus, tastes and preferences are such that marshes are deemed by many to have little use value; a second major dimension of this failure relates to property rights. Salt marshes tend to be owned in the private sector with benefit flow to the public sector if kept in a natural state. Thus, there is an economic incentive to convert natural marsh systems to other land forms. This conversion may or may not be socially desirable. In any case, the market is not providing sufficient information by which to judge.

Concerned conservationists, environmentalists, and others have implicitly recognized (by their actions) that there has been market failure to represent, even approximately, the ecological use values of marsh-estuarine areas. These groups have recognized that current, observed prices of marsh acreage represent only that portion of the use value associated with changes in other land uses (condominiums, frontage for hotel-motels, etc.) as reflected in the land market. All the conservation, ecological, etc., values are being ignored in the current market for marshes.

The existence of market failure underlines the need to establish estimates of the dollar value of marshes. These estimates may provide empirical evidence that there is market failure (as it is possible estimates of dollar value may exceed current market prices). More importantly, estimates of dollar value should enter the decision-making processes of private- and public-decision makers, to ensure an appropriate amount of marsh is retained in current uses. If all use values can successfully be brought forth in estimates of dollar value, the summation will represent the true economic value.

DERIVED DEMAND VALUES

The use value of a marsh area for food production is a direct function of the value of this food flow. As a result,

*Economists have speculated about the nature of "value" for a very long time, even before the "father of economics," Adam Smith, published the first recognized economics book in 1776. It was realized early that there was a difference between "value in use" and "exchange value" (Oser 1970, p. 69) with use value generally greater than exchange value.

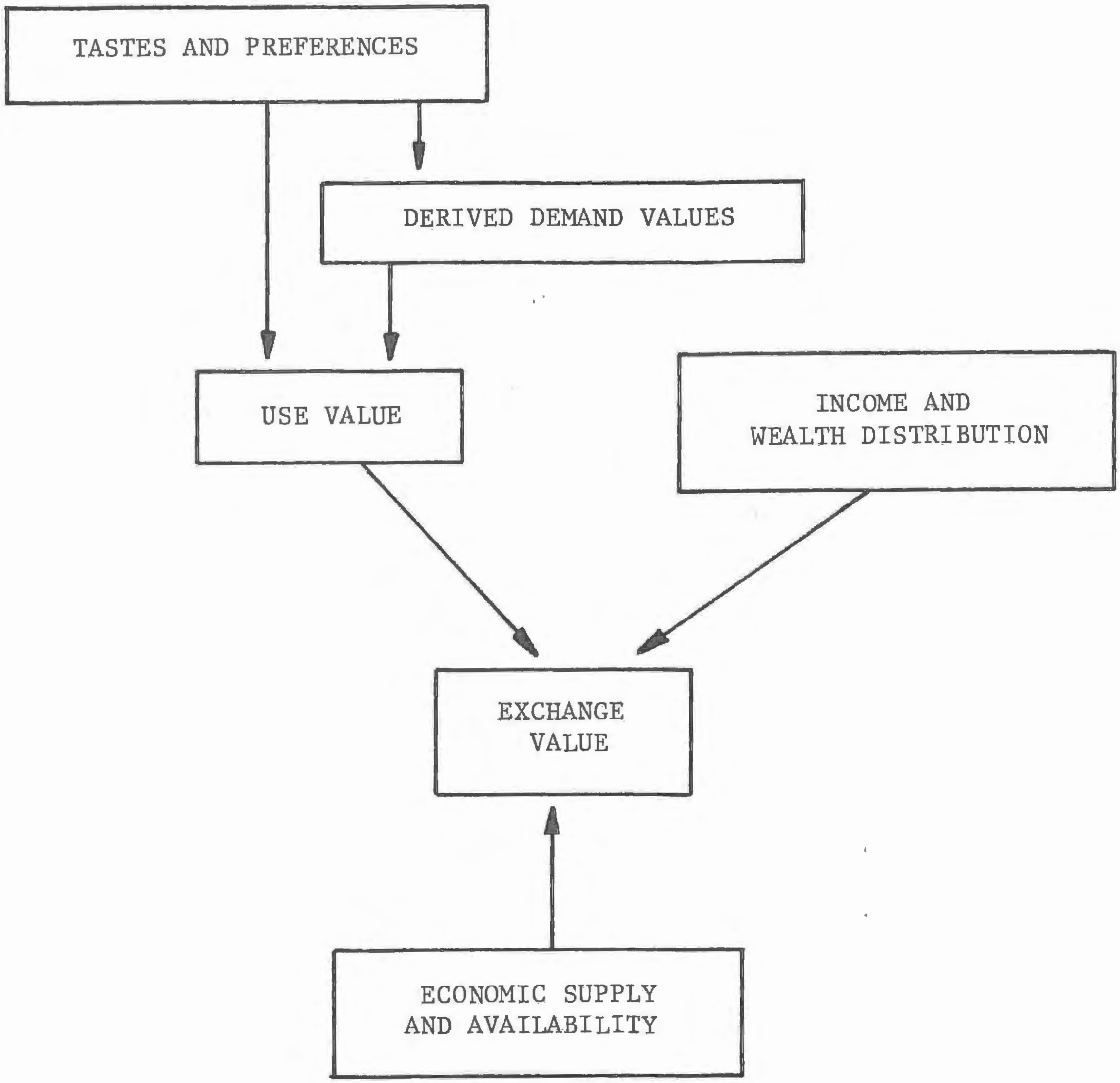

Figure 1. Nature of concept of economic (exchange) value.

this use value is bounded by, and derived from, the market value of a species in a competitive market. If there were no other factors of production (i.e., labor, capital, management) used to produce the marketed catch, then all the (market) food value could be attributed to the marsh. Marketable catches do not just appear without fisherman effort, however, so the marsh can only claim a share of the total exchange value for the catch [unless, of course, one is willing to assume labor, capital, and management (all represented in the level of effort) each to have a value of zero to society]. The remainder of this paper is devoted to estimating this share for marsh areas in blue crab production for human food.

APPROPRIATE ECONOMIC VALUATION APPROACHES

Both the "residuals" and the "marginal value" (production function) approaches build from the same theory of value and will give the same results under certain conditions. Each of these approaches is demonstrated in the remainder of this paper for the Florida Gulf coast blue crab industry, at the aggregate level. These concepts could also be applied at microlevels, where more detail is brought the analysis (Lynne and Conroy 1978).

RESIDUAL VALUE OF MARSHES

The total dockside (exchange) food value of all Florida Gulf coast landings was $2.2 million in 1975 (Prochaska and Morris 1978). This, then, becomes the upper bound on the economic value of the marsh to this process in that year (Table 1).

Subtraction of total expenditures from total sales value leaves (Table 1) $84,952 to $196,111 dependent on the assumed return to labor and management. Landings in the study area (from the Everglades region through the Appalachicola area, along the west coast of Florida), however, represented only about 75% of the total for Florida. Using

TABLE 1.

Sales and costs associated with the Florida blue crab fishery, 1975.*

Sales Effort	Cost	
Sales (dockside) value	$2,223,180	
Expenditures		
Bait	429,065	
Trap replacement	462,068	
Fuel	327,815	
Vessel repair	102,304	
Transportation	39,086	
Supplies	26,171	
Interest on investment	16,994	
Depreciation	8,497	
License	1,699	
Accounting	2,209	
Management and labor charge†	111,159 to	222,318
Total	$2,027,069 to	$2,138,228
Sales less expenditures	84,952 to	196,111
75% of difference	63,714 to	147,083

*Data, except for management return and labor charge, from Prochaska and Morris (1978).
†Assumed at 5 to 10% of sales value.

this factor, the residual return to 506,833 acres (study area marsh-estuarine system in 1975) was $63,714 to $147,083 (assuming constant returns to scale and "economic equilibrium" in the fishery, necessary conditions for the validity of this approach [Lynne and Conroy 1978, 1979]). This represents an average annual return of $0.13 to $0.29 per acre. If the aggregate marsh/blue crab production function were linear [which we argue elsewhere it is not (Lynne et al. 1981)] the *marginal value* of marsh would be the same as the average. Thus, the capitalized value of the marginal acre is around $1.30 to $2.90 (using a 10% capitalization rate), based on its contribution to blue crab production. This capitalized value is an estimate of the economic value to food production over the long term for the marginal acre.

PRODUCTION FUNCTION ESTIMATES

The aggregate production function for blue crabs is posited to have the general form

$$C_t = f(E_t, B_t) \qquad (1)$$

where C_t = (annual) catch in year t, E_t = effort in the fishery, and B_t = maximum potential biomass. The level of B_t, in turn, is affected by environmental factors including the quantity and quality of salt marsh-estuarine areas. It has been proposed that

$$B_t = h(M_{t-1}) \qquad (2)$$

where M_{t-1} = marsh availability in t-1, thus leading to the aggregate production function

$$C_t = f[E_t, h(M_{t-1})] \qquad (3)$$

The expression in Eq. 3 was converted to a statistical expression for estimation of the form

$$C_t = \beta_0 + \beta_1 (\ln M_{t-1})E_t + \beta_2 (\ln M_{t-1}) E_t^2 + \beta_3 C_{t-1} + \xi_t \qquad (4)$$

where β_i = parameters, and ξ_t = error turn, linearly related over time (auto correlation tendancies because of C_{t-1}).

A critique and defense for the structure of Eq. 4 is presented elsewhere (Lynne and Conroy 1978, 1979; Lynne et al. 1981) wherein the choice of the form of Eq. 4 is discussed relative to other possible forms. In fact, the choice of the form demonstrated here became, in the final analysis, a judgment by the authors, given the existing tradeoffs. It is possible, for example, that there was an insufficient range in the data to justify this choice of a nonlinear model (Lynne et al. 1981). Basically, the problem comes down to a lack of knowledge regarding Eq. 2. The t-statistics and discussion regarding statistical reliability are also presented in those papers (Lynne and Conroy 1978, 1979; Lynne et al. 1981). Levels of significance (P_i) were as follows for each of the $\hat{B}_i$ estimates: $P_0 = 0.17, P_1 = 0.06, P_2 = 0.11$, and $P_3 = 0.04$. The R^2 value was $R^2 = 0.78$, and the Durbin-Watson statistic was 2.05 for a sample size of N = 22.

Estimates of the marginal product of marsh (MP_m) are shown for various combinations of effort and marsh acreage in Table 2. Data on marsh availability were derived from aerial photos. Catch-and-effort data were from secondary sources (Lynne et al. 1981). At the average levels of $\bar{E}$ = 32,881 traps and $\bar{M}$ = 508,378 acres, the MP_m = 2.09 pounds per acre. The MP_m increases from 2.06 to 2.13 pounds per acre (Table 2). Also, MP_m increases as man-induced E becomes more intensive. At the average M for the period, the MP_m increased from 0.62 to 2.29 pounds as effort increased from 7,119 to 58,643 traps. The increase in MP_m for increases in E was an expected result, and suggests these two inputs of production are interdependent and that this interaction is positive. Interaction was tested with a linear model having an interaction term. Interdependence between M and E was judged statistically significant (Lynne et al. 1981).

Assuming an average price of $0.131 per pound (calculated from data in Prochaska and Morris [1979, pp. 8 and 24]), the marginal value product of marsh (MVP_m) is $0.27 at the mean values for E and M ($0.131 × 2.09). Using this same price, the range in MVP_m is $\$0.08 < MVP_m < \$0.31$ from the data in Table 2, or a capitalized value range of $0.80 to $3.10 per acre at the margin (using 10%).

The MVP_m is illustrated in Figure 2 for the average effort level ($\bar{E}$), and for two standard deviations on either side of $\bar{E}$. It is, again, apparent that the MVP_m is nearly constant. Also this is a pictorial display of the finding that

TABLE 2.

Marginal product estimates (per acre)[1] of marsh-estuarine areas for given effort levels in blue crab production, Florida Gulf coast.[2]

Marsh Acreage[3]	Effort (pounds/acre)				
	7,119	20,000	32,881	45,762	58,643
499,836	0.64	1.54	2.13	2.39	2.33
504,107	0.63	1.53	2.11	2.37	2.31
508,378	0.62	1.52	2.09	2.35	2.29
512,649	0.62	1.50	2.07	2.33	2.27
516,920	0.62	1.49	2.06	2.31	2.25

[1]Estimates at the margin, for the last additional acre.

[2]Data point selection based on an actual data range from 10,575 to 59,020 traps with a mean of 32,881 and $\hat{\sigma}$ = 13,881.

[3]Data point selection based on an actual range from 501,424 to 514,372 acres and an average of 508,378 and $\hat{\sigma}$ = 4,271.

MVP_m increases with more effort. The shift in the MVP_m function is not linear, however, reflecting the finding that for any given level of marsh, the MVP_m increases at a decreasing rate as effort is increased.

The marginal product of effort (MP_e) is illustrated in Table 3 for varying levels of M. At the mean M and E levels, $MP_e = 215.44$ pounds per acre with a range of $-112.56 < MP_e < 542.59$ pounds. the MP_e declines for increases in E as expected.

The marginal value product of effort (MVP_e) at the mean levels of M and E is $28.22 ($0.131 × 215.44). The range in MVP_e is from $-\$14.74 < MVP_e < \$71.08$ for all estimates in Table 3. The $MVP_e = 0$ around 50,000 traps, suggesting effort should never exceed this level even if the additional costs of further effort are zero. Also, MVP_e declines as marsh acreage declines, but only slightly. This decrease was so minimal, however, that the MVP_e function for $M = \bar{M}$ is

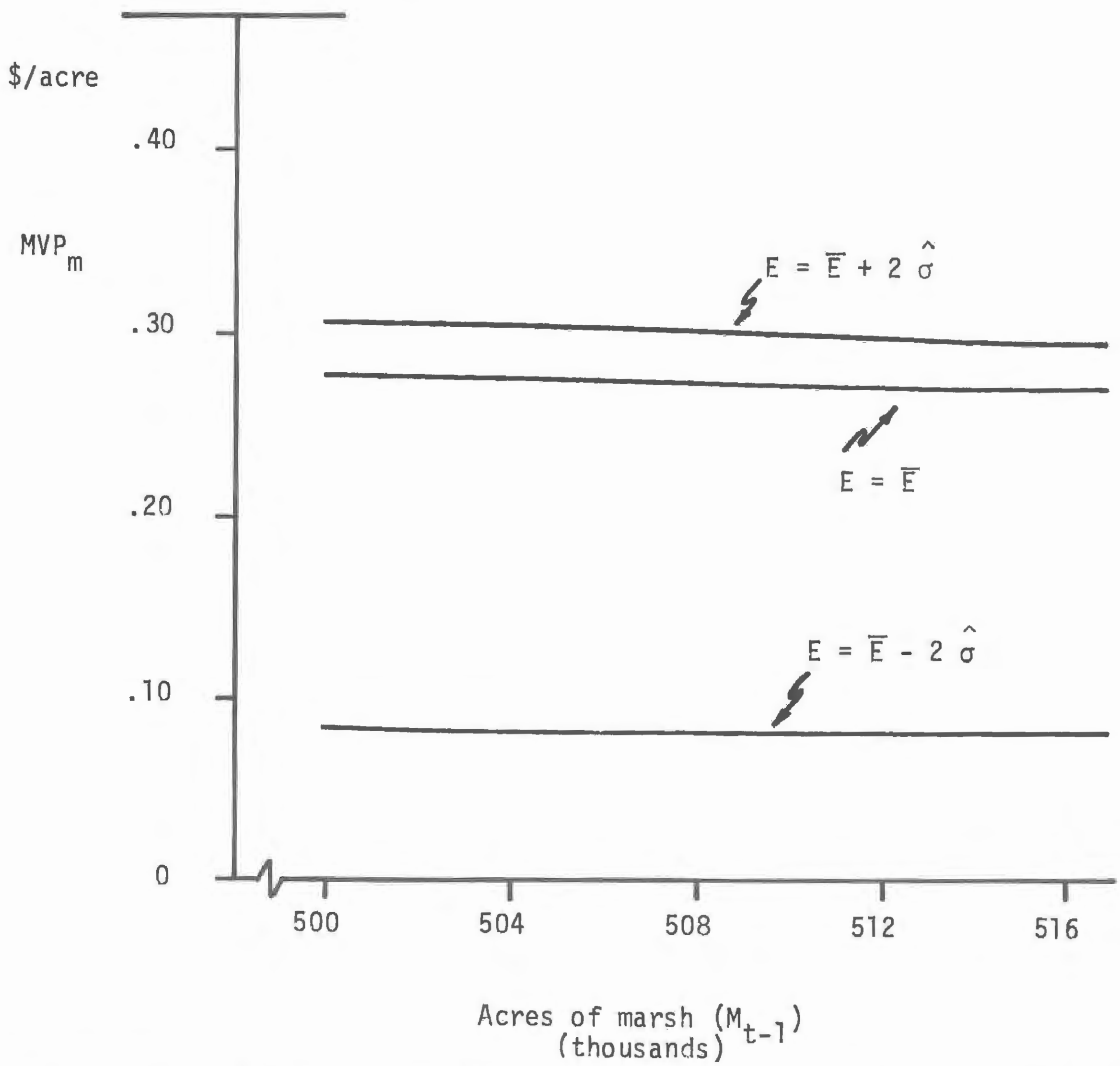

Figure 2. Estimated marginal value productivity (MVP) estimates of marsh-estuarine areas (M) in Florida Gulf coast blue crab production for varying levels of effort (E), and a price per pound of $0.131.

representative of the entire family of all such curves (Figure 3). Thus, while the MVP_e declines for decreases in marsh acreage, the effect has apparently not been significant to Florida's Gulf coast blue crab fishery. Of course, there may be other factors masking the effects. For example, if the technology of fishing crabs improved substantially during the period, the MP_e could have been increasing due to this change in the face of declining MP_e due to marsh decreases, thus offsetting one another. Further refinements in the empirical model would be needed to test this hypothesis.

TABLE 3.

Marginal product estimates (per acre)[1] of effort for given marsh levels in blue crab production, Florida Gulf coast.[2]

Marsh Acreage[3]	Effort (pounds/acre)				
	7,119	20,000	32,881	45,762	58,643
499,836	542.59	378.88	215.16	51.44	−112.27
504,107	542.94	379.12	215.30	51.47	−112.35
508,378	543.29	379.36	215.44	51.51	−112.42
512,649	543.64	379.60	215.57	51.54	−112.49
516,920	543.98	379.84	215.71	51.57	−112.56

[1] Estimates at the margin, for the last additional acre.
[2] Data point selection based on an actual range from 501,424 to 514,372 acres and an average of 508,378, and $\hat{\sigma}$ = 4,271.
[3] Data point selection based on an actual data range from 10,575 to 59,020 traps, with a mean of 32,881 and $\hat{\sigma}$ = 12,881.

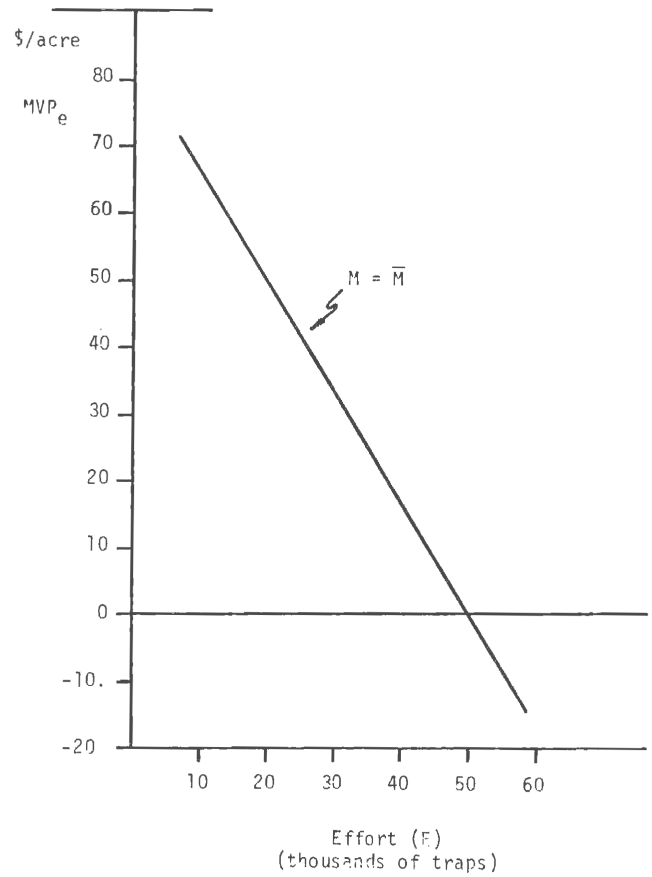

Figure 3. Estimated marginal value productivity (MVP) of effort (E) in Florida Gulf coast blue crab production for varying levels of marsh (M) and a price per pound of $0.131.

COMPARISON OF BOTH APPROACHES

Comparison of the two techniques reveals similar results. The residual value shown in Table 1 should be equal to the MVP_m multiplied by the marsh acreage (Lynne and Conroy 1979), or for 1975:

$$(MVP_m)(500{,}853) = \$63{,}714 \text{ to } \$147.083 \quad (5)$$

The equality in Eq. 5 will be satisfied for a range in MVP_m of $\$0.13 < MVP < \$0.29$, as compared to the range of $\$0.08 < MVP_m < \$0.31$ for the production function approach. Again, of course, these are annual returns and must be capitalized.

IMPLICATIONS FOR BIOLOGICAL RESEARCH EFFORTS

The data problem in relation to defining the contribution of marsh-estuarine areas to marine production processes is severe. Very limited data were available for the study reported on herein. Given that marshes have not been of social concern until relatively recent times, this lack of information and data may be understandable. That is, there has been no apparent need to know how marshes contribute to the economy. As economic development proceeds, however, the marginal value of such information increases as well.

But, what type of information is needed? In particular, what information is necessary to appropriate economic valuation? The answer, in a general sense, is very simple. Economists need inforatmion and data on the *effects of change.* The important measure of value for resource allocation is the *marginal* (exchange) value. More specifically, economists need quantitative information on the expected effects of marsh changes, in quantity and quality, on the growth, recruitment, and mortality rates of all marine species having significant commercial and recreational sport fishing value. This is needed now, and until it is developed, the economist is forced to try methodologies similar in nature to that reported herein. Also, information must be available on catch and the man-induced effort variable, by time and location.

SUMMARY AND CONCLUSIONS

The nature of economic value was explored in the context of the marsh-estuarine area valuation problem. It was noted that economic value is value in exchange, which is affected by the value in use. There has been (and continues to be) "market failure" to more accurately reflect the use value of marsh-estuarine systems to marine-production processes. Economic valuation can still serve a useful purpose, and provide important estimates to the decision process. Two alternative economic valuation procedures were developed and examined.

The results were very similar for the "residuals approach" and the "production function approach." The marginal value product of marsh (MVP_m) estimates generally ranged from $\$0.08 < MVP_m < \$0.31$ per acre from the residuals approach, and $\$0.13 < MVP_m < \$0.29$ for the production function approach. Using a 10% capitalization rate, the present value of the contribution of a marsh-estuarine acre to blue crab production ranged from \$0.80 to \$3.10 per acre. These latter numbers represent one part of the economic value of the salt marsh. There would, of course, be other values that could make the total value of an acre of marsh much higher. The quantities presented herein merely reflect the current value of an additional acre of marsh in producing blue crab for human consumption.

Further information must be developed by biologists and ecologists relating to change. That is, economic value cannot be understood except in the context of marginal value.

Several significant conclusions of the overall study are reported elsewhere (Lynne et al. 1981). The following further considerations are appropos as per this paper: (1) the residuals approach and the production function approach to economic valuation gave consistent results; (2) the economic value of marsh-estuarine areas to marine production processes must be understood soon, as decision makers are changing land use in the coastal zone areas with virtually no quantitative information about such values; and (3) economic valuation cannot proceed without sound estimates of the biological relationships between marsh changes and fishery changes.

This last conclusion has special significance as it relates to this colloquium. Research efforts must be strengthened in this important area. Natural resource and environmental economists may also have to be consulted to ensure appropriate data forms will emerge from this research process. Economic valuation cannot proceed without sound biological research that results in establishing the structural relations.

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*added in proof

DISCUSSION

Q. Ray Rhodes: Could you elaborate a little on why the total value approach is not suitable?

A. Gary Lynne: Using these numbers to illustrate the total dockside value, you see that it is around $2.2 million. The total value then is that figure divided by the total number of acres of marsh that was available in that year. What you are doing is saying that the valid returns to labor, to capital, to management are zero; that the other elements in the production process earn nothing. If this is the case, and I don't think most of you would agree that the other elements in the production process earn nothing, then it is not valid to just take the total value and divide it by the total number of acres, even though the total value wouldn't exist if the acreage were not there. That does not really make any difference because what you are talking about here is the production process with various inputs contributing to the generation of this value. The biological process is contributing, the marsh is contributing through its role in the biological process, and man is contributing by bringing in capital and labor and the entrepreneurial skills to eventually make the product available to society. Therefore, all of these factors of production contribute to that value, and to arrive at the value of any one of those factors of production, you have to separate out that value to allocate it among the various inputs if you like.

Comment–Willard Van Engel: Are we managing for the blue crab, or are we managing for man? What are we trying to conserve, the economic value of the fishery, or are we trying to conserve the population of the crabs? This is a perpetual argument between the biologist and administration. The economic value is one thing, to conserve the resource is another. What are we really looking at? I think this is a very stimulating interesting paper, and it is the kind of information which the fishery administrator is going to look at when he is going to consider effort control, the value of the fishery, and what can we do to increase economic returns. There is another side of this and that is the crabs' side.

Comment–Lynne: I would like to respond to that statement. You have asked a relevant question and it relates back to what society wants. What are your objectives? And that goes back to this business of tastes and preferences. If society's objective is to preserve the blue crab population at all cost, then that will be reflected. If you think that is the relevant goal of society–to preserve the blue crab population at all cost, then you should promote that and try to see if society will buy it, then eventually that will be reflected in tastes and preferences. If that is society's objective, it eventually effects use value, which in turn affects exchange value and this is economic value.

Comment–Van Engel: I would like to emphasize your point three. You need sound estimates of biological relationships between marsh changes and fishery changes. I have mentioned before and you all realize the problems of environmental degradation, what would happen if we had blockage of the Apalachicola River, what would happen if the characteristics of that stream would change? This afternoon, there are some comments I want to make about the effect of some environmental variables on crab stocks, from the crabs' point of view. I have sort of circumstantial evidence that a change in ecology might affect as much as 50% of the population in the Chesapeake area. About 50% of our blue crab stock survives because of the availability of eel grass in nursery areas. The other 50%, I think, is derived from the availability of marshlands. Looking at it from the crabs' point of view, not the economic point of view, don't you agree that we need to look at both of them; we can't consider one without the other.

Comment–Rhodes: I think how you define economic value may have more relevance to the fact that what Van is talking about and what the talk was about are really just subsets of the whole value system of taste and preference. I really think that in a sense when the biologist talks about maintaining the population, there are explicit values built into that statement. Now whether those are worth quantifying, this becomes a difficult question in terms of improving decision making. It may be questionable unless it is blended in with a whole matrix of other species and other uses out there.

Comment–Lynne: One thing I heard you say is that the economic value is a part of a larger sense of values.

Comment–Rhodes: No, I meant how you define economic value.

Comment–Lynne: Well, economic value has a definition. There is only one definition of economic value. There is a whole notion of value though. See value is a very difficult term and it gets murdered alot. Value, in a sense of your personal values, is a quantitative measure of that value, and if your distribution of income is appropriate to that, it is eventually reflected in economic value, if there is a market. Now in case of marshes, and this is one thing you have to understand, that economists understand, is that in the case of marshes there is not a good market; the market does not function very well. So, even if society feels that the marshes are very valuable in the sense of gaining satisfaction just knowing that they are there, or in use value actually going out in them, or whatever, all the various things that contribute to the satisfaction of knowing something about marshes, even if that is extremely high, and even if society at large has tastes and preferences identified such that we would wish to conserve the marshes, if there is not an institutional arrangement of some kind to bring preservation about, it is not going to happen. A market is a form of an institution. Just like a management agency is another kind of institution but the primary function of these institutions is to allocate resources. The market for marsh acreage has not historically even existed in the sense of what we think of a market for other goods. That may be clouding your point, I am not sure.

Q. Ed Cake: I would like to bring something up. I disagree with one of your precepts and that was with the deducting from the total value the cost of goods and services required to obtain that catch. I am of the opinion that that should be utilized in making an economic analysis because without those goods and services the crabs would not be used, and also because of the goods and services there is a multiplier effect. Therefore, the blue crabs themselves, as a resource, are adding much more than just their own value. I think if that was all cranked in your figure would be a little bit more than 13 to 20 cents an acre. I think someone should experiment with that idea. Is that to much to ask?

Comment–Lynne: Well, I am not sure I totally follow what you are asking. Certainly there is a multiplier effect.

Comment–Cake: When you took the $2 million value for the crabs between Apalachicola and, say, Tampa, you then reduced that value by goods and services required to catch them, so that you came up with $180 thousand or $60 thousand worth of blue crabs. I disagree with that. I think that the total value of the crabs is that value at the dockside, back to the marsh.

Comment–Lynne: You mean the total value of the catch, including the multiplier?

Comment–Cake: Not even the multiplier, just take that dockside value.

Comment–Lynne: Then that's the value of the marsh?

Comment–Cake: Yes sir.

Comment–Lynne: But then what is the value of the labor that went into the marsh? Zero?

Comment–Cake: Well, it would be nothing if the blue crabs were not there.

Comment–Lynne: True, but there would be nothing there if it wasn't for the labor. You see it goes both ways.

Comment–Cake: What it is, is the biologist arguing with an economist. I would like to see what the figures would be if you cranked that all in. That is what I am saying.

Comment–Lynne: Well, I think that it is already cranked in. In other words, the economic value of the marsh has to be less than $2.2 million in that particular year at the margin. By taking and dividing $2.2 million by the total acres, the economic value of the marsh has to be less than that by definition. If you are going to pay all the factors of production, what they are earning, if you are going to assume the capital of zero opportunity cost, in other words you can't get any returns on anything else, then that is one assumption you might want to live with, but if you are assuming that labor has no alternative places to find jobs, then you can go with that.

Comment–Edwin Joyce: I wanted to reiterate my agreement with Ed Cake. First, I must say I am not an economist, and I don't want to argue the economics, but I would like to look at it from the other side. It seems to me from the description, it would be like trying to estimate the value of your automobile by taking the retail price and subtracting all the parts, material and labor that went into it. If you look at it from a very practical, administrative standpoint, and you consider $0.13 an acre the economic value for blue crabs (in Florida we have about 100 species of commercial animals of which 75% or more are estuarine dependent), and if you assume that the $0.13 per acre is a median value, and you multiply that by those 75%, you then have a total value of less than $10.00 an acre. I can tell you from an administrative standpoint that if you are trying to argue against the paving over of the Apalachicola Bay system or any other area that approaches the value of those coastal areas, on the basis of less than $10.00 per acre per year, then you have just lost the whole thing.

Comment–Lynne: I would like to make one other comment. I want all of you to understand that the estimates of value that we have here are a reflection of the value society puts on eating blue crabs. It is a reflection of the market price for blue crabs. It is a reflection of the satisfaction, if you like, and the nutritive content, if you like, that they are able to derive from eating blue crabs. It is not a reflection of the value people may place on blue crabs just by the fact that they want to conserve a species, it is not a reflection of any other goal or objective that society may have, it is a reflection only of that portion of the value associated with actual eating of blue crab meat.

Comment–Elliott Norse: Gary, I have been listening to the controversy and frankly there is a fallacy in the argument you presented. The value of the blue crab fishery is not only measured in the net profit that goes to the people who invested the money in harvesting the blue crabs. Okay. The boats that use blue crabs have to get built. That fraction of boats built for blue crabs is a reflection of blue crab value. If blue crabs were not there, the boats would not get built. So that has to be considered. The oil companies sell . . .

Comment–Lynne: Just a minute. One thing at a time. That is considered in the fact that my depreciation figures reflect that.

Comment–Norse: But then the net value we should be assigning is the total value of the fishery, whether it is artificially high or artificially low. All the dollars that . . .

Comment–Lynne: But what you are denying is that that capital could go into building some other particular goods society might want. You are saying that the opportunity cost of capital going into boat production is zero. That there is no other place that society could use that money to build other goods.

Comment–Norse: There is no other place that society could do it as profitably. If there were, then society would not be going into building blue crab boats.

Comment–Lynne: Well, I will go along with that, that is what economic allocations are all about. There is capital being allocated to the blue crab fishery because it is profitable to do it. Right. So all I am saying is that the value of that capital for the blue crab fishery is reflected in the depreciation numbers.

Comment–Norse: Okay. When you are speaking of the value there is something misleading. Because if people walk away from the meeting thinking the value of an acre of marsh is about as much as a cup of coffee these days, they are not going to be too much intent on preserving them. But the value to society as a whole is the value not only . . .

Comment–Lynne: Now you are getting back to what I said initially. The value that we have here is a reflection of the value that society places on blue crab meat.

Comment–Fred Prochaska: There is a little bit of misinterpretation. That 13 cents is this year's production of blue crabs. Now, the capitalized value of it is what it will produce year after year. You don't buy a piece of property for just one year that was somewhere around $3.50. This is only one of the species; there are 100 others, and really those others are probably worth more. So even if you took the $3.50, you have 100 more species, you have $350.00 per acre. So when you say 13 cents an acre, that is not what you are saying the value of an acre of marsh is. That is the value of one year for one species.

Comment–Lynne: I did mention that. We went over that rather quickly. You see you have to figure your capitalization rate and divide that into those numbers and that gives you the value of a stream of benefits over a period of time.

Comment–Norse: But Gary, this is a little unrealistic. I'd be willing to bet that blue crab isn't 1% of the marine resources in terms of dollar value in Chesapeake Bay. The calculation you are saying is actually 1/101 for the total value, if there are 100 other species. Blue crabs are worth a lot more than that in the fishery. What that would give you is a calculation of the value of an acre of marsh that is only based on . . .

Comment–Lynne: . . . because of the interdependencies with other species.

Comment–Norse: Well, that is not quite what I am saying. Van, is the blue crab the biggest fishery or second behind oysters in the Bay, or third or fourth or fifth? What fraction of the total fishery in terms of dollars are blue crabs in the Bay?

Comment–Van Engel: Blue crabs run second, third, or fourth, depending on what year you are talking about. In a relative value of, say, menhaden coming first, surf clams, now about second, but going down hill, and blue crabs somewhere around third, perhaps in economic value vying with oysters.

Comment–Paul Hammerschmidt: In the state of Texas, a pound of blue crab to the fishermen is worth about 20 to 28 cents. Twenty-eight cents worth for the fishermen. The pickers get $1.00 a pound of profit. There is $1.28 already that you are getting out of a pound of crab. It is worth $3.00 to the crabhouse for a pound. And it is worth $5.00 before he sells it. Okay that is what the problem is. With $10.00 per pound . . .

Comment–Lynne: Your committing a real fallacy. Your ignoring the fact that as you step-up the processing scale, or go through the various steps, that other factors of production are brought in . . .

Comment–Hammerschmidt: No, I am talking about cash flow. I am talking about cash flow in terms of dollars per pound of crab. Now, you have $1,000 worth of crabs per acre right there on . . .

Comment–Lynne: No, that is not the value of the crabs. If it is then the value of all the labor and all the capital, and all the entrepreneurial skills that went into it are zero. If you want to live with that, then it is zero.

Comment–Hammerschmidt: No. No. There are four levels of cash flow only. You are not talking about the gasoline that has been moved, you are not talking about the boats that are being built, you are not talking about the restaurant, you are not talking about any of that other stuff. You are talking about four levels only of cash flow for one pound of crab. Why is it going up in price from one level to the next? Why does anything go up in price from one level to the next?

Comment–Norse: The labor and materials have no value unless the people are employed or unless you can sell the materials. The persons employed in a blue crab picking plant would not have a job otherwise.

Comment–Lynne: That may or may not be the case. If there is no other employment for them, then, of course, the total value is divided into crabs. But I doubt that this is the case you see. I question that. I think that there are opportunities for employment in other industries.

Comment–Norse: There are opportunities for employment, but nevertheless the fact that the United States has 6% unemployment attests to the fact that there are people who want to work or could work and can't.

Comment–Lynne: What you are saying is that if we shut down the blue crab industry all of those people would become unemployed.

Comment–Norse: Yes. I think that this is the problem. The problem is you are looking at two kinds of values: net and gross. Okay. Your calculation in net values is measured by the capital that accretes from the investors, and I wouldn't disagree with that. But again, while you are saying that, people will walk away from this room thinking that that is the value of an acre of marshland.

Comment–Lynne: Well, I am afraid it is.

Comment–Norse: Gary, that is not the net value of an acre of marshland.

Comment–Lynne: Now you are still missing the point. The point is that you have different inputs of production that go into a process. You have labor, you have capital reflected in boats and equipment, and these things have a value. What is their value? Well, their value in a function market is what you can buy them at. Okay. Those are inputs that you mix with the other inputs of production, and they all together generate a total value. Together they generate a total value, and that is the gross value. But you cannot take that gross value and tell anybody that that is generated by labor, or the value generated by capital, or the value generated by marsh. Rather, they all contribute simultaneously to the generation of the total value. But the value of any one of them is some share of that total. That is what I have been telling you.

Comment–Norse: I agree with you. When you talk about it, it is just a matter of perception. You talk about the value of an acre of marshland, and you have to separate net from gross. If you do that, then there are two values. As a net value, maybe $3.00 per acre, and the gross may be $1,000 per acre per year.

Comment–Lynne: No. The gross value of the production process is $1,000, but the value of the marsh is something less than that. The total production process, the total value of that is $1,000, but each portion that contributes to it has a portion of that total share. And if you took out any one of the components of it, it would totally collapse. But the total value of each one is still some portion of that total value, not the total value.

Comment–Jim Bishop: One of the things that I would like to bring up, that seems to have been overlooked, is that the marsh is probably capable of producing a lot more crabs than commercial fishermen are catching. I am not an economist. I won't give you any values. The fishery is probably under-saturated so that in fact it is a misnomer to use fishery landing statistics. I do not want to say it is . . .

Comment–Lynne: Well, that is very possible, but many of you in this room know more about that than I do, but again, I will say it in a different way. The estimate we have, is an estimate of the current value that society places on blue crab meat to eat. You eat for various reasons, to survive, but also maybe to get satisfaction out of it. You can get some benefits just from eating, some people love to eat. And this estimate, and supply gets in here too, you see the economic value in that chart I showed you, showing supply on the bottom and demand on the top, these forces come together to establish some price. So, supposedly the fishery is reacting to the demand for blue crab meat; if they produce more the price should go down. That is what I am saying. The price is probably at the point right now where if the prices go much lower–I don't know if that is the case, but it is possible, you see that the fishermen are pretty much in equilibrium. It is possible that if the price dropped anymore that the fishermen would start going out of the blue crab fishing business and go to other kinds of fisheries or other businesses. So that price that you see in the market is probably reflecting a balance of some kind, although I do not know about the equilibrium in the fishery for sure, I am not sure where we are on that. Do you understand what I mean–it is a supply and demand kind of phenomenom working together.

Comment–Bishop: But it is just not a fixed value there, is it?

Comment–Lynne: No, you are absolutely right. It is a fluctuating thing, it is bound to be fluctuating over time.

Comment–Rhodes: Gary, you explained what I was trying to say in terms of the value of the blue crab, you were looking basically in terms of eating the crab meat. What I meant is that we may be bogged down here more in semantics, in terminology and definitions. I see that as a problem.

I think one point that none of the biologists in this room should miss, and I am saying this as a biologist, is that there is inadequacy in my mind in terms of what the population dynamics are of the blue crab. We went through the same thing in management profile work we did in South Carolina, and I came to the profound conclusion that there is a major inadequacy here and that it is the biologists fault. This is going to limit the pragmatic economic analysis of commercial fishery management and the type stuff that Gary is going to do. I think you pointed this out. There is nothing, and I have surveyed the literature, maybe it exists for other species and there is a possibility of transfer, but there is nothing of one of the type of things that Gary alluded to in terms of quantifying the effects of marsh alterations relative to the population dynamics of blue crabs. Also, I don't think we have really nailed down the effects of fishing inputs on changes in blue crab populations and, really in a way, this becomes a major limiting factor in terms of the future of contributions of economic analysis in this whole area; whether we are talking about marshland preservation or whether we are talking about recreational-commercial fishery management.

Comment–Van Engel: I think what we are getting into here is a really important thing–that there is a misunderstanding, a lack of knowledge, probably on the part of the biologist as to what the economist is talking about. It is not a real disagreement, it is just a matter of we don't understand terminology, we do not interpret the same way you do, because we do not have the background, we are just ignorant in that field. I think what is needed may be a matter of educating the biologist. I think, I may ask that Prochaska and Lynne, and others, help us along and tell us more about this—this is an area of study that needs to be done. Ed Joyce has a difficult decision to make if he depends on this information for the evaluation of the marsh. It is a matter of his interpretation of what was said, and you have got to be cautious. He is fearful of how this kind of information, coming out to an uneducated biologist or an uneducated legislator, is going to be interpreted, and everybody is going to interpret it a little differently. So I think you have an education problem on your hands, and I think this might need to be done. I have seen some publications on economics, working with other crustacean fisheries, and they are not educating the biologist. I mean the fault is that the economists are not telling us things in simple enough terms.

Comment—Hammerschmidt: The thing that concerns me is the divide and conquer aspect of economics. You have broken the blue crab out of the marshland habitat, you are saying that they are worth 13 cents an acre, alright.

Comment—Lynne: Let's talk about the capitalized value . . .

Comment—Hammerschmidt: We are dealing with several different user groups in the marshlands . . . I am not quite sure what your definition of marshland is.

Comment—Lynne: Recreational, land development, various species, transportation, you are talking about capital.

Comment—Hammerschmidt: You have a developer come in there and look at an acre of marshland, he is going to say that thing is worth a half-million dollars to me in condominiums. Now what takes precedent—13 cents an acre or half a million dollars an acre? And that is scary, if that stuff has to go before a court and somebody is saying I want to use a dredge to fill that marsh, there is a half-million dollars in condominiums going to go up on that marsh on the basis of what you told them.

Comment—Lynne: Now wait a minute. Again, you see, what the judge would have to be told, is that this value is a reflection of the food value of one species. Now you said several things and I am not sure I can address all of them or remember all of them. First of all, you said something about divide and conquer. Now there is a reason for that; that is the complexity of these biological systems, and the rest of the folks out there know that better than I. The reason we chose blue crabs in the first place was that it seemed to be one of the simpler ones in the sense of at least having some hope of relating landings data to marsh areas, and after listening to Mike Oesterling's presentation, I think we might be on fairly solid ground in what we did. I mean the complexity is there, and it is not only complexity in the biological systems but in the economic systems. Some fishermen are fishing many different species, sometimes simultaneously, so you can get jointness in production. I am not trying to be defensive on that point, I am just trying to say that you have got to start somewhere applying your trade I guess, and we chose blue crabs because it seemed to be one of the easier ones to work with.

Comment—Van Engel: One comment here before I forget. It seems to me that we are developing a dialogue which is really interesting and ought to be continued. Now there is going to be the National Blue Crab Industry Association Meeting in Charleston, South Carolina, in February, and I would like to ask either Gary Lynne or someone from his group to consider the possibility of talking about this or a different version of it at that National Blue Crab Industry Association Meeting. What we could do here is to ask the officers of that National Blue Crab Industry Association to consider a talk on this particular subject. They are the industry people, and I think not so much for their benefit but I think to air this thing a second time or another time, would you consider such a thing if we asked the NBCIA to include something like that on the program? Would you consider it? I do not mean the same thing, maybe the same thing with different explanations or with additional explanations. Let me know, I will approach the NBCIA people and see if they would include that in their program.

Comment—Joyce: Just one quick thing. If you describe what you discussed at $3.50 per acre per year as profit per acre for that one species, then I think you would be closer to the total value that we basically use. But when you talk of it as flat value then I think we are just completely off the track.

Comment—Lynne: Yes, we can work on that.

Comment—Norse: There are systems, logic systems that are dependent on two things happening or you won't get a result. Right? You cannot compute the value of either one of the things to the result if you remove the other. Let me give you an example—what is the value of the labor in the blue crab industry to the productivity of the blue crabs? The answer is you cannot calculate it without reference to the blue crabs. You cannot calculate without the labor; there would not be a blue crab harvest if there weren't both blue crabs and labor. Okay? So you can have all the blue crabs in the world, you can have boats, you can have facilities, if there is nobody to fish them or pick them you don't have blue crabs, it is the same with everything else. You can have all the facilities in the world, but there is no value if you do not have the crabs.

Comment—Lynne: Well, there is no food value at least.

Comment—Norse: There are other kinds of value, this is true. But if we are speaking just of food value, partitioning the elements of value the way you have, you just can't do it. If you take out one component, such as blue crabs, the whole thing is false.

Comment–Lynne: But again you are denying the fundamental concepts of the economics as a notion of opportunity costs. And as long as you, and I will agree with you 100%, are willing to assume that the returns of all the other inputs and other users are zero–in other words, if you shut down the blue crab industry, that all of the labor would go unemployed, all the capital would rust, disappear and would never be transferred into other industries– then I would agree with you. It is just like any other production process. The same thing with agriculture crop productions, it is the same kind of a notion that applies to that. What is the value of any land–it is reflected in the net returns to land.

Summary–Fred Prochaska (University of Florida): A lot of important items have been discussed. It is a complicated subject and there appears to be some misunderstanding. Let me try to summarize the issue as I understand it.

First, the total value approach discussed during this conference is simply the division of total dockside value of crab landings by the number of marsh acres. This is generally an invalid approach for the following reasons. In any economic activity, there are four types of resources: land, labor, capital, and management. In the present case the marsh is the land resource. The total value of crab production can only be attributed to the marsh acreage when the other resources (capital, labor, and management) are free. This is certainly not the case in blue crab production. An example may help clarify the point. If total sales from an acre of citrus are $1,000 per year, how much rent would a citrus farmer be willing to pay to "rent" the acre to grow citrus. Certainly not $1,000 per acre because he has to pay labor, fertilizer, interest and borrow capital, etc. He would first subtract out these other costs from the $1,000 gross revenue to see what is left. This is then the amount of rent he would be willing to pay for the acre in citrus production. This is the annual value of an acre used in citrus production and represents the type of value Dr. Lynne used when discussing marsh acreage.

A second point which has been made is that this is only one of the uses made of the marsh acre. The estimates presented are for only commercial use of blue crabs as food. There is also some value related to blue crabs for recreational users, the value of blue crab as a part of the natural system, and the value of simply knowing the blue crab is there and will continue to be available in the future. This latter value is often referred to as preservation demand in the economic literature. Thus, Dr. Lynne's estimates represent only part of the value of an acre of marsh that is attributable to blue crab production. In addition, it has been pointed out that marsh acreage also contributes value with respect to other species. This is true and the value generated through production of other species has to be added in before the total value of an acre of marsh can be determined.

I think there also is a third point that needs to be emphasized. That is, the annual returns are not the value of an acre if you purchase it or permanently remove it from production. Dr. Lynne noted this when he mentioned the capitalized value was $3.50 compared to approximately $0.13 on an annual basis. Again remember, this is only a part of the total value of an acre of marsh.

One last point needs to be noted. The procedure used to estimate value in Dr. Lynne's paper correctly does so at the margin. This means his estimate is for the value of one acre if you remove it from production, given the total acreage that was available during the study period. Economists are always working at the margin and what this means is that the value of an acre of marsh will increase as additional acres are taken out of production. For example, if we only had one half of the present acreage that is in marsh, the marginal value of an acre would be much higher. That is, today one acre of marsh removed would have a value for blue crab commercial use of $3.50, but if you removed 1,000 acres, the total value would not be 1,000 times $3.50 because the value of the last acres would be much higher than $3.50. This is because there would be less of the products produced by the marsh available in the market. Thus, their prices would be higher. Thank you. I hope this has clarified this important issue.

Comment–Joyce: Thanks Fred, I think you have helped me to understand the issues a little better, but is there some way you could condense your summary so we non-economists could more easily summarize what the main points are?

Comment–Prochaska: I'll try, Ed. The $0.13 is the annual value of an acre only counting the commercial blue crab use. When you capitalize this value you get approximately $3.50. This is, however, only one value an acre of marsh produces. The other values also have to be estimated and capitalized if we want to know the total value. Finally, you have to remember that as more acreage is taken out, each additional acre will have a higher value. I hope that is short enough, Ed. However, I would like to add one final comment. It has been clearly admitted that the estimates you have seen today are only a part of the total. The paper, however, does make significant contributions in a couple of respects. First, it shows the fallacy of the total value approach, and secondly, it presents a method for estimating the value of an acre of marsh. It was done for commercial blue crab production. Now you have to do it for the other 100 or so uses of the marsh acreage before the total value can be determined.

Thank you.

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CYCLICAL AND SEASONAL EFFORT–YIELD FUNCTIONS FOR THE FLORIDA WEST COAST BLUE CRAB FISHERY[1]

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INTRODUCTION

The relationship between fishing effort and catch is a basic input into many biological and/or economic models, especially those used to analyze fishery management alternatives. Time series data generally provide the basis for estimation of the effort-yield function. Even when adequate measures of fishing effort and yield from fishing are available, other data problems are almost always present. In particular, a continuous series of data describing biological and environmental factors rarely exists. Another related problem is explaining cyclical and seasonal patterns in production that are not related to changes in units of effort employed in the fishery. Once variations in effort have been accounted for in the data set, the remaining changes in yield reflected in seasonal and cyclical patterns can be assumed to be due to changes in biological and environmental parameters. The purpose of the research reported in this paper was to develop a statistical model which would provide estimates of an effort-yield function after adjustments were made for biological and environmental factors as reflected by seasonal and cyclical fluctuations.

The Florida west coast blue crab fishery was chosen for analysis because of (1) the importance of this industry to Florida's overall fisheries, (2) a lack of previous research of this nature on the blue crab fishery, and (3) cyclical and seasonal fluctuations are prominent in the fishery (Oesterling 1976).

In this paper cycles refer to fluctuations in annual landings while seasonal patterns refer to fluctuations in monthly landings. The cyclical and seasonal variations in landings may require special management. For the purposes of this paper, discussion of the model development and implications are abbreviated. Major attention is devoted to the presentation of empirical results pertaining to the blue crab fishery.

CYCLICAL AND SEASONAL TRENDS

Blue crab dockside landings on Florida's west coast appear to have moved through three 5-year cycles between the period 1960 through 1976 (Figure 1) (National Marine Fisheries Service 1960–76a, b). All data pertain to hard-shell blue crab landings. The soft-shell crab industry is currently of minor importance in Florida. Landings shown are based on total west coast landings unadjusted for changes in effort or any factor which could cause a cyclical pattern. Peaks were at 5-year intervals, 1960, 1965, 1970, and 1975. Lows were recorded in 1962, 1968, and 1973.

Within each year there was a seasonal pattern of monthly landings. The long-term cyclical variation in yearly landings had a pronounced effect on the level of the seasonal landings. Average (long-term) seasonal pattern in landings was calculated as the average monthly landings for each month during the 1960–76 time period (Figure 2). Landings were lowest for the 17-year period in January, and then increased to a peak of a little over 1.7 million pounds per month in June (Figure 2). When the long-term cycle was considered, the same overall monthly seasonal pattern generally held. The monthly seasonal pattern calculated for the years at the peaks of the long-term cycle (1960, 1965, 1970, and 1975) was low in January, increased through June, and then declined through November. At the peak of the long-term cycle, the seasonal peak of monthly landings was approximately 1.9 million pounds, which was approximately 200,000 pounds above the long-term average seasonal peak. Seasonal patterns developed for the years at the trough of the long-term cycle showed the same general trend with landings lowest in the winter and highest in the summer months. However, the peak and low months shifted back by one month, peaking in May and lowest in December.

Discussion to this point has been concerned with seasonal patterns, the long-term cycle, and the effect of the cycle on the seasonal patterns. Changes in effort over the 17-year period undoubtedly caused at least some of the longer-term cyclical fluctuations in landings. An effort index is shown with annual landings for the 1960–76 period in Figure 3. The effort index is the number of firms in the industry in each year adjusted for the number of traps fished (a formal definition is provided in the following section). In 11 of the 17 years, the effort index changed in the same direction as did landings, thus accounting for part of the cyclical pattern in landings. The proportional changes in effort, however, appear to be less than changes in landings. This implies that the total movement in landings is due to both a change in effort and changes in environmental and/or biological conditions.

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[1]Support for this research was jointly funded by the Florida Agricultural Experiment Station and the Florida Sea Grant College.

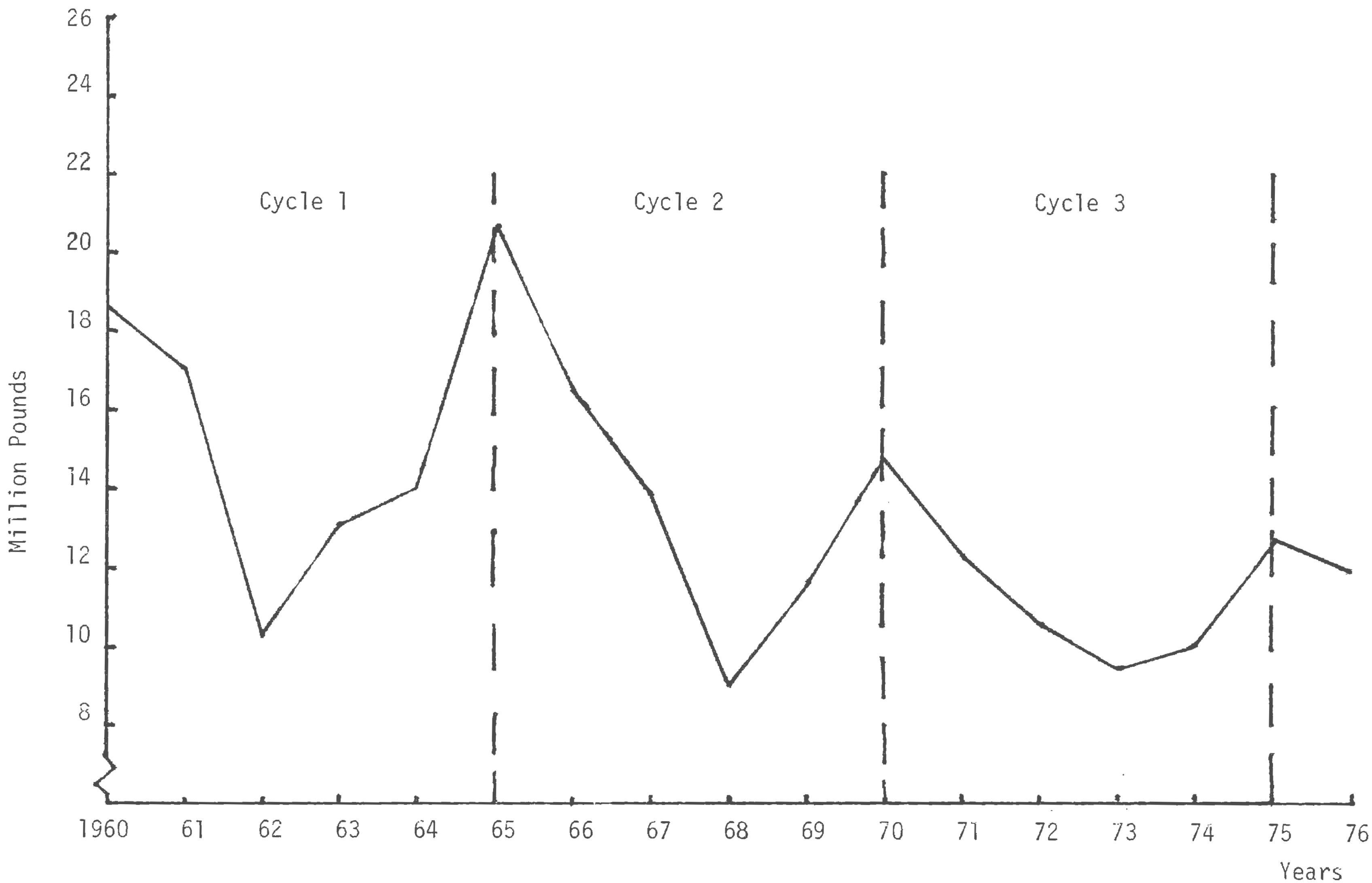

Figure 1. Annual Florida west coast blue crab landings, 1960–1976.

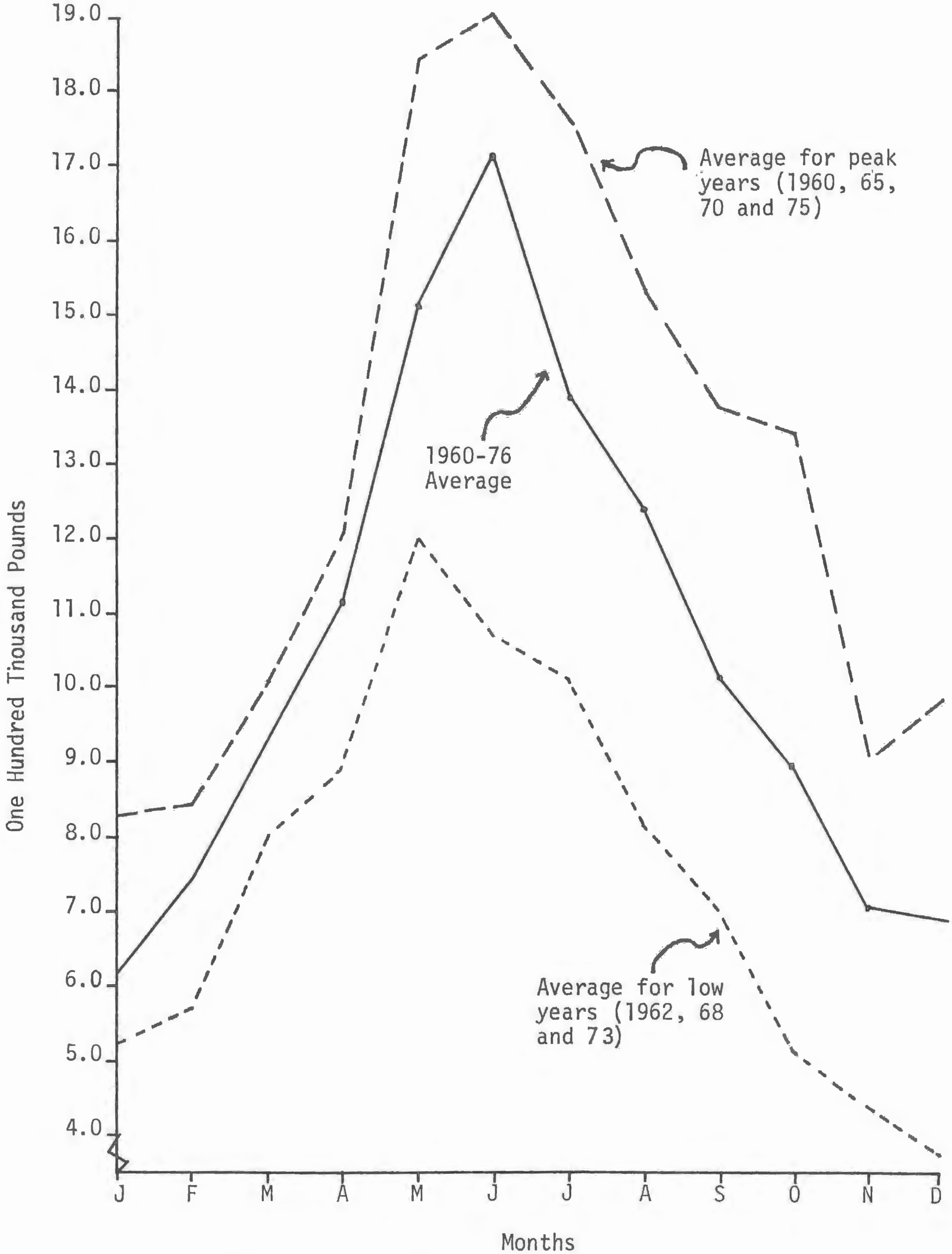

Figure 2. Average monthly landings, Florida west coast blue crabs, 1960–1976.

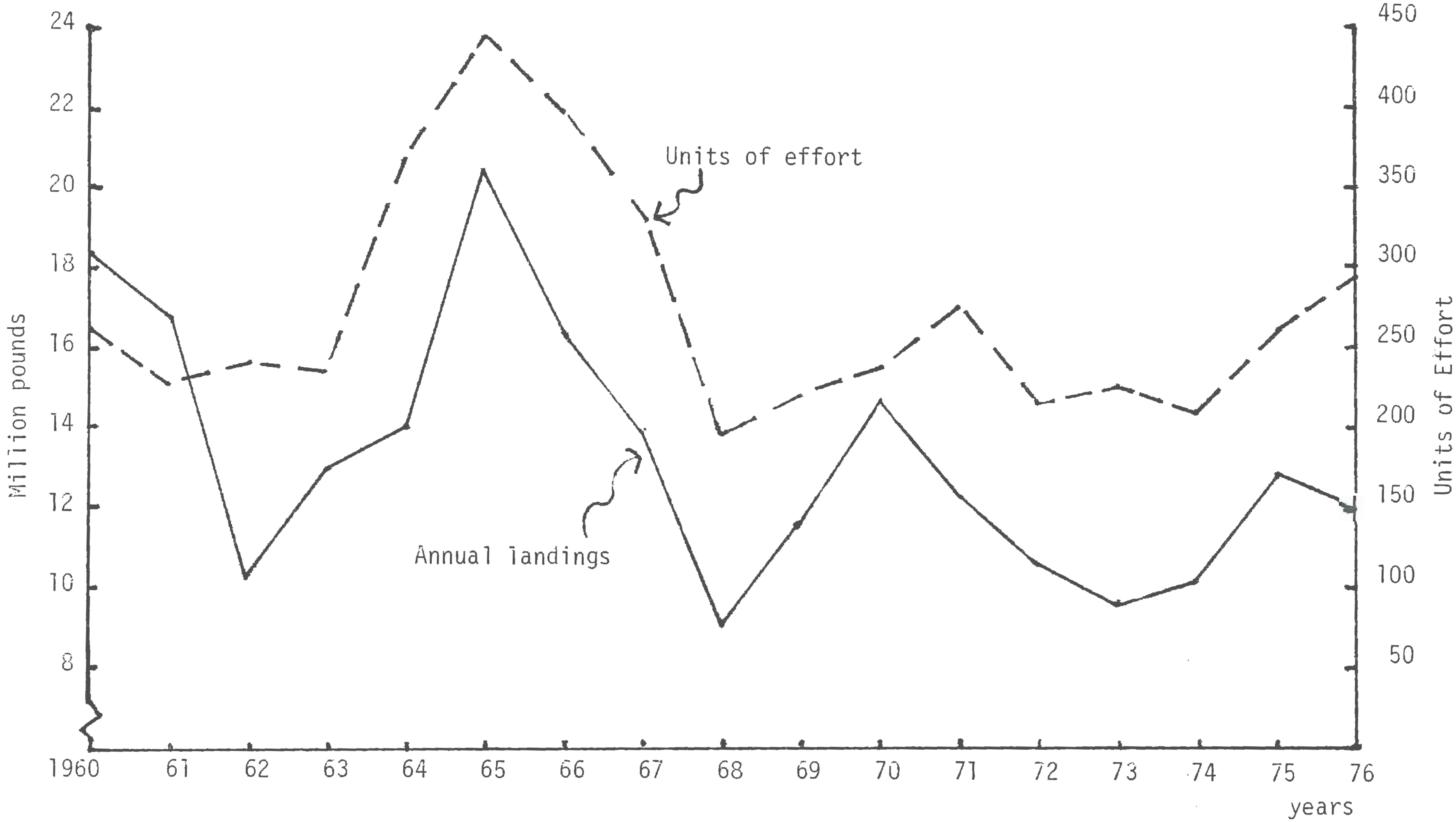

Figure 3. Annual Florida west coast blue crab landings and effort, 1960–1976.

It appears that predicted landings and consequences of alternative fishing management decisions, whether they be private or public, depend on three factors: effort, cyclical fluctuations, and seasonal production patterns. The model developed and presented in the following section is designed to partition these efforts into three separate components.

BIO–STATISTICAL MODEL

The model developed to estimate the partial effect of effort on landings adjusted for cyclical fluctuations and seasonal patterns required definition and estimation of a series of equations. The definitional equation specifying the units of effort is:

$$E_t = F_t\,(R/F)_t\,(R/F)_0^{-1} \qquad (1)$$

where: E_t = effort index in time period t, t = 0 is the base year, 1960; F_t = number of firms in the fishery in time period t estimated as the number of boats and vessels; and R = number of traps. Equation 1 counts the number of firms as the basic unit of effort and adjusts this number so that firms would be on an equivalent basis with those in the base year. (The percentage of total blue crab landings attributed to gear types other than traps has continually declined from 7% of total catch [pounds] in 1960 to less than 1% in 1976.) Four hundred traps per firm is equivalent to four times the size of a firm in the base year, if in the base year the number of traps per firm was 100. The catch function initially specified was

$$C_t = A(t)\,E_t^{\alpha} \qquad (2)$$

where: C_t = monthly blue crab landings in month t, A(t) = seasonal and cyclical omponents to be determined, and α = parameter to be estimated.

To determine the seasonal and cyclical components, A(t) was set equal to A and the equation

$$C_t = \exp\,(A + X_t)\,E_t^{\alpha} \qquad (3)$$

was estimated using a double log transformation and ordinary least squares to generate a "filtered" time series of estimated residuals, $\hat{X}_t$. The estimated residuals were calculated as

$$\hat{X}_t = \ln C_t - \hat{A} - \hat{\alpha}\,\ln E_t$$

A smoothed spectral density using a Parsen window (Fuller 1976) was calculated for the estimated residuals, $\hat{X}_t$. The spectral density suggested the presence of a 12-month seasonal pattern and a 60-month long-term cycle. Equation 3 was then respecified as Eq. 5. The trignometric expressions correspond to the cyclical factors in the model. They were derived using the trignometric identity

$$\sin(A + B) = \sin A \cos B + \cos A \sin B.$$

Thus, the 12-month seasonal pattern $A \sin(\pi/6t + \phi)$ can be written as $B_1 \cos \pi/6t + B_2 \sin \pi/6t$ where $B_1 = A \sin \phi$ $B_2 = A \cos \phi$.

$$C_t = \exp\,[A(t) + U_t]\;E_t^{\alpha} \qquad (5)$$

where: $A(t) = A + B_1 \cos(\pi/6t)t + B_2 \sin(\pi/6)t + B_3 \cos(\pi/30)t + B_4 \sin(\pi/30)t$; t = months 1, ... , 204; and U_t = sequence of identically distributed random variables with $EU_t = 0$; $EU_tU_t' = \Sigma$.

EMPIRICAL RESULTS

Equation 5 was then estimated using generalized least squares to correct for first-order autoregression. The resulting estimated equation was

$$C_t = \exp\,[\underset{(0.740)}{4.632} - \underset{(0.0356)}{0.4585} \cos(\pi/30)t - \underset{(0.0358)}{0.0662} \sin(\pi 6)t$$
$$+ \underset{(0.0419)}{0.1439} \cos(\pi/30)t + \underset{(0.0448)}{0.1825} \sin(\pi/30)t$$
$$- \underset{(0.1328)}{0.4361}\,\hat{U}_{t-1}]\;E_t^{0.3918} \qquad (6)$$

Standard errors of the estimates are given in parentheses. The estimated coefficients explained 79% of the monthly variations in landings ($R^2 = 0.79$).

The estimated coefficient for the effort variable is referred to as the output elasticity. It estimates the expected percentage change in landings for a 1% change in effort. For the Florida west coast blue crab fishery, a 1% change in effort is estimated to change landings by 0.3918% (α = 0.3918). The output elasticity would have been grossly overestimated without the adjustments for seasonality and the long-term cycles. The estimated output elasticity without these adjustments was 0.69 compared to the 0.3918 estimated in the adjusted model. The long-term cyclical effect derived from solution of Eq. 6 is the effort-yield function shift, 23% above and below the mean effort-yield function. The seasonal effect was to shift the function 59% above and below the average function for any given year. These results are illustrated in Figures 4 and 5.

The slope of the effort-yield functions in Figures 4 and 5 reflect the output elasticity, 0.3918. Since the output elasticity is less than 1, the effort-yield functions show diminishing returns. The A-Max effort-yield function in Figure 4 shows expected catch on a monthly basis for given levels of fishing effort during peak years of the long-term cycle. During each month within the year, the function is at a different level due to the seasonality pattern. The effort-yield function is represented by L-Max in the winter months (lowest landings months). As the season progresses the effort-yield function shifts upward towards U-Max. U-Max is the upper limit and is achieved in June. The function then declines the remainder of the year back towards the lowest function, L-Max. Without the adjustments for long-term cycle and the seasonal shifts, the unadjusted effort-yield function would have intersected the three functions in Figure 4.

Identical interpretations apply to the effort-yield functions in Figure 5, except these illustrate the average functions for a year during the troughs of the long-term cycle. A-Min is the average effort-yield function while the seasonal bounds on the shifts in the effort-yield function during the year are L-Min to U-Min (Figure 5). Comparison of Figures 4 and 5 shows the average annual effort-yield function during the maximum cycle year to be considerably above the average annual function for the years during the low of the long-term cycle. In fact, the upper seasonal function for low long-term cycle years is approximately only equal to the average annual function during the peak years of the cycle.

Effort-yield functions illustrated in Figures 4 and 5 represent the extreme values for the period studied. Simply substituting appropriate effort and monthly data into Eq. 6 would allow estimation of 204 effort-yield functions, one representing each month during the 1960–76 time period. Projections for future years, months, and effort levels are also possible. Accuracy of these predictions depends on the stability of the estimated parameters in Eq. 6 and the accuracy in predicting effort levels.

SUMMARY AND CONCLUSIONS

Effort-yield functions developed for the Florida west coast blue crab fishery indicate that at present levels of effort, a 10% increase in effort would result in an increase of 3.9% in landings. Average productivity is declining with additional units of effort.

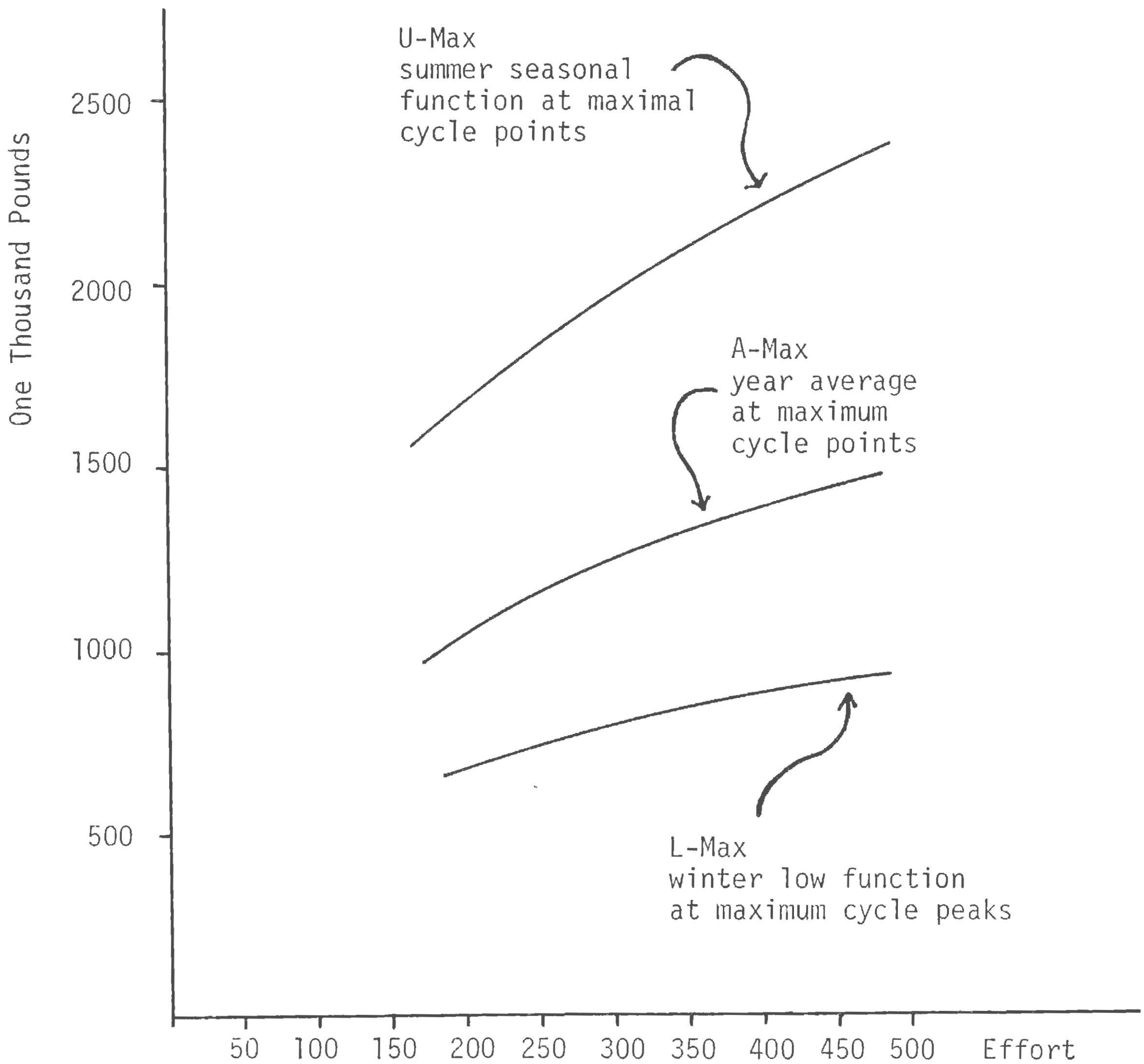

Figure 4. Effort-yield function at maximum cycle.

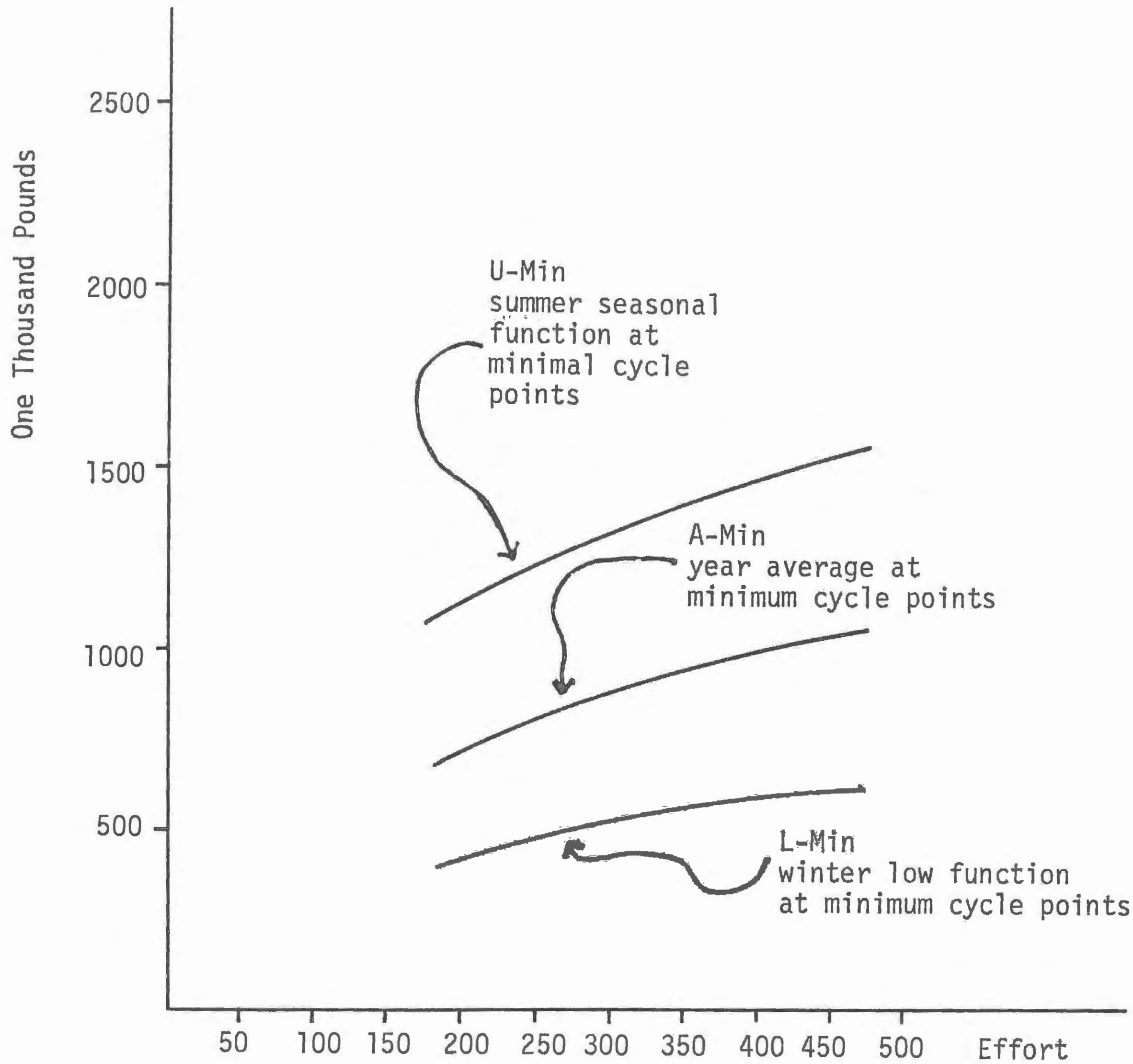

Figure 5. Effort-yield function at minimum cycle.

The effort-yield relationship was shown to shift significantly on a long-term cyclical basis as well as on a monthly seasonal pattern. Peak seasonal landings varied as much as 700,000 pounds per month between the low and high of the long-term cycle. These seasonal and cyclical shifts are assumed to be variations in environmental and biological factors because variations in effort were accounted for in the bio-statistical model. Accounting for the production shifts due to biological and environmental factors is significant because the model does not require biological or environmental data which are usually not available (on a continuous basis) in a form amenable to econometric analysis.

Finally, with respect to the Florida blue crab fishery, the empirical results indicate the potential error in making management decisions with the use of average effort-yield estimates not adjusted for cyclical and seasonal variations. Expected catch-per-unit of effort varies significantly depending on (1) the level of effort used, (2) the month of the year, and (3) the year within the long-term cycle.

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DISCUSSION

Q. Willard Van Engel: I realize Dr. Prochaska is going to be leaving soon and I hate to get you too involved in the question I have, but I am interested in this time series analysis and I wondered if your yield equation includes both the seasonal and the annual cycles or whether you treated them separately?

A. Fred Prochaska: The equation includes both.

Q. Van Engel: Were you able to reduce your residuals to an acceptable level?

A. Prochaska: I believe so, there is only about 20% of the variation unexplained now.

Comment–Ray Rhodes: Fred, for what it is worth, I gave a paper a couple of years ago up in Maryland, and at that time we speculated in the Carolinas and Georgia, that there were some long-term cycles in the annual landings. But we never did any numerical work on it. We just sort of eye-balled the hypothesis. In fact, we have also suggested that this may be. We said that possibly environmental conditions may have been involved with some sort of long-term, climatic factors, and this may have been part of what happened when we had the die-offs back in 1967 and 1968. I have bounced that off of Bob Mahood, who was on the group who did the study of the die-offs in the late 1960's, and he said that after his involvement that he could not rule that out as a possibility.

Comment–Prochaska: My real interest, especially with this audience, is to get you to respond to my interpretation; that seasonal effect, and that long-term cycle effect are due to environmental factors and biological factors. Can you make that conclusion as a biologist?

Comment–Van Engel: We are doing a somewhat similar analysis in Virginia, in the Chesapeake Bay–a time-series analysis of seasonal and annual landings data. We get somewhat similar seasonal cycles with a repeated 12-month correlation, but our annual landings data, available since 1929, do not show as good a cycle, as frequent a cycle, as you have. We are having trouble with it and I am wondering if what you are seeing here in these three 5-year cycles is being created by some other competitive fishery which allows the blue crab fishery to express itself in greater landings about 5 years apart. Are there any other fisheries in Florida which are competitive enough to allow this thing to crop up once in a while and then die back?

Comment–Prochaska: I don't know of any.

Comment–Van Engel: In other words, I am suggesting that in answer to your question about whether you had explained the environmental things, I do not know at the moment whether what you see here in these 5-year cycles, is a response of the population to environmental control or whether it is a response to some other fishery. Probably some people from the Florida area could answer that.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 195–199.

AN ANALYSIS OF DOCKSIDE PRICES IN THE FLORIDA BLUE CRAB INDUSTRY

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INTRODUCTION

Florida blue crab prices can theoretically be affected by a large number of factors. Among these are the quantities of crabs landed in Florida, the quantities landed in other regions of the United States, the prices of substitute products for blue crab meat and claw products, and the incomes of consumers. Other factors such as regulatory policies and practices could also affect prices.

This paper presents an analysis of annual dockside hard-shell blue crab prices in Florida from 1952 through 1976 (National Marine Fisheries Service [NMFS] 1952–1976). The paper is divided into three major sections. First, trends in Florida landings, value, and prices are presented along with a comparison of the relative price differentials between Florida and other major crab-producing areas. The second section discusses four demand- or price-response models estimated to explain the variation in Florida blue crab prices and to determine what variables are important in causing crab price variations. A short summary and concluding statements are presented in the final section.

PRICE COMPARISONS

Florida hard-shell blue crab landings between 1952 and 1976 have varied from a low of 8.1 million pounds in 1952 to a high of 26.6 million pounds in 1965 (Figure 1). Although wide annual variations have occurred, landings generally trended upward until 1965 and, since that time, have trended downward. More detailed treatment of this subject can be found in other papers in these proceedings. Total value of landings has increased gradually with some annual fluctuation to the high of $2.7 million in 1976. This ranked hard-shell blue crabs fourth in volume and eighth in value of all Florida species of fish and shellfish in 1976. Florida landings for the past 5 years have accounted for about 12% of the total United States landings of hard-shell blue crabs.

Dockside prices per pound have trended upward since 1961. Prior to 1961, little change occurred in annual average crab prices (Figure 1). In fact, the deflated or real crab price declined during that time. Since 1961, current prices have increased to the 1976 high of 16.8 cents per pound. Substantial increases (in a relative sense) have occurred since 1971. The real price has also trended upward since 1961 with some annual fluctuations or declines occurring.

Florida dockside prices appear to be higher on the Florida east coast than on the Florida west coast. All price comparisons made in this section compare reported prices only. No attempt is made to explain price differences due to such factors as meat yields, seasonality, etc. East coast prices have been higher for 19 of the 25 years from 1952 to 1976. Reported prices were even in 3 years, and lower than west coast prices for 3 years (Figure 2). Price differentials have ranged from –$0.0093 to $0.0283. The Florida west coast normally produces over one half of the crabs landed in Florida with the average in the past 5 years being 68% of total state landings. This percentage was approximately reversed in the early and mid-1950's.

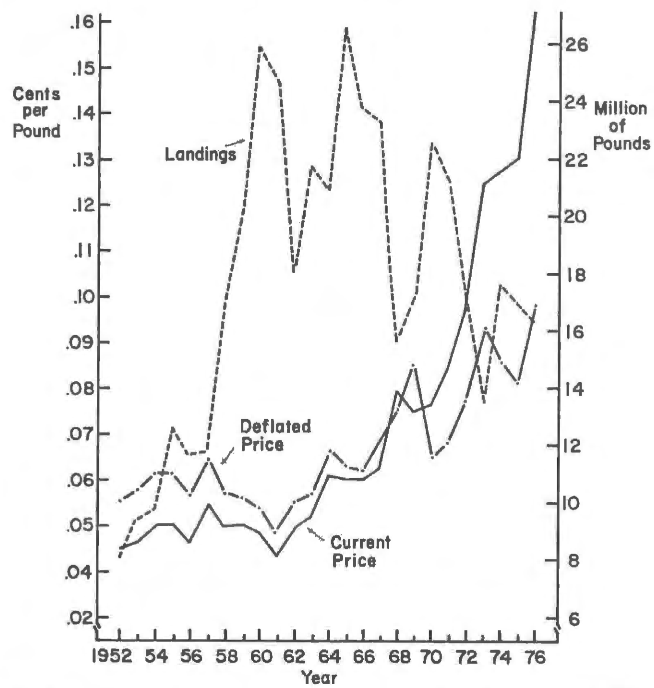

Figure 1. Annual landings and average annual deflated (1967 = 100) and current dockside price for Florida blue crabs, 1952–1976.

Florida dockside prices have normally been lower than those reported for the other Gulf of Mexico states and in the Chesapeake Bay region. South Atlantic region prices have normally been lower than Florida prices. Footnote 2 of Table 1 lists the states included in these regions. Prices paid in other Gulf of Mexico states have been higher than Florida prices in 18 of the 24 years analyzed. Price differentials have ranged from –$0.0040 to $0.0205 (Figure 3). Prices paid in the Chesapeake Bay region have been higher in 16 of the 24 years with differentials ranging from –$0.0096 to $0.0315 (Figure 3). Prices paid in the South Atlantic states have been lower than Florida prices for 17 of the 24 years with price differentials ranging from –$0.0159 to $0.0115 (Figure 3). Reported prices in the

Middle Atlantic states are much higher than those in any other region. However, blue crab landings in this region are nominal. Florida normally ranks third to the Chesapeake Bay and South Atlantic regions in total annual volume of value crab landings.

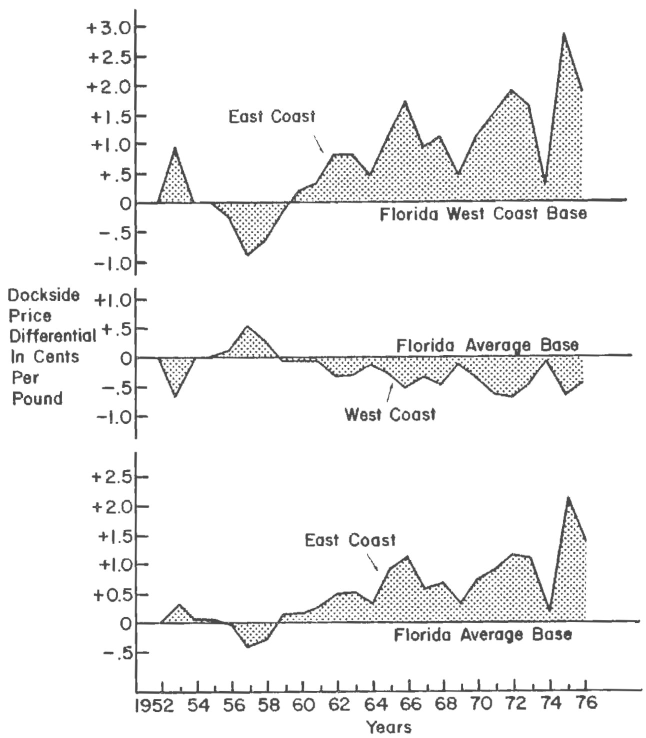

Figure 2. Annual average hard-shell blue crab dockside price differentials for the Florida east and west coasts using average annual Florida price and Florida west coast prices as base prices, 1952–1976.

98% of the annual variation in dockside blue crab landings in Florida. All signs were as theoretically expected. A negative relation existed between price and quantities landed, and a positive relation existed between price and per capita income levels.

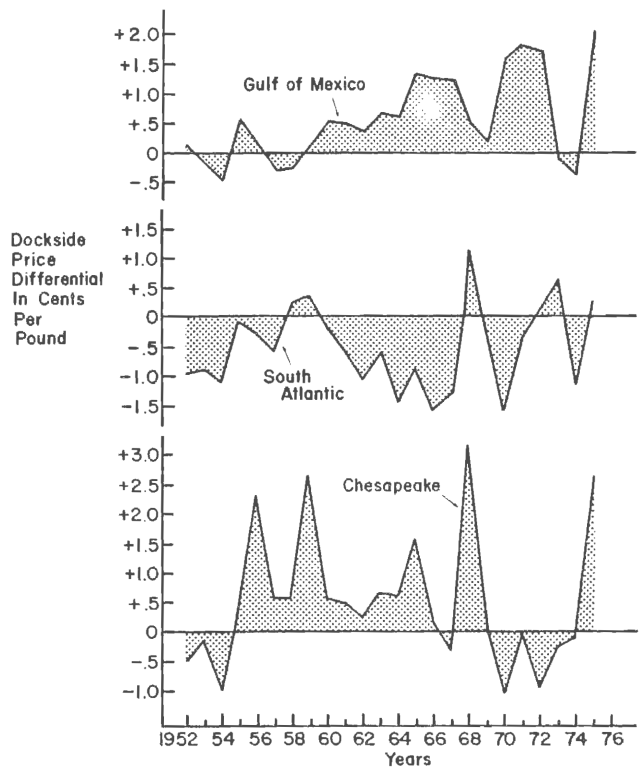

Figure 3. Annual average hard-shell blue crab dockside price differentials for the Chesapeake Bay, South Atlantic (excluding Florida), and Gulf of Mexico (excluding Florida) using Florida average annual price as base, 1952–1975.

ESTIMATED PRICE FUNCTIONS

Four demand models were developed to explain annual variations in Florida blue crab dockside prices. The first model expressed Florida blue crab prices as dependent on total Florida blue crab landings, other United States blue crab landings, and per capita income in the United States. The second model delineates United States blue crab landings into five subregions of the United States to determine if landings in particular regions have independent effects on Florida prices.

Models three and four were specified to determine if different factors influenced price in the Florida east and west coast blue crab fisheries. West coast blue crab dockside prices were analyzed as dependent on Florida west coast landings, Florida east coast landings, rest of the United States blue crab landings, and United States per capita income. Florida east coast dockside prices were regressed on the same variables in the final model.

Total Florida Fishery

The overall model presented in Eq. 1 (Table 1) explained

The effect of Florida landings on dockside price was highly significant statistically although dockside Florida blue crab prices responded relatively little in an absolute sense to changes in Florida total blue crab landings. A 1.0 million-pound increase in Florida blue crab landings will decrease dockside prices by 0.08 of one cent. A 10% change in landings will change Florida dockside prices by 1.9% in the opposite direction (determined by estimating the price flexibility at the mean of −0.19196). The demand for Florida blue crabs appears to be highly elastic.

The sign of the estimated parameter for other United States blue crab landings indicates these blue crabs are a substitute for Florida blue crabs. However, the estimate is not statistically significant at a high confidence level. This potential substitutability is further investigated in Eq. 2, Table 1. Imports could also affect the price of domestic products such as blue crabs. Although some blue crabs are now imported into Florida, as late as 1972 there were no reported imports of blue crabs into the United States (U.S. Department of Commerce 1973, p. 27). Per capita income in the United States has the most significant effect

TABLE 1.

Price response equations for Florida hard-shell blue crabs, 1952–1976.[1]

Equation	Dependent Variable[3]	Constant	Independent Variable[2] Q_F	Q_{FWC}	Q_{FEC}	Q_{GM}	Q_C	Q_{SA}	Q_{MA}	Q_{US}	I	R^2	Durbin-Watson Statistic[4]
1	P_F	0.021395	–0.000784							–0.000082	0.023489	0.98	1.90
			(2.60)							(0.92)	(28.88)		
2	P_F	0.012836	–0.001130			–0.000050	–0.000177	0.000541	0.000776		0.023145	0.99	1.85
			(3.52)			(0.17)	(2.01)	(2.31)	(1.08)		(17.80)		
3	P_{FWC}	0.046690		–0.000410	–0.002948					–0.000169	0.021248	0.97	2.31
				(1.09)	(2.73)					(1.60)	(18.78)		
4	P_{FEC}	0.033700		–0.000426	–0.004069					–0.000004	0.024301	0.99	1.57
				(2.10)	(6.98)					(0.08)	(39.79)		

[1] Number of observations is 25 for all equations. Number shown in parentheses is the t statistic.

[2] All landings data are in millions of pounds landed annually; income is in thousands of current dollars per capita. Landings variables are:

- Q_F = Florida landings
- Q_{FWC} = Florida west coast landings
- Q_{FEC} = Florida east coast landings
- Q_{GM} = Texas, Louisiana, Mississippi, and Alabama Landings
- Q_C = Virginia and Maryland landings
- Q_{SA} = Georgia, North Carolina, and South Carolina landings
- Q_{MA} = Delaware, New Jersey, and New York landings
- Q_{US} = United States landings excluding Florida

[3] All price data are average annual current dollars per pound with variables defined as:

- P_F = Florida price
- P_{FWC} = Florida west coast price
- P_{FEC} = Florida east coast price

[4] This Durbin-Watson statistic indicates no autocorrelation exists at an acceptable significance level except in Equation 4 where the statistic is in the inconclusive range.

on Florida blue crab dockside prices as shown in Eqs. 1 and 2, Table 1. An increase in per capita income of $1,000 results in an increase in Florida dockside blue crab prices of 2.3 cents per pound. The effect of a change in any particular variable on price is discussed with all other variables remaining constant.

Florida blue crab landings made up about 15% of the total United States landings from 1952 to 1976. United States landings were divided into regions to further examine the effects of these other United States landings on Florida prices. These regions were the Gulf of Mexico (Texas through Alabama), the South Atlantic (Georgia through North Carolina), the Chesapeake Bay (Virginia and Maryland), and the Middle Atlantic (Delaware, New Jersey and New York).

The regional model (Eq. 2, Table 1) explained 99% of the annual variation in Florida dockside blue crab prices. The statistical significance level for the effect of Florida landings on Florida prices improved. In this model, a 1 million-pound increase in Florida landings will decrease Florida dockside prices by 0.11 of one cent. The price responsiveness (flexibility) increased to −0.28, which means a 10% change in landings will change prices by 2.8% in the opposite direction at the mean.

Chesapeake Bay region blue crab landings had a significant negative effect on Florida prices. Although the t-statistic of South Atlantic region landings variable was highly significant, the expected negative sign did not occur. Using a one-tailed test of significance then made this estimated parameter not significant. A 1 million-pound increase in Chesapeake Bay region landings would cause a 0.02 of one cent decrease in Florida prices. The income variable was again highly significant and in both models a $1,000 increase in per capita income would increase prices by 2.3 cents per pound.

Florida West Coast Fishery

Dockside prices received by Florida west coast blue crab fishermen were estimated as a function of Florida east and west coast landings, the rest of the United States landings, and United States per capita income (Eq. 3, Table 1). All quantity variables were shown to be negatively related with west coast prices. The income variable had essentially the same strong positive effect on west coast prices as for total Florida prices. The variables specified for this model explained about 97% percent of the annual price variation for Florida west coast blue crabs. East coast landings were the most highly statistically significant and have a larger negative impact on west coast prices than do west coast landings. A 1 million-pound increase in east coast landings will reduce west coast prices by 0.3 of one cent while the same increase in west coast landings reduced west coast prices by 0.04 of one cent. The responsiveness of west coast prices to east coast landings (price flexibility) was −0.29 as compared to −0.06 for west coast landings. This means a 10% change in landings on the east and west coasts, respectively, causes a 2.9 and 0.6% decrease in Florida west coast prices at the means.

Florida East Coast Fishery

Florida east coast prices were analyzed as dependent on the same four variables. This model (Eq. 4, Table 1) explained 99% of the annual variation in east coast blue crab prices. All signs were as expected. However, the rest of the United States blue crab landings did not have a statistically significant effect on east coast landings as did east and west coast landings. Landings outside of Florida have more influence on west coast prices than on east coast prices. A 1 million-pound increase in east coast landings will reduce east coast prices by approximately 0.4 of one cent. A 10% change in east coast landings will change east coast prices by 3.6% in the opposite direction.

SUMMARY AND CONCLUSIONS

The four models specified to explain Florida blue crab dockside prices all explained between 97 and 99% of the annual price variation between 1952 and 1976. Per capita income was the most significant variable in determining the level of Florida blue crab prices. A $1,000 increase in per capita income resulted in over a 2-cent per pound increase in blue crab dockside prices in all models. The estimated income effect was stable between models.

Florida landings were shown to have a statistically significant negative effect on Florida prices in all models. Within Florida, east coast landings were determined to be more significant in determining prices than were west coast landings. Chesapeake Bay region landings of blue crabs were determined to be the principle substitute for Florida blue crabs in the United States. In all models, price flexibilities were low, indicating relatively small dockside price changes for given changes in quantities supplied. This implies a highly elastic consumer demand exists for Florida blue crabs, which means that small price changes result in relatively large changes in quantities consumed.

Some implications of the current research deserve further consideration. In particular, these are the relatively large values for the coefficients of determination estimated for the individual models and the absolute size of the income parameter. These two are not unrelated.

Blue crab prices were relatively stable over the study period, especially during the first half of the series. With relatively little variation in the dependent variable, it is not surprising to have large coefficients of determination when signficant explanatory variables are included in the model. However, before this is accepted as a tentative explanation, further consideration of the income variable is warranted.

The empirical estimates of the income parameters are relatively large and positive. The positive sign is as theoretically expected. The accuracy of the size of the estimated coefficient is less certain. Blue crab meat at the retail level is a relatively high-priced seafood item and, thus, a high-income elasticity is not unexpected. Part of the relatively large income effect may have been due to a positive correlation between increased prices and increased per capita income moving both in the same direction as the result of inflation.

To examine this possibility, deflated prices were regressed on deflated per capita incomes and the original quantity variables. The coefficients of determination estimates for these deflated models decreased only slightly and the absolute size of the quantity variables decreased slightly, suggesting little need for concern.

Further analyses were performed to satisfy concerns for dominant variable problems. If income were acting as a dominant variable, signs and significance levels of the remaining quantity variables would be adversely affected. Estimating the equations without the income variable resulted in unacceptable signs and significance levels for the United States and Florida quantity variables, suggesting no dominant variable problem exists. As a further check, preliminary analyses using a shifting parameter technique for a variable intercept model showed the quantity coefficients to be relatively close to those initially estimated using the ordinary least squares with the income variable included. Additional work in the area of reactive programming is in process.

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DISCUSSION

Q. (Unidentified): Dr. Cato, I would like to ask you, did you center data over 25 years?

A. James Cato: That is correct.

Q. (Unidentified): Do you have a feeling as to whether there would be a different result if you looked at (I realize that this is a statistical problem here) data over the last, say, 9 or 10 years when there has been a greater change in prices, and a greater change in landings, more so since 1970, than in the 30 or 40 years before that?

A. Cato: My answer is that the results would be the same. Your R^2 would probably be lower because you do have a little more variation on that time. If you just look at the last 10 years again, you would only have about 6 degrees of freedom, so you would have some problem with the statistical test.

Q. (Unidentified): On the statistical test involved, you were concerned about the importance of income; per capita income controlling the sign. Although I am not too much of a mathematician, I wonder did you use multiple regressions? It has been suggested in some of the work we do that we don't use that technique but rather use a partial correlation method, which shows the particular importance of each variable in the equation and that these are the values of each variable independent of the other variable. If you use the partial correlation method of analyzing the data, you might come up with something different.

A. Cato: In this case, I think you get exactly the same results.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 201–203.

ECONOMIC VALUE OF THE BLUE CRAB PROCESSING INDUSTRY IN MISSISSIPPI IN 1978

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This paper assesses the current economic status of the blue crab processing industry in Mississippi. Information in this paper was taken from a report *Economic Value of the Seafood Processing Industry in Mississippi, 1978*, which is currently in review. Data for the report were collected through personal interviews with processing plant managers during late 1978 and early 1979.

The seafood processing industry is made up of a relatively large number of firms ranging widely in size and volume of production. While there is an estimated 100 firms on Mississippi's coast, about 20 to 25 of them account for virtually all of the volume processed. Shrimp processors make up nearly half of the processors, with oyster and crab processors accounting for most remaining plants. Finfish processors make up only a small proportion of the total.

Many of the firms concentrate on only one product but others may process multiple species. Shrimp processors are typically larger than processors of other species.

The processing plants are usually privately owned and operated. Many of them are family businesses with the current operators often being second and third generations of the same family in the same business.

Seafood processed by firms in Mississippi significantly exceeds the reported commercial landings. Table 1 shows the National Marine Fisheries Service (NMFS) reported commercial landings for crabs during the past 3 years compared with the total volume processed in plants in the state. The volume of crabs processed exceeded the reported commercial landings for 1978 by 54%. Crab processing volume grew more rapidly than either shrimp or oysters, expanding 68% over the 3-year period. The average output per plant increased by about 34% during the same period.

Table 2 shows the magnitude of sales at processing plants by major product produced in 1978.

Tables 3 and 4 depict the full and part-time employment in seafood processing firms. The breakdown by plant is based on figures reported by individual plants. Plants were classified by the product that accounted for the major proportion of their production and sales.

The crab processing industry employs a significant proportion of the total personnel employed in the seafood industry. Crab processing is labor intensive and, consequently, the output per hour of labor is relatively low. Data collected for this economic analysis did not lend themselves to measurement of labor productivity.

TABLE 1.

Total quantity of crabs processed (in pounds), 1976–1978.

Year	Reported[1] Commercial Landings	Pounds of Processed Crabmeat: Total	Pounds of Processed Crabmeat: Average per Plant
1976	1,334,450	132,500	33,125
1977	1,918,600	145,000	36,250
1978	1,940,100	222,500	44,500

[1]*Mississippi Landings*, NMFS, U.S. Department of Commerce, "Annual Summaries."

TABLE 2.

Seafood sales at processing plants by major product processed (in thousand dollars)[1], 1978

Product	Number of Firms Reporting[2]	Reported Total Sales[3]	Sales per Plant	Calculated Total Sales[4]
Shrimp	5	10,755	2,151	21,510
Oysters	4	4,132	1,033	5,165
Crabs	4	1,254	313	1,565
Finfish	2	4,233	2,116	4,233
Total	15	20,374	1,358	32,473

[1]Firms reporting over 50% of their sales volume from the indicated product category.
[2]Total firms in each category were: shrimp, 10; oysters, 5; crabs, 5; and finfish, 2.
[3]Total reported sales divided by the number of firms reporting sales.
[4]Total sales were calculated by multiplying the average sales by firm times the total number of firms in each category. This assumes that the firms not reporting sales were similar to those who did report sales.

About 20% of the full-time employees in processing plants were associated with crab processing. Part-time employees working with crabs varied from 15 to 25% of the total part-time workers over the 5-month period from April through August.

The estimated annual payroll for part-time crab workers in 1978 was $220,904, and the estimated payroll for full-time production employees was $662,288 for a total of $883,192. Actual wages were not reported but were calculated on the basis of a minimum wage of $2.65 per hour. No estimates were made for wages or salaries for management employees.

TABLE 3.

Full-time employment in Mississippi seafood processing plants, 1976–1978.

Major Product	Management			Production			Total		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
Shrimp									
Total	59	56	61	311	361	376	360	417	437
Avg.	5	6	6	31	36	38	36	42	44
Oysters									
Total	25	25	25	112	122	132	137	147	157
Avg.	5	5	5	22	24	26	27	29	31
Crabs									
Total	13	13	13	129	129	129	142	142	142
Avg.	3	3	3	26	26	26	28	28	28
All plants	87	94	99	552	612	637	639	706	736

TABLE 4.

Part-time employment in Mississippi seafood processing plants, 1978.

Major Product	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Shrimp												
Total				91	307	438	543	511	416	311	146	90
Avg.				23	34	40	45	46	42	39	29	22
Oysters												
Total	185	185	202	207	60	38	45	91	136	158	220	225
Avg.	26	26	25	26	20	13	15	18	23	23	28	28
Crabs												
Total				100	100	107	107	107				
Avg.*												
Total	185	185	202	398	467	583	695	709	552	469	366	315

*No average was calculated because of the small number of plants employing part-time workers.

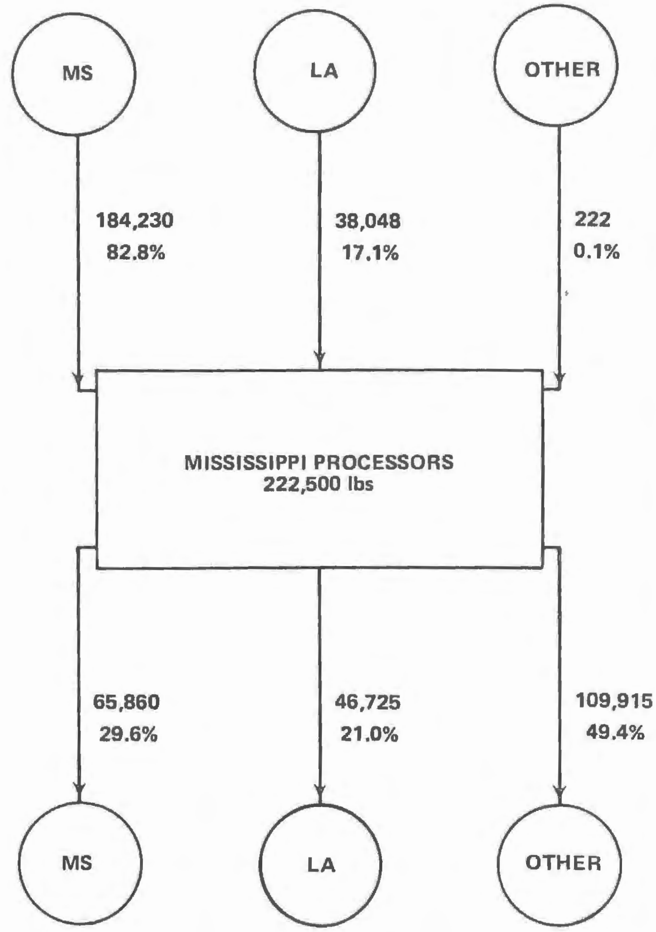

Figure 1. Raw material source and location of first sale of crabs processed in Mississippi, 1978.

Mississippi seafood plants process approximately three and one-half times as much seafood as is landed in the state. A large proportion of the seafood is trucked into Mississippi for processing because of the great distances from the fishing areas to the processing plants and the shortage of deep water adjacent to the plants. Processors estimated that nearly 84% of crabs processed in the state were trucked to the plants and added an estimated $0.05 per pound to the raw product price.

Figure 1 shows a graphic representation of the origin and location of first sale of crabs processed in Mississippi plants during 1978.

About 83% of the total blue crabs processed in Mississippi plants in 1978 were purchased from Mississippi crabbers. Louisiana accounted for about 17%. Other states supplied a negligible proportion of the crabs processed.

Sales were distributed differently. Less than 30% of the processed crabs were sold in Mississippi with nearly one half being sold outside of the state; 21% was sold to buyers in Louisiana.

Table 5 shows the computed margins for blue crabs at various stages in the marketing system. Crabs with a value of $0.22 to the fisherman are processed into a product with an estimated value of $6.34 per pound at the retail level. The high retail margin reflects the large proportion of crab meat which is marketed through away-from-home markets which generally have a higher margin.

Economically, the blue crab fishery in Mississippi is relatively small (Table 6). In 1978, the reported landings were valued at $421,931. The value added by processing was $369,350 for a total value of $791,281. Another $211,411 was added through wholesale and retail margins on processed crabs sold in Mississippi which brings the total to slightly over $1 million for 1978.

The estimated total economic imports of the blue crab industry in Mississippi in 1978 ranged from $2 to $3 million (Table 7). This estimate has been based on an assumed multiplier of 2 to 3. That means, for each dollar generated in the blue crab fishery, an additional $2 to $3 of spending was generated for the state's economy.

Although the blue crab fishery does not represent a large monetary value, it is nonetheless of significance to the fishermen, processors, and workers employed in the blue crab fishery in Mississippi.

TABLE 5.

Computed blue crab margins (in dollars), 1978[1]

	Margin	Cumulative Price
Fisherman's share	0.22	
Value of meat (15% yield)	1.47	
Processing margin	1.66	3.13
Wholesale margin	0.55	3.68
Retail margin	2.66	6.34
Retail price per pound	6.34	

[1]Margins based on data from *Fisheries of the United States, 1978,* National Marine Fisheries Service.

TABLE 6.

Estimated economic value of selected seafood in Mississippi, 1978.

	Shrimp	Blue Crabs	Oysters
Value to fishermen[1]	$ 9,280,276	$ 421,931	$ 730,202
Processing value added	36,630,610	369,350	1,795,640
Wholesale and retail value added	2,497,301	211,411	1,364,688
Total value	$48,408,187	$1,002,692	$3,890,530

[1]Computed from reported commercial landings, *Mississippi Landings,* December 1978, National Marine Fisheries Service.

TABLE 7.

Estimated total impact of the Mississippi seafood processing industry on the economy of the state (in millions of dollars).

	Processing Value Added	Landings, Processing, and Sales	Estimated Total Economic Impact Range[1]
Shrimp	$36.6	$48.4	$ 96.8 – $145.2
Oysters	1.8	3.9	7.8 – 11.7
Crabs	0.4	1.0	2.0 – 3.0
Finfish[2]	2.2	3.7	7.4 – 11.1
Total	$41.0	$57.0	$114.0 – $171.0

[1]Based on a multiplier range of 2 to 3.

[2]Only two firms were primarily finfish processors. Detailed information was not presented because it might violate the confidentiality of the data provided by those firms.

Proceedings of the Blue Crab Colloquium, Oct. 18–19, 1979, 205–214.

PROCESSING: METHODS OF COOKING AND PACKING CRAB MEAT, MECHANIZATION

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INTRODUCTION

The blue crab industry has changed little since its beginnings. Lee et al. (1963) surveyed processing plants in the Gulf and Atlantic states in 1961 and found that a steady supply of raw product, inadequate labor force, and marketing of the picked product were problems common to both regions. In an address before the National Blue Crab Industry Workshop in 1978, George H. Harrison, past president of the National Blue Crab Industry Association, gave the following view from industry:

> "I am supposed to give a view from industry. That could probably take several days and to condense it down into just a few minutes is a little hard to do. You always start when somebody talks about history and I don't pretend to delve into the history of the blue crab industry except in a very sarcastic kind of way. We will start with my family as an example: in 1902, my grandfather put some crabs in a basket, dropped them into a retort and cooked them, took them out and cooled them off, took out his old trusty knife, picked them, put the crabmeat in some oyster cans, put them in a box and iced them up, put them on a steamboat and shipped them to the market. In 1977, if the retort has not fully rusted away, I am sure somebody salvaged it and patched and may be still using it because that is the kind of industry that we have. The cans today are smaller, made of lighter alloys but are basically the same thing. And if that old wooden fish box could still be found and somebody could repair it, we would still be using it. The steamboat has given way to the truck; thank God Henry Ford gave us a little progress. The Barlow Knife ground off and now we got rid of wooden handle. An last but not least, the same fish market is receiving crabmeat from all of us or many of us at least. In short, the past 75 years have given us rather little progress in essence. The crabmeat industry today, is where the bulk of the U.S. food industry was just 50 years ago!" (Rhodes and VanEngel 1978).

Thus it appears that while some advances have been made in processing technology and mechanization, the problems common to the industry since its inception are still with it today.

PROCESSING

Typical processing schemes for Gulf and Atlantic crabmeat are shown in Figures 1 and 2, respectively.

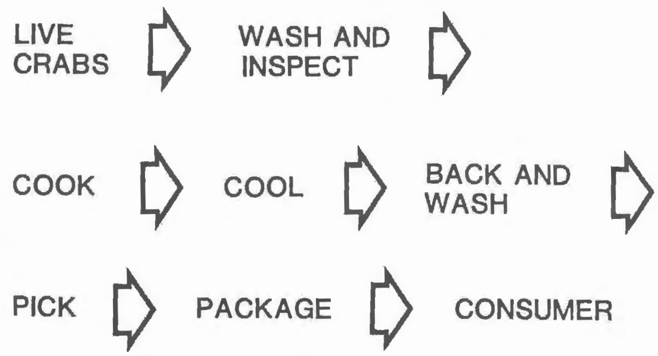


Figure 1. Processing scheme, Gulf states.

Live Crabs

Crabs are normally delivered to the processor by boat or by road vehicle shortly after being harvested. The interstate trucking of live crabs over long distances has necessitated development of procedures to minimize mortality. A university study of the survival rates of crabs shipped from North Carolina to Baltimore showed that adequate ventilation, a cool temperature, and an upright position in the shipping container were the three factors which in combination guaranteed the highest number of live crabs reaching their final destination.

Once in the plant, those crabs not immediately cooked were stored in a cooler at a temperature between 40 and 50°F.

Cooking

Each state that produces crab meat has its own regulations governing the methods of cooking live crabs. In some states only pressure cooking or open steam is allowed. Traditionally, the Gulf states have cooked crabs by boiling.

Boiling

In the boiling operation, a vat is filled with water and live steam introduced through pipes at the bottom. The water is brought to a boil, the crabs placed in the vat, and cooked for 15 minutes after the water has started to boil again. They are hoisted or dipped from the vat and spread on tables to air cool.

If boiling is the preferred method of cooking, steam-heated water is more desirable than heating water with gas jets. For one thing, the water can be heated to a boiling temperature much faster than with gas. Depending upon

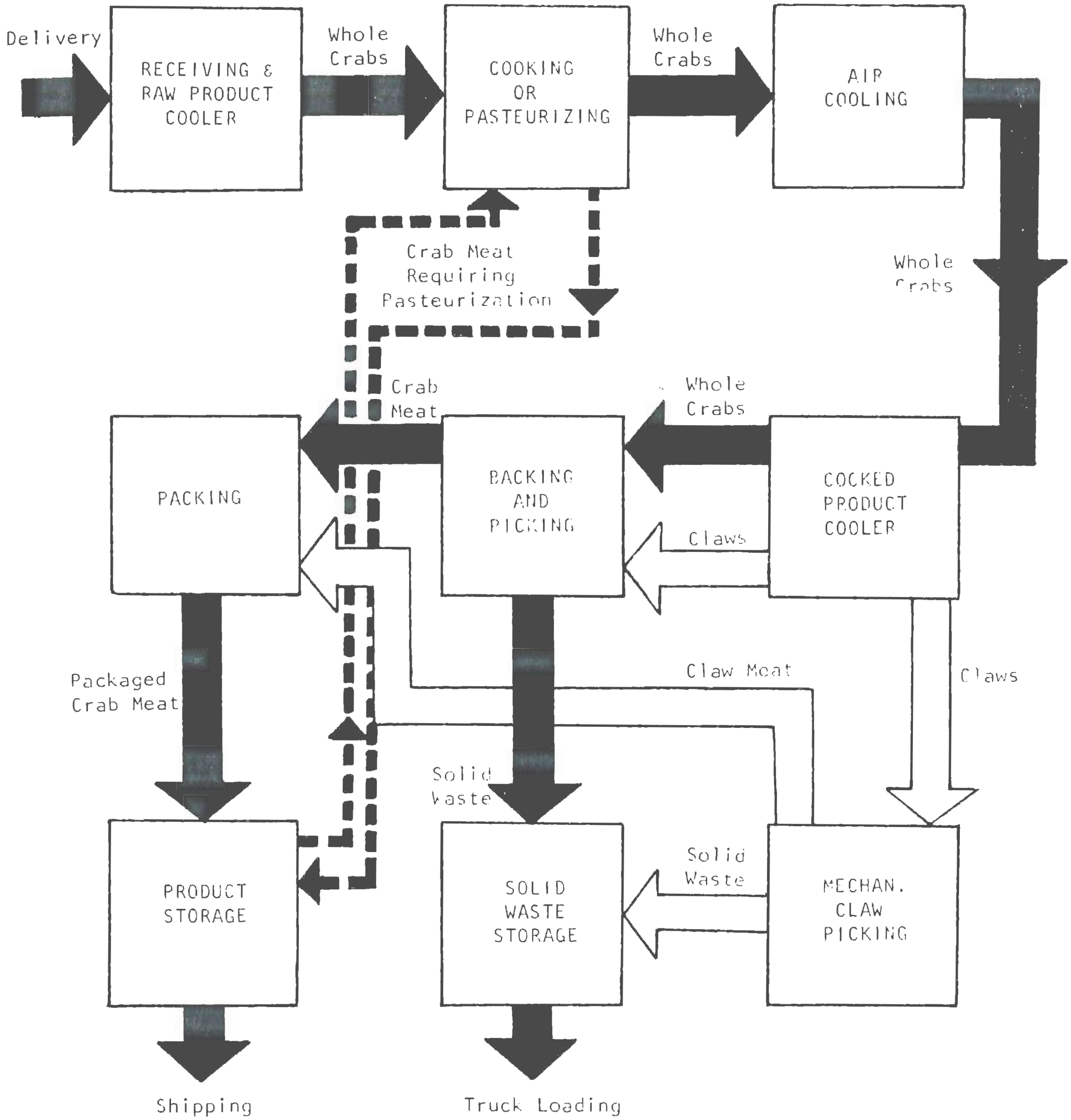


Figure 2. Processing scheme, Atlantic states (modified from Miller et al. 1974).

the quantity of water to be heated, steam spreader design, steam pressure, etc., water may be brought to a boiling temperature within a few minutes; whereas with gas heat, the water may take an hour or longer to begin boiling. In addition, steam-heated water can be brought to a boil faster again after submerging the cool crabs. Probably the most efficient way to heat water with steam is with the use of a spreader at the bottom of the cooking vat through which live steam is forced. In this way, the water is briskly agitated and quickly heated.

Steaming

The steam cooking of crabs involves placing them in a metal basket or expanded metal car, enclosing it in a retort and introducing steam at 15 pounds per square inch (psi) (250°F) for approximately 10 minutes. Vertical and horizontal retorts are illustrated in Figures 3 and 4, respectively.

Each cooking method has its advantages and disadvantages. Ulmer (1964) in a study of the techniques used in processing blue crabs found that:

1. The cooking process very markedly reduced the bacterial population in crabs.
2. Experimental evidence indicated that spoilage bacteria are brought into the packing plant on the live crabs and are reinoculated into the crabmeat after it is cooked. A high order of plant sanitation is essential.
3. Pressure steaming crabs at 250°F (15 psi) for 10 minutes produced higher yields than did pressure steaming for either longer or shorter periods.
4. Steam boiling crabs at 212°F in tap water for 10 to 15 minutes produced higher yields than did pressure steaming at 250°F for 10 minutes. The boiling time is considerably less critical than is steaming time.
5. Successively steam boiling several baskets of crabs, at least up to 10, in the same water had little effect on yield or bacterial counts of picked meat.
6. Natural variables, such as season and source, and biological factors, such as physiological condition and sex of the crabs, have a distinct influence on yield. Data were inadequate, however, to show that any definite yield pattern is produced by these variables.
7. Refrigeration of crabs overnight, after they had been properly cooked, increased both yield and shelf life. Refrigeration was essential during hot weather.
8. Debacking and washing properly cooked crabs prior to overnight storage also increased yield. Highest yields were obtained when a combination of debacking and refrigeration was employed.
9. Crabmeat produced from boiled crabs could not be distinguished organoleptically from crabmeat produced from steamed crabs. When a preference was indicated, it was more frequently for boiled meat than for steamed meat.

A boiling operation has a cheaper initial equipment cost. All that is needed is an open vat with gas or steam jets to heat the water. A steaming operation, however, requires a boiler to generate steam and a cooking retort. Both items are expensive. The advantages and disadvantages of each cooking method are summarized below:

Steaming Under Pressure

Slightly lower meat yield
Less water to get on pickers' hands and arms.
Cooking time begins shortly after packing retort with crabs; no need to preheat water.
Initial equipment cost high.

Boiling

Slightly higher meat yield.
Crabs messier to pick.
Water must be brought to boiling before adding crabs; after adding crabs, it needs to be brought to a boil again for cooking time.
Comparatively low initial equipment cost.

PRESERVATION

Most blue crab meat is presently marketed in the Gulf states as a fresh, refrigerated product with a shelf life of 6 to 20 days. Several techniques for preserving blue crab meat have been developed to extend the shelf life. Heat preservation procedures, pasteurization and sterilization, and freezing are in use today by the industry with varying degrees of success. Product acceptability is usually lower for preserved meat than for the fresh product.

Pasteurization

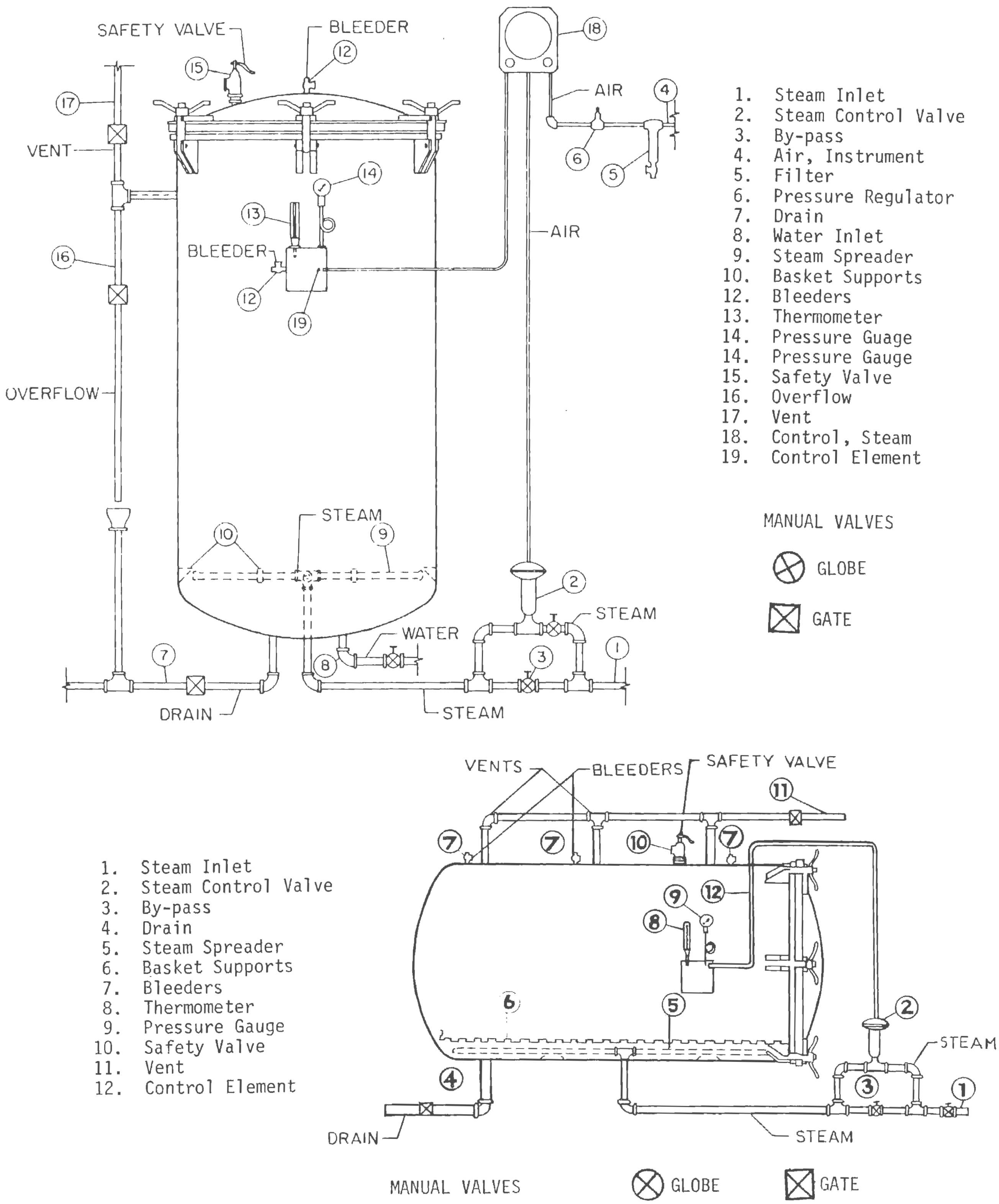
Pasteurization is the process of heating picked crab meat in a hermetically sealed can in a water bath until an internal temperature of 185°F is reached. The meat is held at that temperature for one minute. Heat penetration capabilities for each retort may vary and must be determined for each water bath. After reaching and holding the crab meat at the proper temperature, the crab meat should be cooled to 100°F within 50 minutes after removal from the water bath. Although pasteurized crab meat has an extended shelf life, it must be kept under refrigeration at temperatures above freezing but not exceeding 36°F. A pasteurization tank hookup is illustrated in Figure 5.

Sterlization

Production of heat-sterilized crab meat is limited. The sterilization procedure involves cooking the crab meat in a hermetically sealed can in a retort until commercial sterility is reached. Problems arising from sterilization include heat-induced coloration changes in the meat, textural changes, and an "off flavor."

Freezing–Picked Meat

The quality of frozen crab meat, under conventional processing techniques, does not measure up to the fresh or pasteurized product. Changes in the texture of the meat and a loss of flavor are characteristic of blue crab meat held at 0°F. Strasser et al. (1971) found that rapid freezing using Freon 12 (dichlorodifluoromethane) or low temperature nitrogen, storage below 0°F, and vacuum packaging extended the shelf life of blue crab meat and provided a product that was highly acceptable when compared with fresh, refrigerated meat. Strasser et al. (1971) noted that the quality of frozen-stored crab meat was directly related to the rapidity at which it was frozen.



Figures 3 (upper left) and 4 (lower right). Vertical and horizontal retorts, respectively (from Flick et al. 1976).

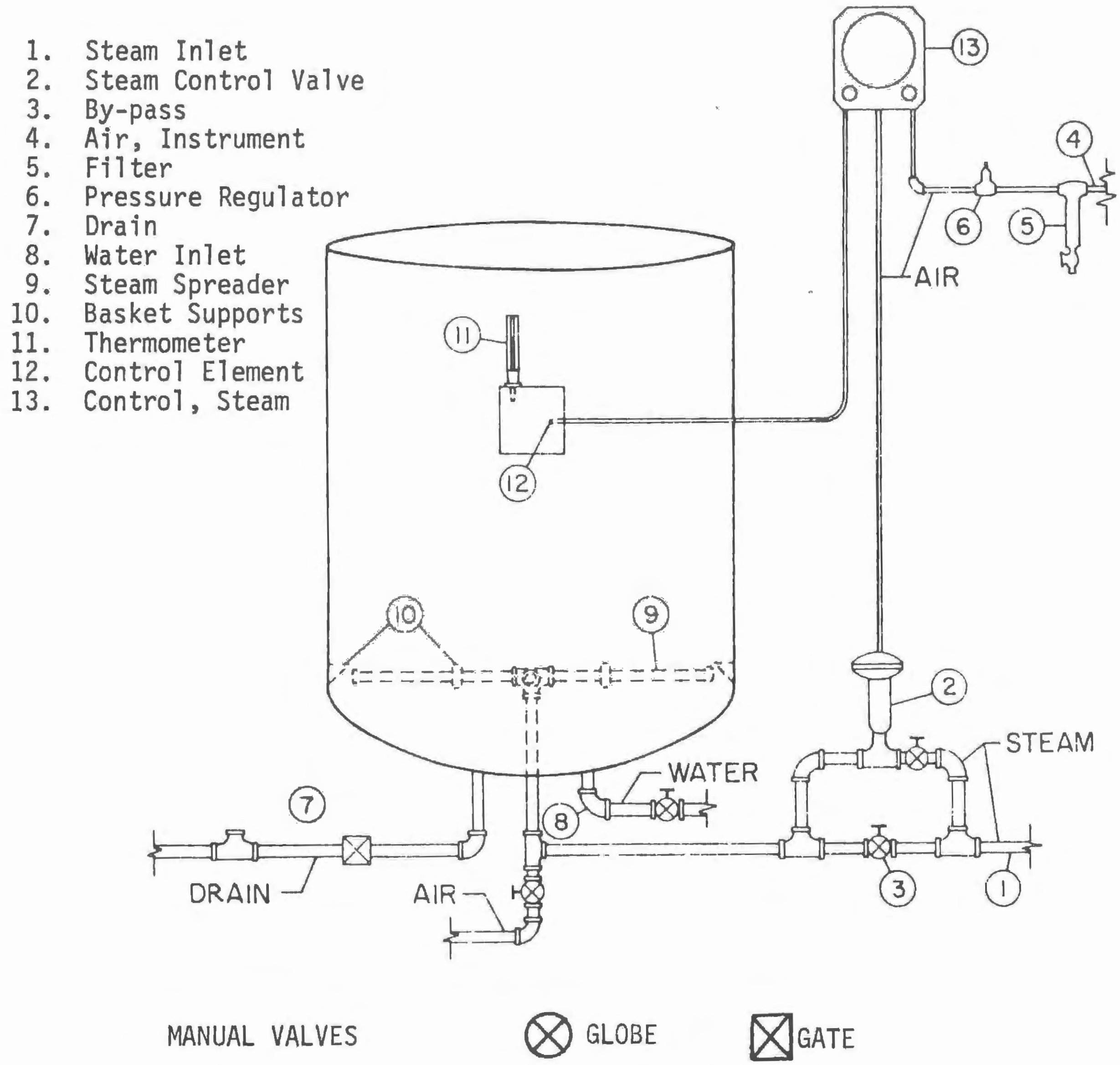


Figure 5. Pasteurization tank hookup (from Flick et al. 1976).

Freezing–Raw, Cleaned Cores

The seasonal nature of the crab fishery and the limited shelf life of the product are responsible for the "glut" and "famine" conditions characteristic of the blue crab industry. The assurance of a steady supply of raw product throughout the year would help to stabilize the industry.

In the past some crab processors on the east coast have attempted to freeze whole crabs for the purpose of controlling the supply cycle during the year. In most cases the meats from these frozen crabs were of poor quality. The freezing of cleaned crab cores has proven to produce a more acceptable product. Meats picked from frozen cores are far superior to regular commercial meats that have been frozen. A series of experiments were designed to determine the best procedure for freezing raw crab cores and cores from crabs given a minimum and a maximum cook. They were either shelf frozen at 0°F or quick frozen in Freon (Tinker and Learson 1970). The cores were placed in plastic bags and stored at 0°F for 2 months. The results of these experiments were as follows:

1. The quality is best retained in the meats picked from crab cores that were given a lesser cook and quick frozen in Freon;
2. Meats picked from cores which had been given the maximum cook showed quality slightly lower than the cores given the lesser cook; and
3. Meats picked from quick frozen cores were always superior to the shelf frozen cores in all the quality attributes (appearance, odor, flavor, and texture).

All the results obtained in studies for the cooking of crabs have shown that meats from crabs given a lesser cook were better in quality after freezing, pasteurizing, and sterilizing than commercially picked meats. It was felt that the minimal cooking process caused less damage to the meats and, therefore, they could be frozen, pasteurized and/or sterilized without too much further reduction in quality.

The quick freezing of crab cores from crabs exposed to a shortened or minimum cook can provide the industry with another method of preservation during the periods of low supply. The shorter cook and accelerated freezing cause less damage to protein. Also, by leaving the meat intact in the cores there is less physical damage to the meat than would occur during the normal picking operation.

MECHANIZATION

Blue crab meat production is still predominantly a hand operation. In the Gulf states, workers pick the white meat and crack open the claws so that the meat can be removed still attached to the cartilage and one of the claw pincers. This product is called a "crab finger" or "claw finger." On the east coast, the white meat is similarly picked by hand, but the claws are mechanically picked to remove the meat from the cartilage.

The physical structure of the internal crab body with its segments and partitions has impeded the development of mechanical means of picking the meat while still retaining some of the cohesiveness of the muscle fibers.

Within the past few years considerable effort has been expended toward the development of a crab-picking machine in response to the declining labor force in the blue crab industry. A brief review of the development of mechanical processing follows.

Crabmac (I and II) and Lumpmac (I and II)

The first two machines produced were the Crabmac I and II, and Lumpmac I and II. These machines were not adopted by the industry because of several serious disadvantages. The Crabmac II punch was not adjustable and had to be changed for different size crabs; it required precise longitudinal as well as lateral orientation of crabs. The punch action also crushed interior bone cavities. The orienting device at the punching station did not function properly; cleaning and maintenance of the machine were difficult because of the large number of mechanisms and adjustments. The Lumpmac II, which was an attachment to Crabmac II, was not feasible because it was not designed to allow stripping of picked lump meat from the blades. It also required precise angular and lateral orientation of the crab cores as well as longitudinal location. The Lumpmac II also pulled out lump cavity bone pieces if the core was missing. Adjustments for the different size and shape of the lump cavities could not be made while the machine was operating. To optimize lump contour and size-setting adjustments, the crabs had to be pregraded by size and sex.

A review of Crabmac/Lumpmac I has not been included because they were quickly replaced by the number II models.

Lockerby Xtracto

This machine is based on U.S. Patent 3,299,325, and uses centrifugal force to extract lump and flake meat from prepared core halves. The machine is designed to hold two fixtures, each holding 12 core-halves which have been hand loaded and held in place by spring clips. The halves are oriented so the meat will be extracted through the center. The fixtures are placed in a stationary row and rotated about a center axis through two speeds. The lump is extracted at the lower speed and swept through a discharge hole in the stationary bowl by a slow rotating teflon wiper blade. The lump meat is then extracted at the higher speed. Separate containers for lump and flake index into position under the bowl before the machine runs through the corresponding speed.

The machine was not adopted by the crab industry for several reasons. Pieces of the flaked meat were ejected during the high speed or lump cycle, and the lump meat collected did not contain many large premium pieces. Apparently, the meat was broken into smaller natural segments during exit from the core bone cavity upon either impact with the stationary bowl or tumbling by the wiper blade segments during exit from the core bone cavity. The loading of each core half required raising two spring-loaded fingers and placing the core half in position behind three stationary lugs, then releasing the fingers. The labor requirements for manually preparing the core halves and loading the fixture were excessive. Basically, pickers could produce the meat quicker than could the machine.

Reinke Shaker

The concept of the Reinke shaker is simple. A rotating inclined perforated drum with counterrotating paddle blades tumbles the prepared cores or top slices and shakes the flaked meat loose. The meat then falls through the perforations onto a conveyor belt where it is carried to a bone culling and packing station. The cores travel through the drum and are discharged at the lower end. The shaker was designed to receive prepared cores which have the top slices and lump previously removed by hand. Top slices were processed separately in the machine. Four people were required on the upper conveyor to cull the bone and pack the meat when running at capacity.

The machine was demonstrated; however, it was not used on a production basis. One of the problems was that the lump had to be removed by hand; the core had to be sliced in half. With just a little additional effort, a crab picker could perform the same function.

Tolley Picker

Centrifugal force was used in this machine to extract the lump and flake meat through the top of the core after a top slice had been cut away. As designed, the machine was quite large (approximately 20 ft long) and utilized 35 spinning fixtures mounted on a side conveyor chain.

Each fixture held two crab cores which were continuously loaded separately by two people at a rate of 60 per minute. The top slice was cut from each core by a pair of rotary saws or knives. The first saw in each pair was used only if the top slice was to be picked by hand. It was set to remove the top bone to expose the top meat. The second saw made a deep cut to remove the entire top slice. Both saws were spring loaded in toward the cores to a setting for small and medium size crabs. A guaging device moved the saws outward for extra-large crabs. The top slices drop into a hopper to await further processing. At the next station, the crossbone was trimmed from the core to further expose the lump meat. The fixtures then pass through three spinning stations, first rotating at a slow speed to remove the lump, then at a middle speed to remove the larger pieces of flake and, finally, at a high speed to remove the smallest pieces. The meat was discharged and moved along on a conveyor belt so that shell and cartilage could be removed.

The machine was never put into production because the lump meat was not removed as large premium pieces. However, the cores were almost completely devoid of meat.

Reinke Debacker-Cleaner-Bobber

This machine has been used on a production basis by the J. M. Clayton Company, of Cambridge, MD, the Milbourne Oyster Company, of Crisfield, MD, and by the Tidewater Seafoods, Inc., of Newport News, VA. The machine is relatively simple in construction using a straight line, continuous feed conveyor chain arrangement to transport crabs through the operating stations. Two or three loaders decore crabs by hand and place them in an oriented position on conveyor chain carriers. The carriers use a curved lip at the front to position the crab at the back shell hinge; two spikes penetrate the underbody shell and hold the crabs in a fixed position. The carriers hold the crabs tilted with mouth end high so the mouth can be removed.

First station: two closely spaced rotary saw blades split back shell and cut away mouth area.

Second station: split shell sections are removed by a steel rod arrangement. The center rod rides in the groove formed by the saw and supports crab for next operation. Two outer rods are inclined relative to the crab and gradually force the back shell sections off as the crab proceeds to the third section.

Third station: plastic wiper combs remove gills and viscera, assisted by water jets.

Fourth station: sensing device measures thickness of the core and adjusts rotary saws which trim off legs and swim fins along the knuckles. Cores are discharged from the end of the conveyor chain into plastic bags.

This machine is used by the industry and does have some merit. However, it does not pick the meat, but only prepares the core for a subsequent manual or automatic crab picking operation.

Tolley Debacker-Cleaner

The crabs, including claws, are loaded onto carriers which are attached to a straight line continuous motion conveyor. The carriers hold the crab in position as follows: To load, the crab is positioned on the carriers by using two vertical pins which locate the leading edge of the back fins just outside the knuckle. After loading, a curved, pivoting lip clamps down on the shell hinge area and a cutter at the front edge of the carrier clamps down on the mouth of the crab cutting out the mouth area completely. After moving a short distance, the crab is firmly clamped into position. The carriers first pass through a core remover which consists of pairs of properly spaced rotating bars. The rotating bars are synchronized to operate with the carriers. The declawed crabs then move through a debacking station where a stationary hook raises the back shell. Then a stationary plow knocks off the back shell. The crabs next move under rotating brushes which loosen and wipe off the viscera; water jets complete the removal of viscera. The mouth cutter and hinge clamp then open completely and the declawed, debacked and cleaned crabs fall out of the carriers at the end of the conveyor into a container.

The machine was not adopted by the industry because it did not produce a complete core by itself. The debacked and cleaned crabs still had to be bobbed by hand. This step was unfortunate because the crabs had to be handled again before they were ready for picking.

Tolley Crab Lizzy

The crab lizzy consists of two large wheels mounted vertically and geared together. The upper wheel contains the core punch knives which are split with one side movable so the cutting width can be adjusted to crab size, while the little wheel synchronized with the knive stations of the adjustable anvils (also split). Debacked and cleaned crabs are loaded on each anvil station as it rotates past. The anvils adjust to the width of the crab by the use of pins which fit in between the back fins and adjacent legs. The adjustable pin shifts the moving core half out to the corresponding crab width and the adjusting mechanism then locks. As the mating core punch knife approaches contact, a positioning bar on the anvil station contacts a cam bar attached to the moving knife half setting the knife to the adjusted position of the moving core half. This results in a mating cutter (punch) and (anvil) die set to each crab. The knives made curved cuts at the knuckles, thus completing formation of a core. After the knife and anvil lose contact, the movable knife half opens, the ejector bar pushes the core free, and the core falls onto a conveyor, ready for further processing.

The machine was not adopted by the seafood processing industry because it was slow and only processed 28 crabs per minute; the configuration allowed for only one person to load and was not adaptable to higher speeds.

Tolley Top Slice Meat Remover

This machine squeezes the meat from the top slice by using a closing wedge cavity. Two loaders placed 6 to 8 top slices in each wedge cavity (12 cavities) as it rotates by. When a wedge is closed, the squeezed meat protrudes past the outer edge of the wedge cavity. The wedge fixtures rotate past a stationary inclined knife which severs the top slice meat. The meat falls into a container below the knife and is packed with other flaked meat. Near the bottom of rotation the wedge cavities open and the top slice bone falls clear.

The machine was not utilized because it did not substantially reduce the amount of labor needed to pick crabs.

Harris Extractor (Hammermill)

The Harris extractor system has been used in many plants for years. At present, it is being used in the Blue Channel Corporation plants in South Carolina; Tidewater Seafoods, Inc., Newport News, VA; RCV Seafoods, Morattico, VA, and Keyser Brothers, Lottsburg, VA. There are other plants that also utilize the machine. The machine is basically used in two operations: (1) for claws and two processing lines, and (2) for claws and for cores with lump meats previously removed. The cores and claws are first crushed in the mill. Then a mixture of shell, bone, and meat is discharged into a brine flotation tank. The specific gravity of the brine is controlled so that the heavier shells will sink to the bottom of the tank where they are carried out by conveyor while the meat flows to the surface and is carried by pump-induced water current to the opposite end of the tank where it is skimmed off by a flume. The flume discharges the meat into a perforated stainless steel conveyor belt where the meat is first washed with fresh water and then inspected by hand.

The machine is sold for a set price plus installation. A royalty cost is assessed on the amount of pounds produced.

The increasing cost of labor has created an industry demand for the mechanized processing of blue crab meat. Some of the processing equipment produced has been adopted by industry while others have not progressed past the developmental and prototype stages.

The machines previously described were discussed in some detail because their visibility to the industry was well documented.

In discussing the following machines, some information may be lacking because the individuals and companies concerned have not released substantial information concerning their inventions.

Innovative Seafood Systems

Innovative Seafood Systems of Rockville, MD, developed a machine which removed the lump and flake meat with hydraulics. Cooked crabs are manually placed into a holder in the machine. A saw cuts the crab cores on the inside of the knuckles and an additional saw removes the viscera. The machine contains two dies that match and index against the crab cores. One hole is opposite the back fin meat while the other holes are opposite the leg meats. A stream of water pressure was applied to the die hole opposite the flake meat washing the meat free from the shell. Water pressure was subsequently applied to the hole opposite the lump meat. Both meats were discharged onto an inspection table. The meats were separated in a two-stage operation so that both the lump and flake meat could be obtained from the crab. The crab core is held on a rotating disc and transferred to the various steps by the use of pneumatics.

The machine has not be placed in operation because the lump meat was broken into fragments by the water pressure. Additionally, one of the inventors was involved in a fatal car accident and the company ceased operations.

George H. Harrison

George H. Harrison, Harrison Seafoods, Inc., Newport News, VA, has developed a machine to produce a single grade of crab meat. All individuals who have been given access to the machine have been requested to sign a legal statement forbidding them to comment on the machine unless permission has been received from Mr. Harrison. Consequently, this writer is unable to comment because the necessary legal documents have not be processed. It is recommended that anyone interested in the machine, its capabilities and costs, should contact Mr. Harrison at his office in Newport News, VA, or at his home in Poquoson, VA.

Savory Seafoods, Inc.

A new machine has been marketed by Savory Seafoods, Inc. (Tolley, Reinke, Brooks, and Rogers). The machine has been placed in several crab plants in Virginia and Maryland (The J. M. Clayton Company, Cambridge, MA; Meredith and Meredith, Wingate, MD; and P. K. Hunt and Son, Hampton, VA) on an experimental basis. This machine has generated considerable interest in the seafood processing industry. The machine has not been offered for sale, but the inventors have stated their desire to place a machine within the seafood industry on a lease/royalty basis within the near future. Basically, crab cores are produced either by hand or by the Reinke Debacker, then placed into small cavities in a specially designed tray. The cores are oriented with the knuckle side up and a sheet of rubber is placed over the cavities which, in turn, is secured by a clamp. The crab basket is placed on an off-centered cam and vibrated at extremely high speeds in a concentric motion so that the meat is shaken from the cores. The meat is produced in one grade with little or no shell. Lump meat cannot be produced. The yields are reported to be higher than that which can be obtained with hand pickers.

Unfortunately, the high rotation experienced in the machine causes metal fatigue and it is not possible at the present time to operate the machine for extended periods without serious structural fatigue. The production of the cores and their placing in the basket does consume considerable time and effort. However, there is some thought that the increasing cost of labor may make the machine economically competitive.

Communating Machines

There have been several reports that crab meat has been produced from communating machines which produced minced meat. Some of the machines are manufactured by Baade, Beehive, Payole, and Bibun. Basically, the crabs are bobbed, placed on a neoprene band, then fed into a rotating drum. The drum is perforated and the pressure exerted on the crab core between the drum and the neoprene belt squeezes the meat through the perforations to the inside of the drum. A wiper scrapes the meat from the inside of the drum to the outside where it is collected in a container.

There have been several problems with meat produced in this fashion. The meat is produced in very small particles and is only suitable for use in further processed items such as crab cakes and stuffed crabs. It appears that the market for such meat is limited and those already producing meat with the Harris machine have not been able to develop sufficient sales to parallel maximum production capability. Secondly, the pressure between the neoprene belt and the drum causes considerable crushing of the shell (red crab excepted) and some of the shell is included in the final product. Consequently, the meat is gritty and is considered objectionable by taste panelists. At present, little, if any, meat is being produced with the machine.

Michael Rossnam

Mr. Rossnam of Maryland has produced a machine that has not been widely demonstrated to the seafood industry. Attempts by this writer to view the machine were unsuccessful. Basically, crabs were placed into the machine and the meat was removed with a vacuum.

No comment can be given about the suitability of the machine except that the industry members who have viewed the machine felt that it had some limitations. At present, the machine is not being used by the industry.

Key Electro Sonic

The Key Electro Sonic Company has produced a complete line to process red crabs. A machine has been purchased by a blue crab processor in North Carolina but he has not reported on the suitability of the machine. The complete process line includes cookers, butchering machines, and roller extractors. Several companies purchased the equipment for red crab meat production and have expressed their satisfaction with the equipment.

The equipment may not be completely suitable to blue crab processing because red crab meat is produced in only one style of pack.

Bird Centrifuge

Cooked crabs (any species) are cleaned and eviscerated, then chopped or ground to a suitable particle size (less than 3 cm). The mixture of meat and shell is fed into a centrifuge with a continuously circulating brine (15%) system. In the centrifuge (200-800 rpm) a pool of brine is held on the outside of the bowl. The shell material sinks to the outside where it is conveyed away. The meat floats with the brine and is screened out at the exit port.

The machine has not been used with blue crabs, however, crab plants in Alaska and Maine have used the equipment for their respective local (king and sand) crabs. It is not known whether the centrifuges are currently being used.

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DISCUSSION

Q. **May Usannaz**: What is the proper way to cool boiled crabs? I've heard old timers say that you are supposed to leave them at room temperature until they are cool before you put them in a cooler.

A. **Mike Moody**: Certainly if you put them in a cooler they will cool much faster. The only problem you might have is that you will warm your cooler up, thus possibly creating problems with the other foods already in there. Ideally, you would have a separate cooler to put the crabs in to chill until they can be handled and picked. You could leave them at room temperature as long as they were picked quickly thereafter. Once the crab meat has been picked, then move the meat to your cooler immediately. Some people cool whole crabs overnight. Many people will back the crabs as soon as they are cool enough to handle. Dr. George Flick may want to comment on this also.

Q. **Larry de la Bretonne, Jr.**: Could you outline the differences in having the crabs under the water and on top of the surface in terms of boiling and cholera organisms?

A. **Moody**: Larry has a good point. In examining methods of cooking, we found that sometimes a crab leg or part of the body would be sticking out of the water, and in some cases, the crab itself would float at the surface while being cooked in boiling water. These crabs do not cook sufficiently and will have cool spots. The crabs should be completely submerged under the water to get a total, reliable cook.

Q. **Elliott Norse**: Did you see a little tiny epidemic or was it a matter of detection? Could cholera have been there for a long time, perhaps at very, very low levels?

A. **Moody**: If we knew that we could answer a lot of questions. We don't know. Certainly we had an epidemic, we had 11 people become sick. It was a cluster, so to speak, not an isolated case.

Q. **Dr. Gordon Gunter**: Was there ever a time when cholera was endemic to Louisiana?

A. **Moody**: Yes.

Q. **Gunter**: How long ago was that?

A. **Moody**: In 1830 or 1832, we had severe cholera epidemics in New Orleans, In fact, at one point, one out of every seven persons in New Orleans died from either cholera, yellow fever, or some other disease.

Q. **Ray Rhodes**: George, what is the status on that centrifuge machine?

A. **George Flick**: Basically, the machine had a lot of fatigue problems in the metal. The vibrations were very tough on the metal and welds, so the machine had a hard time staying together. The outlook for success with that machine has been somewhat diminished; in fact they feel that another way may be the better way to go. Kim [Kimball Brown, Hunt's Crabmeal Company, Hampton, Virginia], do you want to make any comment on that? You are associated with that company.

A. **Kim Brown**: Perhaps I could. That machine is owned by Sea Savory and the prospects for that machine for continued productivity are pretty nil.

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GENERIC IDENTIFICATION OF COOKED AND FROZEN CRABMEAT BY THIN LAYER POLYACRYLAMIDE GEL ISOELECTRIC FOCUSING: COLLABORATIVE STUDY[1]

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ABSTRACT Ten collaborators were required to focus the urea-extracted proteins from 14 crabmeat samples. Six of the samples were knowns and were labeled as to their species. Eight samples were unidentified as to species and were labeled with letters. The 8 unknowns were identified by comparing the focused patterns with the patterns of the 6 species-labeled crabmeat samples. Seventy-nine samples were identified with 97.5% accuracy. This method had been adopted official first action.

INTRODUCTION

The method as reported earlier (Krzynowek and Wiggin 1979) states that identification of species with a genus is possible in cooked crabmeat. However, cooked crabmeat from the Cancer genus, Jonah (*C. borealis*), rock (*C. irroratus*), European edible (*C. pagurus*), and dungeness (*C. magister*), all display the same protein pattern when thin layer polyacrylamide gel isoelectric focusing is used unless extreme care is taken. Species identification with a genus requires several days of analyses, multiple plates at varying pH ranges, and sample concentration.

It was felt that this effort was beyond the scope of a collaborative study and unnecessary for differentiation among the commercially available cooked crabmeat (e.g., snow, king, dungeness), all from different genera. The different genera are easily distinguishable by their specific protein banding patterns after isoelectric focusing. The analysis for generic identification requires one plate at pH 7-9 and about 24 hours for a reliable identification. For purposes of a general method for widespread use, the method was amended from species identification to generic identification for the collaborative study.

Ten collaborators were each sent 14 cooked and frozen crabmeat samples. Six of the samples were labeled as follows: red (*Geryon* spp.), blue (*Callinectes* spp.), snow (*Chinonectes* spp.), king (*Paralithodes* spp.), stone (*Menippe* spp.), and Jonah (*Cancer* spp.). The remaining 8 samples were unidentified and were labeled with letters. These included the 6 genera, 2 in duplicate. Different duplicates were sent to each collaborator, so that sampling would be unbiased. Additional items supplied to collaborators were supplied for convenience only, and comparable substitutions could be made.

Collaborators were instructed to identify the unknown samples by comparing their focused protein banding patterns of the known samples focused on the same plate. Bands were stained according to Righetti and Drysdale (1974).

METHOD

(*Caution:* Inhalation, ingestion, or absorption of acrylamide may cause nervous system disorders. Wear disposible gloves when preparing and handling gels.)

Principle

Urea-extracted proteins are exposed to pH gradient created by isoelectric focusing on thin layer of polyacrylamide gel. Pattern of sample is compared with those of known genera.

Apparatus

Thin layer isoelectric focusing equipment (TLIEF).—MRA Model M-150 (Medical Research Apparatus, Cephas Road, Clearwater, FL 33515), or equivalent.

Constant temperature circulator.—Any which can maintain 0 to 10°.

Power supply.—Constant power-type capable of maintaining constant power of 1 watt up to a minimum of 500 V.

Reagents

(a) *Anolyte solution.* – 0.1% (v/v) ph 7-9 ampholyte. Store in refrigerator.

(b) *Catholyte solution.* – 1.0% (v/v) ph 9-11 ampholyte. Store in refrigerator.

(c) *Ampholyte solution.* – Mix 2 parts ampholyte pH 7-9 (dry content 40%) and 1 part ampholyte pH 3.5-10 (dry content 40%). (Brinkmann pHisolytes and LKB Ampholines have been used interchangeably [LKB Instruments, Inc., 1221 Parklawn Dr., Rockville, MD 20852]). Store in refrigerator.

(d) *Urea.* – 10M ultra pure (Schwarz/Mann, Orangeburg, NY 10962); prepare fresh daily.

[1]Reprinted in part with permission from *J. Assoc. Off. Anal. Chem.* 64(3):670–673, 1981.

(e) *Ammonium persulfate solution.* – 10%; prepare fresh weekly.

(f) *Polyacrylamide mixture.* – Dissolve 20 g acrylamide and 0.8 g N_1N'-methylene-bisacrylamide (Bis) in H_2O and dilute to 100 mL. Store in refrigerator.

(g) *Stain I.* – 0.1% anhydrous $CuSO_4$ and 0.05% Coomassie Brilliant Blue R-250 in HOAc-EtOH-H_2O (10 + 30 + 60).

(h) *Stain II.* – 0.1% Coomassie Brilliant Blue R-250 in HOAc-EtOH-H_2O (10 + 25 + 65).

(i) *Destain.* – HOAC-EtOH-H_2O (10 + 10 + 80).

Preparation of Sample

Blend 1 gram thawed crabmeat equal to mL 10 M urea 2 minutes using mechanical blender, or until well macerated using hand tissue grinder. Blender method yields darker bands after staining. Centrifuge at 3000-13,000 × g, draw off supernate, and refrigerate for same day use.

Preparation of Gel

Prepare gel mold according to specifications of ampholyte manufacturer, using 1 mm spacer bar. Prepare gel fresh daily by adding following reagents sequentially to flask for 250 × 110 × 1 mm gel: 16.4 mL 10M ultra pure urea, 6.0 ML *50% glycerol,* 10.0 mL polyacrylamide mixture, and 2.4 mL ampholyte solution. Degas under vacuum for 3 minutes. Add 100 μL 10% ammonium persulfate and degas additional 1 minute. Quickly transfer gel to mold with Pasteur pipet. When gel has polymerized (approximately 30 minutes), refrigerate mold at least 15 minutes, and carefully remove template and spacer, leaving gel adhered to glass plate. Place plate on cooling platform over thin film of *light paraffin oil.*

Determination

Thoroughly wet electrode strip (supplied by TLIEF manufacturer) with anolyte solution and align on gel surface with anode. Wet second strip with catholyte solution and align on gel with cathode. Place these wicks on edges of gel, approximately 90 mm (center to center) apart and aligned such that Pt electrodes embedded in slab cover plate rest on wicks and provide electrical contact. Place 5 × 10 mm wicks of Whatman 3 MM paper close to, but not in contact with, anode wick. Pipet 20 μL extract onto each sample wick. Two wicks of 20 μL extract each can be laid on top of each other to obtain darker protein pattern after staining. Cool platform to 0–10° and connect focusing equipment to power supply. Observe proper polarity. Apply 1 watt constant power up to a maximum to 500 V. Continue focusing at 500 V constant voltage approximately 20 hours.

Switch off power and remove gel from cooling slab. Clean paraffin oil from plate and put elastic bands around glass plate and electrode wicks. Stain protein at room temperature as follows: stain I, 4 hours; stain II, 4 hours; destain, 1 hour. Identify unknown samples immediately after destaining by comparing patterns with known extracts.

RESULTS AND DISCUSSION

Table 1 shows the sampling plan used and summarizes the identifications made by the 10 collaborators. Of the 79 unknown samples that were focused using this method, 77 were correctly identified. Sample T was reported with no result from Collaborator 5 and was not included in the statistical analysis. Collaborator 5 did, however, correctly identify Sample Q–the blind duplicate of Sample T. The two incorrect identifications were made by Collaborator 2. Samples T (king) and P (Jonah) were incorrectly identified as Jonah and snow, respectively. It is difficult to account for the incorrect identifications because no photograph or depiction of the patterns was submitted with their results. The overall average for correct identifications was 97.5%.

Five collaborators documented a deviation from the collaborative method. To obtain supernate, they had to use speeds up to 13,000 × g instead of the stated 3,000 × g for 30 minutes. In most cases, centrifuging time was reduced to about 4 minutes. The method, as now outlined, reflects these comments and gives a range of centrifuging speeds. The time and speed necessary to obtain supernate can be determined by the individual laboratories.

The collaborative study showed that, while banding patterns were similar among laboratories, differences did occur due to focusing time, protein loading, and extraction procedures. Reliable identifications from multiple laboratories necessitate that authenticated samples be focused simultaneously with the unknowns.

It is recommended that the proposed method for generic identification of cooked and frozen crabmeat be adopted official first action.

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TABLE 1.

Results of collaborative study of the method for generic identification of crabmeat by thin layer polyacrylamide gel isoelectric focusing.

		Collaborator*										
Sample	**Sample Code**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**No. correct/no. samples**
Blue	R	C	C	C	C	C	C	C	C	C	C	12/12
	K			C					C			
Red	S	C	C	C	C	C	C	C	C	C	C	13/13
	O		C				C	C				
King	Q	C	C			C	C			C	C	14/15
	T	C	W	C	C	N	C	C	C	C	C	
Jonah	I	C		C	C	C	C	C	C	C	C	10/11
	P		W						C			
Snow	H	C		C	C	C	C	C	C	C	C	12/12
	J		C		C	C						
Stone	G	C	C	C	C	C	C	C	C	C	C	16/16
	L	C		C	C			C		C	C	
No. correct/no. samples		8/8	6/8	8/8	8/8	7/7	8/8	8/8	8/8	8/8	8/8	77/79

*C = correct identification; W = wrong identification; N = no result.

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GOOD MANUFACTURING PRACTICES: SHELLFISH INDUSTRY

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In an article by Ernest J. Briskey (1976), which appeared in *Food Technology*, he made a very interesting point in outlining the development of regulatory agencies and acts:

> ". . . . our nation managed to survive for more than 100 years without a single federal regulatory agency. The first to come was the Interstate Commerce Commission, established in 1887 to control the railroads. It was almost two decades before our second major federal regulatory legislation, covering meat, food, and drugs was enacted in 1906. That was the last until the economic and technological developments during and following the great depression led to the creation of the Federal Power Commission in 1930; the Federal Communications Commission in 1934; the Federal Maritime Commission in 1936; and the Civil Aeronautics Boards in 1938."

Dr. Briskey continues by writing:

> "In recent years, some Americans have apparently been asking whether any risks are worth bearing regardless of the benefits. Acting at least partly within the framework of this mood, Congress and the administration reacted with a flood of new laws and regulations in the late 1960s. We now have the Environmental Protection Agency; a Hazardous Substance Labeling Act; a Clean Air Act; a Food, Drug, and Cosmetic Act; an Explosive and Combustible Act; a Consumer Product Safety Act; an Occupational Safety and Health Act; and many more, with even greater numbers in prospect. In all, we have more than 50 regulatory agencies in the federal government, many of which exert controls over the food industry. Each state, in addition supports at least one agency, and most have several, to regulate various aspects of the food business."

It was in the climate of the 1960s when the Food and Drug Administration (FDA) issued its first Good Manufacturing Practice (GMP) entitled "Human Foods, Current Good Manufacturing Practice in Manufacture, Processing, Packing or Holding." This document describes such criteria as sanitation, plant and grounds, equipment and utensils, sanitary facilities and controls, sanitary operations, processes and controls, and personnel; however, these apply generally to the manufacture of all food products including blue crab meat. As many of you are well aware, for years it was rumored that a GMP specifically for the blue crab processing industry was forthcoming. As many of you are also aware, there certainly was ample precedent to assume that a blue crab GMP was "in the mill" in as much as there already existed specific GMPs for the candy industry, for bakery goods, the tree nuts and peanut industry, the smoked fish industry, and a GMP was proposed, but subsequently withdrawn, for the molluscan shellfish industry.

The regulatory philosophy of the FDA with respect to an industry-by-industry approach has apparently changed. The FDA indicates that the problems addressed by the umbrella GMPs are common throughout all segments of the food industry, e.g., personnel, plant construction, and sanitation. Accordingly, the agency believes the most efficient way to proceed now is to revise the umbrella GMP regulations rather than repetitively propose identical regulations for numerous segments of the industry.

In looking over the proposed revision of the umbrella GMP, two items are deserving of special mention. The proposed GMP specifies holding temperature:

> ". . . foods that can support the rapid growth of microorganisms of public health significance or that are subject to decomposition as a result of microbial multiplication shall be held in a manner that minimizes the growth of those microorganisms. Compliance with this requirement may be accomplished by any effective means, including:
> a) maintaining refrigerated foods at 45°F or below as appropriate for the particular food involved.
> b) maintaining frozen foods at 0°F or below.
> c) maintaining hot foods at 140°F or above."

Look a little more closely at item a), maintaining refrigerated foods at 45°F or below. For years the generally recognized upper limit for the refrigerated storage of perishable food products has been 40°F. In fact, many state laws require the holding of refrigerated food, including crabmeat, at 40°F or below; furthermore, in the candy industry GMP, the FDA required 40°F or below. However, with energy costs being what they are, the FDA has examined the requirement because they found the cost of maintaining foods at 40°F was significant. A refrigerator operating at an ambient temperature of 70°F requires 20% more energy to operate at a temperature of 40°F than to operate at a temperature of 45°F.

I am concerned about the impact this regulation may have on the shelf life of marine food products if the upper limit of 45°F is adhered to throughout the distribution channels. In fact, there is another set of regulations the FDA has proposed called "Model Retail Food Store Sanitation Ordinance" which states that, ". . . potentially hazardous food requiring refrigeration after preparation shall be rapidly cooled to an internal temperature of 45°F or below." As of this writing, this proposal is still in the initial stages; however, it is not altogether unlikely that crabmeat, as well as other seafoods, may encounter 45°F at the retail level. I feel the blue crab industry should be very careful in implementing any product storage temperature above 40°F. Moreover, I feel the industry should go a step further and actively encourage retailers to keep seafoods at 40°F or below, irrespective of any ordinances which allow for an upper limit of 45°F.

The second thing I would like to mention regarding changes in the proposed umbrella GMP is that of product coding. The current GMP addresses the coding issue by stating:

> ". . . meaningful coding of products sold or otherwise distributed from a manufacturing, processing, packing, or repacking activity should be utilized to enable positive lot identification to facilitate, where necessary, the segregation of specific food lots that may have become contaminated or otherwise unfit for their intended use."

Because the FDA considers voluntary product recalls by manufacturers one of their most useful regulatory tools, the agency is proposing to expand the coding provisions in the new GMPs. Wording on the proposed GMP reads:

> ". . . based on coding's recognized utility and accepted use in many segments of the food industry, the agency believes product coding should be mandatory for all foods. Accordingly, the agency is proposing, except where specifically exempt, to require permanently legible marks at a readily visible location on each finished food package delivered or displayed to purchasers (except for over-the-counter retail sales at the site of manufacturer), so that the code marks can be easily seen on the unopened package. The marks must identify at least the plant where the product was packed and the product lot or packaging lot. It is recognized that a packaging lot may contain food manufactured on more than one day but packaged on a single day."

There are some exemptions but they apply basically to retailers. As is apparent, the proposed coding requirement is somewhat more stringent than the coding provision of the current GMP.

There are other revisions in the proposed umbrella GMP; however, I see no point in listing them individually, because many of them are merely a codification of what the processing industry is already going.

While the proposed GMPs do have some new provisions, a few of which we just discussed, and some of which may cause problems to certain companies within the industry, I am of the opinion some of the biggest problems come from within the industry itself. I have been to a number of crab plants over the past several years, in operations which range in size from small to large, and I have formed the opinion that the vast majority of owners and operators within the industry are good, honest people who take pride in their plants and the product they produce. However, there is a segment of the industry, although small, that casts a giant shadow. These are the people who do not put a single nickel back into the business for general maintenance, much less improvement. Consequently, part of the general public has the wrong impression about the industry as a whole. Furthermore, many of these mavericks— there are good mavericks and bad mavericks, we are talking about the bad—create problems for the rest of the industry by stretching the truth about product content, thus they are able to underprice the processors who are selling their products for what they are. These are examples of issues I would like to see the GMPs address and the FDA enforce.

One thing the GMPs do not address is the specific processing parameters by which crabs are to be cooked. Obviously, the umbrella GMP cannot be so specific; however, these processing parameters are, in some instances, spelled out by the states. Some states require that crabs be cooked under pressure (steamed), and some states will allow crabs to be either boiled or steamed. Ever since I started with Virginia Tech in its marine food products program, I have heard discussed the merits of boiling versus steaming and vice versa. I do not plan to indicate which I feel is the best method, they both have advantages and disadvantages. Some of my good friends at Texas A&M and I have been looking at the boiling process, and at the effect backing and eviscerating live crabs prior to boiling have on the microbiological quality of the meat, the texture of the meat, and the energy efficiency of the process. The verdict isn't in yet, but the rationale of the study is that if you eliminate some of the primary sources of bacteria prior to cooking, the cooking process will be much more efficient in destroying microbial populations. Furthermore, since a large percentage of the bulk has been eliminated prior to cooking, the energy required to cook the product may be significantly reduced.

Regarding the steaming process, at Virginia Tech we have been looking at various variables which may affect the efficiency of the steaming process. Variables we are investigating include: ambient temperature, physiological state of the crabs, and cooking time. Again, the verdict is not in—but one of the things we have found is that steaming crabs in anything but a full retort runs the risk of significantly undercooking the crabs.

In closing this talk regarding GMPs, let me stress—no matter how well you maintain your plant or how thoroughly you cook, refrigerate, sanitize, and anything else related to good manuacturing practices, unless plant workers follow reasonably good sanitary practices, the final link in the chain is weak. The reason is obvious; crabmeat is one of the few high protein foods I can think of that is so thoroughly handled subsequent to the cooking step, a step which is, in part, designed to reduce bacterial numbers.

Cathy Biediger, a recent graduate student of Dr. Ranzell Nickelson (Texas A&M), conducted a study on "The Effects of an Employee Educational Program on the Bacteriological Levels of Blue Crab Meat." What Ms. Biediger found was that a large plant, which has a relatively high employee turnover, benefitted significantly from an employee sanitation workshop; however, a smaller operation, which had workers that had been with the plant for years and was traditionally known for producing meat of good bacteriological quality, did not benefit as dramatically.

In essence, what the study found was that employee educational programs may be of very direct and positive influence on large operations which have a high employee turnover rate. The educational training indicates the need for good sanitary practices and the consequences of poor practices. It would probably be erroneous to assume that smaller plants do not benefit by the employee sanitation program since any reinforcement of existing knowledge or explanation of reasoning behind established sanitary practices is beneficial. Consequently, I would offer for your consideration as an additional good manufacturing practice, the establishment of a periodic employee-education program.

In conclusion, I think it is probably fair to say, if you happen to be a crab processor, or any food processor for that matter, that your definition of a GMP may reflect the ability of your company to comply or perhaps cope with the regulations. If you happen to have no problem with them, then GMP may stand for ***Good, Meaningful, and*** perfectly ***Practical.*** If you are having a problem, then you may define them as ***Grief, Misery, and*** pittifully ***Picky.*** My feeling is that most processors fall somewhere between these two extremes, consequently your definition is in the form of a prayer—***"Give Me Patience."***

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REVIEW OF WASTEWATER REGULATIONS FOR THE SEAFOOD INDUSTRY

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On August 29 [1979], the Environmental Protection Agency (EPA) withdrew the best available technology (BAT) effluent guidelines for all seafood categories. Through persistent and detailed lobbying by the National Food Processors Association (NFPA), the National Fisheries Institute (NFI), and some additional pressure exerted by the National Marine Fisheries Service (NMFS), the EPA was finally convinced that the regulations, set to go into effect in 1983, were not based on valid data or assumptions. Therefore, the regulations to be met now will stay in force until the EPA reevaluates the entire seafood wastewater situation. Additionally, seafood processing plants renewing their permits will not have to meet the BAT standards.

This is especially important to the blue crab business because a study of six crab plants in Maryland that used manual labor to pick crabs showed that these plants could not meet the BAT regulations for the two most troublesome components of wastewater–biochemical oxygen demand (BOD) and total suspended solids (TSS). That is, those plants could not meet the regulations without buying their own water-treatment equipment.

In reviewing wastewater regulations, historically the laws have been one of constant change. Another major change was made during the summer of 1979 which affected the complete system of EPA/state permits.

The federal government became directly involved with industrial wastewater primarily after the passage of the Federal Water Pollution Control Act in 1972. That Act gave the EPA a mandate and the authority to (1) prohibit the discharge of toxic pollutants in toxic amounts; (2) to establish a goal for water quality that must be met by 1983, allowing for safe recreation, and for the protection and propagation of fish, shellfish, and wildlife; (3) to make grants to municipal sewage systems for construction or upgrading of equipment to meet the water quality standards; (4) to help development of regional wastewater treatment systems; and (5) all of the above to lead toward totally eliminating pollution discharge by 1985.

Evolving from the Federal Water Pollution Control Act came the National Pollution Discharge Elimination System (NPDES) program of permits. The NPDES permit system is the instrument by which the EPA intended to meet the 1983 goal. The permits were required only by those seafood plants that drained their process water back into a body of water. If the plant was hooked up to a city treatment system, then the permits were not applicable, but, eventually some pretreatment regulations, developed by local sewer boards, will have to be met. If a plant consistently processes less than 3,000 pounds of live crabs per day, the EPA does not require a permit.

Most states have developed the necessary program to administer, with EPA approval, the permit system. These permits, however, are not just for seafood plants; they apply equally to other food producers, to industry, and to the municipal sewage systems. The program has two sets of regulations that all industry must meet, but not necessarily the same set of specific requirements. The first set of regulations for blue crabs and some other seafoods was published in 1974. These are known as the best practicable technology (BPT) standards. The overboard discharge of a plant was to comply with this regulation by July 1, 1977, using the "best practicable control technology currently available." At that time this meant installing a screen in the wastewater stream to strain out solids, and trying to keep spilled meat out of the wastewater stream. This is known as dry cleanup, i.e., sweeping the floor, cleaning off the tables, and putting this solid waste into garbage cans before hosing down the picking or packing rooms. That keeps the meat and body parts out of contact with the water thereby cutting down on the leaching of nutrients into the wastewater stream. These BPT regulations set limits on TSS, oil and grease (O&G), and pH of the wastewater. Some states have added settleable solids (SS) to their permits; other states do not require that TSS or O&G be regulated. It all depended on what agreement the state had with the EPA. States also have the option of enforcing more stringent regulations than those set by the EPA. The Maryland study also found that crab plants were not meeting TSS requirements of the present BPT standards.

The second set of regulations, intended to go into effect in 1983, was the BAT requirements. By 1983, there was to be less TSS and O&G in the wastewater, plus a new indicator of the organic load called biochemical oxygen demand (BOD). These regulations were to be met by using the "best available technology economically achievable." To meet those regulations, a processing plant would have to buy some expensive water treatment equipment if that plant could not hookup to a local sewage treatment system.

The original Water Pollution Control Act was amended in 1977 by the Clean Water Act. Part of that amending Act requested that the EPA review all BAT effluent guidelines to see if they were economically achievable, and if they were in fact reasonable. If they were found to be achievable and reasonable, then they would be reissued as best conventional pollutant control or BCT standards. After about a year of study, the EPA proposed that for all seafood categories, except small and medium Tanner and dungeness crab plants, the BAT and BCT standards remain as they were. In other words, the EPA did not want to change any of the existing regulations. The NFPA, NFI, and NMFS had felt that the BCT standards would be less stringent than the original BAT regulations. Those groups disagreed with the economic analyses used by the EPA.

The Clean Water Act had a provision that requested the EPA to conduct a one-year study to examine the effects of disposing untreated seafood plant wastes into marine waters. Through a strict legal interpretation of the provision, the study was only carried out in Alaska. The study did not take into account the special conditions of the seafood industry in the warm Gulf of Mexico, or the large bottomfish industry in New England. Their findings were to have been submitted to Congress in January [1979], but a formal report still has not been submitted [October 1979]. However, during a meeting in May 1979, of an advisory council to the Department of Commerce on fisheries matters, an EPA spokesman said that nothing really would be changed because their study found both beneficial and not-so-beneficial effects–it all depended on the local situation.

Thus, the industry is back where it started in 1974. However, that only lasted a few months. In August, the EPA published a final rule which said they were not going to enforce the BAT standards for all seafood categories. They are continuing to study the wastewater situation and, eventually, they will propose a new set of effluent standards, called the BCT regulations. The BCT standards will be more restrictive than the present BPT regulations.

Another major change, which took place during the summer of 1979, was a revision of the entire NPDES regulations. The final rules were issued in June. A review of these revised rules is strongly recommended. A summary of the NPDES regulations is presented below.

Permit Application

If the processing water goes back into the surrounding waters a NPDES permit is required. The permit must be applied for because the state does not visit each plant to issue a permit. There are certain forms which must be filled out and filed. Also, there are civil penalities which can be brought against a plant if it does not have a permit.

A plant with an existing NPDES permit soon to expire must submit a new application at least 180 days before the expiration date.

If the plant has been expanded or reduced in capacity, or a new product line added, then a new application for that wastewater discharge must be submitted 180 days prior to beginning the additional discharge.

Once a permit has been received, state and federal personnel can come into the plant at reasonable times to sample the overboard effluent; they can examine and copy any records that are required to be maintained; and they can check on the method used for sampling.

Wastewater must be sampled periodically; the permit gives information as to how often. The sampling procedure should be designed to test for all possible pollutants in proportion to the quantity and the total volume of water put back overboard. The more varied the waterflow, the more often it will have to be sampled. It is also in the best interest of the seafood processor to sample numerous times so that an average can be obtained.

One paragraph in the regulation states that if the discharge point is situated so that it cannot be sampled, then the EPA or state inspectors can come inside the plant and sample directly. This may present a new set of problems because the wastewater stream may be more concentrated in the plant than it is at the discharge point.

Some plants may have the pipe submerged in the water or in a location where it is not possible to take a sample. In that situation, a sampling manhole should be considered. It does not have to be elaborate. Find a suitable location along the buried pipeline, dig down to it, cut a section out whereby sampling gear can be fitted and the flow rate can be determined. In other cases, a hole may be cut in the dock and a step ladder installed down to the end of the pipe.

All sampling data have to be reported on a monthly or quarterly basis to the state pollution control authorities. In Mississippi, computer preprinted forms are sent to the plants. The sampling data are filled in and returned.

If part of the effluent discharges into a sewage treatment system and another portion goes overboard, then an adjustment can be made to the permit regulations.

A NPDES permit is not required for those businesses or persons who shed crabs if less than 100,000 pounds of harvest-weight animals are handled a year. Also no permit is required for holding green crabs in addition to the shedding facility. Floating crab cars are not covered by these regulations.

The state attorney general can bring civil prosecution and impose fines against any plant owner for willful or negligent violation of any permit standards or permit changes, and for reporting inaccurate sampling data or for interferring with any sampling device.

The entire objective of these regulations is to have zero discharge of wastewater by 1985. By that time, the EPA expects, or at one time did expect, that all seafood plants' effluents would be treated by a municipal or regional treatment plant which could result in larger sewer treatment bills for the processor.

The municipal treatment plant bill would be computed by a charge for the volume of water a seafood processor sends to the treatment facility based on the concentration of either BOD, TSS, or O&G, or any combination thereof. Additionally, an Industrial Cost Recovery (ICR) charge would be imposed.

The ICR charge is a very complicated item. It is supposed to be a charge to industrial users that is in proportion to the cost in federal monies it took to build in the capacity of a treatment plant to process that industry's particular waste properties. Other factors, such as water flow or particular pollutants which add to the cost of treatment, may also be considered in that charge. Federal law will finance 75% of the cost of building or expanding sewage treatment plants, but they want that money back. Congress decided that the ICR charge was the way to do it. Furthermore, Congress would allow the local sewage board to keep up to 50% of the recovered funds for maintenance and expansion.

When the Water Pollution Control Act was amended in 1977, there was a provision requesting the EPA to conduct a study of the implications of the ICR charge because nobody was aware of the ramifications. An 18-month grace period was put into effect which stopped the enforcement of the ICR charge by any sewage board until clarification could be made. In the meantime, sewage boards applying for federal monies still had to draw up an ICR charge plan to obtain the money, but they were not to put that charge into effect until further notice.

That 18-month period terminated at the end of June. During that time, Congress had considered legislation to further extend the moratorium—the House had a bill to add 2 years, and the Senate had a bill to extend it for 1 year. To give Congress time to enact a final bill, the EPA administration granted an extension to the original grace period until December 1, 1979. Hearings on the matter would take place in March 1980. Eventually everyone will be assessed for the ICR charge, but it is not too clear what that charge will incorporate.

June was a busy month for the EPA. Seven days after the final rules revising the NPDES system came out, the EPA published a proposed regulation consolidating permit programs of four federal laws, one of which we have been talking about. Along with that, there would be a set of new forms to fill out when applying for a new permit or a renewal. The draft copies I've seen are quite detailed. There will be one general form and several specific ones.

The general form, besides questions/answers, requires that you send in a topographic map of the area where your plant is located. The area covered by that map must extend 1 mile beyond your property boundaries, and it must show where your water intake is, and where your wastewater discharge point is. You have to pinpoint your plant on the map and outline it; show the map scale; draw an arrow pointing north; figure out your latitude and longitude; if you are on a river, you must show the direction of the flow or, if you are in tidal waters, show the direction of the ebb and flow. The EPA recommends you use a U.S. Geological Survey map of the 7½-minute series. They are available from local drafting supply stores.

On the more detailed form, you must submit a line drawing of your entire plant. You must indicate where each operation takes place in your production process. Additionally, you are required to draw an outline of your water flow from where it comes into the plant through each operation, indicating how much water flows through each operation and how much water is used in packing, or in cooking, or spilled, and how much goes overboard.

You are also required to give complete details of your pollutant sampling, i.e., BOD, TSS, pH, etc., detailing average readings, the maximum found, how many samples were taken, and what type of sample.

The comment period is already over. After publication of the interim final rules, criticisms may be mailed to the EPA. After that, comes the final ruling. So you can see that the seafood industry has two big items to contend with—the FDA quality control regulations and the EPA wastewater regulations.

There is also another aspect of the wastewater effluent situation—solid waste disposal. What can you do with the solid scrap the screens take out of the discharge? It is a very serious problem on top of all the other ones.

As far as dissolved waste is concerned, I think the seafood processors still have a chance to have reasonable regulations written. Now that the BAT standards have been withdrawn, there is a little breathing space wherein the processors and especially the national industry associations can try to make the EPA administrators use their heads and use good data during the time they are reconsidering the regulations.

The EPA especially needs to keep in mind that seafood wastes are not at all like other industrial wastes. It may smell a little bit but it does not necessarily pollute. They need to take a good look at bioenhancement, or the fertilizing of estuarine waters. They have disregarded that fact in the past because they couldn't put a number on it. And I agree, you probably can't. But that in itself is a unique characteristic of the seafood industry's so-called pollution.

I believe the concept of zero discharge is misguided, especially in the case of marine waters. The EPA has traditionally thought in terms of freshwater rivers and streams. A report submitted to the EPA on the gradual "cleaning" up of tuna-cannery wastes to the point of zero discharge in Los Angeles harbor showed that over an 8-year period, during which time the wastewater was screened, then pretreated, and finally sent to a treatment plant, there was a net and permanent reduction in fish populations, bottom invertebrates, and even sea birds. When the BOD and TSS were high in the water, there was a highly productive and diverse resource. When they were low—after being taken out by waste treatment plants—the animal numbers correspondingly were low.

What that study suggested was that managed amounts of screened wastewater can be put into the water to maintain a good nutrient balance and let the treatment facilities take care of the health hazards of domestic sewage and toxic industrial wastes.

In a nearshore estuarine area which must support a tremendous population of young and adult fishes and invertebrates, taking out food resources and returning some of the nutrients to the water may be a circle which should remain unbroken.

NOTE ADDED IN PROOF:

Almost 3 years have passed since the colloquium was held and there has been no official announcement by the EPA concerning the reissuing of the 1984 wastewater regulations. That is not to say that the time interval has been quiet. As stated in the presentation, the EPA withdrew the proposed second level of regulations, which were to take effect in 1984, after a great deal of criticism had been directed toward the agency's standards and the methodology they had utilized to arrive at them. This was in August 1979. They contracted with a consulting firm to make an economic analysis of the impact their proposed regulations would have on the seafood industry. In July 1980, the first draft was published. It was sent out for industry review. In May 1981, a second draft was published and commented on. In the meantime, several trade associations took the EPA to court claiming that the cost reasonableness test formula that the agency used to justify their proposed regulations was not based on valid assumptions. The case was won and the EPA has had to revise their entire approach to setting industrial levels of compliance.

The revised BCT regulations were to have been announced in June of this year; however, the Office of Management and Budget in making their review has held them up. They could appear in the *Federal Register* at any time. Trade association spokesmen say that the new compliance levels will not be nearly as restrictive and costly as the original ones were. They may not go much beyond the BPT screening requirements.

Another change has taken place since 1979. The Industrial Cost Recovery provision discussed in the presentation has been dropped after much opposition by industry. The government, however, did require that any municipal sewer system which received federal monies for construction purposes between 1973 and 1977 must collect the ICR charges they should have gotten from industry but didn't. It is possible that some seafood plant owners may get a bill from the city with these charges added to it.

During this time, there appeared another anti-business addition to wastewater regulations called the Industrial Cost Exclusion clause. This would have denied any federal money for sewerage construction if part of that expansion was for handling industrial wastewater. That would have forced businesses to either directly bear the prorated costs of municipal expansion in relation to their wastewater flow or industry would have had to install their own treatment equipment. This ICE provision was killed.

DISCUSSION

Q. **Russ Miget**: Allison, I am still confused. I thought I knew what was going on. Are we up to zero discharge by 1983?

A. **Allison Perry**: No, there is not anything going to take place in 1983 right now. Zero discharge was the ultimate goal of the EPA, and was to take place in 1985.

Q. **Miget**: Will the EPA now consider land applications in addition to treatment by municipal sewage plants? There is also a possibility of wetland application, it could even be, perhaps, a bioenhancer in this instance.

A. **Perry**: As I see it now, the EPA wants all plants to hook into a treatment system. They have encouraged this by the ICR portion of the Clean Water Act, whereby a local sewage board can keep one half of the money they collect.

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CRAB SCRAP–CONVENTIONAL AND PROSPECTIVE UTILIZATION

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ABSTRACT After 4 years of involvement with crab-scrap disposal in Hampton, Virginia, the hub of the blue crab industry in the world, two factors have become glaringly apparent. The community-at-large, most of whom consider crabmeat a gourmet's delight and many of whom benefit directly from the influences of the industry in their community, has no knowledge or concern about the importance of crab-scrap disposal. Similarly, crab factory owners, totally engulfed in production, processing and sales, seem to ignore or try to forget, the tragic consequence that would ensue if their only vehicle for crab-scrap disposal–crabmeal production–were to vanish.

The blue crab catch from the Chesapeake Bay ranges annually from 50 to 80 million pounds. Of a 50-million-pound annual catch, 10% can be deducted for "cook loss," and another 12% to "picked meat." The remaining 78% or 39 million pounds is "crab scrap." Therefore, the blue crab industry in Chesapeake Bay is responsible for the disposal of 20,000 tons of waste in a low-catch year, and as much as 30,000 tons in good years. The Virginia Shellfish Sanitation Code states that each crab factory, despite the availability of private or public disposal services, is solely responsible for their own scrap.

During the 19th century, there were no regulations nor problems regarding scrap. It was dumped into creeks and estuaries, scattered on farmlands, piled in remote areas, or buried in pits. During the 1920s and 1930s, the industry realized it could no longer treat crab scrap with such abandon. One of the first collection services was started in Hampton, VA, during the mid-1930s. Scrap was collected, sun dried on flats, and ground for fertilizer.

This method was soon replaced by the system that is used throughout the Chesapeake Bay and Pamlico Sound areas today. Scrap is collected and conveyed into a rotary drum dehydrator which is heated by an oil-fired furnace. The dried scrap then passes through a cyclone separator to a hammer mill. Nearly 100% of all crabmeal produced is now sold to feed mills for resale to the poultry industry.

Dehydrating and grinding crab scrap is not the total solution to pollution problems. The exhaust emission from cyclone separators, in volumes upwards to 20,000 cubic feet per minute, is moisture laden, contains some degree of particulate, and carries odors that many find objectionable. In most instances, to rectify this condition with air scrubbers and odor-control devices would require funds in excess of the total worth of the plant involved. Meal plants are confronted with two choices–comply or close. Compliance, in one known situation, would require $180,000.

The Hunt Crab Meal Company of Hampton, Virginia, processes the largest volume of blue crab scrap in the entire industry. Should this plant cease to operate, the entire blue crab industry in the lower Chesapeake would be in peril, if not totally out of business.

The severity of the problem of complying with air pollution control regulations is demonstrated by an incident that occurred at the Hunt plant in the fall of 1977. A major mechanical breakdown and ensuing scrap processing downtime required gaining permission from the city council to dispose of the scrap at the city landfill. Permission was granted at the rate of $5 per truckload or, in this case, $15 to $20 per day. Within 3 weeks, the city denied depositing more than one load per day because the landfill employees had threatened mutiny due to the objectionable odors from the scrap even though the scrap was immediately covered with 18 inches of earth. As an alternative, the city granted permission to deposit scrap at a private landfill. This resulted in a fee of $20 per load or between $60 and $80 per day. This continued for approximately 2 months. The city then received strenuous complaints from the Air Force whose runway glidepath swarmed with seagulls because of its proximity to the landfill. This occurred just as the plant was coming back on-line. If the Hunt plant had not come back on-line at that time, crab factories would have had to close down completely.

At present an incinerator is under construction with funding from the federal and local governments in combination with the National Aeronautics and Space Administration. It has been made abundantly clear that completion will not provide an alternative for the disposal of crab scrap.

Aside from pollution-compliance problems, crabmeal processors are uneasy because the poultry industry is the only market for crabmeal. Poultry feed includes a scientifically calculated blend of ingredients. Crabmeal constitutes only one half of 1% of the total of those ingredients. To some of the larger feed mills that amount is too insignificant to include in their formulas. Smaller producers include crabmeal but may eliminate it entirely for a period of weeks or months. Within the past 4 years, two former, regular users have dropped crabmeal completely because of fluctuations in protein percentages from their various sources and the inconsistancy of supply. This is the result of natural causes, such as weather and climate conditions as they affect crabbing, the availability of crab pickers, and the market price of other feed ingredients.

Another long-range concern of some crabmeal plant managers is the decline in the protein percentage of crabmeal that would result from wide use of a recently developed picking machine. This machine, unlike others currently in use, produces excellent quality meat and provides nearly 100% extraction of body meat. Crab factories could appreciably increase their meat yield but this would correspondingly reduce the protein content of crabmeal. Feed mills require a guaranteed 31% protein in crabmeal. A reduction of only 3 or 4% could eliminate crabmeal from feed formulas.

The selling price of crabmeal is based upon the bulk price of soya meal in the Chicago market. The return on crabmeal, though somewhat variable, is generally accepted to be 70% of soya meal. However, crabmeal producers cannot predict whether feed mill computers will "pull" or "drop" crabmeal from their formulas in any given week. In view of these marketing considerations and the spiraling costs of labor, fuel, maintenance, repairs, etc., that confront all industries, it is becoming increasingly evident that meal plants must struggle to operate on anything better than a breakeven basis.

What, then, does the future hold for the crabmeal business? This is a matter that should be seriously considered by the entire blue crab industry.

There is only one known alternative to the conventional method of disposing of crab scrap. It is the revolutionary prospect of engaging in the production of chitin and chitosan. This has been accomplished at laboratory levels by research interests in the United States during this decade. Japanese firms are producing chitin on a limited basis.

Chitin, though discovered in the mid-1930s, has not been afforded much attention by potential commercial users. In simple terms, chitin is to exoskeletal crustaceans what cellulose is to wood, or glucose is to humans. It is a marine polymer which provides a bond for calcium in the shell structure of crustaceans including crabs and lobsters, as well as shrimp and krill. Its prospective uses are many, such as in insecticides and rodenticides, in water purification, in filtration of trace elements of heavy metals from sea water, in food processing, in food casings, in medicines and surgery, in burn care, and in many others.

Simply defined, production of chitin requires separating the protein and calcium, then chemically extracting the chitin from the calcium. There are two criteria important to the location of a chitin plant. First, it should be central to the sources of raw materials. A plant located near the lower Chesapeake would be within minutes of the highest concentration of blue crab catching in the area and within 200 miles of crabbing operations throughout southeastern Virginia, Maryland, and North Carolina. Secondly, it would be advantageous for a plant to be located as near as possible to a source for the chemicals required in processing since the cost of bulk chemicals varies with the distance that they must be transported. It is considered by some that the major limiting factor to engaging in full fledged chitin/chitosan production is the transportation of raw materials to the manufacturing facility.

Continuing research, studies, analysis, and performance projections conclude that industrial production of chitin/chitosan is entirely feasible and economically viable. Also to be considered in measuring the profitability of chitin manufacturing is the substantial revenue to be had from the protein concentrate byproduct and the red-dye pigment, astaxathin, that it contains.

The blue crab industry deserves the plaudits of ecologists and environmentalists rather than their criticism and disdain. Catching regulations contribute to annual yield sustainability, all factories comply with rigid processing disciplines and, with the production and marketing of crabmeal, the industry accomplishes total resource utilization. The advent of substantial industrial chitin/chitosan production could eliminate meal plant pollution liability, stabilize the economics of crab-scrap disposal, and produce polymers that would be of great benefit to humanity and the environment.

DISCUSSION

Q. (Unidentified): Do you decarbonate this crab waste with sulfuric acid or hydrochloric acid?

Q. Kimball Brown: Are you referring to chitin production?

A. (Unidentified): Yes.

A. Brown: In the area of chitin production, I don't feel confident to respond; I am not a scientist although I participated in the research as an engineer. I engineered some of the pilot procedures. The steps in chitin production are basically deproteinizing and demineralizing. I wish I could give you a better answer. There is a great deal of "know how" in it, to say the least, and there are a number of alternatives in the initial separation of protein and the calcium.

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CURRENT CONSUMER–ORIENTED TRENDS IN NUTRITION AS RELATED TO CRABMEAT

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The term nutrition has myriad interpretations and applications depending on to whom you talk.

My approach to the subject of nutrition is from the perspective of consumers as it relates to the blue crab industry.

One can hardly pick up a newspaper or magazine these days without seeing a reference to nutrition. What was once an individual or, at most, a family-oriented matter has developed into a topic which has come under nationwide scrutiny. Consumer advocacy groups, government agencies such as the Food and Drug Administration (FDA), Federal Trade Commission (FTC), and the U.S. Department of Agriculture (USDA), members of the food processing industry, and even the Congress of the United States are just a few showing increased interest in nutrition. Indeed, the magnitude of the issue of nutrition is such that a select committee of Congress has (1) already proposed several specific guidelines called "'Dietary Goals for the United States," (2) mandated and awarded grants for nutrition education in public schools, and (3) is presently considering legislation on nutrition labeling that would have a direct impact on the processing industry. In other words, whether we agree or not, the subject of our nutritional status as a nation is one that will remain in the forefront for sometime to come–we will not be able to ignore it–no matter how hard we may try.

This emphasis on nutrition is not new, but has taken on a different thrust in the past decade. No longer is the concentration on malnutrition in the form of deficiency diseases, but, rather the emphasis now is an unprecedented interest in present-day degenerative diseases–heart disease, cancer, and diabetes, to name a few. There is great controversy between scientists and nutritionists over whether or not diet can have a controlling or preventive effect on those diseases. Indeed, there is a great deal of controversy over whether or not the basic food supply and diet of the general public are nutritionally sound. This debate has been brought to the forefront of public attention via the recommendations of several public groups, among them the Select Committee on Nutrition and Human Needs of the U.S. Senate. According to the Honorable George McGovern, chairman of the select committee, the "dietary goals of the United States" are "not a legislative initiative. Rather, they simply provide nutrition knowledge with which Americans can begin to take responsibility for maintaining their health and reducing their risk of illness" (Senate Select Committee 1977).

Although these dietary goals have been the object of both praise and acrimony, and are subject to revision, their basic message is one you will be hearing for some time to come. It would behoove you, therefore, to familiarize yourselves with this "legislative initiative," and formulate from it your own opinions and, perhaps, plan to use some of its basic tenets in your marketing or consumer-education plans.

Some of the dietary goals which are pertinent to the blue crab industry are discussed below.

The first goal states: only as much energy in the form of calories should be consumed as can be expended and, if overweight, decrease caloric consumption and increase energy expenditure. This is, perhaps, the least controversial of the dietary goals.

This is a simple enough concept to understand, but looking at the facts, e.g., about 15 million Americans are obese to the extent that they raise their risk of ill health, and billions of dollars are spent each year in diet aids, it is readily seen that understanding is one thing, but putting the concept into practice is another (Krueger 1978). This does not mean that Americans are not trying to diet–on the contrary, a significant proportion of the population is participating in what Dr. Jean Mayer calls the "rhythm method of girth control," indicating that the results of dieting often are transient (Senate Select Committee 1977).

The calories per 100 grams of steamed blue crab muscle are approximately 96 as opposed to the approximate 300 calories in a comparable portion of beef, therefore, a considerable dietary caloric advantage is inherent in eating crab. Furthermore, these calories are derived mainly from high-quality, easily digested protein. A breakdown of the macronutrients found in crabmeat shows that per 100 grams, 18.4 grams of protein produce approximately 73.5 of the total 96 calories, 2.5 grams of fat produce 22.5 of the total calories, with a zero value for caloric carbohydrate (data from National Marine Fisheries Service). To reduce the number of calories ingested daily, crabmeat is a viable, albeit in some instances more expensive, alternative to other meats and meat substitutes. Add to this the fact that the incidence of dieting in households increases with income, from 40% in households with incomes under $10,000 to 57% in households with incomes of more than $25,000, with billions being spent on expensive "dietary" aids (Krueger 1978), the relative cost becomes less of a factor.

Because total fat consumption in the United States has increased from 125 grams/person/day in 1910, to 157 grams/ person/ day in 1976 (Celender et al. 1978), dietary goals recommend that overall fat consumption be reduced from approximately 40% to about 30% of energy intake, and that 30% be divided equally between saturated, monounsaturated, and polyunsaturated fats. Comparing crabmeat with the cooked edible part of a choice grade of beef chuck (armcut), crabmeat has 2.5 grams of fat and beef contains 19.2 grams per 100 grams. Crabmeat also compares favorably with cooked roasting chicken whose comparable portion of flesh only (exclusive of skin) contains 6.3 grams of fat (Watt and Merrill 1963).

Considering a person who consumes, on the average, 2,400 calories per day, the total energy from fat (saturated and unsaturated) derived from a 100-gram serving of crabmeat would be 22.5 calories or less than 1/100th of the total daily caloric intake—a miniscule amount considering what is recommended in the dietary goals.

Perhaps the most controversial dietary goal is one which recommends that dietary cholesterol consumption be reduced to about 300 mg per day. The cholesterol level in blue crabmeat varies from 87 to 102 milligrams per 100 grams, depending on the source (Senate Select Committee 1977). Subscribing to numbers only, this appears to be a considerable amount. However, it is known that the ability of the body to metabolize cholesterol is genetic, and setting a dietary goal in terms of a number assumes, therefore, less meaning. In addition, it is not known how much of the cholesterol found in flesh is actually absorbed by the body, so, again, a number goal becomes less meaningful. When total dietary intake is considered, how often crab is eaten must be taken into consideration, also. In general, crabmeat is not eaten in a quantity or frequency that would lead to a problem.

Finally, the dietary goals recommend a reduction of sodium by reducing the intake of salt (about 40% sodium) to 5 grams per day. National Marine Fisheries Service figures for raw blue crab muscle indicate that it contains 337 mg per 100 grams. In sheer number values this sounds high especially in comparison with beef which has about 65 mg per 100 grams. But, once again, as with cholesterol, total dietary intake and frequency that the average consumer eats crabmeat must be considered. Other factors, such as genetics and dietary balance, must also be taken into account.

How will all of this affect the processing industry? How can these facts be used to an advantage? The Honorable Mr. McGovern's Select Committee, to put a little "teeth" into the dietary goals, proposed several ways that Congress could achieve the implementation of the goals.

First, Congress proposes to provide money for health and nutrition education in classrooms and cafeterias of the nation's schools for school food service workers, and for the general public via the media and Extension Service (Senate Select Committee 1977).

This public education drive has already begun. I believe that for anything truly positive to come from these dietary goals, it is incumbent on us as part of the seafood industry to become involved and help shape the direction that this public education will take. We can have a positive and beneficial effect. Educating the public to the benefits of crabmeat and seafood consumption in general is good, sound, long-ranged planning.

Second, the Committee did not stop with education. A further recommendation emanating from the Committee, which will certainly impact greatly on the food industry, is that Congress require labeling for all food, with those labels to contain information which supposedly will enable the consumer to make informed choices in buying foods (Senate Select Committee 1977).

Bills to this effect are currently in congressional committees. One of these bills, S. 1652, was introduced this past summer by Senators McGovern, Kennedy, and others. This bill is entitled the "Nutrition Labeling and Information Amendments of 1979 to the Federal Food, Drug, and Cosmetics Act." It provides for labeling ingredients in descending order of prominance by weight and so stating that system on the label, with necessity for quantity or percentage declaration left to the discretion of the Secretary of Health, Education, and Welfare (HEW); labeling of the total calories per serving; amounts of macronutrients in terms of their caloric contribution; amount per serving of sodium; amount per serving of cholesterol; and finally, the bill gives the Secretary of HEW authority to prescribe a system of symbols, figures, or other devices that will enable consumers to comprehend the nutrition information on the label. According to Mr. McGovern, it is anticipated that an experimental pilot labeling program will be established and evaluated (McHale 1979). Two years (from point of adoption of the bill) has been targeted for industry implementation, and a total of $18 million has been set aside for educating the public on how to use nutrition labels and labeling effectively.

A second bill, HR 42, is now in committee in the House of Representatives. This bill, which would amend the Federal Food, Drug, and Cosmetic Act and the Fair Packaging and Labeling Act, encompasses more than the McGovern bill. Introduced by Congressman Rosenthal, it is now in the Subcommittee on Health and Environment. The bill calls for labeling in order of predominance—specifically by percentage analysis of nutritional content, net weight, and drained weight of any canned or frozen product whose packing medium constitutes a substantial proportion of total weight. It also provides for the location of the label; for criminal prosecution of violation; for open dating of perishable food in the form of "pull dates;" for a temperature and humidity storage condition statement; for label disclosure of the name and place of business of the manufacturer, packer, and distributor of a food; for standardization of grading; and for a unit- and item-pricing provision among other things.

While Congress has been considering these two bills, the FDA, the FTC, and the USDA have not been idly sitting. As a result of the findings of the Joint Consumer Food Labeling Survey held in 1978, these three agencies are now meeting to come up with their own recommendations for labeling. These recommendations are tentatively scheduled to be published for the first time in the *Federal Register* at the end of October, and will then be open for comment until approximately January 1, after which the joint agencies will act to implement their recommendations.

Drafts of these proposals are not being made public, but I understand some of the items being considered are that: (1) Congress change the laws to provide that all ingredients be listed on the label, including individual spices, colors, and flavors; (2) Congress grant the appropriate agency powers whereby that agency can determine what is necessary in labeling actual amounts of ingredients; (3) sodium content labeling be required; (4) total sugar content labeling be required; (5) cholesterol labeling and defining the term "low cholesterol" and "cholesterol free" be required; (6) format of the label be changed; and (7) open dating for perishable foods.

It is hard to predict what will become of these federally initiated nutrition objectives, but there are some definite things going on right now that might help make the seafood industry's implementation of these objectives easier. First of all, the National Marine Fisheries Service is cooperating with Pillsbury and Honeywell companies in developing a nutrition data bank for food products called NUTRI–CODED Nutrition Analysis System. This is a computer program that can give the nutritional value of a recipe, and which has or will have the capability of printing out a nutrition label.

I learned from a source in the Consumer Affairs Division that NMFS is using the service first and foremost to obtain nutritional information for its own recipes, but the source did not preclude the possibility that the service might be made available to industry for a cost. This would be a boon to the small processor in complying with nutrition labeling.

Studies are also being conducted at the University of Chicago on Point of Purchase Labeling as an alternative to comprehensive labeling on the actual product (Shyette 1979). This idea came about as a result of several issues, such as (1) a concern whether or not the information anticipated to be required on a label serves any real, cost-effective purpose to the average consumer, or is it simply a case of information overload that can result in what F. J. Francis (1979) of the University of Massachusetts calls "chemophobia." Most consumers seem more concerned with minimizing perceived negative health effects than in maximizing possible health benefits; (2) whether the mass of information may take up too much room on the label, thereby destroying an aesthetic advantage in selling; and (3) assuming that the average consumer knows enough to comparison shop from a label, which is doubtful, the physical inconvenience and time cost involved are deterrents to scanning several shelves, picking up and replacing numerous items for examination. This study involves nutrition labeling of in-store printed matter attached to shelves as well as take-home information for the consumer. The FDA is reportedly interested in the outcome of the study.

This is just a brief overview of some of the nutrition-oriented activities now being carried on. Where will all of this lead? Certainly only time will tell, but I believe that those who have a vested interest in this industry can carve out a definite marketing advantage for themselves by using the current national preoccupation with nutrition to their advantage. I believe that our salvation will come with educating the public about their total dietary intake, and, in the long run, increase the consumption of crabmeat and other seafoods as a natural consequence of this education.

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NOTE ADDED IN PROOF:

Much of the information contained in this paper, though current at the time of writing, is no longer appropriate. The Dietary Goals referred to have now been somewhat modified into Dietary Guidelines. Also, research is constantly being conducted to determine cholesterol levels in a variety of seafoods and it does appear that newer, more sophisticated assaying techniques are revealing significantly lower quantities of cholesterol in many shellfish including crab. With regard to labeling of foods, it looks as though the only regulation that may surface in the near future is one requiring the labeling of sodium content.

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