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# A Pilot Study to Test Ventless Traps as a Means to Quantify Populations of the American Lobster (Homarus americanus)

Carin Louise Poeschel

# A PILOT STUDY TO TEST VENTLESS TRAPS AS A MEANS TO QUANTIFY POPULATIONS OF THE AMERICAN LOBSTER (*HOMARUS AMERICANUS*) IN MAINE

By

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An Abstract of the Thesis Presented
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The American lobster, *Homarus americanus*, is Maine's most valuable marine fishery. The state of Maine has an economic interest in the protection of this resource. The health of this industry depends on effective management for sustainability. However, there is little quantitative information on American lobsters less than harvestable size.

A study was conducted to evaluate the utility of traps modified to catch sublegal lobsters. With the aid of fishermen from six of the eight Maine coastal counties over a four-month time period (July through October, 2000), data were recorded to compare catch rates in experimental traps with no escape vents and standard traps with vents, meeting Maine lobster regulations.

The purpose of this survey was to determine whether non-vented or vented traps are better at (1) detecting spatial and temporal differences in juvenile lobster abundance and (2) predicting patterns in the harvest of legal lobsters. I tested the hypothesis that non-vented traps will be better than vented traps at detecting differences in juvenile abundance by month and county. Furthermore, I evaluated the correlation between catch

measured by research traps and statewide landing patterns, an index of patterns in abundance.

In this study it was found that vented (standard) traps more accurately reflect statewide spatial patterns of catch than non-vented traps. It was also found that spatial and temporal differences depended on the trap type. Furthermore, catch-per-unit-trap-haul provided a better index of abundance than catch-per-unit-trap-haul-set-over-days. Possible sources of error include: not all coastal counties participating in the survey, wide range of soak times, trap saturation and size variations per fishermen and inconsistent participation per county. Implications from the research suggest that sea sampling of standard traps may be a useful predictor of catches. Furthermore, the new method (ventless traps) proved to be worse than the old method (standard, vented traps) in assessing American lobster populations greater than 40 mm CL to harvestable size.

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I must also thank Carl Wilson and the Maine Department of Marine Resources for providing me with the opportunity to work on the Ventless Lobster Trap Survey. I extend my thanks to all who participated in the database entry and development of this survey at the MDMR. I must also thank Carl Wilson for providing constructive criticism on grant proposals and this thesis.

The Maine Department of Marine Resources, Richard Arnold of Thistle Marine, and the University of Maine through the 2000 Marine Studies Fellowship Program supported this project. Richard Arnold, not only provided financial support but also provided me with a number of job opportunities and hands on training with his electronic

fishing logbooks. Further support of this project was provided by a graduate teaching assistantship in the Department of Animal and Veterinary Sciences.

The fishermen in Cumberland, York, Lincoln, Knox, Hancock and Washington County volunteered their time, effort, boats and skill to make this survey possible. A special thanks goes out to Ernie Lugdon of South Bristol, who provided me with the opportunity to view and assess the recording process. I would also like to offer a special thanks to Dr. James Halteman who never tired of answering my statistical questions and Louis Morin for all his help in spatial analysis, particularly determining fisherman locations.

Finally, a special thanks to my parents who encouraged me to succeed from start to finish. They provided with me an opportunity for which I am ever grateful. One final special thanks goes out to all my friends who provided me with the desire to finish when things got tough.

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# INTRODUCTION

To create and develop an accurate index of abundance and forecast harvests is a challenge in any fishery. Unlike terrestrial animals, which scientists can view on a day-to-day basis, fishery scientists tend to have fewer quantitative tools at their disposal. To understand the dynamics and potential yields of a fishery, fishery scientists require accurate indices of abundance (Hilborn and Walters, 1992; Pitcher and Hart, 1982). The most commonly used quantitative tools for fisheries to collect data include traps, nets, acoustic arrays or visual observations by divers or remote cameras. Length and weight of a catch is probably the most commonly collected type of data due to it being the easiest data collection method (Hilborn and Walters, 1992). Population dynamic models, based on accurate quantitative information can provide an interpretive glimpse into fisheries ecological and biological interactions.

The role of stock assessment is to provide the best technical support for fisheries management. It means providing regular updates and feedback about the population and its estimated production potential. Another role of stock assessment is to quantify management alternatives as precisely as possible. Furthermore, it is important for stock assessment to provide information on the fishery over a spatially heterogeneous area (Caddy, 1989; Hilborn and Walters, 1992).

The American lobster (*Homarus americanus*) fishery is the largest single species fishery in New England and the Canadian Maritime Providences. In the state of Maine the lobster fishery is the most economically valuable marine resource. The US harvest comprises 40% of the total North America catch (Acheson and Steneck, 1997). Maine catches the most lobster of any state. The lobster fishery is predominately fished within

20 km of shore. The peak season is between summer and early fall. The height of the peak varies regionally and by year and is dependent on a number of biological and physical factors.

It is beneficial for surveys and indices of abundance to be established in order to foresee, if not prevent over fishing. The western rock lobster (*P. cygnus*) of Australia is probably the best example of a lobster fishery in which scientists have developed a larval settlement index and combined it with trap catches of older juveniles to forecast harvests (Caputi, 1986; 1995). No such forecasting capability exists for the American lobster. Nonetheless, scientists are developing good insight on larvae abundance and settlement of American lobsters in New England (Incze, et al 1997 and Wahle and Incze, 1997). At this time, scientists lack detailed quantitative information on juveniles over 40mm carapace length (CL) after they leave near shore nurseries. Campbell (1990) in southwestern Nova Scotia developed a juvenile index for American lobsters by assessing the size frequencies of lobsters in trap catches. He found the survey beneficial to understanding juvenile abundances. In Maine, Steneck and Wilson (2001) recently showed that geographical differences in lobster trap catches correspond to differences in population densities of juveniles measured by diver censuses.

The objectives of this study are to determine (1) if non-vented traps are a better quantitative tool than vented traps for a juvenile abundance index, and (2) if non-vented and vented trap catch rates reflect statewide spatial and temporal patterns in landings.

# LITERATURE REVIEW

The rock lobster (*Panuliru cygnus*) of western Australia is probably the most famous example of a lobster fishery in which a settlement index and juvenile survey is used to predict landings. It is a forecasting system American lobster fishery scientists would like to emulate. Caputi and Brown (1986) were the first in the lobster industry to predict recruitment success in western rock lobsters through a larval settlement index and an index of juvenile trap catches. Caputi and coworkers (1986; 1995) have shown that juvenile indices provide an independent check on predicted recruitment based on puerulus, postlarval settlement. The index recorded length frequency, number of pots sampled, CL, sexes, time between trap hauls (soak time) and pot type. Caputi and Brown (1986) found that variations in recruitment indices could be explained by juvenile estimates. They found that environmental factors did not strongly affect recruitment to the fishery after the juvenile stage. The puerulus and juvenile indices complement each other with puerulus providing a long-term (up to four years) indication of likely trends in catch, while the juvenile index provides more accurate predictions for the following harvestable lobster season (Caputi, et al 1995).

The American lobster is found along the Atlantic coast from Newfoundland to Virginia. Within the Gulf of Maine (GOM), it is concentrated at depths between zero and approximately 100 meters. The American lobster has a complex life cycle. It has three larval stages and one postlarval stage, all planktonic (Wahle and Cobb, 1994; Factor, 1995; Incze, et al., 1997). The transition into the fourth stage is marked by anatomical, biological and physiological changes (Wahle and Cobb, 1994). Hatching occurs from spring to early summer and is temperature dependent (Wahle and Cobb, 1994). When a

lobster settles, during the fourth larval stage, it is habitat specific and prefers a shelter-providing habitat, like cobble (Wahle, 1992; Wahle and Steneck, 1991 and 1992; Palma, et al. 1999). It has been hypothesized that if habitat is limiting a demographic bottleneck may occur (Wahle and Steneck, 1991), in which the availability of shelter limits recruitment to harvestable sizes.

Early benthic phase lobsters range in size from 5-40 mm in carapace length (CL) (Wahle and Steneck, 1991). Lobsters between settlement and approximately 25 mm CL are mostly habitat restricted and are very susceptible to predators (Wahle and Steneck, 1991). They usually begin to emerge from shelter providing habitats around 25 to 40 mm CL. The emergence may be due to food and/or shelter limitation (Wahle and Cobb, 1994). As an adult the American lobster can weigh up to several kilograms (Campbell, 1989). Spanning approximately four orders of magnitude in body mass, the American lobster is the largest benthic decapod crustacean in the northwest Atlantic.

In Maine, it has been demonstrated that juvenile densities are much higher to the west of Penobscot Bay than to the east (Wahle and Steneck, 1991; Cowan, 1999; Steneck and Wilson, 2001). Statewide patterns in the commercial catch reflect these demographic patterns (Steneck and Wilson 2001).

Over the past 120 years there have been massive fluctuations in the lobster fishery (Acheson and Steneck, 1997). The fishery between 1880 and 1919 fluctuated from approximately 5000 to 11100 metric tons. From the 1920's to 1930's the fishery experienced a "bust," harvests varied between 2500 and 3200 metric tons. After 1940, catches increased to a range of 11000 metric tons and remained relatively stable until the late 1980's (Acheson and Steneck, 1997). By 1990 the lobster industry was considered to

be in a booming phase. Currently scientists are still in a "boom" phase with no clear sign of an impending "bust." Between 1990 and 2000 Maine landings surged from 11800 to 25700 metric tons.

With lobster fishing technology evolving from wind powered boats and wooden traps to faster, bigger diesel powered boats, hydraulic lifts and sophisticated electronic navigation equipment such as depth sounders and geographical positioning systems and double vinyl coated wire traps fishermen can haul approximately 400 traps per day (Acheson and Steneck, 1997). In fact, collectively, fishermen currently make more than 20 million trap hauls per year (Miller, 1989). Increases in fishing effort and advanced technologies along with independent trawl surveys and studies throughout the Gulf of Maine (GOM) indicate that the resource is at an all time high (Steneck and Wilson, 2001).

The variation of catches in the lobster fishery over the past century or so has led researchers to collect information on stock abundance. On the state level within Maine two surveys are performed by the Maine Department of Marine Resources (MDMR), a Port Landing Survey and a Sea Sampling Survey. Both of these surveys have long-term databases. Since 1966 the Port Landing Survey has monitored changes in landed portions of catches. The project collects data on sex, CL and fishing effort throughout the season at local area docks within the Boothbay region. Two major limitations with this survey exist. First, there is a lack of information on the sublegal portion of the lobster catch and second, the survey is geographically limited to a few points in Maine.

A second survey, conducted by the National Marine Fisheries Service (NMFS), is the ground fish trawl survey, which began in the 1970's. It is one of the few long-term

time series recording lobster abundance. Although the project has a large geographic coverage along the shelf waters of the northeast US, it may not accurately describe lobster fishery abundances for several reasons. One is that ground fish, not lobsters, are the target species for this survey. Second the survey is not stratified by habitat, which means yearly fluctuations in the index may be more related to differences in the type of bottom of sampled. Third, the survey is conducted in federal waters outside the three-mile state limit, missing the near shore fishing grounds where lobsters are most abundant.

Sea Sampling of the commercial catch began in Maine in 1985. This program too was geographically limited to a few sites until 1998 when it expanded beyond Boothbay Harbor to gain a better representation of the fishery. Even though Sea Sampling provides data on the sublegal fraction that Port Sampling does not, the data obtained on sublegal lobsters are limited by the fact that escape vents in traps allow many sublegal lobsters to escape.

Young of year (YOY), newly settled lobsters, studies have also been analyzed since the late 1980's, mostly through suction sampling in Maine and Rhode Island (Incze et al, 1997; 2000). Suction sampling surveys have not only demonstrated the link between larval supply and the abundance of benthic YOY lobsters, but that cohort strength can be monitored for two to three years, until lobsters begin to leave their nurseries (Incze et al. 1997; Wahle and Incze, 1997). Currently there are promising signs from geographic patterns in lobster populations that a linkage between YOY settlement and subsequent recruitment to the fishery exists. Along the Maine coast Steneck and Wilson (2001) showed a correspondence between areas with large juvenile populations and harvest "hot spots." Similarly, Miller (1997) demonstrated along the Nova Scotia

coastline that segments of the coast that consistently received a high postlarval supply also had relatively strong harvests. However, variations in larval settlement may not be reflected in subsequent recruitment to the adult population if density-dependent factors limit recruitment (Fogarty and Iodine, 1986; Breen 1994).

Little quantitative informatiön remains on lobsters between 40mm CL and harvestable size. Since lobster traps are designed to catch legal size lobsters, very few sublegals are caught. If sublegals are caught during trap surveys, they are usually excluded in data analysis to avoid excessive variation in catch rates since the number and size of escape vents and lath spaces vary by fisherman (Estrella and McKiernan, 1989). It is estimated that within the coastal waters of Maine 80 to 95% of commercial inshore catches consist of new recruits (Hsiang-tai Cheng, 1991; Estrella and Morrissey, 1997; Acheson and Steneck, 1997; Campbell, 1989). To gain a better idea of harvestable stocks, a few surveys involving lobsters greater than 40 mm CL have been conducted.

Following Caputi and Brown's success (1986; 1995) Campbell (1990) developed a juvenile index for American lobsters in lower Argyle, southwestern Nova Scotia through trap surveying. Campbell's (1990) research showed a three-fold increase in landings, which allowed for pre-recruit abundance to be useful in determining future trends. Although he found that trap dimensions and fishing effort also affected his abundance estimates he demonstrated a significant correlation ($R^2$=0.834) between the pre-recruit abundance index and the recruit yield for the following fishing season. A similar correlation was found for two fishing seasons later.

When using trap catch data it is important to evaluate whether it provides an accurate index of abundance. The challenge it to know which expression of catch data is

the best index of abundance: catch-per-unit-trap-haul (CPUTH), or catch-per-day (CPD), which is most commonly referred to in previous literature as catch-per-unit-trap-haul-set-over-days (Addison, 1995; Estrella and McKiernan, 1989). CPD is the catch divided by the number of soak days. Addison (1995) analyzed the distribution of lobsters among experimentally fished pots with historical catch data. In that case CPUTH was not a good index of stock abundance and most likely not linearly related to abundance, since lobster populations on the large scale are patchy; fisheries are spatially discrete and separated by intervening areas of low densities and trap saturation may have occurred in high density areas. Trap saturation effects can generate a non-linear relationship between catch and abundance, which may pose difficulties in estimating abundance (Addison and Bell, 1997).

Estrella and McKiernan (1989), however, discuss the benefit of using CPUTH and CPD for indices of abundance after performing a sampling survey, which included soak times, from 1981 to 1986 and relating it to historic commercial landings. CPUTH has been reported to be unreliable due to it being insensitive to seasonal changes in catchability and trap saturation. However, CPUTH is useful in assessing annual abundance trends if immersion times do not vary significantly. CPD on the other hand can improve upon CPUTH since it takes into account soak times, which vary over the season (Thomas, 1973). CPD varies over the season because fishermen behave differently throughout the season to maximize their catch. If catches are poor after only a few soak days, they increase the soak time to decrease effort and increase profit. If catches are high, with a short soak time interval, a fisherman will calculate how often he needs to haul his traps to make his effort profitable.

Another issue of measurement is whether or not traps are a good method for collecting quantitative data. Through Steneck and Wilson's (2001) research they found that lobster trap catches (CPUTH) corresponded significantly with population densities as measured by divers. Traps were used in both Campbell's (1990) and Caputi's (1986:1995) studies successfully, but both found that trap dimensions affected data, particularly the escape vents. In Maine, there is a set trap size, 0.3605 cubic meters, which fishermen cannot exceed. However, trap volume can vary a great deal within the limit. Fogarty and Borden (1980) found that traps usually become saturated after a soak time of six to seven days. Time to saturation will depend on a number of factors such as population density, seasons and habitat.

In the ventless lobster trap survey, the distribution of lobsters among vented pots and non-vented pots provided information on lobsters between 40mm CL and harvestable size. With the results of the catches one can begin to assess whether vented and/or non-vented traps are useful quantitative tools to track lobsters greater than 40 mm CL to harvestable size and to interpret geographical and temporal differences in abundance.

# MATERIALS AND METHODS

**Sampling Procedure:**

For the year 2000 fishing season 26 Maine fishermen were recruited to voluntarily collect data for the survey. Harvesters from six of the eight coastal counties participated: York, Cumberland, Lincoln, Knox, Hancock and Washington (Figure 1). Each fisherman was provided with an instruction sheet describing an experimental trap (non-vented), the categorical gauge and how to disable vents. Lobster traps are required by law in Maine to have openings (vents), to allow sublegal lobsters to escape. The trap must have at least one rectangular vent no less than 49 mm by 146 mm or have two or more circular vents with a diameter no less than 62 mm. Traps are legally constrained to a volume of 0.376 cubic meters, however linear dimensions may vary. The Maine Department of Marine resources supplied each fisherman with a logbook, categorical gauge and experimental trap tags, which allow for vents to be legally closed, for this survey.

The logbook contained waterproof paper, with four tables per page. Two tables were to record experimental trap data and two for control trap data with space to record lobster sizes, sex, and presence of eggs (berried), as well as the harvesters name, boat name, fishing trap location (Latitude/Longitude or Loran coordinates), bottom type fished, bait type, and soak time (number of days between trap hauls).

The gauge had twelve categorical markings, each category corresponding to a size interval shown in units of millimeters and inches (Table 1). Lobsters greater than or equal to 83 mm (category 8) CL are legally harvestable. By law, the vent-disabled traps were marked with special scientific tags approved by the state of Maine.

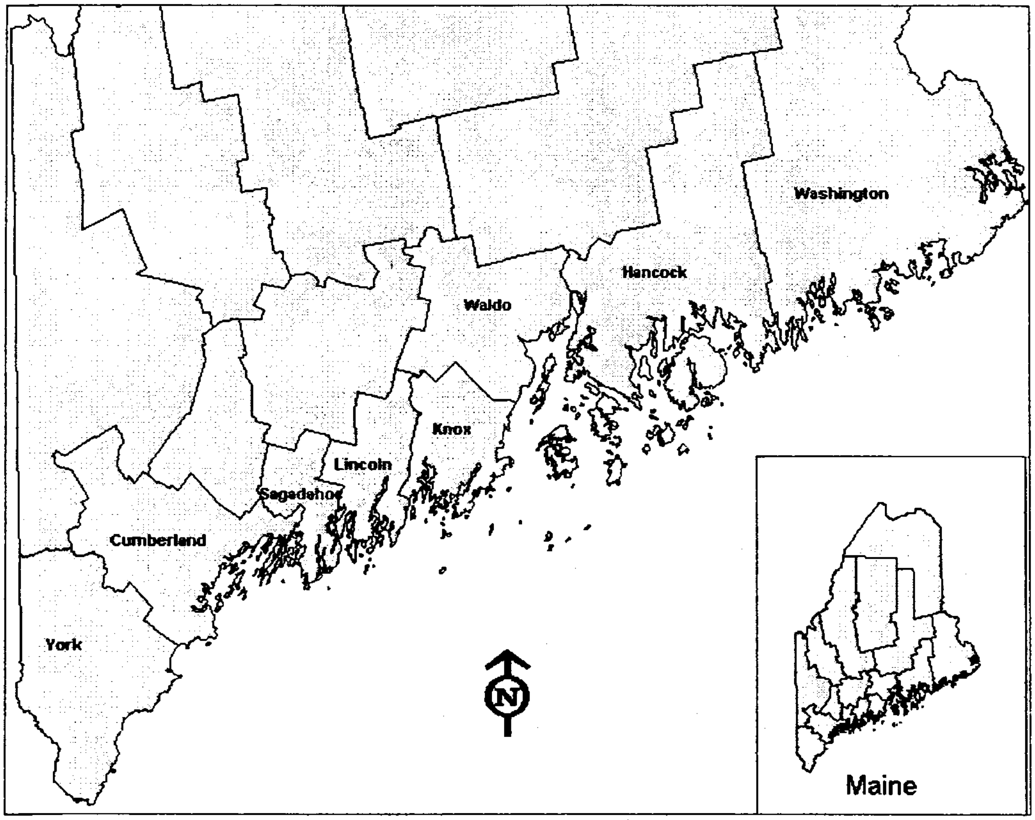


Figure 1. The eight coastal counties of Maine

Table 1. Gauge sheet with categorical sizes with a corresponding upper limit of each size interval shown in mm and inches

| Category | ≤1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | ≥12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Millimeter | ≤23 | 33 | 43 | 53 | 63 | 73 | 83 | 93 | 103 | 113 | 123 | 123+ |
| Decimal (in.) | 0.906 | 1.29 | 1.69 | 2.01 | 2.48 | 2.87 | 3.27 | 3.66 | 4.06 | 4.45 | 4.84 | 4.84+ |
| Fraction of in. | 29/32 | 1 9/32 | 1 22/32 | 2 | 2 15/32 | 2 27/32 | 3 8/32 | 3 21/32 | 4 1/32 | 4 14/32 | 4 26/32 | 4 26/32+ |

The number of traps and soak time depended on the individual fisherman. A fisherman could fish a maximum of 12 traps for the survey, half of which were experimental, with escape vents removed, and half of the standard vented type (control traps). Participating fishermen provided their own traps for the experiment and disabled their own vents.

Experimental and control traps, were to be fished in pairs within the same area, habitat type and soak time. Harvesters were asked to at least set one pair of traps on a rock/cobble bottom habitat. It was suggested that fishermen put their experimental traps into their regular hauling rotation, typically a soak time of three to seven days, but we requested that the soak time not exceed 14 days. The survey began in June 2000 and ended in January 2001. Harvesters reported that hauling and recording these traps took on average an extra 15 to 30 minutes per trip. Fishermen returned their data to the Maine Department of Marine Resources where it was entered into a spreadsheet database (MS Excel). Loran coordinates were converted into latitude/longitude using Positioning Aid 2.1a, software developed by the U.S. Coast Guard Research and Development Center.

**Data Analysis:**

Only data from the months July, August, September, and October were used in the analysis because too few data were available from other months. Statistical analyses were conducted using Systat statistical software.

To test the hypothesis that catch rates (CPUTH and CPD, dependent variable) varied significantly ($p<0.05$) by month and region (independent variables) a two factor ANOVA (analysis of variance) was conducted. The two factor ANOVA was used for several reasons: experimental or observational data can be used, it allows for non-equal sample sizes (important since not all counties participated the same over four months), and allows testing interaction between treatments. A square root transformation was used to homogenize variances and normalize distributions. To determine which regions and months were significantly ($p<0.05$) different a Pairwise Tukey Comparison was performed.

A linear regression was used to determine whether there was a significant relationship between catch rates (both CPUTH and CPD) and lobster abundance (measured as landings per km coastline). Raw landings were converted to landings per km of coastline. Year 2000 landings were used because spatial differences in abundance as measured by fishery independent surveys (Steneck and Wilson 2001, Wahle and Steneck 1991, and Cowan 1999) corresponded with historical landing data, and it is acknowledged that the fishery is nearly fully exploited (ASMFC, 2000). Landings were standardized to per km estimates to allow comparison of catch rates among counties

# RESULTS

**Size Composition and Soak Times:**

The overall size and soak time distributions of lobsters caught in the two trap types, experimental (non-vented) and control (vented) vary significantly. The experimental traps caught the vast majority of lobsters, most of which were juveniles. However, the control traps caught more legal lobsters (Table 2). The majority of lobsters caught ranged from category four (53 mm) to eight (93 mm) (Table 1; Figure 2).

Table 2: Overall CPUTH percentages for each trap type catch

| | Experimental | Control |
|---|---|---|
| Sublegal | 83.19% | 9.86% |
| Legal | 2.93% | 4.02% |

The range and ratio of sublegal to legal lobsters per experimental trap catch and control trap catch varies by county (Figure 3). The soak times ranged from one to fifteen days with three (18.6%), four (16.56%) and five (15.32%) day soaks the most common (Figure 4). The soak time distributions from county to county differ with respect to frequency (Figure 4). The mean soak time was eight days. It should be noted that the soak times distributions for the two trap types are virtually the same (Figure 4).

**Catch Rates by County and Month:**

CPUTH varied by county and month, but the degree of difference depended on the lobster size and the type of trap used. Catch rates per haul of sublegals were more than four times higher in experimental traps than standard traps. For sublegal lobsters in experimental traps there were significant main effects of county and month but no significant interaction (Table 3a; Figure 5a); differences in CPUTH among counties were

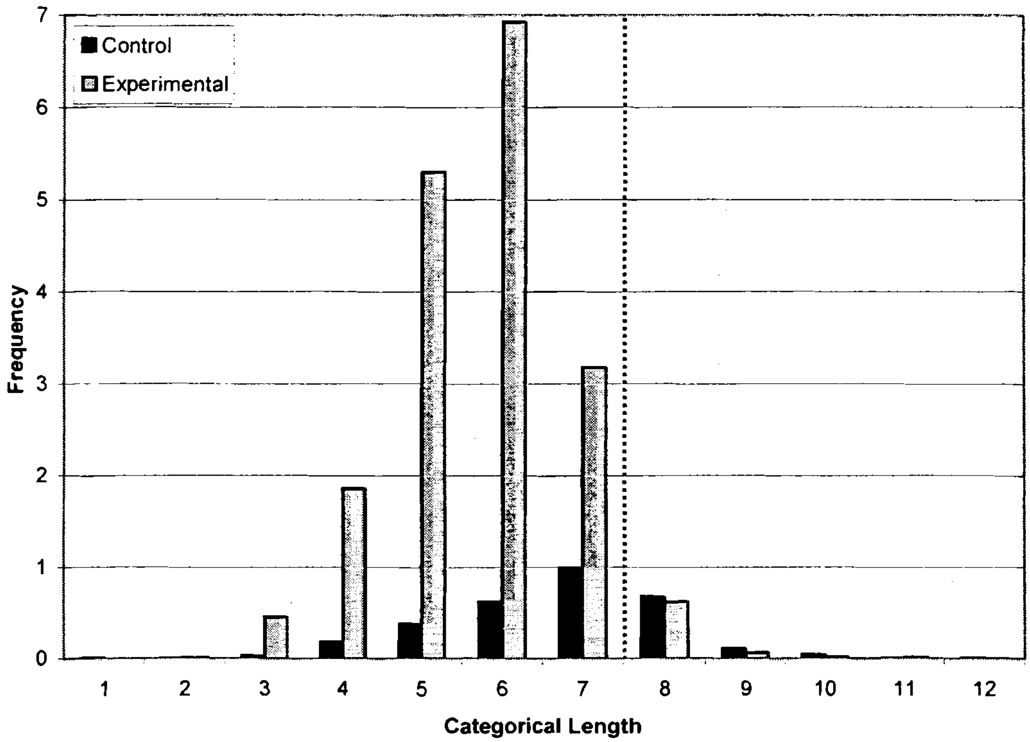


Figure 2. Size frequency distribution for each trap type, experimental (non-vented) and control (vented) from July through October. The dotted line separates the sublegal and legal catch.

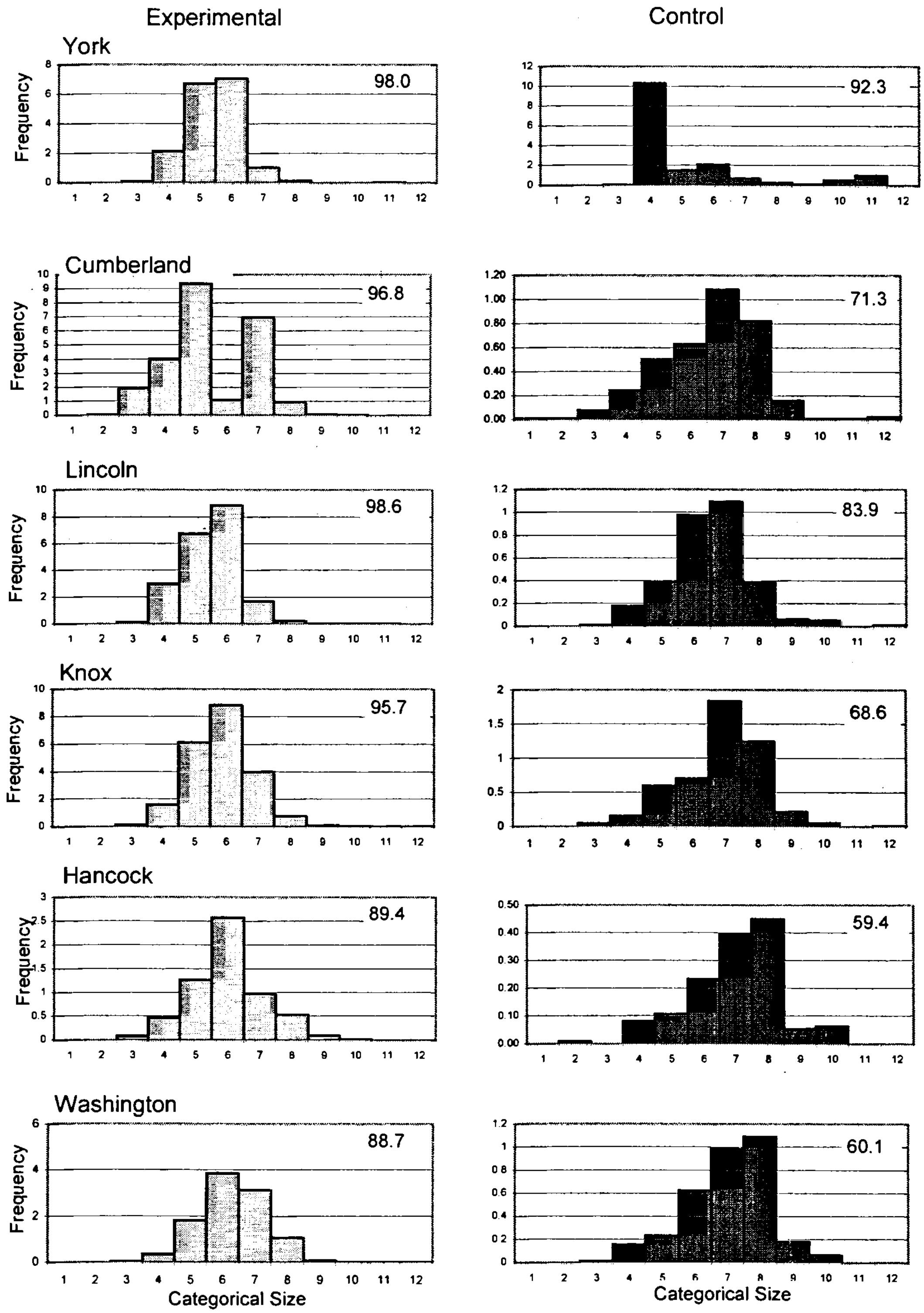


Figure 3. Lobster size frequency distribution of all six counties from July through October for each trap type, experimental and control. A ratio of sublegal to legal catch is inserted in each figure

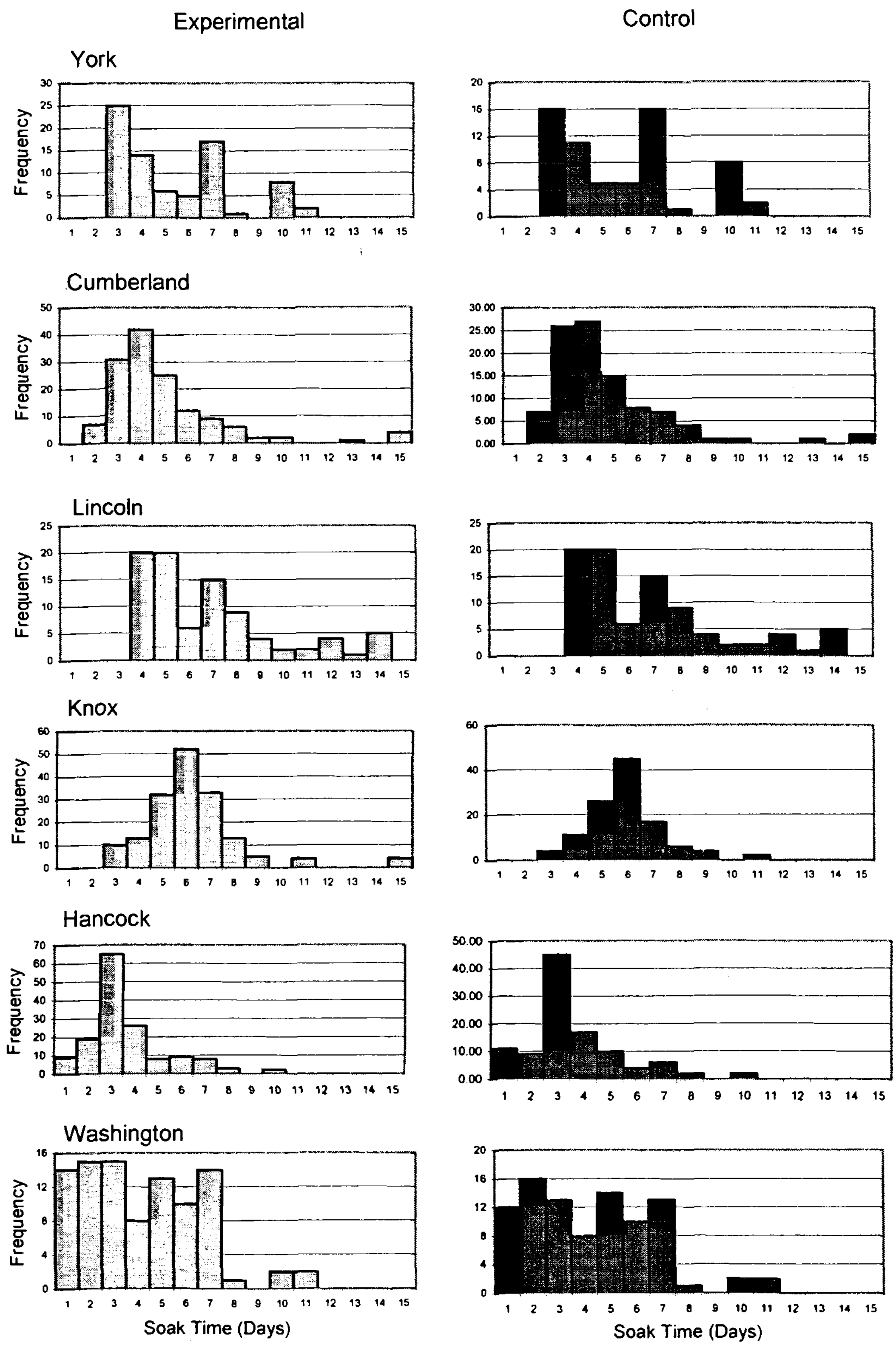


Figure 4. Soak time distribution for six counties from July through October by trap type, experimental and control.

Table 3. Two-Way Analysis of Variance of Catch-per-Unit-Trap-Haul for each category, (a) experimental sublegal, (b) experimental legal, (c) control sublegal and (d) control legal.

A. Experimental Sublegal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 155.714 | 3 | 51.905 | 17.566 | 0.000 |
| COUNTY | 554.847 | 5 | 110.969 | 37.555 | 0.000 |
| MONTH*COUNTY | 58.419 | 15 | 3.895 | 1.318 | 0.185 |
| Error | 2127.488 | 720 | 2.955 | | |

B. Experimental Legal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 1.551 | 3 | 0.517 | 1.375 | 0.249 |
| COUNTY | 20.383 | 5 | 4.077 | 10.842 | 0.000 |
| MONTH*COUNTY | 33.521 | 15 | 2.235 | 5.943 | 0.000 |
| Error | 270.349 | 719 | 0.376 | | |

C. Control Sublegal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 14.044 | 3 | 4.681 | 6.970 | 0.000 |
| COUNTY | 53.085 | 5 | 10.617 | 15.808 | 0.000 |
| MONTH*COUNTY | 18.776 | 15 | 1.252 | 1.864 | 0.024 |
| Error | 372.083 | 554 | 0.672 | | |

D. Control Legal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 4.327 | 3 | 1.442 | 3.307 | 0.020 |
| COUNTY | 30.657 | 5 | 6.131 | 14.055 | 0.000 |
| MONTH*COUNTY | 10.251 | 15 | 0.683 | 1.567 | 0.078 |
| Error | 241.232 | 553 | 0.436 | | |

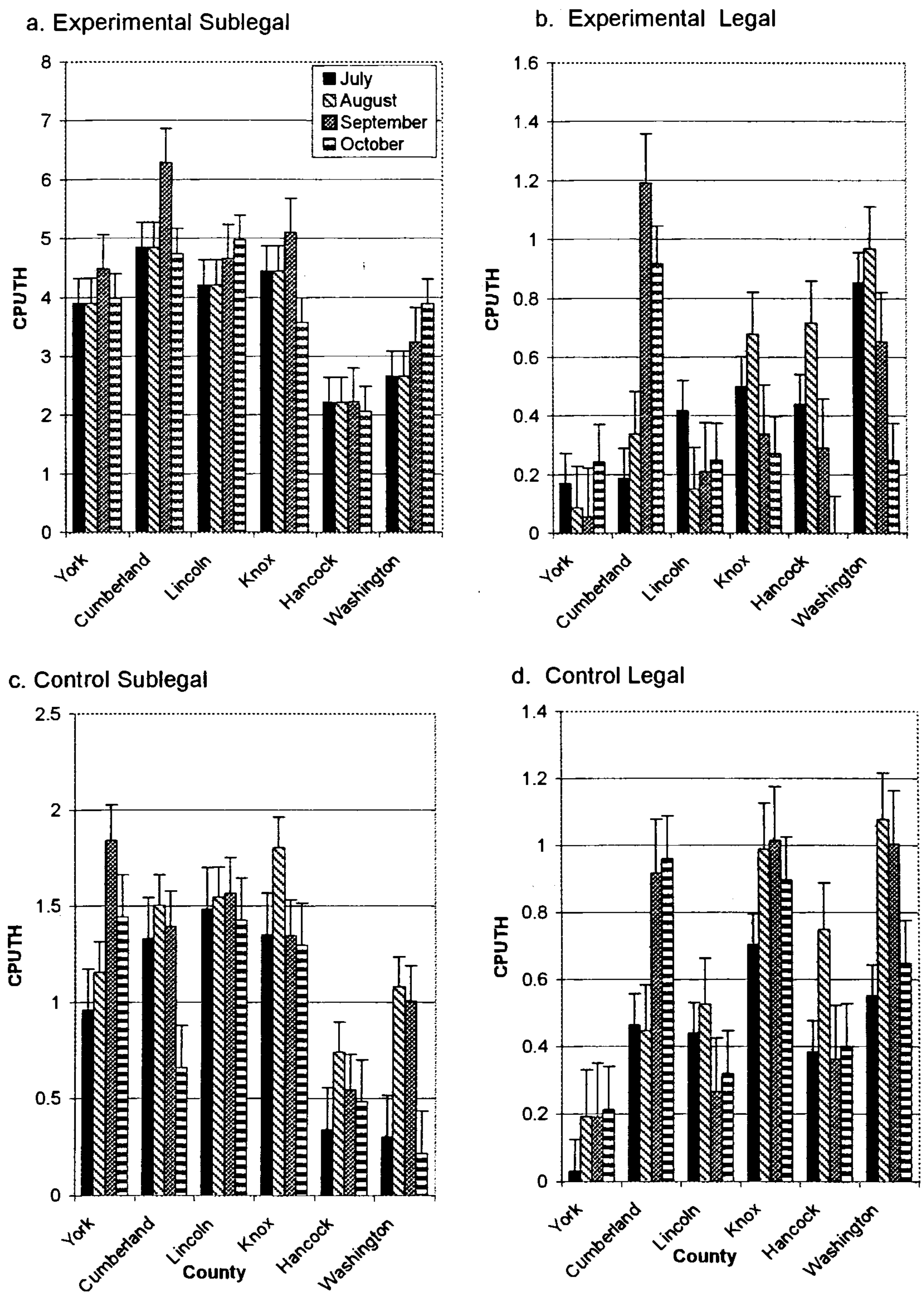


Figure 5. Catch-per-Unit-Trap-Haul for each lobster size and trap type catch, (a) sublegal experimental, (b) legal experimental,(c) control sublegal and (d) control legal from July through October for all six counties who participated in the Ventless Lobster Trap Survey.

relatively consistent over time (month). For legal sized lobsters in experimental traps, there was a significant county effect, but no month effect, and a significant interaction (Table 3b; Figure 5b). Differences among counties were less consistent over time for legal lobsters. For sublegal lobsters in control traps there were significant main effects of county and month as well as a significant interaction (Table 3c; Figure 5c). This significant interaction suggests county-to-county differences in CPUTH were less consistent over time than they were in experimental traps. For legal lobsters in control traps there were significant main effects of county and month but no interaction (Table 3d; Figure 5d). Differences in CPUTH among counties were relatively consistent over time.

CPD also varied by county and month, and the degree of difference also depended on the lobster size and type of trap used. These differences did not match the CPUTH differences. Catch rates per day of sublegal lobsters were about three to four times higher in experimental traps as in standard traps. Daily catch rates of legal lobsters were about the same. For sublegal lobsters in experimental traps there were significant main effects of county and month as well as an interaction (Table 4a; Figure 6a). Differences in CPD were comparatively inconsistent over time and space. For experimental legal sized lobsters there was a significant county effect, but no month effect; however, there was an interaction (Table 4b; Figure 6b). The differences in CPD among counties were less consistent over the months. For sublegal sized lobsters in control traps there was significant main effect of county and month, but no interaction (Table 4c; Figure 6c). Differences in CPD among counties were relatively consistent over time. For legal sized lobsters in control traps there was a significant main county effect and a marginally

Table 4. Two-Way Analysis of Variance of CPD for each category, (a) experimental sublegal, (b) experimental legal, (c) control sublegal and (d) control legal.

A. Experimental Sublegal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 10.705 | 3 | 3.568 | 4.883 | 0.002 |
| COUNTY | 93.398 | 5 | 18.680 | 25.563 | 0.000 |
| MONTH*COUNTY | 75.562 | 15 | 5.037 | 6.894 | 0.000 |
| Error | 500.556 | 685 | 0.731 | | |

B. Experimental Legal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 0.509 | 3 | 0.170 | 1.912 | 0.126 |
| COUNTY | 3.721 | 5 | 0.744 | 8.388 | 0.000 |
| MONTH*COUNTY | 8.168 | 15 | 0.545 | 6.137 | 0.000 |
| Error | 60.597 | 683 | 0.089 | | |

C. Control Sublegal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 2.301 | 3 | 0.767 | 4.174 | 0.006 |
| COUNTY | 8.466 | 5 | 1.693 | 9.217 | 0.000 |
| MONTH*COUNTY | 3.992 | 15 | 0.266 | 1.448 | 0.120 |
| Error | 98.105 | 534 | 0.184 | | |

D. Control Legal

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| MONTH | 0.788 | 3 | 0.263 | 2.638 | 0.049 |
| COUNTY | 6.445 | 5 | 1.289 | 12.943 | 0.000 |
| MONTH*COUNTY | 3.044 | 15 | 0.203 | 2.037 | 0.012 |
| Error | 53.184 | 534 | 0.100 | | |

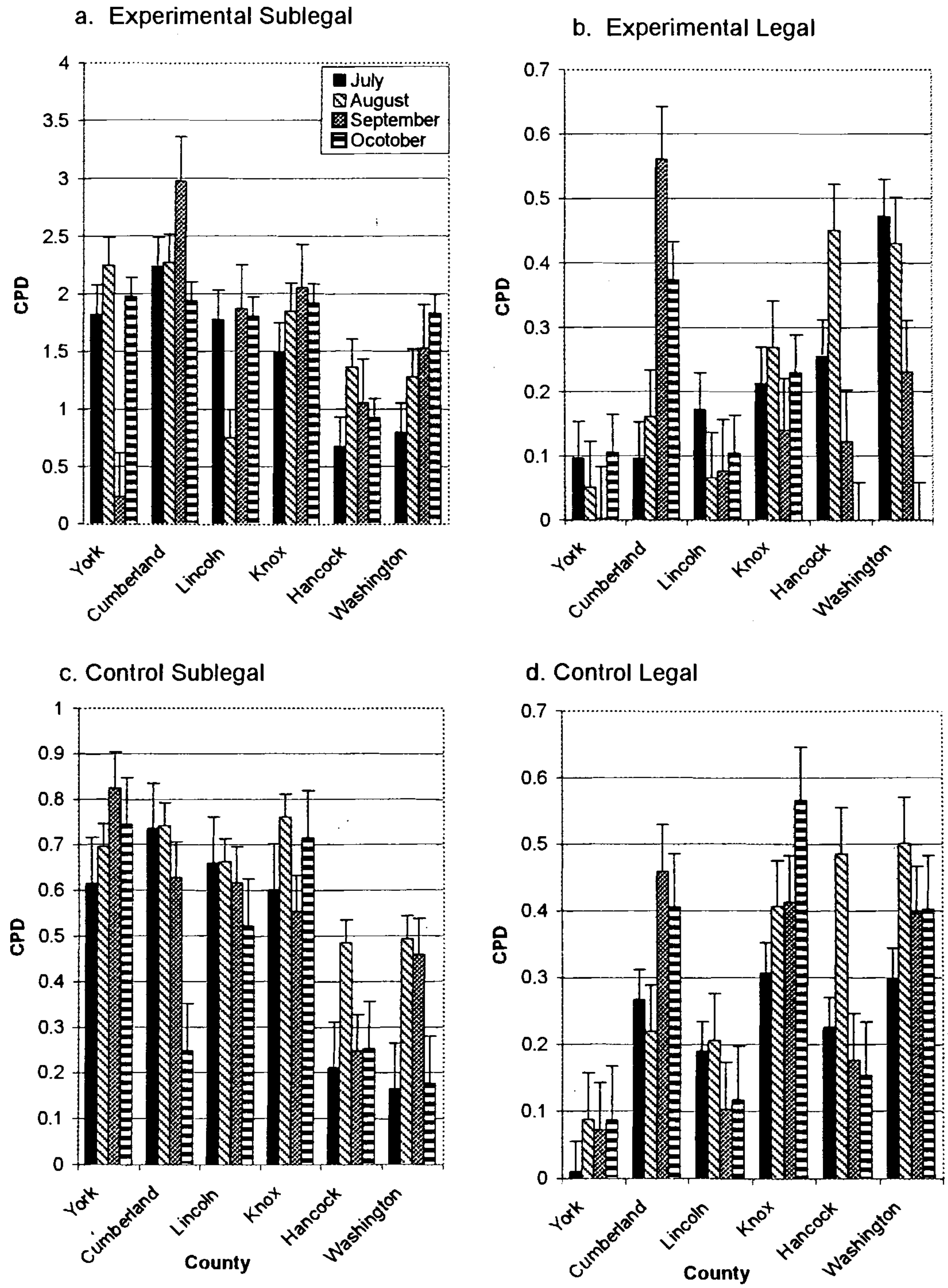


Figure 6. CPD for each lobster size and trap type catch, (a) sublegal experimental, (b) legal experimental, (c) control sublegal and (d) control legal from July through October for all six counties who participated in the Ventless Lobster Trap Survey.

significant main month effect with a significant interaction (Table 4d; Figure 6d). Differences in CPD for this group were inconsistent over time and space.

**Correlation Analysis:**

Year 2000 landing data (Figure 7) were assessed with the correlation analyses between landings per km of coastline and CPUTH for each lobster size and trap type. For experimental traps there was a marginally significant relationship between landing/km and CPUTH for sublegal lobsters (Table 5a; Figure 8a) but not legal lobsters (Figure 8b; Table 5b). For control traps there was a strongly significant relationship between landing/km and CPUTH for sublegal lobsters (Table 5c; Figure 8c) but not legal lobsters (Table 5d; Figure 8d). In this case landings per km of coastline explain 45% of variation per trap haul. By contrast landing per km of coastline explained only 17% of the variation in CPUTH of sublegal lobsters in experimental traps. In all the trap catch categories there is an extreme value, which could have a disproportionate effect on the regression. By excluding the extreme value, the relationship between landings per km and CPUTH for each trap catch category remains the same. The only difference is the how landings per km of coastline explain a percentage of variation per trap haul. For example by excluding the outlier in the control sublegal catch category, landings per km of coastline explained only 25% of variation per trap haul.

Correlation analyses between research trap catch per day and landings per km of coastline were evaluated for each lobster size and trap type. For experimental traps there was no significant relationship between landing/km and CPD for sublegal and legal lobsters (Table 6a,b; Figure 9a,c). For control traps there was a marginally significant relationship between landing per km and CPD for sublegal lobsters (Table 6c; Figure 9b).

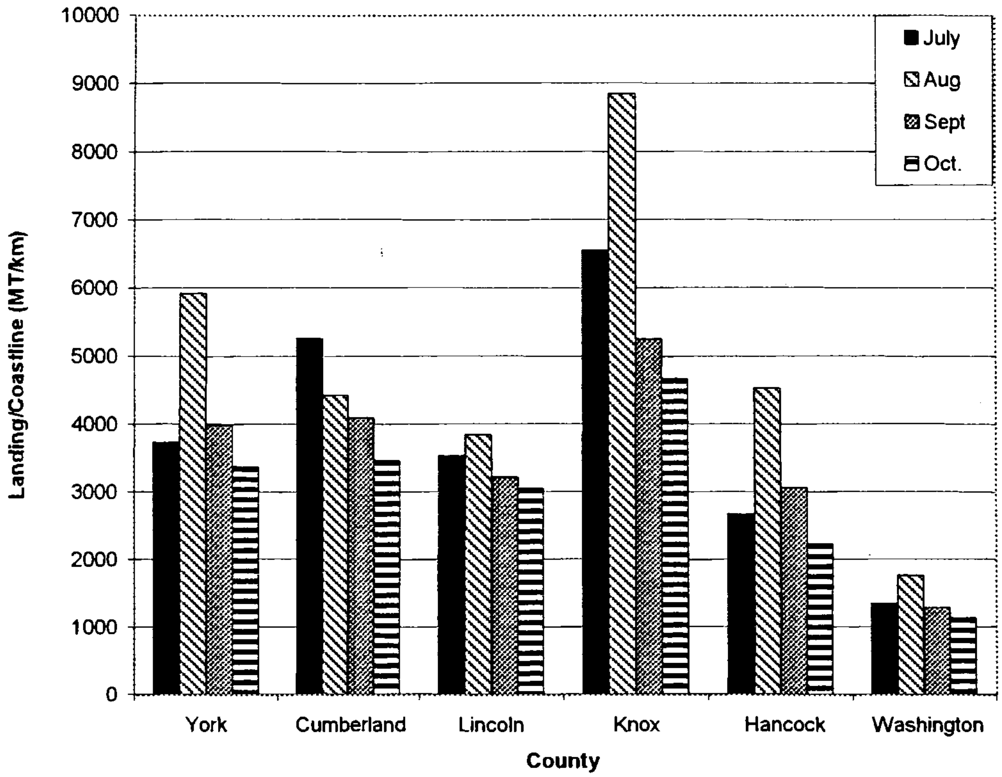


Figure 7. Year 2000 commercial landing data normalized per length of coastline (km) for American lobsters in Maine for counties that participated in the Ventless Lobster Trap Survey from July through October.

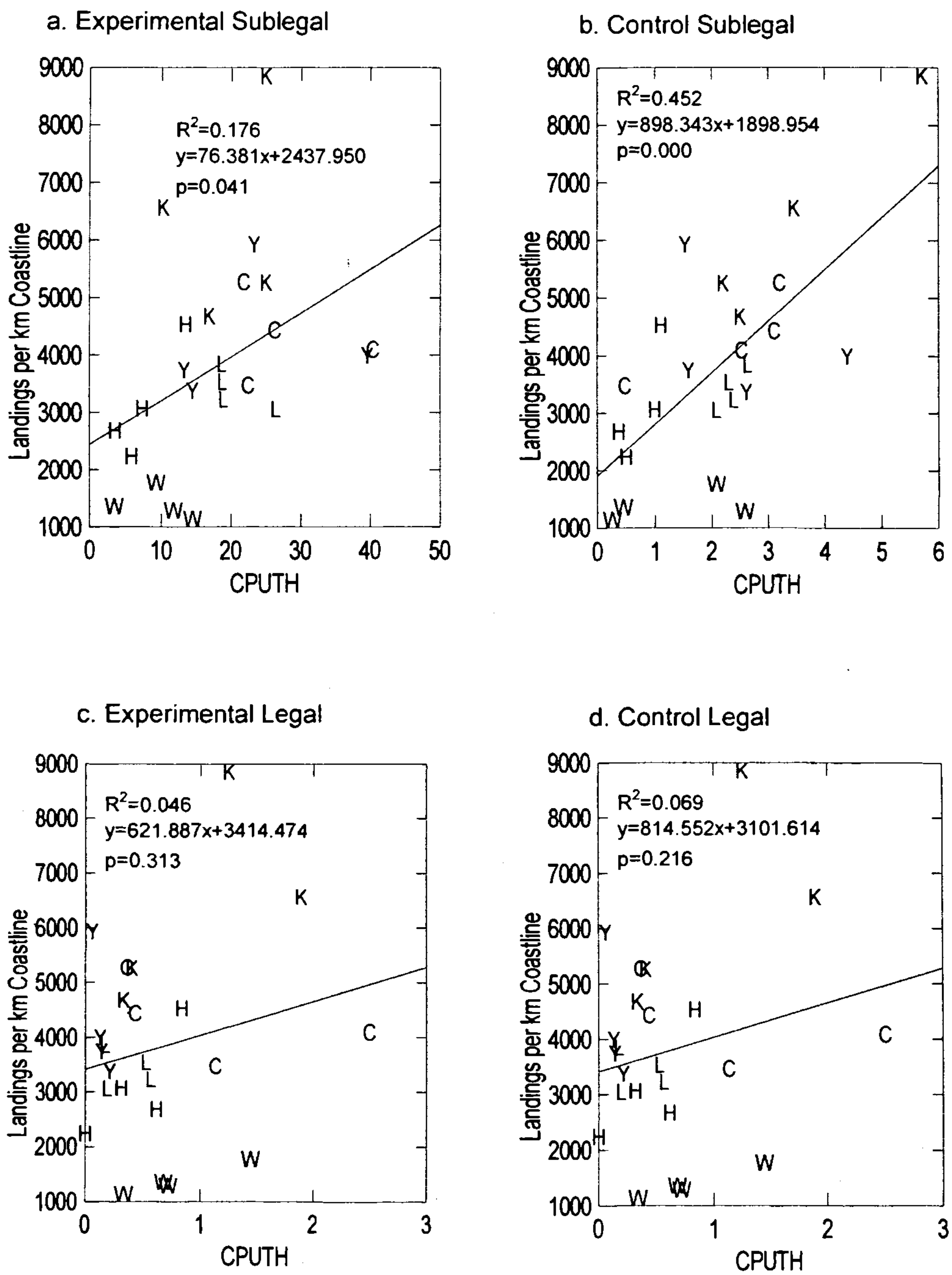


Figure 8. Linear regression between year 2000 commercial landings and research trap catches (CPUTH) for legal and sublegal lobsters in vented (Control) and non-vented (Experimental) traps. Each capital letter indicates the county represented at each x/y coordinate: Y=York, C=Cumberland, L=Lincoln, K=Knox, H=Hancock, W=Washington.

Table 5. Regression and Correlation Analysis of Catch-per-Unit-Trap-Haul for each size trap catch, (a) experimental sublegal, (b) experimental legal, (c) control sublegal and (d) control legal.

A. Experimental Sublegal

N: 744 $R^2$: 0.069

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 231.578 | 1 | 231.578 | 55.151 | 0.000 |
| Residual | 3115.623 | 742 | 4.199 | | |

y= 76.381x+2437.950

B. Experimental Legal

N: 744 $R^2$: 0.000

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 0.000 | 1 | 0.000 | 0.001 | 0.982 |
| Residual | 366.829 742 | 0.494 | | | |

y= 621.887x+3414.474

C. Control Sublegal

N: 578 $R^2$: 0.084

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 40.809 | 1 | 40.809 | 52.581 | 0.000 |
| Residual | 447.041 | 576 | 0.776 | | |

y= 898.343x+1898.954

D. Control Legal

N: 577 $R^2$: 0.012

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 3.479 | 1 | 3.479 | 6.749 | 0.010 |
| Residual | 296.464 | 575 | 0.516 | | |

y= 814.552x+3101.614

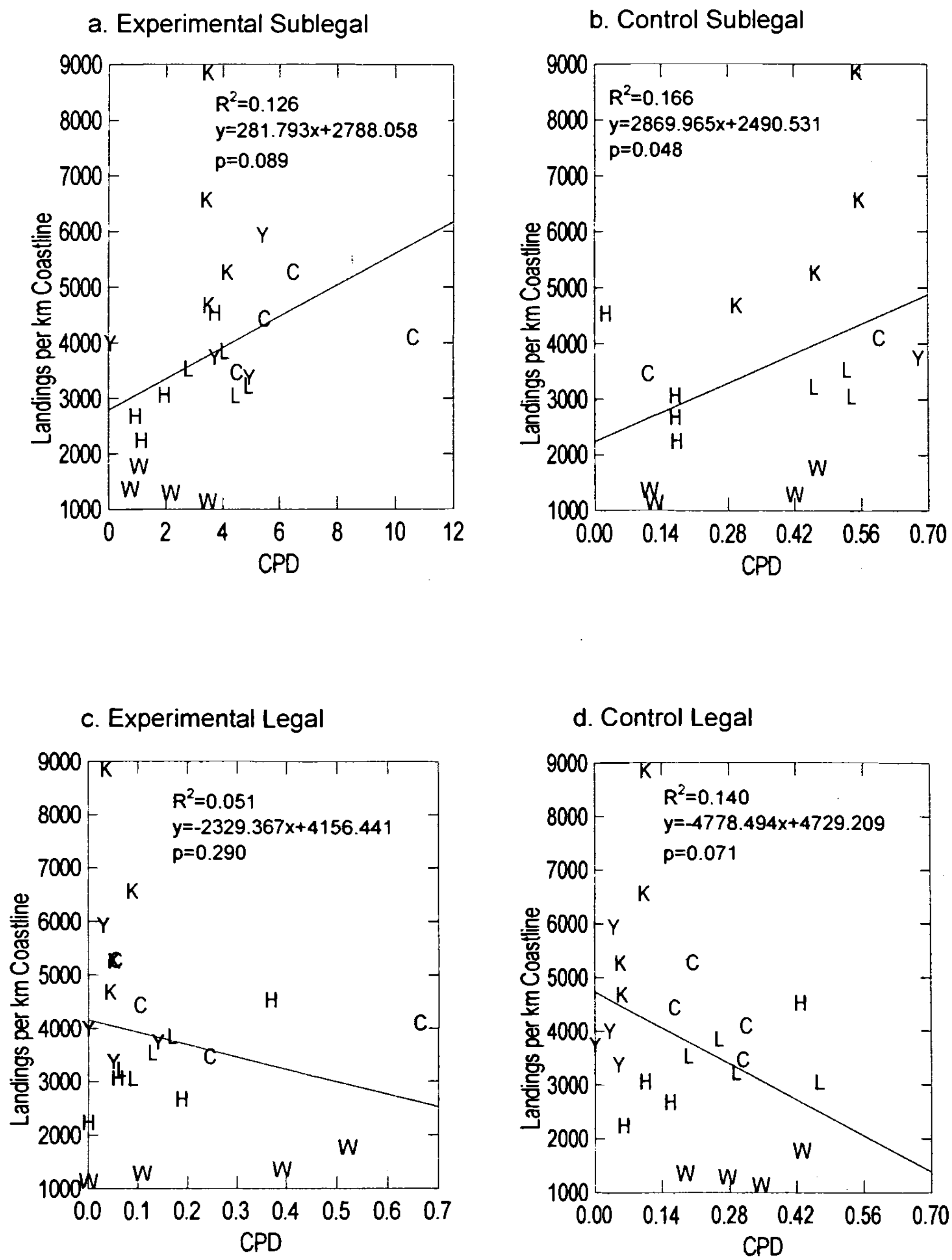


Figure 9. Linear regression between year 2000 commercial landings and research trap catches (CPD) for legal and sublegal lobsters in vented (Control) and non-vented (Experimental) traps. Each capital letter indicates the county represented at each x/y coordinate: Y=York, C=Cumberland, L=Lincoln, K=Knox, H=Hancock, W=Washington.

Table 6. Regression and Correlation Analysis of CPD for each size trap catch, (a) experimental sublegal, (b) experimental legal, (c) control sublegal and (d) control legal.

A. Experimental Sublegal

N:24 $R^2$:0.126

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 14.559 | 1 | 14.559 | 3.174 | 0.089 |
| Residual | 100.904 | 22 | 4.587 | | |

y= 281.793x+2788.058

B. Experimental Legal

N:24 $R^2$:0.051

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 0.034 | 1 | 0.034 | 1.176 | 0.290 |
| Residual | 0.645 | 22 | 0.029 | | |

y= -2329.367x+4156.441

C. Control Sublegal

N: 24 $R^2$: 0.290

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 0.244 | 1 | 0.244 | 4.386 | 0.048 |
| Residual | 1.224 | 22 | 0.056 | | |

y= 2869.965x+2490.531

D. Control Legal

N: 24 $R^{2:}$ 0.140

| Source | Sum-of-Squares | df | Mean-Square | F-ratio | P |
|---|---|---|---|---|---|
| Regression | 0.063 | 1 | 0.063 | 3.586 | 0.071 |
| Residual | 0.384 | 22 | 0.017 | | |

y= -4778.494x+4729.209

In this case landings explained only 16% of variation of CPD. There was no significant relationship for legal lobsters in control traps (Table 6d; Figure 9d). Again, in all the trap catch categories there is an extreme value, which could have a disproportionate effect on the regression. By excluding the extreme value, the relationship between landings per km and CPUTH for each trap catch category remains the same.

# DISCUSSION

The relationships between landings per km coastline and research trap catches provide important insights into the utility of traps as a quantitative tool. The sublegal catch in experimental traps was three to four times higher than in standard traps (Figure 5 and 8). Due to escape vents being closed there was less "in" and "out" movement of juveniles through the experimental trap since the only exits possible were the entry heads. Lath spaces were also a means of escape, but only for lobsters small enough (category one to three) to squeeze through them.

Despite the larger catch in experimental traps, the relationship between sublegal catch and landings per km of coastline was stronger for standard vented traps. The findings suggest that experimental traps provide researchers no added information. It could be concluded that the Ventless Lobster Trap survey is not providing us with benefits that were anticipated. Our research traps may not always provide a representative picture of regional catches. This may be due to trap saturation, which has been reported in American lobsters (Wilson and Steneck, 2001), but it is unclear how widely it occurs (Wilson, personal communication). Once saturation occurs, lobsters no longer enter, causing one to view a restricted portion of the population. In theory to maximize harvest, a fisherman will want to haul his traps at the exact soak time it takes to fill up his trap. For this survey lobstermen had to decide which trap type, experimental or control, to use to maximize effort. Trap placement also has an affect on catch rates. Trap size as well may have an affect on trap catch. Different dimensions may allow for different saturation limits, as well as affect a lobster's behavior in entering a trap. The

effect of trap size on catch rates, however, cannot be evaluated here because not all the fishermen reported their trap dimensions.

The CPUTH and CPD regression lines of sublegal catches in experimental and control traps further supports prior evidence that sublegal lobsters are more abundant along the western Maine coastline (Figure 8; Figure 9) (Wahle and Steneck, 1991; Steneck and Wilson, 2001; Cowan, 1999). Geographical trends in sublegal catch from the experimental and control traps from Hancock and Washington county were lower than in counties to the west (Figure 5 and 6). Geographical trends from control trap catches for both CPUTH and CPD revealed a stronger relationship to year 2000 commercial landing data than experimental trap catches (Figure 5, 6 and 7).

Catch measured as CPUTH provided a stronger relationship to landings per km coastline and a better index of abundance for this survey. In contrast Estrella and McKiernan (1989) found CPD to be a better indicator of abundance than CPUTH in their study. CPD may have been better for Estrella and McKiernan's experiments since they corrected for variable immersion times through an adapted equation.

Soak time and saturation effects may have affected measures of catch (CPUTH and CPD). With CPUTH measures, one can view how low-density populations take longer to reach saturation than high-density populations. With CPD, one is given a glimpse of how fishermen are trying to efficiently maximize their effort. However, with CPD, after a certain soak time, one cannot assess if the population density is high or low.

This survey analysis has revealed the issues needed to address to improve a trap-based index of abundance. They include: more fishermen per county, including all eight coastal counties involved (the larger the population the greater the statistical power), and

the inclusion of trap size as a variable. It will also be important to understand how trap saturation affects survey results. By continuing this survey and incorporating ways to solve the issues of concern, more sophisticated analyzes can be made to help predict future harvests one year in advance (example, Caputi et al., 1986; 1995).

In conclusion it is a challenge in fisheries to develop and create an accurate index of abundance and forecasting tools for trends in a harvest. We have been able to evaluate traps as a quantitative tool in population studies of the American lobsters. One of the most important findings is that standard vented traps revealed a stronger relationship to the year 2000 commercial landings than experimental non-vented traps. Thus, non-vented research traps provide little or no added information with the 2000 ventless survey data. In other words, catch rates (CPUTH) of vented traps are likely to be useful in forecasting trends in population size. It was also concluded that CPUTH is more strongly related to patterns of landings than CPD.

The ventless lobster trap experiment may lead others to develop a more sophisticated non-vented modified trap, which would include decreasing lath spaces, entry heads and blocking escape vents, to create a better forecasting tool for lobsters between 20 and 40 mm CL. Further assessment of different forecasting tools and current active programs like the Port Landing and Sea Sampling Survey is necessary to create a valuable accurate index of abundance.

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