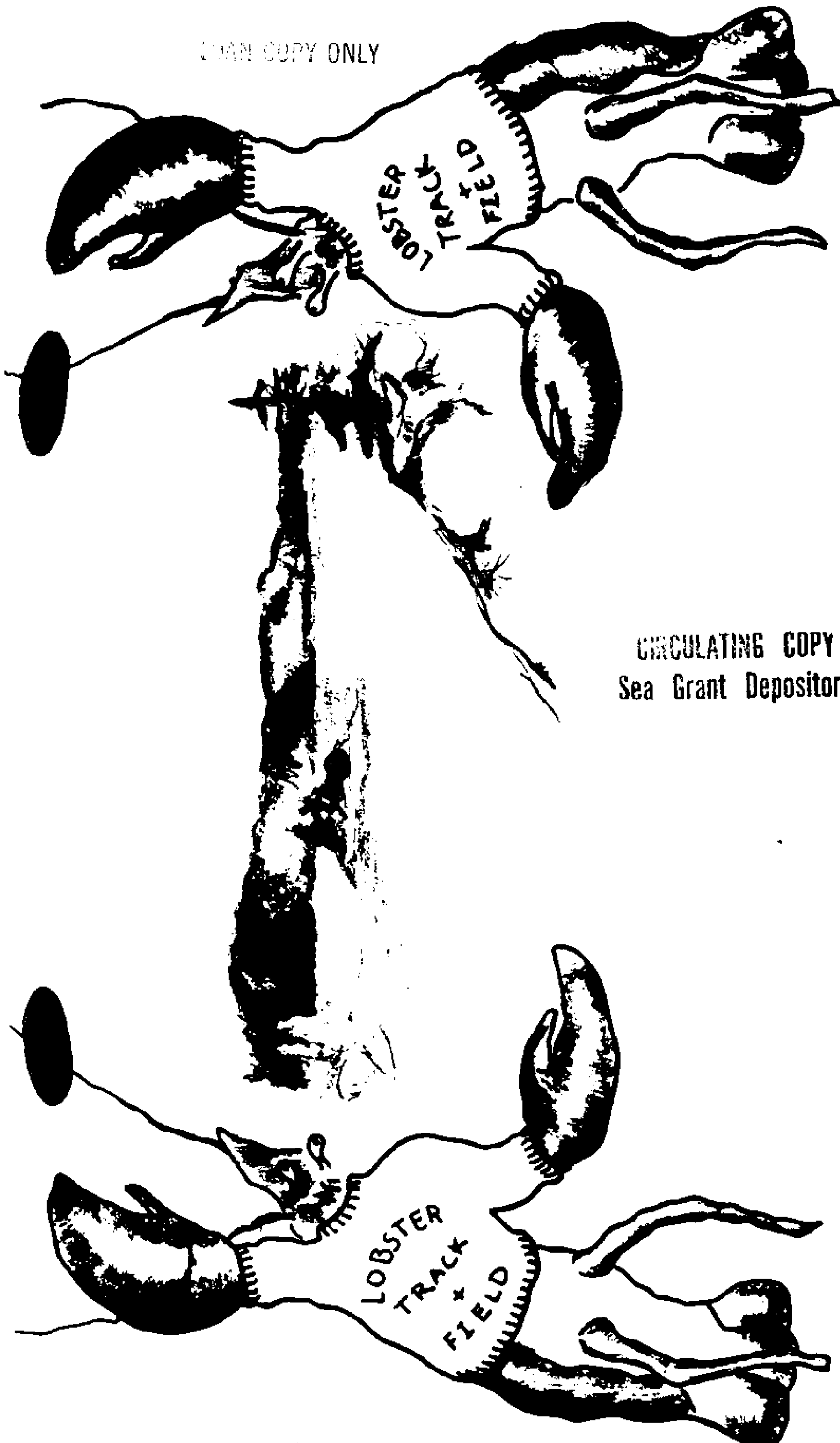
LOBSTER
TRACK
+
FIELD
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Lobster Track and Field Team

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Ocean Projects-1988

Abstract

This project was designed in order to study the relationship between salinity fluctuations and lobster behavior in the Great Bay Estuary. Other environmental parameters such as temperature and depth were also examined. At different locations in the Bay, traps were sampled to obtain information on lobster distribution. Trapped lobsters were tagged as part of a mark and recapture program. From 372 lobsters that were tagged only one had been returned with the aid of local fishermen,. A radio transmitter was also designed in order to easily follow the movements of one lobster over a period of about one week. Experiments were preformed in lab to examine the effects of reduced salinity on lobster behavior. It was hypothesized that lobsters would react to reduced salinity in one of three ways: move towards the ocean where the salinity is higher, mover to pockets in the Bay itself where salinity is more favorable, or to remain in one location and die. Based on the data collected, we feel that lobsters will try to avoid the salinity drop and move to a different location. More work will need to be done however.

Introduction

Yearly fluctuations in the Great Bay habitat

Salinity in the Great Bay Estuary varies greatly, depending on the time of year and the exact location. The range may go from a high of about 30 ppt.(parts per thousand) in midwinter down to 0 ppt. at times, such as in the Spring of 1987. The salinity values will vary for each individual location along the estuary due its distance from the ocean and the amount of Spring runoff that it receives. Spring runoff consists of heavy rains, melting snow, and river runoff; each location is subject to different amounts.

Along with salinity, the temperature within the Great Bay Estuary is also variable with regards to location and season. The water is the coldest in the winter, at an average temperature of about -2^{o}C and then reaches a high of about 25^{o}C in the summer months.

An eight year study (1973-1981) was conducted by The Jackson Estuarine Laboratory which monitored yearly fluctuations of temperature and salinity at seven different stations, stretching from Portsmouth Harbor to Great Bay. We replotted data from three of the seven stations in order to better visualize how the habitat varies from season to season. These stations were approximately equidistant apart and were suspected to have different degrees of salinity and temperature because of their location relative to spring runoff. The stations chosen were Station 1 (Portsmouth Harbor), Station 4 (Little Bay), and Station 7 (Great Bay). Figures 1 and 2 depict the results of this analysis.

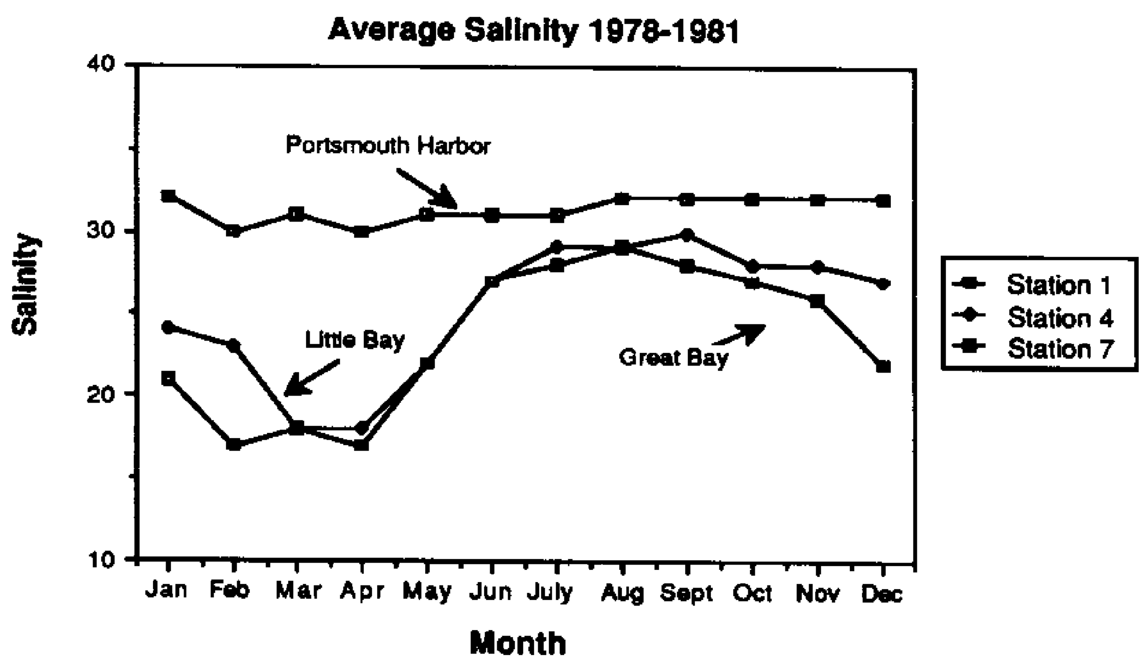


Figure 1. The average salinity at stations 1, 4 and 7. Monthly data from 4 years (1978-1981) was averaged and plotted. The salinity at station 1 (Portsmouth Harbor) is approximately constant throughout the year. The reason for this is that the harbor isn't affected by river runoff. The same would hold true for other areas which are open ocean. Station 4 (Little Bay) and Station 7 (Great Bay) however, receive a lot of Spring runoff. This explains the drop in salinity seen in the months of March and April.

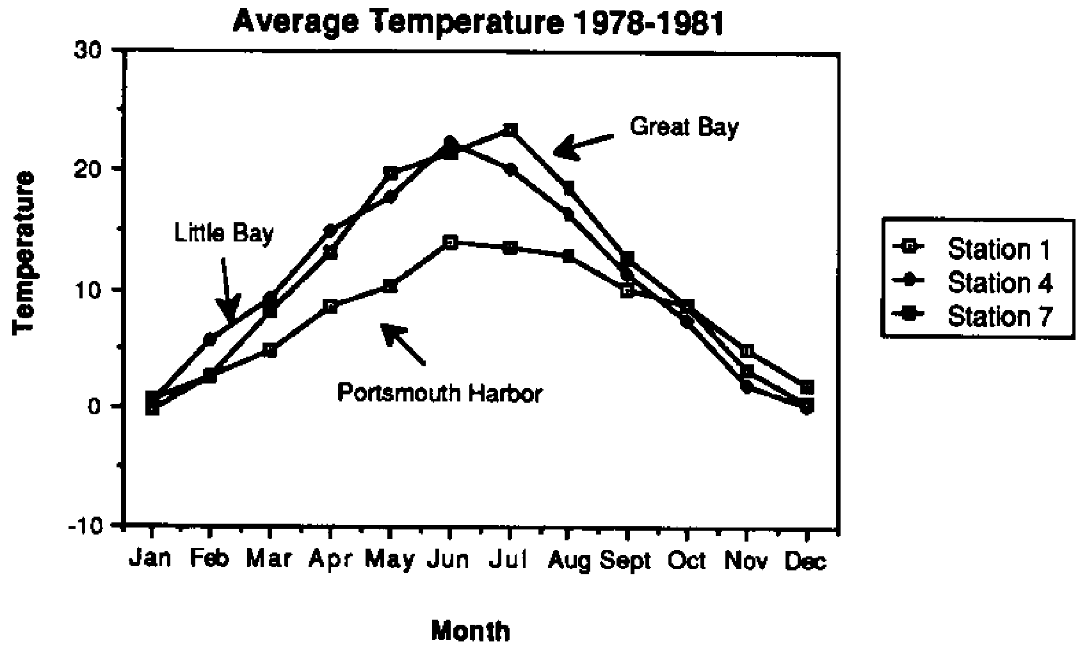


Figure 2. Seasonal changes in temperature in Great Bay.As in Figure 2 monthly data from 4 years was averaged. All three stations exhibiting the same trend throughout the year. The water temperature reaches its lowest value during the winter then steadily increases until mid-summer at which time the value drops again. As in figure 1, Portsmouth Harbor is unique because it is the open ocean. Therefore the water temperature never reaches the high temperatures that Little Bay and Great Bay does.

Responses of lobsters to changes in salinity and temperature

Salinity may affect an animal through changes in several chemical properties of the water. Firstly, the total osmotic concentration of sea water reduces as it is diluted with freshwater. In almost all cases, the concentration of salts in estuarine water is directly proportional to osmotic concentration. Secondly, the relative proportion of solutes within estuarine water varies with the salinity. Thirdly, the concentration of dissolved gases varies with the salinity, with fresh water containing more oxygen than sea water at the same temperature. Finally, the density and viscosity of water varies with salinity, with fresh water lighter than salt water. Lobsters may respond directly to the change in salt concentration or to any of the above factors. (McLusky, 1981). This response may take the form of osmoregulation through ion exchange mechanisms in the gills. In brackish water crustacea, ions apparently can be absorbed against an osmotic gradient. Unfortunately, if the salinity drops too low, the lobsters cease to be able to regulate and are therefore forced to become osmoconformers (Rosen, 1951).

Estuarine organims are affected not only by the magnitude of salinity cahnge, but also by the rate of change. It is well known that if the salinity changes slowly, many organisms can adapt themselves to live in the new salinity, whereas a rapid change of similar magnitude may prove fatal (Green, 1968). If they don't immediately adapt, a lobster may seek to escape or otherwise reduce contact with the water. Such behavioral responses are common in many estuarine animals (McLusky, 1981). For example, in Bideford River, Prince Edward's Island (an estuarine environment), a heavy runoff in the spring of 1967 caused meltwater to build up an extraordinarily deep fresh water layer (salinities dropped to less than 1ppt.). Some specimens of the lobster *Homarus americanus* , which overwinters in burrows in the estuary, were observed dead in their burrows. However, the main concentration of overwintering lobsters was down estuary of the area where the mortalities occured (Thomas and White, 1969).

Well documented accounts of mass mortalities in the sea are rare. It has been shown that changes in temperature or salinity, toxic phytoplankton blooms, and oxygen lack were the most frequently reported causes of such mortalities (Thomas and White, 1969). Wide seasonal and short-term variations in temperature and sporadic variation in salinity are known to occur and either singly or in combonation may result in conditions that are unsuitable for lobster survival. Heavy mortalities occur at times among lobsters that are held in large numbers by the industry. Often this is because of the above averse environmental conditions (McLeese, 1956).

Preliminary experiments by McLeese in 1950 showed that lobsters can be acclimated to withstand high temperatures under favorable conditions of salinity and oxygen. Further, the lethal levels of salinity and oxygen vary with the temperature. Upper level temperature is raised by an increase in thermal acclimation and is lowered by a decrease in the salinity. The lower lethal salinity is raised by an increase in the level of thermal acclimation. It is lowered by acclimation to reduced salinity (McLeese, 1950).

In summary, McLeese found that for lobsters acclimated at 20ppt. at various temperatures, the lethal salinity varied from 8.2 to 11.5ppt.. Lobsters acclimated at 25ppt., the lethal salinities ranged from 9.2-14.8ppt.. Finally, for lobsters acclimated at 30ppt., the lethal salinity levels were from 6-16.4ppt. (McLeese, 1956). We replotted McLeese's data to show the relationship between lethal salinity andtemperature, at different acclimation salinities. the different lines are the different salinities the lobster was acclimated at (Fig. 3).

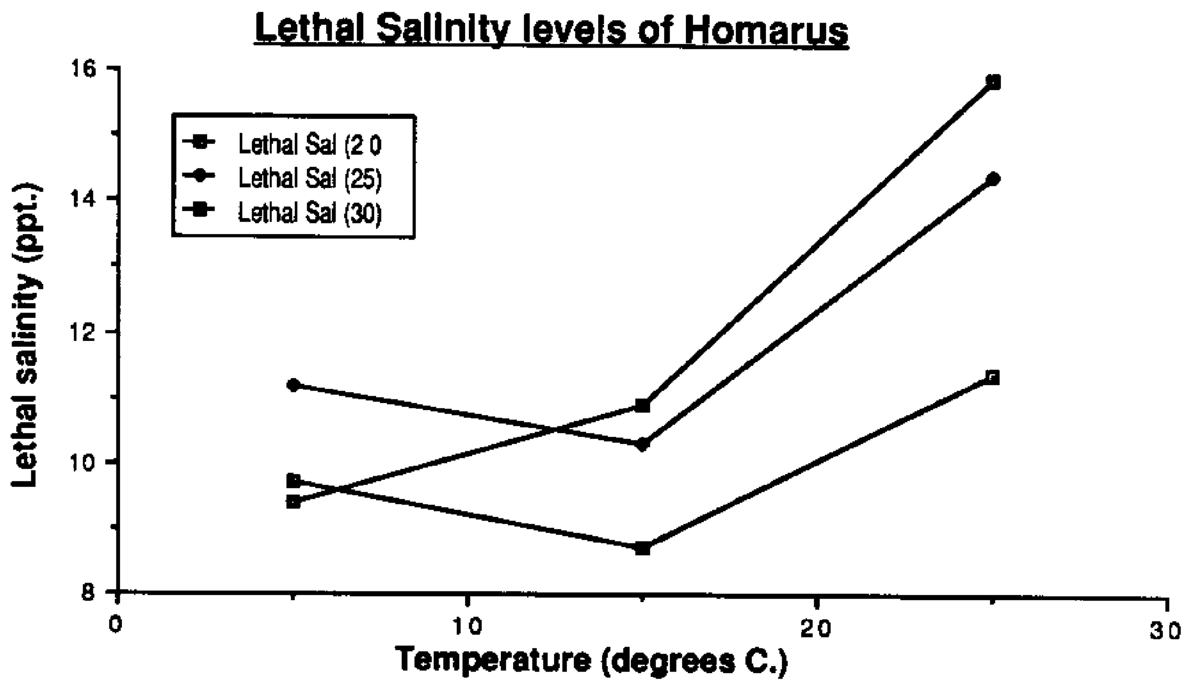


Figure 3. This graph shows the lower lethal salinity levels for *Homarus* . The lethal limits varies with the temperature to which the lobster was acclimated . The higher the temperature, the higher the salinity lethal limit will be in most cases. However, the amount of oxygen dissolved in the water also varies with temperature and will have a great effect on the survival of lobsters.

The temperature in Great Bay in the spring is approximately 10-15°C (fig. 2). At this temperature the lethal salinity can be found to be around 9ppt.. On the average, the salinity in Great Bay is 15 ppt. in the spring, suggesting that lobsters could survive the spring runoff (fig.1). However,if the salinity in the Bay rapidly drops below this, the lobsters could die. If the change is slower, it may give the lobsters time to go to a more acceptable place, most likely near the Atlantic Ocean.

Lobster Catches

The main motivation for this study centers around declining lobster catch in the Great Bay Estuary during periods of increased rainfall. Past catch data was obtained in order to examine the possible effects of rainfall on the strength of the fishery and this was correlated with JEL data.
However, this information (annual reporting by fishermen of catch and equipment inventory) gathered by N.H. Fish and Game was not helpful when examining the Great Bay Estuary, for it is presented as total catch for all N.H. waters (including offshore fishery). Also a reporting deadline of Jan. 10 for

each previous year splits catch data into seperate years (at the slowest period in the fishery as well as) about the time during which the fishery is most likely effected by enviornmental parameters. Therefore it is difficult to use this information to look at the effects of continuous variables such as rainfall on the yearly catch.

Lobster activity or movement (catchability) is qualified by the state of the fishery. Local fishermen refer to the lobsters as moving (or active) when they are being caught in traps. It is presumed lobster activity is dormant (movement does not exist) when the catch is poor or none.

Lobster movement is seen to be affected by enviornmental variables in the area along the coastline of York, Maine. Lobster fishing is prohibited in the York river (in York Harbor) and local fishermen set their traps at the mouth of the river (in hopes of a catch). The fishery in that small area greatly increases after periods of rainfall when lobsters in the river emmigrate to the coastal waters(>sal) (pers. com.). This suggests that lobsters avoid potentially lethal drops in salinity by moving towards the ocean. However, because no exact record of Great Bay Lobster catch exists , a field catch study is neccessary to quantify Lobster population and movement within the estuary. This field study can provide information on lobster location (catch site) as well as activity. Lobsters are caught and tagged in order to examine trends and determine the range and direction of movement in actual individuals. This information can be correlated with hydrographic data to describe the relationship between lobster movements and salinity changes (enviornmental parameters)in the estuary.

Hypothesis

It is our hypothesis that in response to reductions in salinity lobsters will respond in one of three ways: they could move towards the ocean where the salinity is much more constant, they could move to other isolated pockets in the Bay where the salinity is more favorable, and finally the could remain in one place and die.

Objectives:

The overall goal of this project was to determine where lobsters go in the spring and how they respond to seasonal changes in their habitat. The objectives for the project were as follows:

1. *Determine if shifts in the lobster population up and down the estuary are correlated with changes in temperature and salinity.*
2. *Determine the range of movement of individual lobsters by tagging them at specific locations and recapturing them elsewhere.*
3. *Analyzye and replot existing data to determine if lobsters can tolerate seasonal shifts in temperature and salinity*

4. *Develop an acoustic telemetry transmitter/receiver system capable of tracking a single lobster.*

Methods

Behavioral Analysis

A plastic tank was constructed with two troughs at one end and a partition originating at the troughs, separating the tank into two halves approximately 3/4 of the entire length. The end of the tank opposite the troughs had two holes with a set of rubber tubes placed in them to keep the water level constant (Fig. 4). The tank was initially filled with salt water pumped in from the estuary with a measured salinity ranging from 18-19 ppt. The tank was covered in black plastic to reduce the surrounding illumination. The lobsters used were acclimated in sea tables with water from the estuary with the same salinity range as that initially in the tank. A lobster from the sea table was placed in the tank and allowed to acclimate for ten minutes. Salt water from the estuary was introduced into one trough through a flow meter at a rate of 2-2.5 liters per minute. Fresh water was introduced at the same rate into the trough on the side of the tank where the animal was in a resting position. Salinity readings were monitered using a refractometer, at one minute intervals in the vicinity of the animal nearest the fresh water input (Fig. 5). The salinity at which the lobster is driven out of its resting place and toward the salt water side was determined. This level of salinity was called the salinity avoidance threshold.

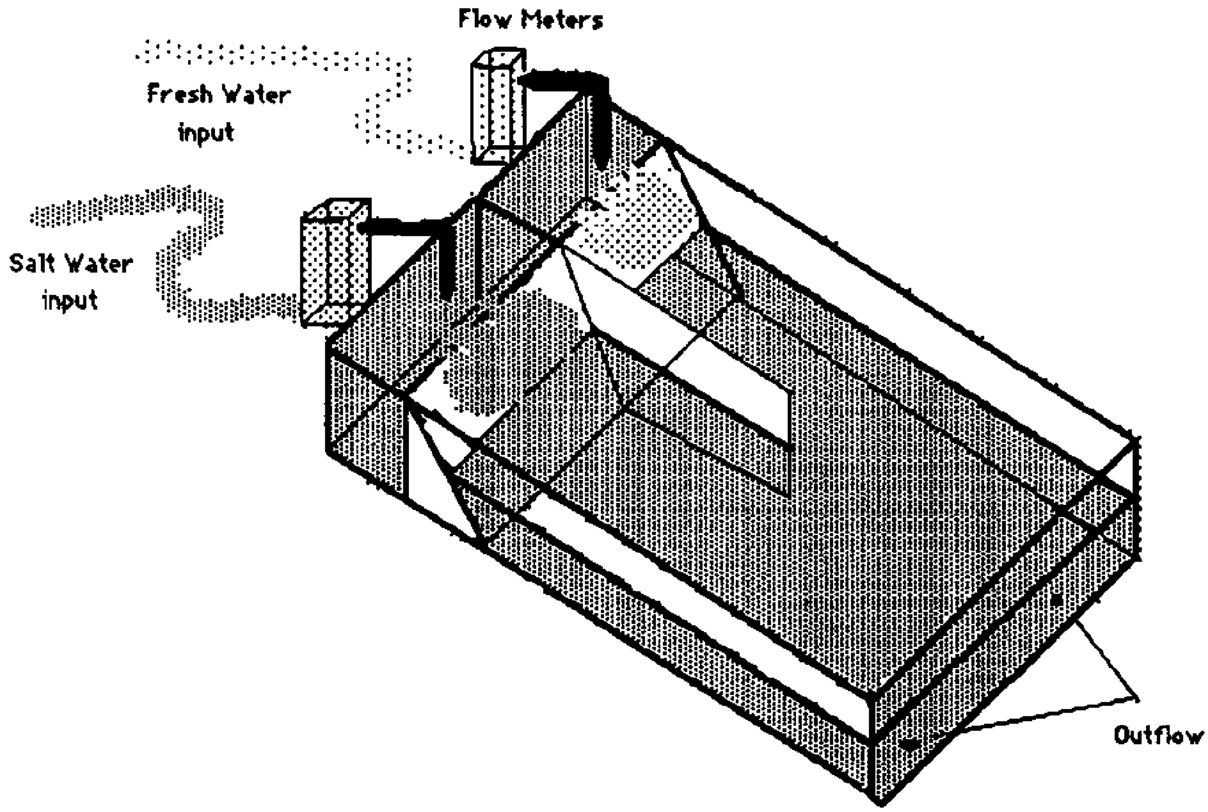


Figure 4 -**Behavioral Testing** Salt water is introduced from the left side of th tank, and fresh water was run at the same rate into the other trough. The incoming fresh water creates a gradient of reduced salinity on that side of the tank. Salt water is represented by heavy dotting, and fresh water by lighter dotting. The water level in the tank is kept constant by the outflow at the far end.

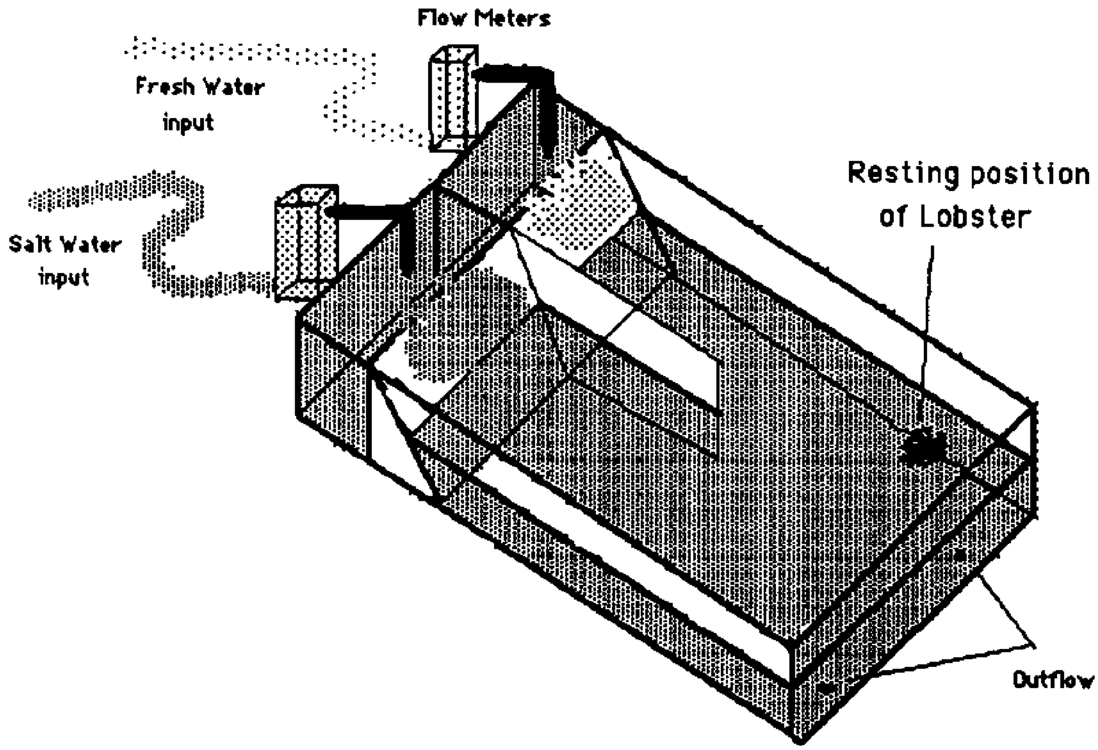


Figure 5: Fresh water was introduced to the side of the tank where the lobster had a resting position. The resting position was determined to be when the lobster stayed in one place for at least five minutes.

Project lobster traps

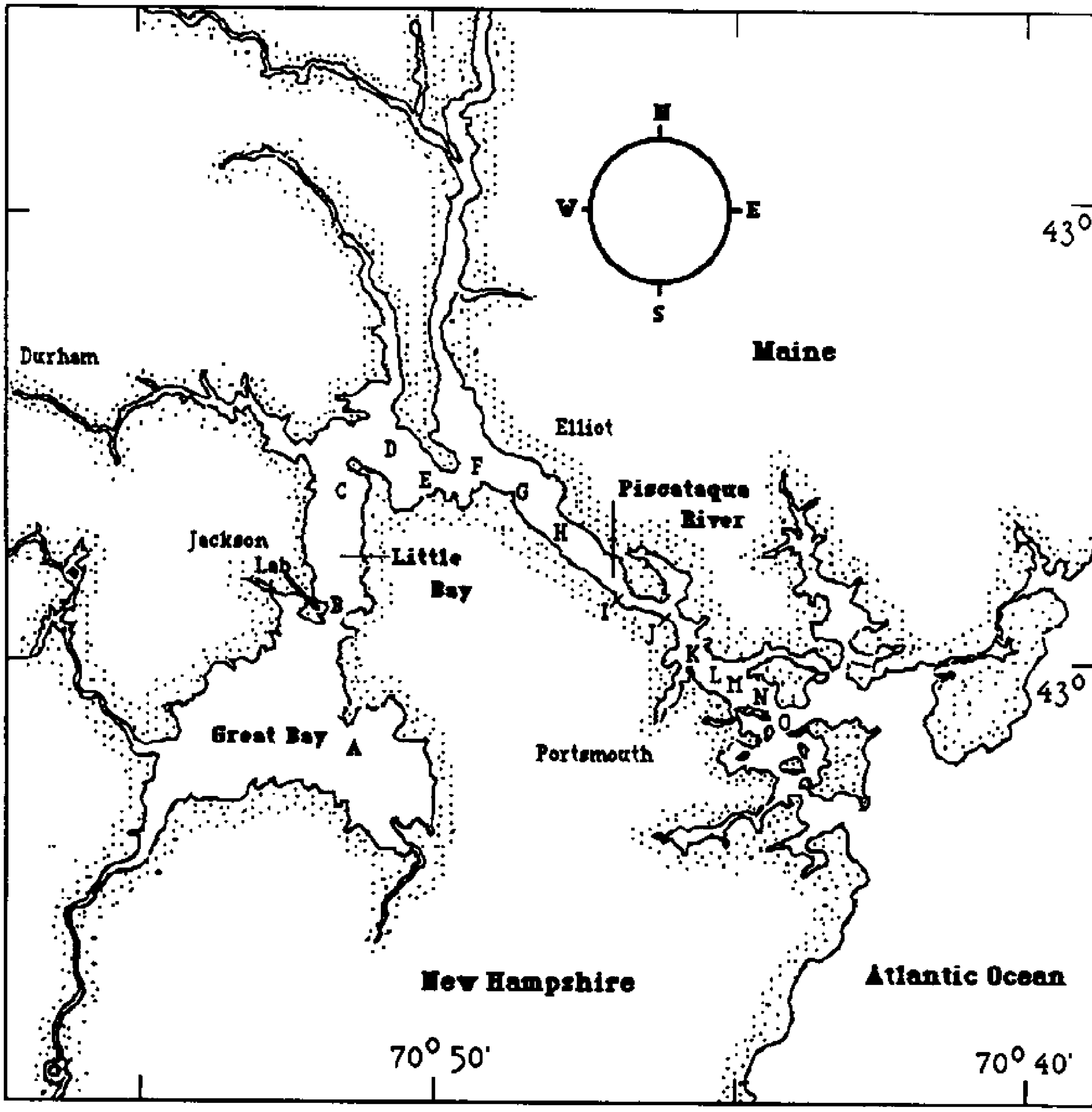
A permit for the collection and marking of lobsters was granted by the New Hampshire Fish and Game Department. Field gear used to obtain Lobster population data included plastic coated wire traps from Flite Line Lobster Traps of Portsmouth, New Hampshire.These rectangular traps measured 36 x 21 inches, and were equiped with nylon heads (6" rings) and (6" x 1 3/4") escape ports, and ballasted with six common building bricks. Sixteen traps were rigged (individually) with a length (@ 10 fathoms) of 5/16" dacron potwarp. Styrofoam bouys of a bullet configuration, measuring 5"x 11" were employed and these were assembled with oak spindles four feet in length. The white bouy barrel was painted with four inch letters "UNH" in black (this was in accordance with the NH F&G permit).

Whole Clupea harengus purchased from the Portsmouth Fishermans Co-operative were used to bait the traps. The traps were fished in pairs (replicates) at eight seperate locations along the estuary (see Key and Map 1).Sampling occured during slack tide (usually Low). At each station individual lobsters caught were measured Measured from the rear of the right eye socket to the dorsal-caudal margin of the carapace. (with ruler to the nearest millimeter and sexed . Sex, size, date and site were recorded for each animal captured (no weights). Unique charachteristics such as absence of claws (cull) or ovigerous females (berried) were noted as well. Prior to release each lobster was given an identifying tag with a number (see below). Hydrographic data (sal. temp, depth) was recorded at stations when lobsters were found. This information was collected using a Nansen bottle to sample bottom water. Salinity was measured with a refractometer; Temperature with a thermometer, and depth was recorded using a fathometer. The traps were rebaited and reset in the original location.

Traps were removed from the estuary on December 8,1987 becuase Great Bay freezes during the winter months and the JEL docks and research boat were removed. Fishing resumed April 19, 1988 once the research boat and dock floats were replaced at Adam's pt.

Commercial Trapping

Additional Trapping with a commercial fisherman, John Bowden of Elliot, Me., was introduced in order to obtain a larger number of tagged individuals, as well as sample the lower portion of the estuary (Piscataqua river). Project personnel accompanied the fisherman (Captain Bowden) to record catch data, and tag and measure the non-legal shorts (less than 3 3/16 inches or 81mm.) and berried females (all discards). Approximately 80 wire traps set along the Piscataqua river from Shiller Plant to Naval Prison were sampled (weather permitting). This area of 'commercial' fishing was divided into seven areas of approximate equal size, and each one was labeled as a seperate station for catch data(see Key and Map 1). The same type of trap and bait were employed as the above project but with a much greater fishing effort (note- few other fishermen had traps working these areas on these trips). Water sampling using the Nansen bottle was not possible on these trips due to swift currents and lack of time. Use of a Salinometer may prove this task feasible. No catch sampling was performed during the winter months because fishing gear was extracted due to the weather and declining catch. Fishing resumed the first week of April, 1988.



Trap Sample Locations

Water Body.	Chart key	Location	Depth*
Great Bay	A	Nannie Island	15
	B	Adams Point	43
	C	Little Bay	48
	D	Goat Island	46
	E	Dover Point	47
U. Piscataqua	F	Gen. Sul. Bridge	36
	G	Sea-3 Pier	18
	H	Simplex Wire	20
L. Piscataqua	I	Shiller Plant	35
	J	95 Bridge	24
	K	Gypsum Plant	35
	L	SML Bridge	45
	M	Badger's Island	32
	N	Navy Yard	52
	O	Naval Prison	68

* approximate average in feet

Tagging of Lobsters

The lobsters captured by the methods descibed in the previous section were tagged prior to release. The tags employed were FTL-69 manufactured by the Floy Tag and Manufacture Company, Seattle, Washington. These consist of a coded yellow polyvinyl chloride tubing (38mm) attached to a stainless steel Sphyrion anchor by a polyethylene monofilament leader(3/4"). The yellow tubing is imprinted with the following: **(000>999)-UNH-862-2100-REWARD.** Lobsters are tagged by inserting (the anchor) with a hypodermic needle through the connecting membrane between the carapace and the first abdominal segment and implanted in the right dorsal extensor muscle. (Tagging technique adapted from Scarrett 1970). After receiving a tag, the lobster was released at the site of original capture. The entire handling period lasted @ one minute.

As stated on the tag a reward was offered for the return of a tag number and location data. This reward consisted of @700 dollars worth of lobster fishing gear (used during this study) which was to be given to a randomly selected individual (at the end of the study) who returned tag information.A poster was used to inform local fishermen of the research project and the type of catch data needed, as well as provoke an awareness for tag sightings. This poster was displayed at fishing gear supply stores and commercial pounds. The telephone number on the tag is to be used to call in information regarding tag number, recapture site and depth, and lobster size.

Telemetry Development

The initial move into telemetric studies of underwater animals appears to have been conducted in 1956 at the Seattle Laboratory of the National Marine Fisheries Service. This study involved the attatchment of ultrasonic transmitters to salmon so that their migration up the Columbia River could be monitored. This same equipment was used again for similar research in 1964 and 1967. (Stasko and Pincock, 1977) With the dawn of the 1960's and the ready availability of transistors, the use of telemetry became more common. In the early 1970's D.G. Pincock developed one of the simplest forms of telemetric tracking. This technique involves the use of a transmitter which sends out pulse trains at frequencies between 20 and 300 KHz. The transmitter uses pressure waves which are generated by small piezo-electric transducers which are most commonly made of lead-zirconate-titanate. A single hand held directional hydrophone is then used to monitor an area and it is possible to determine location by listening for changes in signal amplitude. This system will only give a rough measure of position, as opposed to the more exact positions which other, more advanced systems may offer. (Symposia of the Zoological Society of London, 1982)

Since these initial studies using underwater biotelemetry, many studies have advanced and refined these systems such that various forms of data, other than location, may be simultaneously obtained. Biotelemetry has been used on studies ranging from the migration of Salmon previously mentioned to the daily behavioral patterns of Spiny Lobsters. (Stasko and Pincock, 1977) For example, extensive discussion of heartbeat and depth transmitters is found by Lawson et al. 1974. They used the process of modulation, varying the frequency of the transmitted carrier wave in coded form, to transmit information about heaartbeat or depth on a carrier wave of approximately 50 KHz. (Konwisher, Lawson, and Sundnes, 1974) To provide an idea of the physical dimensions of these systems consider that D.B. Pincock developed a small ultrasonic transmitter with dimensions of 6 mm X 25 mm (cylindrical), which maintained a range of 200 m and a transmitting life of ten days. (Pincock and Luke, 1981) Another significant study which demonstrates the development of telemetry involves the study of feeding habits of Salmo trutta which was conducted at Airthrey Lock, University of Stirling. In 1975, a system developed by I.G. Priede and A.H. Young adopted the previously mentioned heartbeat transmitter which was implanted in brown trout. This transmitter operated at 220 KHz with a lifespan of 4-7 days depending on the selection of the batteries. (Priede and Young, 1977) By May of 1978, R.L. Oswald reported in far more detail on the feeding activities of the Salmo trutta using a much more stable, lighter weight, and smaller transmitter. (Oswald, 1978) A difference of three years had greatly enhanced the level of research, and thereby the correlation of data to theories regarding the species.

Design Considerations:

After completing a literature search on previous methods of underwater tracking, it was necessary to consider what factors of the lobster tracking project would be of significance in the final design of our telemetry system. The first significant factor is environmental. The lobsters will be tracked from a base point of Jackson Lab, Durham Point New Hampshire, in Great Bay/Little Bay . This means that the transmitter will be operating in salt water, however the salinity level of the bay varies with the tide and the flow of the five rivers which feed into the bay. Average depth in the bay is approximately 30m and it is fairly narrow, which reduces the need for an extremely large range.

The lobsters will affect the transmitters by their range of motion. Although this is unresearched for the most part, a study in 1981 used electromagnetic waves transmitted from rock (spiny) lobsters to the surface where a 40,000m area was covered by a grid of loop antennas (every 6m.). Although the depth range involved for adult lobsters was 30-150m, the activity or range of motion was limited to approximatedly 100m. This study also showed that the lobsters were inclined to return to a 'den' in a cyclic manner similar to some form of rest period. (Phillips, Joll, and Ramm, 1984) Although the bay lobsters may have greatly different actions, the speed with which they cover this distance should be fairly slow.

The physical size of the transmitter must be as small as possible, taking the other design considerations into account of course, and also have a fairly low buoyancy. The approximate life span of the transmitter should be a minimum of nine days to allow for a reasonable data spread on the individual lobster being studied. The final design consideration, as is always the case in any project, is too keep costs to a minimum. In this case the absolute maximum budget for the electronic tracking system was approximately $800.

The overall system to be used will be modified from the system outlined by Pincock (Symposia of the Zoological Society of London, 1982) which used directional hydrophones to monitor the transmitted pulse trains. The receiver and hydrophone will be commercially obtained. This leaves the design of a pulse train transmitter to be the main aspect of the telemetry portion of this project. Based on the previous examples of telemetric systems, the following list is a compilation, in order of consideration for the design of a transmitter.

1) Frequency Selection
2) Transducer Specifications
3) Oscillation Electronics
4) Power Source
5) Encapsulation and Packaging

Frequency selection is very well defined. The use of ultrasonic transmitters is universal for salt water systems. "Acoustic tracking is used where the underwater attenuation is high, precluding the use of RF (radio frequency) tags. This includes ***all salt water*** ..." (Symposia of the Zoological Society of London, 1982 , p. 15) The range was further defined by other significant studies such as Lawson's comment that "most [salt water telemetry systems] frequently employ frequencies between 40KHz and 80KHz." (Kanwisher, Lawson, and Sundnes, 1974, p. 251)

Experimental data has verified the correlation between transmitters with frequency between 20 KHz and 100KHz with ranges from 200 to 5000m, and several curves which show the correlation between range, frequency and transmitter output. These curves are shown in figure 6 below. (Stasko and Pincock, 1977)

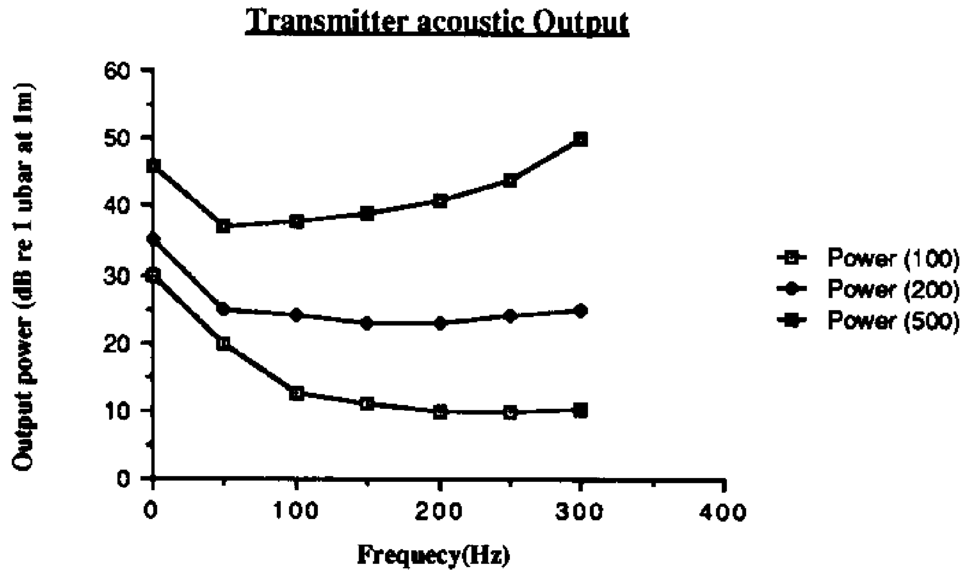


Fig.6 : Transmitter acoustic output needed for OdB signal-to-noise ratio at various frequencies and distances(meters) using a receiver with 1 kHz bandwith in coastal seawater.

Another useful form of a similar graph is to display the transmission loss experienced by ultrasonic waves propagating through sea water at several frequencies. Figure 7 illustrates such effects. Since the most appropriate frequency range for salt water systems seems to be between 40KHz and 80Khz, and considering that the environment being examined is lower in salinity as well as being fairly confined to small depths, it is acceptable to select a value in the upper level of this range. Allowing a margin of range fallability and realizing that the higher the frequency the smaller the transducer, the value of 70KHz has been selected. It should be noted, however, that this value is able to fluctuate considerably based on other design factors.

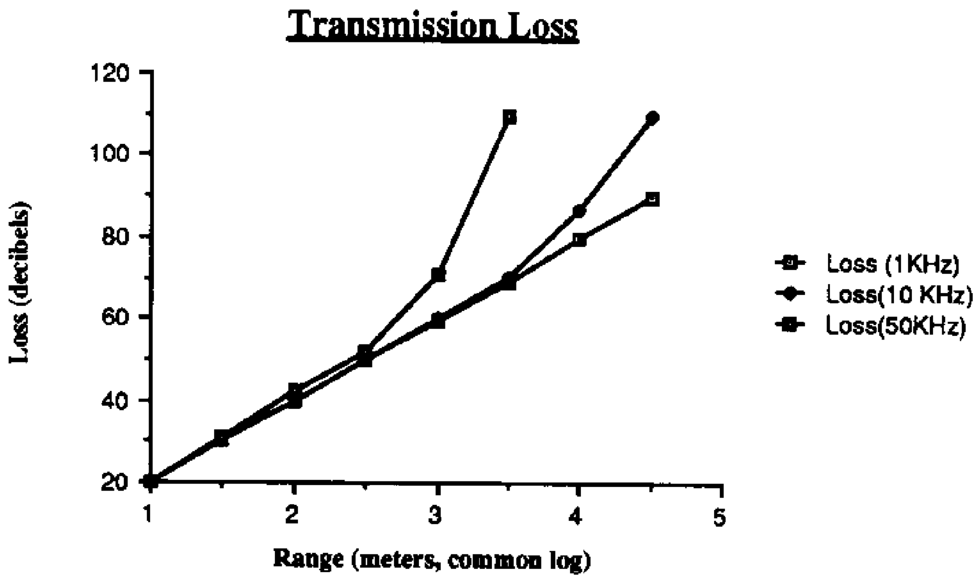


Fig.7 : This graph demonstrates that as the range of the transmitter increases, the transmission loss also increases. There is a much sharper loss at the higher frequencies such as 50 KHz than at the lower frequencies like 1 KHz.

Transducer Determination was well outlined by previous studies. D.B. Pincock claims that all transducers for biotelemetry (except for very high power transmitters)should use a ceramic transducer made of Type 5 material. (Pincock and Luke, 1981) The transducer is nearly universally accepted to be a cylindrical, length not to exceed diameter, radially vibrating, electric to accoustic, PZT (lead-zirconate). (Stasko and Pincock, 1977) Since this project does not require a very high power transmitter, it was a simple decision to use the transducer defined above. The dimension of the transducer are defined by the frequency with which they will operate.

The Oscillation Electronics is the first area in which significant design is possible. The significant factors of this aspect are to use as little power as possible, keep the size reduced, and output a 70 KHz wave for the transducer. There are many possible forms of this circuit ranging from the simplistic squegging oscillator which uses but a single transistor but is very difficult to stabilize, (Pincock and Luke, 1981) to the complex multi-stage amplifier/comparitor developed by I.G. Priede and A.H. Young. (Priede and Young, 1977) Given the advancements in chip technology since the development of the aforementioned systems, it was more appropriate to design the electronics for better precision than provided by the squegging oscillator, without adding all the flair of the more complex circuits. Since certain chips were made available free of charge, the design revolved around those chips. The 555 timer and the LS7400 Quad NAND gate (see specifications in Appendix) were implemented in a two module system, a pulse train generator and a frequency generator. The 555 timer is capable of providing both functions based on how it is configured. Figure 8 a shows the basic configuration for any pulse train, figure 8 b will illustrate the necessary configuration for the pulse generator, while figure 8 c illustrates the proper setup for a frequency generator, which will produce the output waveform as shown in figure 10.

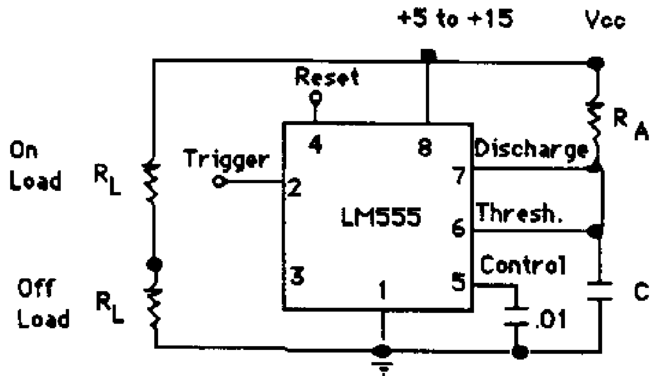


Figure 8A

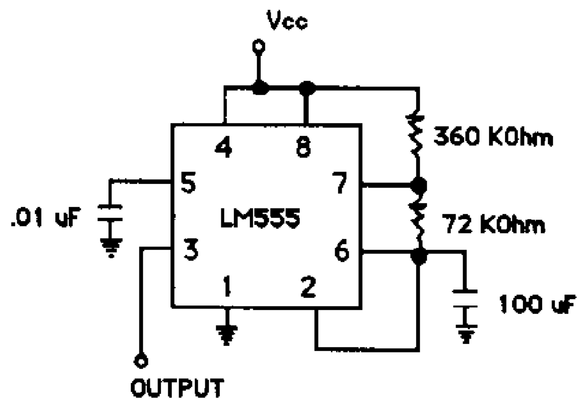


Figure 8b

Pulse Generator

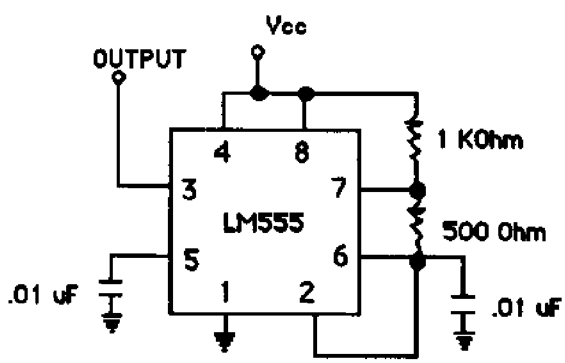


Figure 8c

Frequency Generator

The calculations for figures 8 b, and c are as follows:

Pulse Generator with pulse width of 5 seconds, and pulse seperation of 30 seconds.

Note: Since the 555 timer cannot produce pulse trains with $t_1 < t_2$ an invertor must be attached to the output of the 555 timer so the values may be adjusted such that the pulse width $t_1 = 30$ seconds while the pulse seperation $t_2 = 5$ seconds prior to inversion which gives the desired pulse train.

$$t_1 = .693 * (R_A + R_B) * C$$

$$t_2 = .693 * (R_B) * C$$

Let C=100 uF for commercial availability

Thus: $R_B = 72.15$ KOhms ==> 72 KOhms

t_2 becomes 4.9896 seconds

$R_A = 360.9$ KOhms ==> 360 KOhms

Frequency Generator with desired frequency of 70KHertz

$$f = 1.44/((R_A+R_B)*C)$$

Using figure 9, select value.

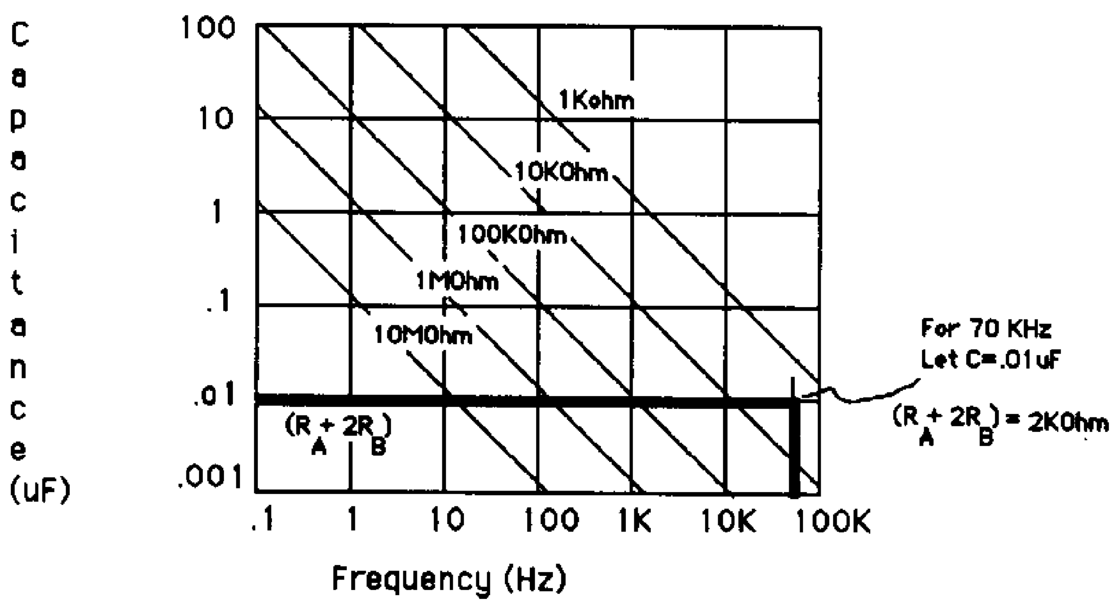


Figure #C Frequency Determination

Thus: $R_A + 2\,R_B = 2057 \Longrightarrow 2000$

Let R_A=1KOhm thus R_B = .5KOhm

The actual frequency is therefore ==> 72KHz

The final circuit involves ANDing the two modules to produce a 72KHz wave modulated on to the desired pulse train. To cut down on circuitry, the quad nand is configured to build the AND gate needed. The final result is shown in figure 12 The effect is to provide the transducer with a 72KHz signal for 5 seconds every 30 seconds.

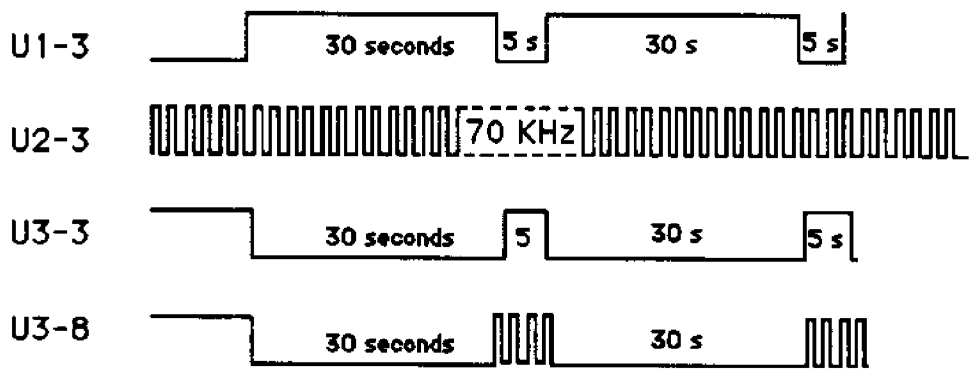


Figure 11 Timing Diagram of Circuit

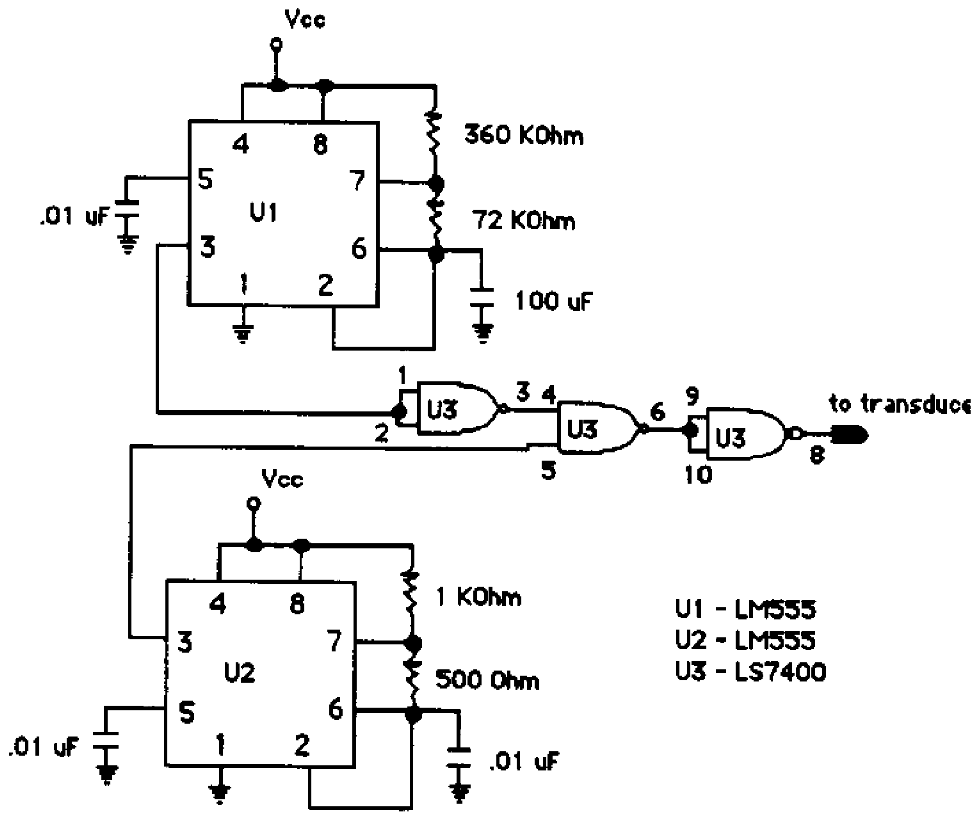


Figure 12 Circuit Schematic

Power source design once again has been clearly defined as a standard for the transmitter just designed. The highest powered battery proportional to the small size stringents caused by the environment is the mercuriic oxide baattery. According to Pincock, these batteries maintain a very stable voltage until nearly drained . (1)

Finally, Encapsulation is being based on previous research by Winsor Watson III of UNH. Currently there are two approaches, placing the unit in a tube and filling it with an oil bath, or an epoxy coating. This project chose the latter since it has reduced size and increased performance (thinner layer), as well as being simple. It will be accomplished via the use of Sylgard a quick drying waterproof epoxy which will coat the entire transmitter.

Results and Discussion

Physical Parameters and Behavior

The salinity in the estuary is known to fluctuate seasonally. It also varies in relation to the proximity of the ocean. In other words, the further from the ocean an area is, the lower the salinity and the greater the effect of spring runoff. The data from Jackson Lab was examined and the relevant numbers were replotted and regraphed. The following results were obtained. At station 1, which is located at the mouth of Portsmouth Harbor, the highest average temperature occured in July and was 13°C. The lethal salinity for lobsters acclimated at this temperature is 11ppt.. The average salinity recorded at this station in July was 31ppt. (fig 12).

Station 4 (midway between Great Bay and the Atlantic Ocean) was examined next. The highest average temperature was in June and was 21°C. The lower lethal salinity for lobsters acclimated at 21°C is approximately 9ppt.. The average salinity for the month of June at station 4 wa 28ppt. (fig 12).

At station 7, which is the farthest station from the ocean, the highest average temperature occurs in July, and was found to be 25°C. The lethal salinity for lobsters acclimated at 25°C was 14ppt. (McLeese,1956). The average salinity for the month of July at this station was19ppt. (fig12). The higher the temperature, the more sensitive lobsters are to reductions in salinity. The time of year when the temperature was the highest, the average salinity at these various stations was well above the lower lethal limit. These results imply that lobsters should have no diffuculty surviving in these areas during the summer months.

The same 3 stations were looked at again, this time looking at temperatures and salinities during the coldest part of the year. For all the stations the lowest temperatures occured in January and were all 0°C. The average salinity at this time for station 1 was 33ppt. ,for station 4 it was 24,finally for station 7, the average salinity was 21ppt. (fig 12). Lobsters are less sensitive to reduced salinities at lower temperatures. This would indicate that the average salinities at all three stations were well above the lower lethal limits. Once again, it is probable that lobsters would not be adversely affected by these salinities.

Average Monthly Salinities for Stations 1-7

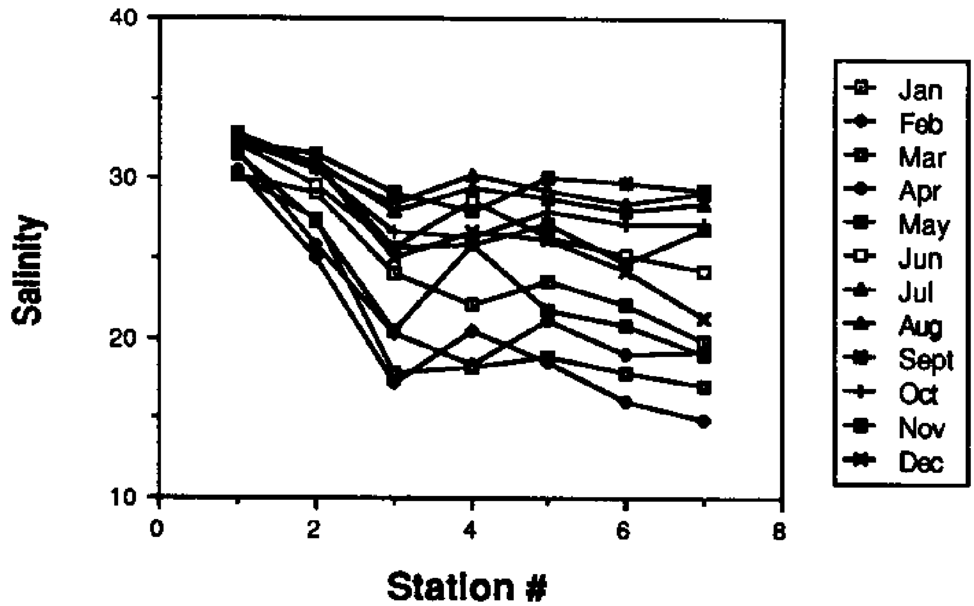


Fig. 12 : This graph shows how the salinity changed monthly in various areas of Great Bay and the surrounding areas. It gives a good indication of how the salinity changes as distance from the ocean increases.Finally it shows where seasonal highs and lows in salinity occur.

Finally, the data was examined, focusing on the spring, specifically the months March and April. For station 1 in March, the average temperature was 8°C. At this temperature the lethal salinity 9.5ppt.. The average salinity in this area was 30ppt.. The average temperature at station 4 was 15°C and the lethal salinity is 9ppt.. The average salinity during this time at station 4 was 18ppt.. Finally, at station 7, the average temperature during March was 14°C. The lethal salinity is approximately 8ppt.. The average salinity is around 12ppt. (fig 12).

In April, the average temperature at station 1 was 8°C. The lethal salinity is 9.5ppt.. The average salinity was 30ppt.. For station 4, the average temperature was 8°C the lethal salinity is 8.5ppt. and the average salinity at this station was found to be 20ppt.. Finally, at station 7, the average temperature was 12°C. The lethal salinity for this temperature is around 9.5ppt.. The average salinity was 16ppt. (this is the site of the lowest average salinity of the year). April and March are the months where the lowest average salinities are found at each station. The lowest average salinity (found at station 7) is still 6.5ppt. above the lower lethal salinity limit. This would indicate that in an average year, lobsters in the Bay can survive the reduced salinity created by spring runoff (fig 3).

However, 1981 was not an average year. From the data obtained from Jackson Lab, a drastic reduction in salinity occured in the month of March. The salinities ranged from 5ppt. below average for station1 to 15ppt. below average for station 2. The mean salinity drop for all stations was 8.8ppt. below average. The average normal salinities for stations 1, 4, and 7 for the month of March were 30, 19, 12 respectively (this also shows the reduction of salinity as the distance from the ocean increases). In 1981 the salinities at these stations were 25, 9, and 6. In the area around station 1, the average salinity in 1981 was well above the lower lethal limit. However, at station 4, the average salinity is very close to the lower lethal limit. And at station 7, the average salinity in that year was close to or lower than the lower lethal limit (see fig 13).

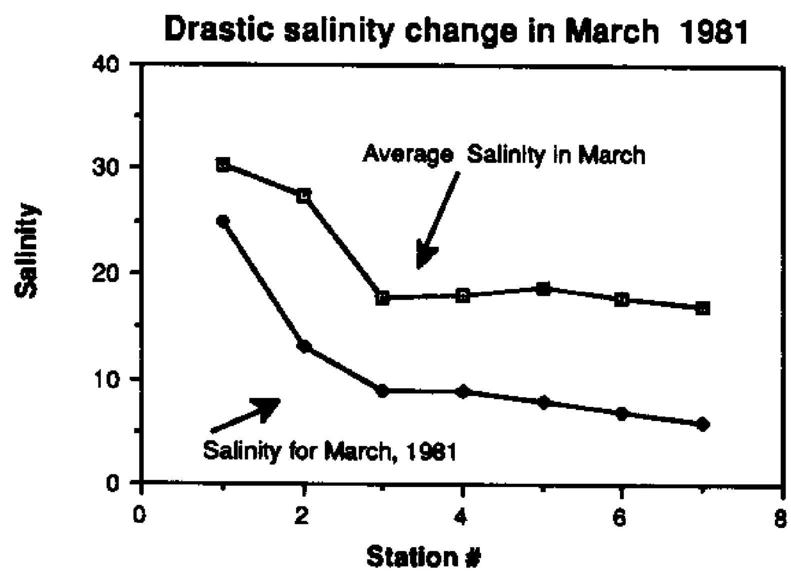


Fig.13 : In 1981, there was a drastic drop in salinity occuring in all months. This reduction can be seen most dramatically in the month of March. Salinity for all the stations in the month of March was compared to the average salinity.

This data indicates that in years such as this (with a drastic reduction in salinity) the lobsters could do one of three things: migrate towards the ocean, seek isolated pockets within the Bay with more favorable salinities, or stay in the area of low salinity and most likely die.

Behavioral Responses of Lobsters to Low Salinity

Experiments to determine the response of lobsters to reduced salinity were preformed at Jackson Estuarine Lab. The lobsters were subjected to gradual reductions in salinity until they moved to the area of the tank with the highest salinity. The salinity at which they were driven out of their resting position was called the salinity avoidance threshold. From the laboratory data, it was found that the mean salinity avoidance threshold was 11.6ppt. at 9°C at an initial salinity of 18ppt. (Fig.14).

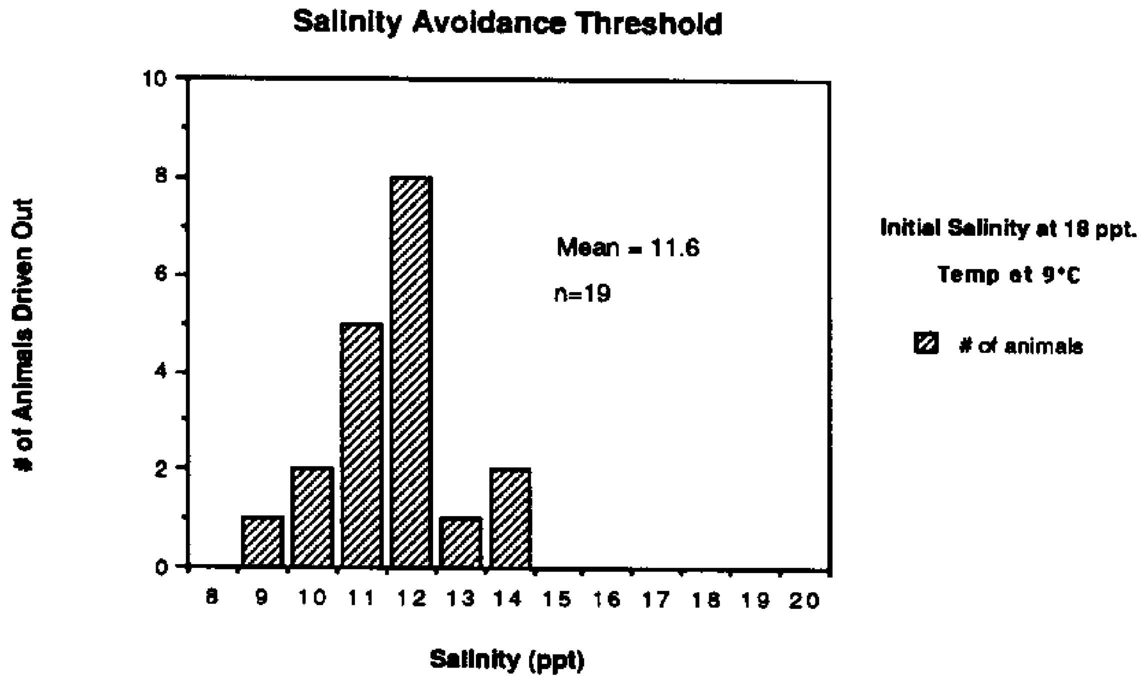


Fig. 14: This is a histogram showng the salinities at which lobsters will become disturbed and seek a better location. It shows the frequency of lobster avoidance at different salinities. The mean of the salinities is defined as the salinity avoidance threshold.

As the salinity decreased, the lobsters became increasingly agitated,their antenna flicked rapidly and there was increased movement of the scaphognathite. As the salinity approached the salinity avoidance threshold, the lobsters finally moved to the salt-water input side of the tank (Fig.15).

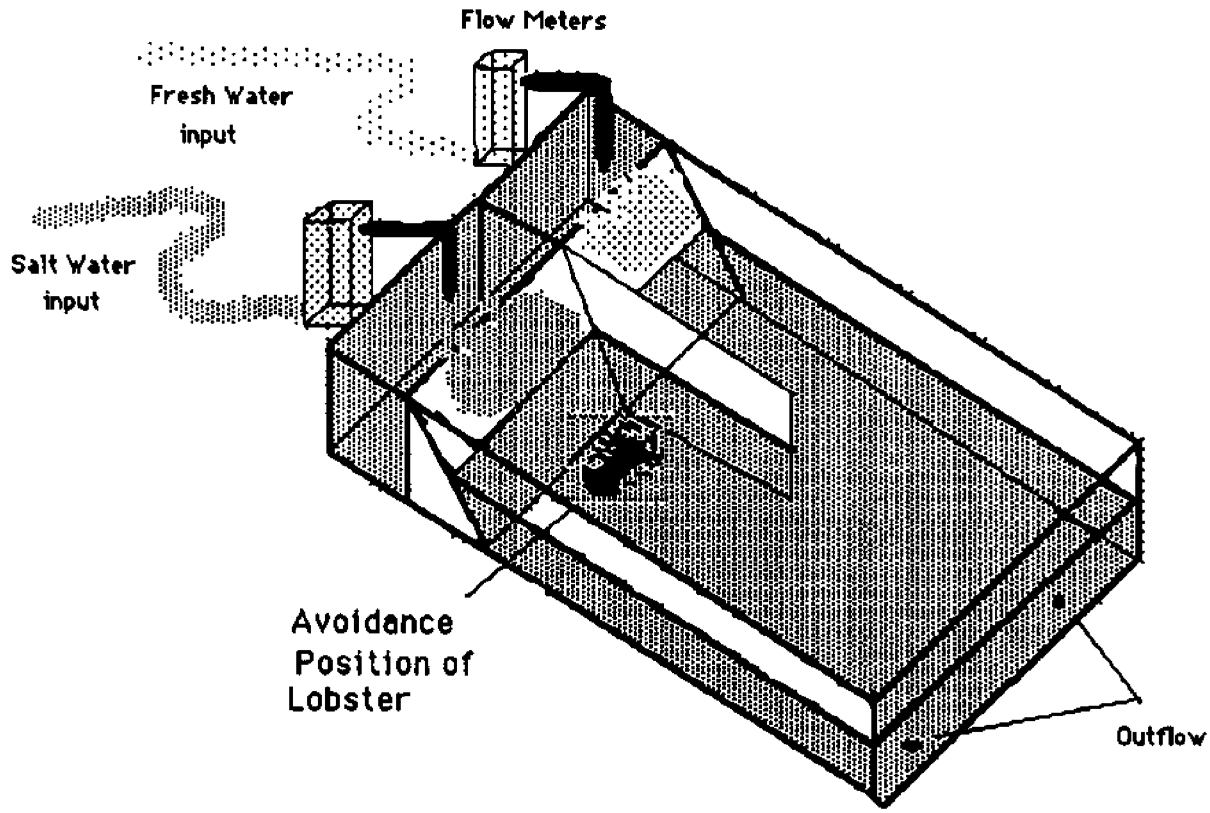


Fig. 15 : This is a diagram of the tank after the fresh water has been introduced. The fresh water came in on the right side of the tank. In order to avoid the lower salinity produced, the lobster has moved to the left side of the tank, where the salt water was running.

This demonstrates that lobsters are indeed able to sense changes in salinity and their behavior is affected by these changes.This data could be extrapolated to the conditions in Great Bay. In an average year, the salinities at all stations remain at a tolerable level, even during the spring runoff months. Therefore the lobsters could remain in all parts of the Bay. From interviews with lobstermen and direct observation, it is evident that the lobster catch during these months farther up in Great Bay is reduced. This catch reduction may be due to the fact that the lobsters become disturbed and as the salinity drops, they could move towards the ocean (where the salinity is higher) or to isolated places in the Bay where the salinity is also favorable. It is not likely that the lobsters remain in the Bay and perish.

Project lobster catch

Last fall, 29 lobsters were captured in our traps lying in the upper bay. These included shorts and keepers and were tagged by project personnel (Appendix A). At present there are no recaptures from this group. No lobsters have been captured at these sites this spring. Few traps besides those belonging to this project were fishing in the upper estuary during the sample dates in late and early spring. Lobster activity is sparse as illustrated by the small numbers caught. Lobsters were found to occur mostly around the pilings at the SEA-3 pier. Perhaps this area offered boundary layers for protection from the enviornment. The small number of captured lobsters and insignificant amount of hydrographic data collected is inconclusive. Zero catch for the spring may suggest that the enviornmental parameters are not well above the lethal limit, and lobster activity remains low. Winter and spring weather conditions preclude possibility of steady sampling. Sampling of this area will continue into the summer months in hope of expanding the data.

Commercial catch

Commercial trap catches (taggable lobsters) in the fall (December 13 & 18) amounted to 101 shorts and berried females (Appendix B), and in the spring (April 10,15,17,21) 240 individuals (Appendix C). Table 1 shows how the non-legal catch was distributed for the dates of sampling.

Commercial catch

Sample Dates	Trap Location							
	I	J	K	L	M	N	O	T/D*
December 13, 1987	5	8	4	7	0	0	17	41
December 18, 1987	0	11	6	1	2	38	2	60
April 10, 1988	0	1	0	7	0	18	20	46
April 15, 1988	6	17	15	0	0	40	xx	78
April 17, 1988	3	14	5	5	0	14	3	44
April 21, 1988	0	6	7	17	0	22	20	72
Total catch/Site	**14**	**57**	**37**	**37**	**2**	**132**	**62**	

Table 1 Commercial catch locations showing the numbers of non-legal lobsters tagged on each date of fishing.

* total catch per date sampled

xx traps here were not sampled until a later time because of excess current. Recapture site of tag # 0158.

Lobster catch by commercial fishing makes up most of our catch data, and this can be attributed to the greater amount of fishing effort. The distribution of the lobster population within the estuary (rslt2) seems to lean toward the Atlantic Ocean. The population may center in that area to avoid possible lethal limits in the upper portion of the estuary. These lower areas also contain very deep holes in which lobster might lie in low water temperature protected from severe salinity changes. More specific hydrographic data will be collected in future study using a salinometer.

During the spring sampling the catch often included large keepers which were clean of the scum usually found on lobster residing in the Piscataqua river. This is a probable indicator of lobster migration into the estuary from offshore. These were also found in deep water by the Naval Prison. Error exists in the commercial catch because the areas do not include replicate traps and fishing effort is unequal. Sampling will continue with commercial fishermen so that complete data will be recorded monitoring the catch growth and movement of the population.

Mark and Recapture

One tagged lobster was recaptured in the spring. The individual had originally been tagged on April 10 at the Naval prison and was retreived on April 15 at the same location. Tag # 0158 was recaptured 5 days after release with no substantial movement from origin. This could be attributed to a stable enviornment or an area where lobsters are protected (from lethal enviornmental parameters) and can remain active. The single return in the recapture study represents approximately .25% of the 371 individuals tagged to date. This return is not enough to be conclusive.

This study relies on the help of fishermen for successful tag returns; error may exist because most of the tagged lobsters are considered commercial discards and fishermen may not examine these individuals closely because they have no commercial value. Keepers, if caught, are presumed to be removed from the population and study pool. Tagging studies will continue through the summer (tags have been known to remain intact even after ecdysis).

Conclusions

Lobsters in Great Bay possibly behave in one of three ways in response to reductions of salinity during the spring runoff: they either move to isolated pockets of the Bay where the salinity is more suitable, or move towards the ocean where the salinity is higher, or they could remain in the Bay and simply perish. The data obtained from Jackson Estuarine Lab indicates that most years lobsters are able to survive the reduced salinity created by the spring runoff. Examining the data for the last 10 years it is apparent that there are some years which the salinity drops drastically to levels at or below the lower lethal salinty. It is not entirely clear whether the lobsters expire or migrate, but the literature indicates that there is some mortality but the majority of lobsters go to other areas (Thomas and White, 1969).

The behavioral studies indicated that lobsters become agitated at reduced salinities which are still above the lethal limit. This may cause them to migrate to higher (more favorable) salinities during the spring runoff months in an average year. Even if they did stay in the Bay the salinity is

Acknowledgements

This project would not have been possible without the supervision of our advisors W. W. Watson and Hunt Howell. The organization of this material was driven by our central nerve system with [illegible] of computer [illegible]. Hunt was [illegible] in the field, on the fish [illegible] to collect lobsters. This is especially true for those miserable days (Right Watson??). Thanks goes to the staff at [illegible] Lab for supplying salinity and temperature data and use of [illegible] of the [illegible], John Bowden, whose dedication to science was exemplary, as well as Ed Heaphy for allowing us to tag along

usually high enough to allow for survival in a normal year.

The project will continue over the summer and into the next year in order to complete all the stated objectives. The traps now set will be sampled during this time and data from previously tagged lobsters will also be provided by local fisherman who recapture them. This should make clear the migratory patterns of the lobsters in the Great Bay. The behavioral studies will also continue to find a more precise value for the salinity avoidance threshold.

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Appendices
Trap Sample Locations

Water Body.	Chart key	Location	Depth*
Great Bay	A	Nannie Island	15
	B	Adams Point	43
	C	Little Bay	48
	D	Goat Island	46
	E	Dover Point	47
U. Piscataqua	F	Gen. Sul. Bridge	36
	G	Sea-3 Pier	18
	H	Simplex Wire	20
L. Piscataqua	I	Shiller Plant	35
	J	95 Bridge	24
	K	Gypsum Plant	35
	L	SML Bridge	45
	M	Badger's Island	32
	N	Navy Yard	52
	O	Naval Prison	68

* approximate average in feet

Appendix A
Student Project
catch and hydrographic data

Tag (#)	Sex (m/f)	Size (mm)	Site (key)	Depth (ft)	Temp (C)	Sal (ppt)	Dates (catch-recapture)
0	m	88	A	12	6.0	22	11/17/87-
1	m	80	B	42	5.1	25	11/22/87-
2	m	80	E	42	5.0	26	11/27/87-
3	m	69	G	23	5.5	28	11/27/87-
4	m	75	G	20	5.5	28	11/27/87-
5	m	73	G	20	5.5	28	11/27/87-
6	f	72	G	20	5.5	28	11/27/87-
7	f	79	G	20	5.5	28	11/27/87-
8	f	68	G	20	5.5	28	11/27/87-
9	f	83**	G	20	5.5	28	11/27/87-
824	m	77	H	25	4.9	25	12/06/87-
10	m	88	H	25	4.9	25	12/06/87-
11	m	82	H	25	4.9	25	12/06/87-
12	m	78	H	25	4.9	25	12/06/87-
13	m	73	G	20	4.9	25	12/06/87-
14	m	72	G	20	4.9	25	12/06/87-
15	m	72	G	20	4.9	25	12/06/87-
16	m	78	G	20	4.9	25	12/06/87-
17	m	80	G	20	4.9	25	12/06/87-
18	m	87	D	52	4.6	22	12/07/87-
19	m	84	D	52	4.6	22	12/07/87-
20	m	79	D	52	4.6	22	12/07/87-
21	f	76	D	52	4.6	22	12/07/87-
22	f	76	D	52	4.6	22	12/07/87-
23	f	80	D	52	4.6	22	12/07/87-
24	f	76	E	39	4.2	18	12/07/87-
26	m	84	E	39	4.2	18	12/07/87-
27	f	73	E	39			
					4.2	18	12/07/87-
28	f	80	E	39	4.2	18	12/07/87-

* berried female
** missing claw (cull)

Appendix B
Tagged Lobsters from commercial traps DEC. 13, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
25	m	75	K	
29	m	78	K	
30	f	77	K	
31	m	77	J	
32	m	72	J	
33	f	75	K	
34	f	76	J	
35	m	78	J	
36	m	72	J	
37	f	76	J	
38	f	74	J	
39	m	79	J	
40	f	79	L	
41	m	76	L	
42	m	78	L	
43	m	75	O	
44	f	79	O	
45	m	81	O	
46	f	76	O	
47	m	79	O	
48	m	76	O	
49	m	79	O	
50	m	73	O	
51	m	77	O	
52	f*	80	O	
53	m	80	O	
54	m	81	O	
55	f	80	O	
56	m	80	O	
57	m	79	O	
58	m	75	O	
59	f	75	O	
60	f	79	L	
61	m	69	L	
62	m	79	L	
63	f	78	L	
64	f	76	I	
65	m	79	I	
66	m	78	I	
67	f	80	I	
68	f	80	I	

Appendix B
Tagged Lobsters from commercial traps
DEC. 18, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
69	m	78	N	
70	m	75	N	
71	m	71	N	
72	m	75	N	
73	m	69	N	
74	m	65	N	
75	m	75	N	
76	m	69	N	
77	m	70	N	
78	m	71	N	
79	f	71	N	
80	m	75	N	
81	m	73	N	
82	m	72	N	
83	f	80	N	
84	m	76	N	
85	m	75	N	
86	f	67	N	
87	m	78	N	
88	m	73	N	
89	m	73	N	
90	m	76	N	
91	f	75	N	
92	f	70	N	
93	m	67	N	
94	m	78	N	
95	f*	86	N	
96	f	78	N	
97	f	77	N	
98	f	77	N	
99	m	79	N	
100	m	77	N	
101	f	78	N	
102	f	74	N	
103	f	56	N	
104	m	76	N	
105	m	73	N	
106	m	75	N	
107	f	76	O	
108	f	76	O	

Appendix B (continued)
Tagged Lobsters from commercial traps
DEC. 18, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
109	m	77	M	
110	f	78	M	
111	f	80	L	
112	f*	89	K	
113	f	79	K	
114	f	75	K	
115	f	78	K	
116	m	77	K	
117	f	78	K	
118	f*	80	J	
119	f	72	J	
120	m	80	J	
121	m	75	J	
122	m	71	J	
123	m	73	J	
124	m	80	J	
125	m	74	J	
126	f	77	J	
127	m	78	J	
128	m	75	J	

Appendix C
Tagged Lobsters from commercial traps
APR.10, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
129	m	75	N	
130	m	73	N	
131	m	79	N	
132	f	70	N	
133	m	65	N	
134	m	80	N	
135	f	77	N	
136	m	75	O	
137	m	74	O	
138	m	73	O	
139	m	80	O	
143	m	72	O	
144	m	79	O	
145	f	80	O	
146	m	81	O	
147	m	75	O	
148	f	76	O	
149	m	81	O	
150	f	80	O	
151	m	76	O	
152	m	81	O	
153	m	80	O	
154	m	79**	O	
155	f	79	O	
156	f	80	O	
157	f	81	O	
158	f	79	O	4/15/88,O
159	m	1	N	
160	m	79	N	
161	f	62**	N	
162	f	77	N	
163	m	79	N	
164	f	77	N	
165	f	73	N	
166	f	71	N	
167	m	74	N	
168	m	79	N	
169	m	75	N	
170	f	74	L	

Appendix C
Tagged Lobsters from commercial traps
APR.10, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
171	m	75	L	
172	f	77	L	
173	f*	84	L	
174	m	78	L	
175	m	78	L	
176	m	82	L	
177	f	73	L	
178	m	77	J	

Appendix C
Tagged Lobsters from commercial traps
APR. 15, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
179	m	76	K	
180	f	74	K	
181	m	79	K	
182	f	80**	K	
183	m	77	K	
184	m	79	K	
185	f	78	K	
186	f	76	K	
187	m	72	K	
188	f	78	J	
189	m	79	J	
190	f	79**	J	
191	m	76	J	
192	m	82	J	
193	f	78	J	
194	f	72	J	
195	m	79	J	
196	f	78	J	
197	m	74	J	
198	f	74	I	
199	m	80	I	
200	m	77	I	
201	m	79	I	
202	m	77	I	
203	f	78	I	
204	m	74	J	
205	f	72	J	
206	f	65	J	
207	f	80	J	
208	m	78	J	
209	f	77	J	
210	m	78	J	
211	m	77	K	
212	f	80	K	
213	m	70**	K	
214	m	72	K	
215	f	79	K	
216	f	79	K	
217	m	79	N	
218	f	77	N	

Appendix C
Tagged Lobsters from commercial traps
APR. 15, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
219	f	80**	N	
220	m	78**	N	
221	f	76	N	
222	m	78	N	
223	f	75	N	
224	f	79	N	
225	f	80	N	
226	f	76	N	
227	f	77	N	
228	f	78	N	
229	m	81	N	
230	m	80	N	
231	f	80	N	
232	f	78	N	
233	m	80**	N	
234	m	77	N	
235	f	79	N	
236	f	80	N	
237	f	80	N	
238	m	78	N	
239	m	78	N	
240	f	79	N	
241	f	74	N	
242	f	76	N	
243	f*	89	N	
244	m	77	N	
245	m	78	N	
246	f	80	N	
247	m	79	N	
248	m	77	N	
249	f	77**	N	
250	m	80**	N	
251	m	77	N	
252	m	76	N	
253	f	66	N	
254	f	77	N	
255	f	74	N	
256	m	80	N	

Appendix C
Tagged Lobsters from commercial traps
APR. 17, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
257	m	73	O	
258	m	59	O	
259	m	74	O	
260	m	79	M	
261	m	77	M	
262	f	70	L	
263	m	62	L	
264	m	78	L	
265	m	57	L	
266	f	77**	L	
267	m	75	K	
268	f	75	K	
269	m	76	K	
270	f	76	K	
271	f	77**	K	
272	m	70	J	
273	m	76	J	
274	f	65	J	
275	f	78	J	
276	m	75	J	
277	f	77	J	
278	f	74	J	
276	f	77**	J	
280	f	75	J	
281	m	77	J	
282	f	77	J	
283	f	75	I	
284	m	78	I	
285	f	77	I	
286	m	77	J	
287	m	80	J	
288	f	77	J	
289	m	77**	N	
290	m	69	N	
291	m	74	N	
292	f	74	N	
293	m	77	N	
294	m	77**	N	
295	f	72	N	
296	f	75	N	

Appendix C
Tagged Lobsters from commercial traps
APR. 17, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
297	f	77**	N	
298	m	73	N	
299	f	65	N	
300	f	78	N	
301	f	71**	N	
302	m	72	N	

Appendix C
Tagged Lobsters from commercial traps
APR. 21, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
303	f	77	L	
304	f	76	L	
305	m	72	L	
306	f	74	L	
307	m	80	L	
308	m	79	L	
309	m	77	K	
310	f	74	K	
311	f	79	K	
312	m	77	O	
313	f	79	O	
314	f	75	O	
315	f	73	O	
316	f	68	O	
317	f	65	O	
318	f	78	O	
319	f	77	O	
320	f	78	N	
321	m	80	N	
322	f	80	N	
323	f	77	N	
324	f	77	N	
325	f	81	N	
326	m	78	N	
327	m	78	O	
328	m	73	O	
329	f	79	O	
330	m	73	N	
331	m	80	N	
332	m	80	N	
333	m	79	N	
334	f	75	N	
335	f	75**	O	
336	f	78	O	
337	m	78	O	
338	f	80	O	
339	m	78	O	
340	m	78	O	
341	f	77	O	
342	f	76	O	

Appendix C
Tagged Lobsters from commercial traps
APR. 21, 1987

Tag #	Sex	Size (mm)	Site #	Recapture
343	f	77	O	
344	m	78	N	
345	m	76	N	
346	f*	85**	N	
347	f	77	N	
348	f	77	N	
349	m	78	N	
350	m	73	N	
351	m	80	N	
352	f	80	N	
353	f	74	N	
354	f	78	L	
355	f	78	L	
356	f	79	L	
357	f	76	L	
356	f	79	L	
359	f*	76	L	
360	m	78	L	
361	f	81	L	
362	m	79	L	
363	m	80	L	
364	f	79	L	
365	f	78	K	
366	m	75	K	
367	f	66	K	
368	f	67	K	
369	m	77	J	
370	f	80	J	
371	f	77	J	
372	f	78	J	
373	m	80	J	
374	m	78	J	