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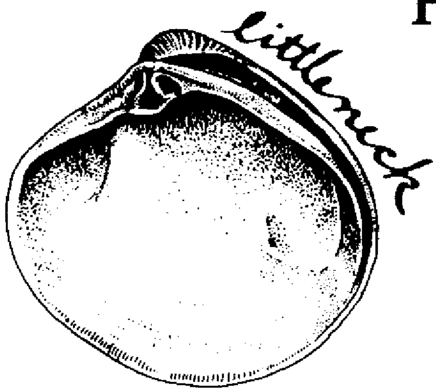
Survival of Southern Hard Clams in Refrigerated Storage



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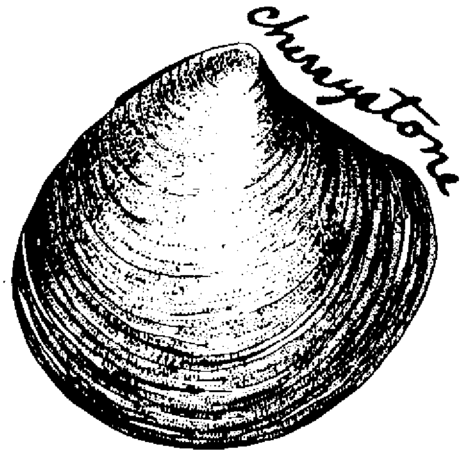

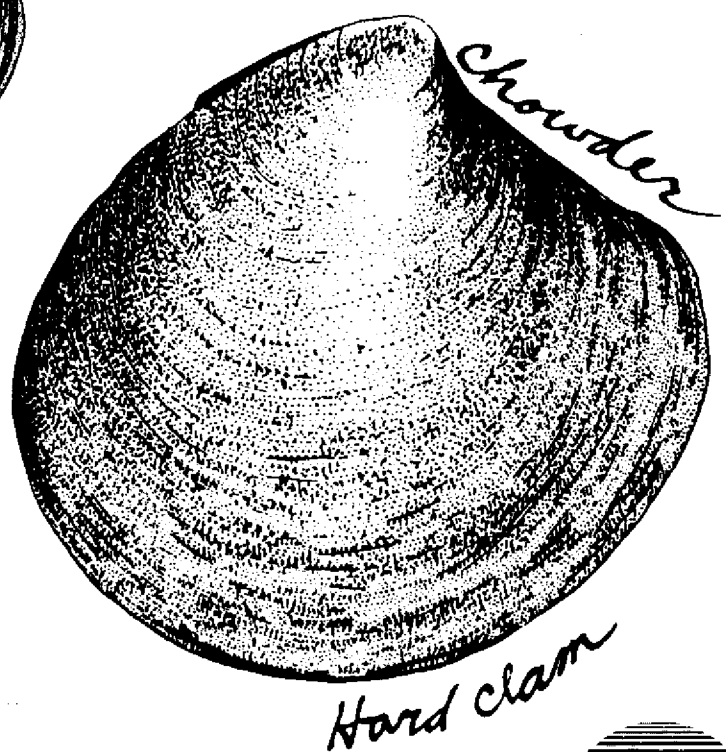

SEA GRANT

Florida Sea Grant College Program

SURVIVAL OF SOUTHERN HARD CLAMS IN REFRIGERATED STORAGE

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SURVIVAL OF SOUTHERN HARD CLAMS IN REFRIGERATED STORAGE

INTRODUCTION

Hard clam (quahog) fishing along the southeastern coasts of the United States has been a traditional fishery, but recent levels of production suggest the present resource may be underutilized. For example, in Florida, annual hard clam production during the early 1900's ranged from 500,000 pounds (meats) to greater than 1 million pounds, recorded in 1932 (Figure 1). Production remained steady until 1945-47 when a major decline occurred, possibly due in part to a devasting red tide (1, 2) affecting major productive clam beds in coastal waters of Collier County (Ft. Myers, Florida). Since this devastation, production from the primary beds in Southwest Florida has never recovered, and annual production from Florida beds scattered along the remaining coasts has been erratic depending on available supply, commercial interest, profitability, and other factors. Since 1950, most annual production was less than 150,000 pounds, with harvests almost exclusively from the east coast centered in Brevard County (Indian River). In 1984, hard clam production about Grant, Florida (Brevard County) escalated to in excess of 6.5 million pounds (3). This degree of exploitation demonstrated latent potential for this traditional fishery, but the new clam resource came with certain inherent problems. The viability and marketability of the resource was in question. This study addressed the latter issue.

Commercial hard clams harvested in Florida are primarily the northern quahog, Mercenaria mercenaria, and the southern quahog Mercenaria campechiensis. Both species can be found along both Florida coasts, yet M. campechienis is more dominant in commercial harvests from the west coast (4). Likewise, these species are thought to hybridize in the environment (4, 5). Also, a third species or sub-species, M. mercenaria texana, has been reported along the northern coast of the Gulf of Mexico extending westward beyond Apalachicola Bay (4). Thus, this distribution of diverse species and probable hybrids complicates identification, such that commercial interests collectively refer to all species as (southern) hard clams.

The marketability of these hard clams has been hampered by limited survival when placed in common refrigeration. This problem has been previously noted in earlier mariculture studies (6, 7) which suggested M. mercenaria survived better in refrigeration than did M. campechiensis. Likewise, their hybrid demonstrated better survival than M. campechiensis (8). In general, the hard clams from southern origin which are acclimated to warmer environmental temperatures, appeared less

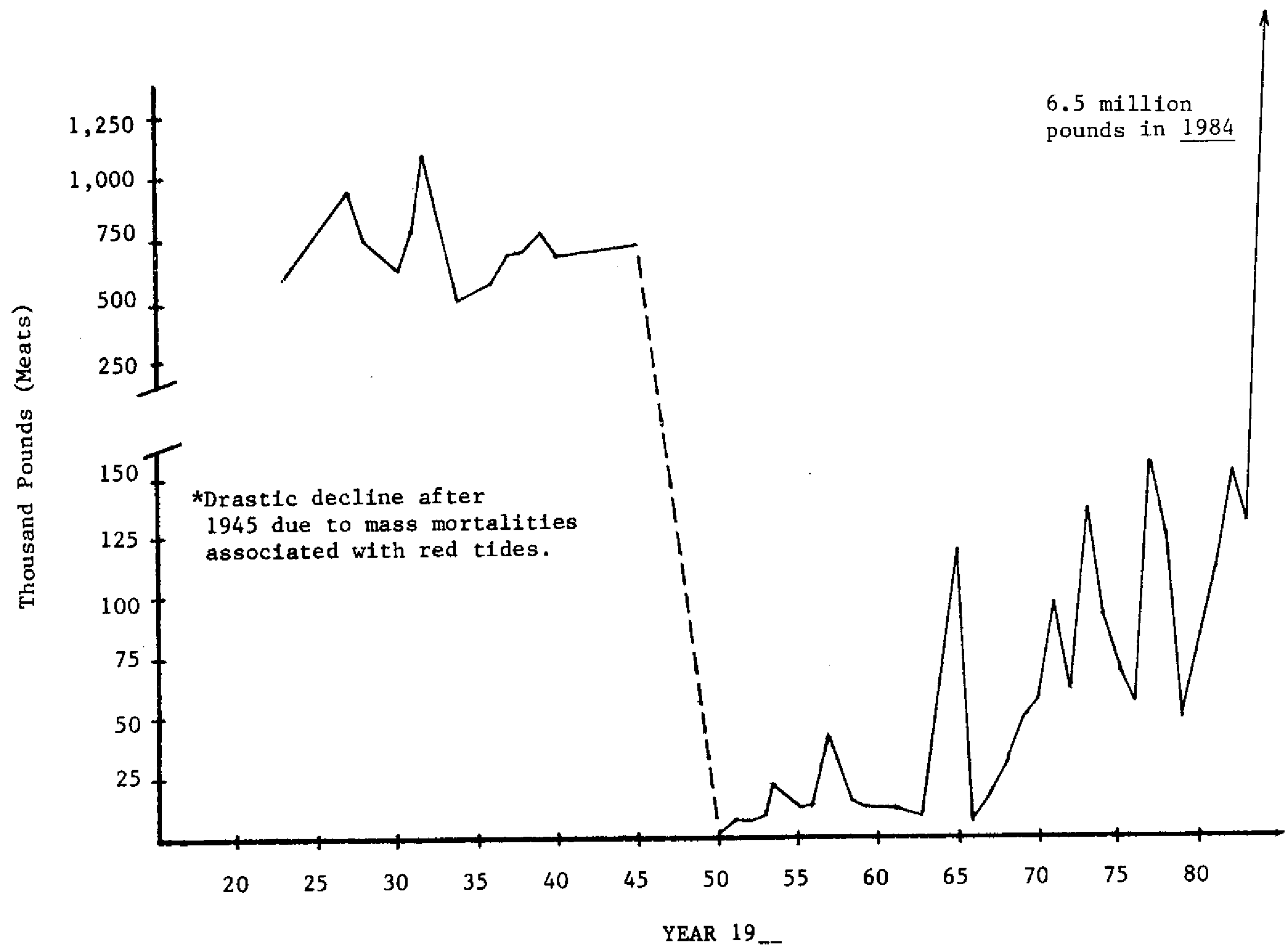

Figure 1. Annual production of hard clams in Florida (Source: Previous Florida Board of Conservation Annual Reports and National Marine Fisheries Service Annual Fisheries Report for Florida).

tolerant of cold refrigeration temperatures. Wholesalers combat the problem with local distribution which can be limited, seasonal, and less profitable. Attracted by more distant markets, they have tried to acclimate the clams to higher refrigeration temperatures and/or maintain inventory in submerged cages. Their results have not been encouraging. Submerged storage is considered too laborious and vulnerable to adverse environmental changes. Also, use of elevated refrigeration temperatures may conflict with shellfish regulations which specify live storage in temperatures less than 50°F (10°C) (9).

Thus, the objective of this study was to investigate survival of (southern) hard clams in variable conditions and refrigeration temperatures with the intent of recommending a practical method to improve their marketability.

METHODS

DIRECT REFRIGERATED STORAGE

All hard clams were harvested from Florida waters. Samples from the Indian River ('IR'--Grant, FL) were collected with hand (bull) rakes, while samples from St. Joseph Bay ('SJ'--Port St. Joe., FL) were taken with a customized surface dredge (Figure 2). Species identification was based on prior descriptions (10, 11) and personnel communications (Florida State Museum, Gainesville). The IR clams included both M. mercenaria (Mm) and M. campechiensis (Mc), but Mm typically constituted over 80 to 90% of the samples. In contrast, the SJ clams were predominantly Mc with some possible M. mercenaria texana. Because species distinction is impractical for commercial application, the clam samples were simply treated as IR and SJ hard clams. The IR clams came from a predominantly sand bottom, whereas the SJ clams were harvested from a sticky, mud bottom, with varying amounts of broken shell.

Immediately after harvest the clams were wrapped in moist burlap bags, placed in 151 qt. coolers lined with a shallow bed of ice and transported (3-4 hours) to laboratory refrigeration. Internal cooler temperature ranged from 40 to 50°F. Upon arrival, the clams from one location (IR or SJ) were randomly sorted into shallow baskets of 50 clams (2-3 individuals deep). Each basket, considered one unit, was lined with burlap which was kept moist for humidity control during the entire storage period. Despite the common commercial practice of dry refrigerated storage (including use of fans), prior experience indicated that the SJ clam would rapidly dehydrate without humidity control. Three units were placed in each separate walk-in refrigerator, 40°F, 50°F, and 60°F (4.4°C, 10°C, and 15.6°C). This arrangement constituted one trial. Samples were

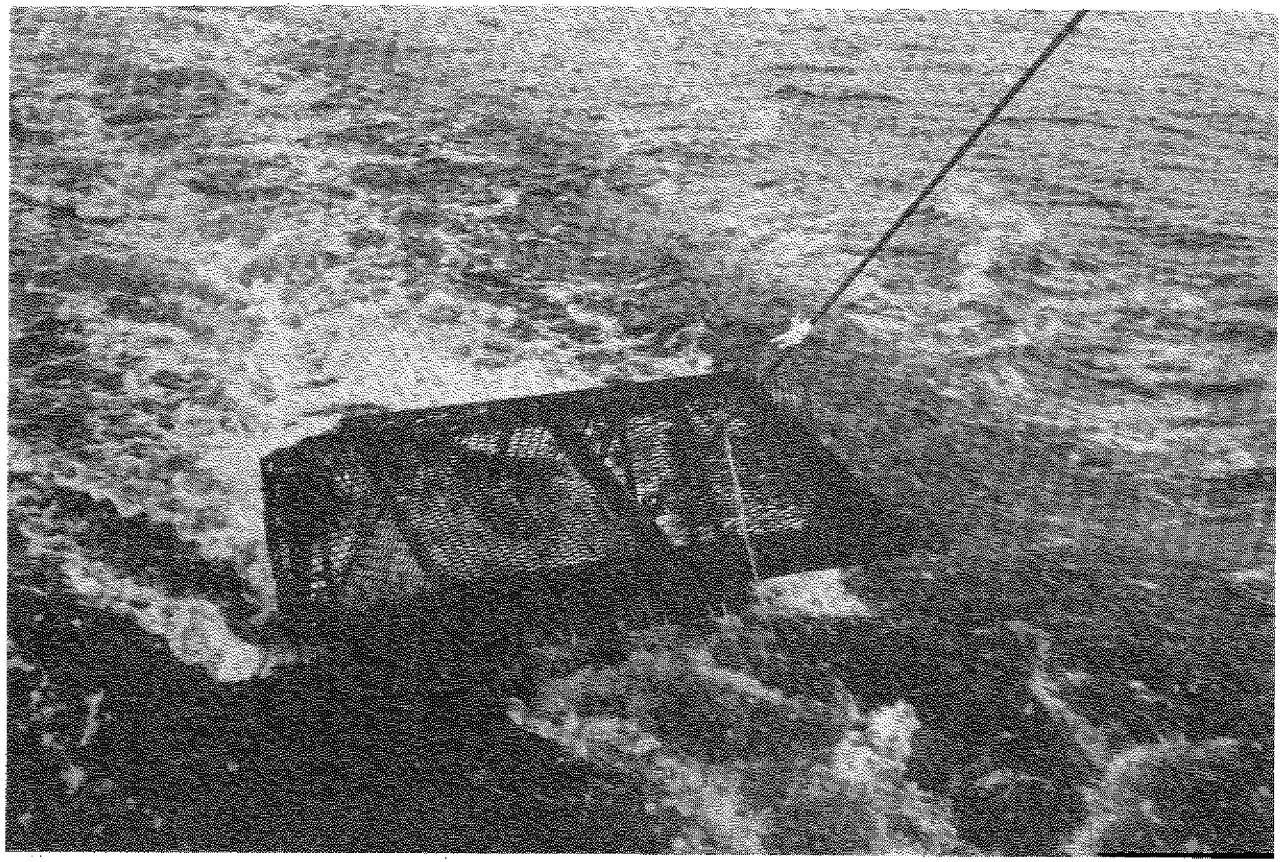

Figure 2. Surface dredge used to harvest hard clams from St. Joseph Bay, Florida.

taken from both locations (IR and SJ) for direct refrigeration trials conducted during January through August.

Clam survival was monitored on a daily basis. Preliminary work demonstrated that the method of daily checks did not increase mortality when compared to less frequent checks at seven day intervals. Each unit was examined for live clams. Live clams were either tightly closed or would shut when gently agitated. Clams which continued to gape despite agitation were termed 'severely stressed'. Preliminary experience had shown that continuous gaping was not an accurate sign of death, especially in colder refrigeration (40°F). Such stressed clams often responded, or shut, when exposed to room temperature (20°C--5 min.). Henceforth, these 'stressed' clams were segregated per unit because experience indicated that this condition was a preamble to mortality, which generally followed within 1 to 3 days. Although subsequent exposure to room temperature could distinquish actual death, for all practical purposes the 'severely stressed' or continuous gaping condition was considered 'commercially dead', or commercial mortality (Figure 3). This definition was used to illustrate the practical results relative to industry applications.

Daily clam survival was monitored until mortality exceeded 50% per individual units (25 deaths/50 clams). As clams died, the shell width, length and height (hinge width) were recorded for possible correlation with mortality rates. The range in clam size from both locations was selected at 2 to 3 inches in width.

PRE-SUBMERGED STORAGE

Further trials were conducted to demonstrate the influence of a pre-submerged storage prior to direct refrigerated storage. The intent was to maintain a readily accessible inventory and possibly "condition" the clams for subsequent refrigerated storage. All harvest locations, methods and refrigerated storage procedures were similar as used for the direct refrigeration trials. One series of pre-submerged trials employed continuous flow-through storage bins positioned at Indian Pass adjacent to St. Vincent Island (McNeills, FL) at the west end of Apalachicola Bay. A submerged pump directed ambient water from the inlet through six individual tanks. Each tank (4x4x4 ft) could hold approximately 8 to 10 bushels of clams randomly pre-loaded in plastic trays. The tanks were sheltered from sunlight and rain but there were no temperature controls or aeration. The water flow rate was 4-6 gallons/minute. The ambient water conditions during the trial period (May-June) ranged from 78-88°F (25.5-31.1°C) and 15-32 ppt salinity. After 28 days in the pre-submerged ambient water bins, surviving clams were transported to laboratory refrigeration (40°, 50° and 60°F) to complete the test trials. Three trials were conducted for SJ clams only.

A second series of pre-submerged trials employed recirculating water (25 ppt salinity) maintained at 60°F (15.6°C) in a walk-in refrigeration room. The recirculating units (200 gallon capacity) and filtration units were conditioned with artificial saltwater for one month prior to use. Each unit held over one bushel of clams sorted in plastic trays. Clams harvested from IR or SJ were directly pre-submerged in the 60°F recirculating units for 14-16 days prior to removal and placement in refrigerated storage (40°, 50°, and 60°F). Three trials were conducted per harvest location.

BACTERIAL ANALYSIS

Extra SJ clams handled and stored in the same manner as for SJ clams used in the direct refrigeration trials, were sampled and submitted for bacterial analysis. These clams were harvested during March and April. Live clams were sampled after 2, 5, 9 and 13 days refrigerated storage. Dead clams (confirmed mortality) were sampled on day 9 less than 24 hours after death, and day 10 after 24 hours from the approximate moment of death. Carefully shucked clams (3-4 meats and juice) constituted one sample. Two samples were taken per the various time and temperature regimes. The shucked samples were blended for 90 seconds in phosphate buffer (5:1 dilution). Appropriate spread plates were incubated (25°C) for 72 hours on nutrient agar supplemented with 0.5% NaCl.

RESULTS AND DISCUSSION

Through all trials and storage methods there was no discernible pattern in mortality relative to clam size. As illustrated in Figure 3 there was an obvious distinction between clams considered commercially dead (continuous gaping), and actual or confirmed mortality. For practical purposes the stressed, or commercially dead clams, would be the best measure for refrigerated survival or marketability. This condition was most common for SJ clams stored at 40°F, but became more prevalent for SJ and IR clams at 40° and 50°F during warmer months when the temperature of the harvest waters exceeded 77°F. The continuous gaping resulted in obvious dehydration of the internal meat despite storage in moist burlap. Absence of moist burlap allowed more dehydration and rapid death, especially for SJ clams.

The SJ clams were less tolerant in all storage temperatures than were the IR clams harvested approximately during the same

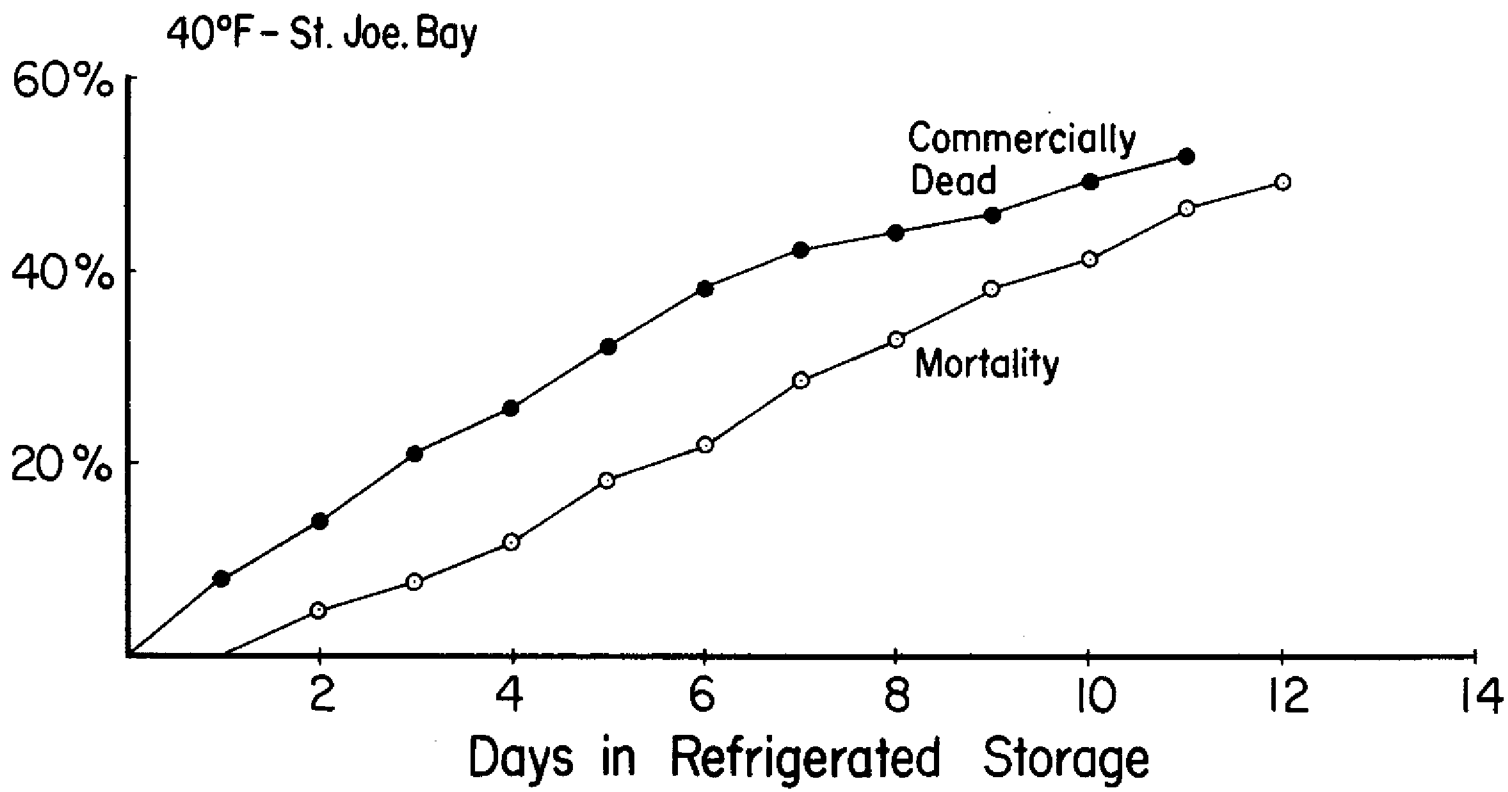

Figure 3. Cumulative mortalities for hard clams, harvested in July from St. Joseph Bay, while stored in 40°F refrigeration. Percent (%) Mortality includes confirmed deaths, and Commercially Dead includes mortality plus clams displaying 'stress' (continuous gapping).

time from similar water temperatures. For example, in June the IR clam survival rate exceeded the survival for SJ clams in all storage temperatures (Figure 4). This difference in survival rate persisted through all trials in January through July (compare Figures 5 and 6). These graphed results are consistant with previous observations (6, 7, 8) which suggested Mercenaria mercenaria, which are more prevalent amongst IR clams, are more cold tolerant than M. campechiensis, typically harvested from Florida's west coasts. The results were distinct despite harvest from similar water conditions and latitudes.

The onset of warmer seasonal water temperatures depressed the survival rate for all hard clams irregardless of harvest location (Figures 5 and 6). The most pronounced decrease in survival rates occurred when harvest water temperatures exceeded 77 to 78°F, during June. The sequence of trials began in April, showing depressed survival during the early summer months, then increased survival in January through March.

A 20% commercial mortality would be considered unacceptable, thus this level was chosen to simply compare the various survival rates per harvest location, season and storage method (Table 1). Both harvest locations yield clams with adequate survival in refrigeration (40°F) for marketability when water temperatures are below 77-78°F. During this time marketing strategies for SJ clams must be arranged to assure distribution and utilization within approximately 10 days, while IR clams have at least two weeks (14 days) of confident refrigerated shelflife. During summer months SJ clams are practically nonmarketable in common refrigeration, with shelflife less than 3 days, and the shelflife for IR clams is restricted to less than one week (7 days).

In some trials the warmer refrigeration temperatures (50° and 60°F) enhanced the survival of clams from either harvest location (Table 1). This was most evident for clams harvested during June, but as harvest water temperatures continued to increase to 88°F the SJ clam survival in 50°F refrigeration was depressed. These results are further evidence to suggest a shift in the thermal (cold) tolerance as the clams, irrespective of species, acclimate to their ambient conditions. Likewise, these results suggest refrigerated storage above 40°F could prolong shelflife during the summer months.

Strong off-odors resulting from the spoilage of individual clam deaths precluded the continued use of 60°F refrigeration. Although the overall survival rates at 60°F refrigeration exceeded those at 40°F, odors from individual mortalities would be offensive in a retail setting. Likewise, bacterial growth rates on live and dead clams stored in 50°F and 60°F refrigeration suggested regulatory caution. In 50°F storage, the total aerobic plate counts (25°C) on live SJ clams increased

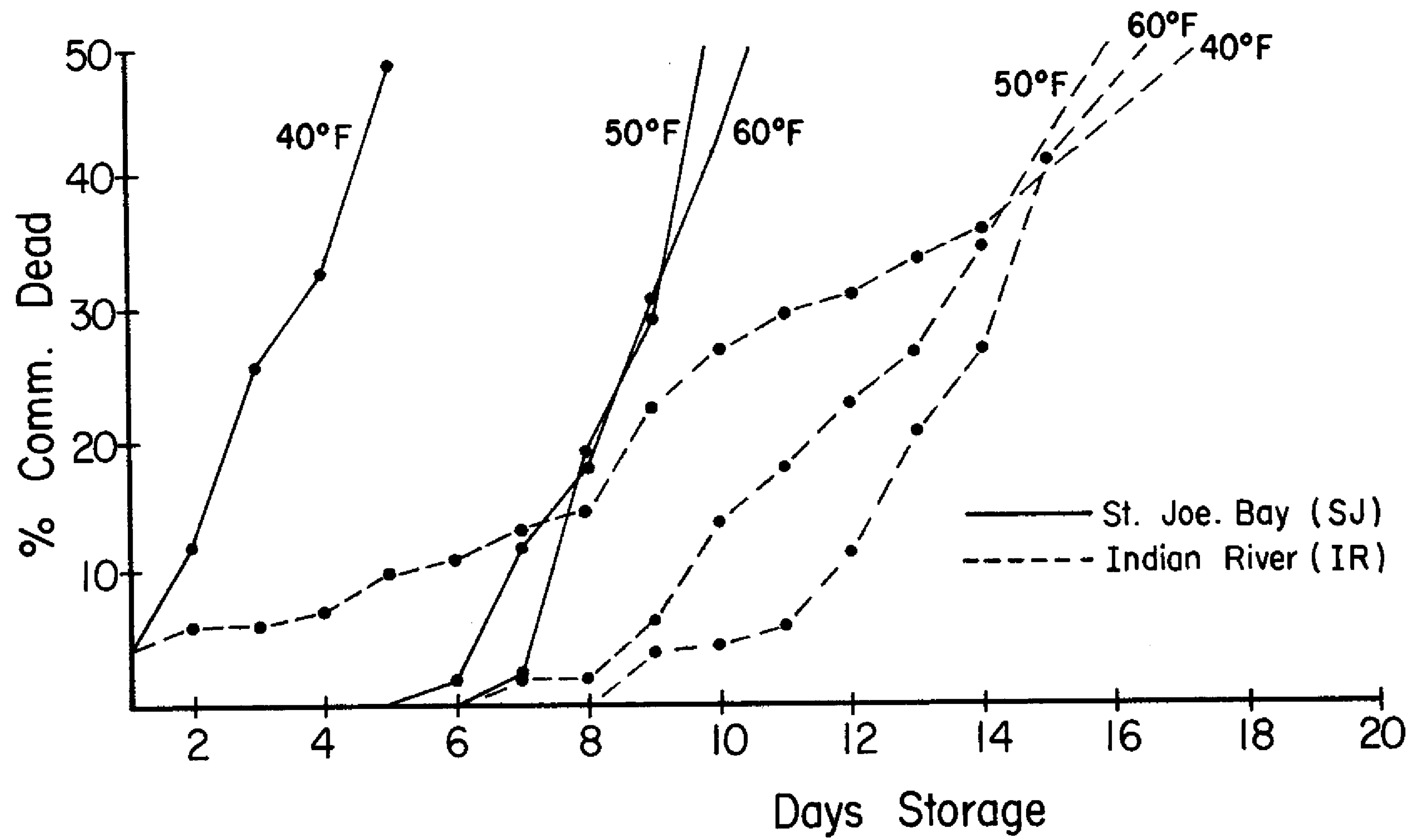

Figure 4. Percent commercially dead for SJ and IR hard clams in refrigerated storage (40°, 50° and 60°F) after harvest in June from water temperatures of 81°F and 78°F, respectively. Each plot represents results from one trial.

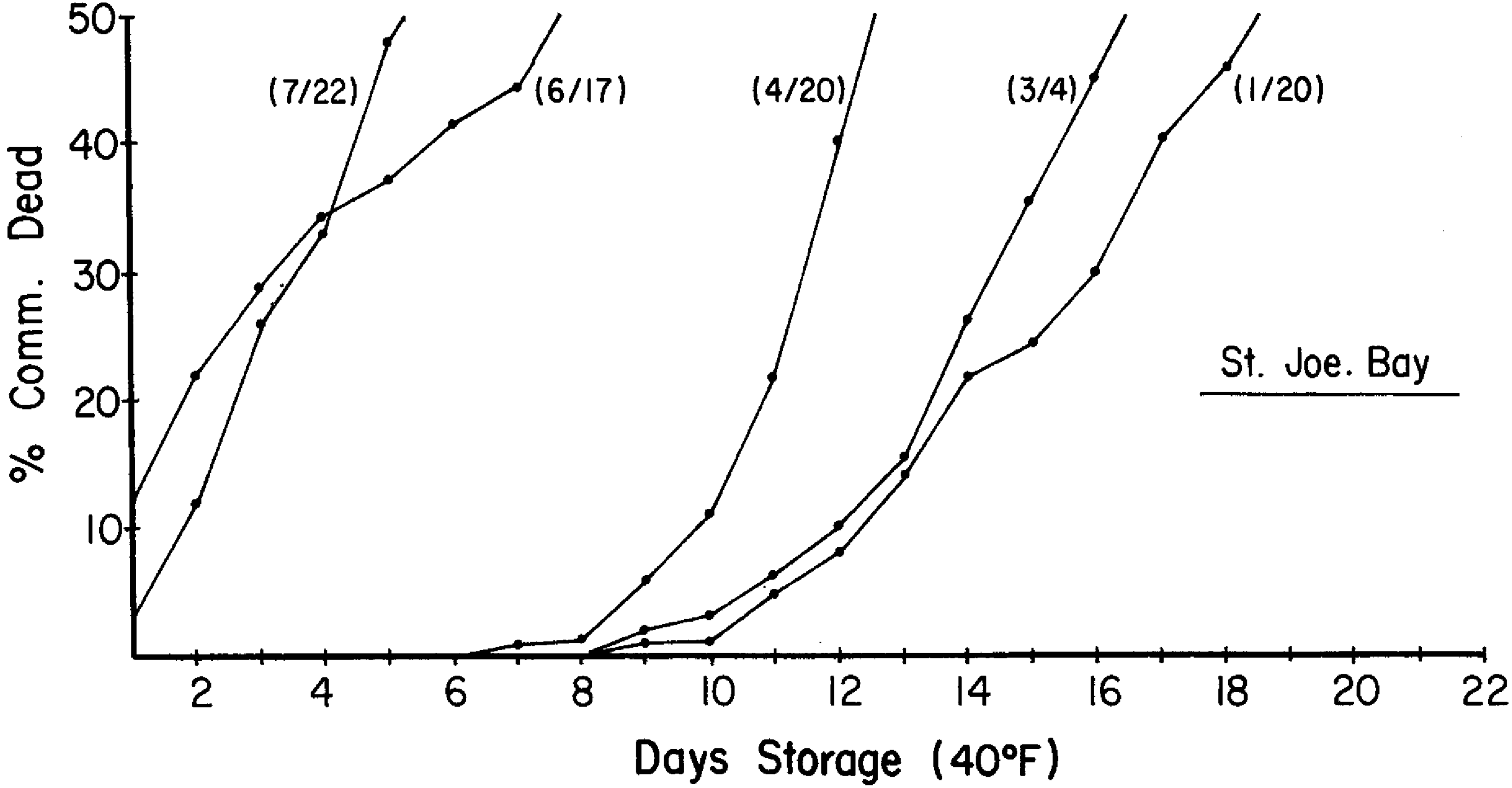

Figure 5. Percent commercially dead in 40^{O}F refrigerated storage for hard clams harvested from St. Joseph Bay during different months (month/day). Each plot represents one trial.

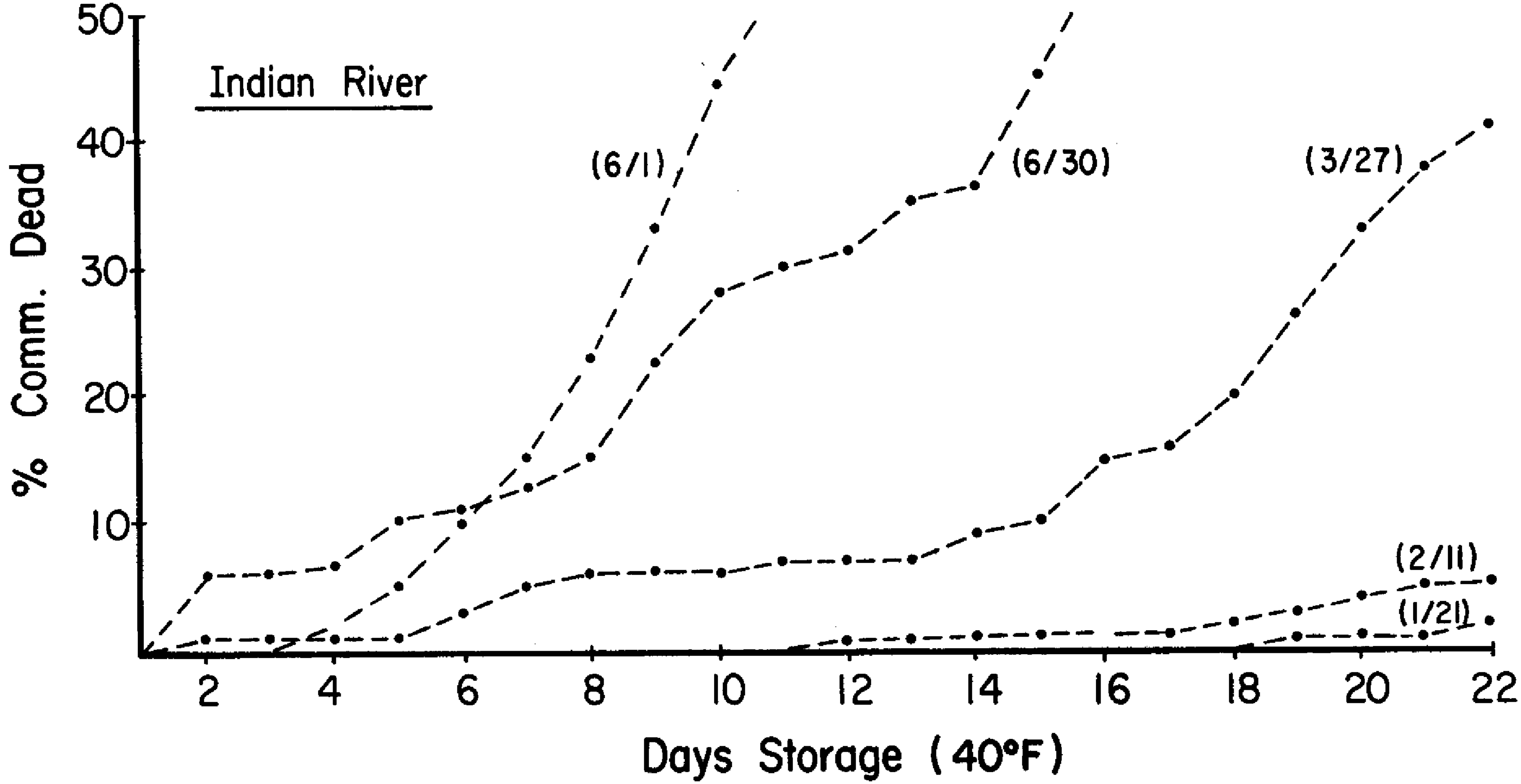

Figure 6. Percent commercially dead in 40°F refrigerated storage for hard clams harvested from Indian River during different months (month/day). Each plot represents one trial.

TABLE 1 Marketability, or total days in direct refrigerated storage, until hard clam mortality exceeded 20% commercially dead. Each harvest period represents data from one trial subjecting clams to refrigerated storage temperatures.

ST. JOE. BAY (SJ)

HARVEST		REFRIGERATED STORAGE		
Time	Temp.	40°F	50°F	60°F
Jan. 20	63°F	14	12	--
Mar. 4	63°F	14	15	--
Apr. 20	77°F	11	11	--
June 17	81°F	2-3	8	8
July 22	88°F	2-3	1-2	7

INDIAN RIVER (IR)

HARVEST		REFRIGERATED STORAGE		
Time	Temp.	40°F	50°F	60°F
Jan. 22	63°F	22*	22*	--
Feb. 11	63°F	22*	21	--
Mar. 27	72°F	18	15	--
June 1	78°F	8	12	13
June 30	86°F	9	12	13

* All refrigerated tests were terminated after 22 days.

3 log cycles by day 9 while rapid growth was immediately evident in 60°F refrigeration (Table 2). Also, bacterial growth increased rapidly on dead clams (Table 3). These results do not necessarily reflect the potential consequences for pathogenic or indicator microorganisms. Thus the regulatory guidelines for storage of live clams may require further examinations particular to hard clams.

Pre-submerged storage in ambient water conditions did not significantly increase the subsequent survival of SJ clams in 40°F and 50°F refrigerations (Table 4). In comparing the survival rates for SJ clams harvested from similar June water temperatures, the average marketability (less than 20% mortality) for pre-submerged clams stored at 40°F was only extended 1 to 2 days beyond that for clams placed directly in the same refrigeration. During the 28 days of storage in the ambient, flow-through bins the average clam mortality ranged from 2.5 to 6.8 percent. These deaths probably represent the percentage of 'weak' clams which would have died most immediately in refrigerated storage. Thus, the pre-submerged period allowed some culling (removing dead clams) and conditioning to provide more tolerant clams. Surviving clams appeared 'cleaner' both on the surface and inside the shells. This condition suggests the pre-submerged clams had gone through some degree of "purging" such that they were cleaner than the same clams dredged from a mud bottom. Flavor and color of the clam meats was not affected during the pre-submerged period. Thus, despite some obvious benefits, the decision to use pre-submerged storage in ambient conditions must consider the limited extension of marketability (1 to 2 days in 40°F refrigeration) and readily accessible inventory versus the costs for extra labor and facility maintenance. Under the best conditions, 4 days at 40°F, this system appears impractical.

Trials with pre-submerged storage in 60°F recirculating water yielded conflicting results relative to harvest location (Table 4). After 14 days submerged storage the refrigerated shelflife or marketability of SJ clams was significantly increased relative to SJ clams harvested from the natural environment prior to direct refrigeration in 40° and 50°F (compare Tables 1 and 4). In contrast, the same comparison for IR clams harvested from water temperatures above 78°F indicated depressed survival; whereas, survival was similar for all IR clams harvested in May (78°F). Thus, in comparing 60°F pre-submerged results for clams harvested from water temperatures ranging from 83 to 88°F, the SJ clams responded more favorably. The 60°F pre-sumberged condition for SJ clams provided at least 6 days additional shelflife in 40°F refrigeration, and 4 days in 50°F. The depressed survival for IR clams can not be explained by these trials. Commercial experience suggest the use of moist burlap is an irritant to IR clams. Average mortality for IR or SJ clams during the 14 day

TABLE 2 — Aerobic plate counts (35°C; microorganisms/g) for live SJ clam samples (meats) after days of refrigerated storage.

	STORAGE TEMPERATURE		
DAYS	40°F	50°F	60°F
2	8.3×10^2	1.6×10^3	2.2×10^5
5	2.4×10^3	2.6×10^3	7.6×10^6
9	3.0×10^3	2.3×10^6	4.9×10^6
13	9.0×10^3	1.4×10^6	1.1×10^7

SJ clams--St. Joseph Bay

TABLE 3 — Aerobic plate counts (35°C; microorganisms/gm) for live and dead SJ clam samples (meats) after 9 days of refrigerated storage.

	STORAGE TEMPERATURE		
DAYS	40°F	50°F	60°F
9, Alive	3.0×10^3	2.3×10^6	4.9×10^6
* 9, Dead	5.3×10^5	5.3×10^6	2.5×10^7
*10, Dead	3.3×10^5	4.2×10^7	1.8×10^7

SJ clams--St. Joseph Bay

* Dead at day 9 and 10 implies samples on day of death and 24 hours after death, respectively.

TABLE 4 Marketability, or total days refrigerated storage until hard clam mortality exceeded 20% commercially dead. Intermediate storage included 28 days in flow-through 'ambient' holding facilities or 14 days in recirculating water facilities maintained at 60°F (15.6°C). Each harvest period represents data from one trial subjecting clams to intermediate submerged storage prior to refrigerated storage.

PRE-SUBMERGED STORAGE (ambient)
(SJ clams--St. Joe. Bay)

HARVEST			**INTER. STORAGE		REFRIGERATED STORAGE		
Location	Temp.	Time*	Days	Temps.	40°F	50°F	60°F
SJ	81°F	5/21	28	81°-86°F	3	9	11
SJ	88°F	7/23	28	86°-88°F	6	7	11
SJ	88°F	8/27	28	86°-88°F	4	8	11

PRE-SUBMERGED STORAGE (60°F)

HARVEST			**INTER. STORAGE		REFRIGERATED STORAGE		
Location	Temp.	Time*	Days	Temps.	40°F	50°F	60°F
SJ	86°F	8/8	14	60°F	12	14	--
SJ	88°F	9/3	14	60°F	8	13	--
SJ	86°F	9/15	14	60°F	9	17	--
IR	78°F	5/23	14	60°F	16	17	--
IR	88°F	8/31	14	60°F	6	8	--
IR	83°F	10/1	14	60°F	6	8	--

* Time expressed as month/day.
** Interim storage, post-harvest and prior to refrigeration.

submerged storage was less than 2 percent per trial. All clams emerged 'cleaner' than when immersed, and the meat color and flavor was unaffected.

RECOMMENDATIONS

The following recommendations are particularily pertinent to the onshore handling of hard clams harvested in Florida. Commercial interests must be mindful that these recommendations are based on results with control refrigeration temperatures.

1. As harvest water temperatures approach 80°F, (26.5°C) (May-September) traditional handling and marketing practices should be adjusted to suit the decreasing survival rate for clams placed in refrigeration.

2. The recommended storage temperature should be below 50°F (10°C). Although, storage in 50°F (10°C) could prolong survival, use of these temperatures would require more regulatory scrutiny. Further bacterial analysis using specific pathogenic and indicator organisms would be necessary before formally approving storage temperatures at or above 50°F.

3. Intermediate storage in 60°F recirculating salt water systems could be used to prolong the refrigerated shelflife for SJ hard clams (predominantly <u>Mercenaria campechiensis</u>). Further trials, with attention on additional water conditions (salinity and temperatures), could prove more beneficial to both SJ and IR clams. An objective should be shorter periods for submerged conditioning.

4. Industry adaptations for any intermediate submerged storage must consider integrating the storage temperature and time with the prevailing guidelines for depuration facilities.

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