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THE EXTENT OF LOBSTER DISCARDING DURING THE 1996 NORTHWESTERN HAWAIIAN ISLANDS COMMERCIAL LOBSTER FISHERY AND ITS EFFECT ON THE AMENDMENT 9 HARVEST GUIDELINE SYSTEM

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INTRODUCTION

This report assesses the extent of lobster discarding during the 1996 Northwestern Hawaiian Islands (NWHI) commercial lobster trap fishery, the validity of the estimation procedure's assumptions, and the effect of this additional source of mortality on the Amendment 9 harvest guideline system. Necessary modifications to the Amendment 9 harvest guideline formula to account for additional sources of mortality (e.g., discarding) are discussed and procedures to estimate discards proffered.

Discarding may occur by species, gender, size, or a combination of these factors. One stipulation for passage of Amendment 9 to the Fishery Management Plan for the Crustaceans of the Western Pacific Region (Crustaceans FMP) was an assessment of lobster (spiny and slipper) discarding during the 1996 commercial fishing season, and the National Marine Fisheries Service Honolulu Laboratory (NMFS-HL) was asked to develop a shoreside monitoring program to determine the extent of this discarding.

Background on Amendment 9

Under Amendment 9 of the Crustaceans FMP a constant harvest rate strategy is used to establish harvest guidelines for the NWHI lobster fishery. The guideline is set annually by the NMFS Southwest Regional Director, using data from the commercial fishery. The harvest guideline is expressed in terms of total allowable number of lobsters (spiny and slipper combined) that can be landed and is computed as:

$$HG_{t+1} = r \cdot N_{t+1} , \qquad (1)$$

where HG = the harvest guideline, r = harvest rate associated with a specific risk of overfishing (e.g., a 10% risk of overfishing) and is presently set to 13%, N = the number of exploitable lobsters in the population, and t is the year index. The estimate of exploitable population is derived from a population model (see Polovina et al., 1995) using reported (logbook) commercial catch and effort data as input and the NMFS-HL is responsible for its estimation. The population model expresses the number of exploitable lobsters at time t (the present time period) as a function of the number of exploitable lobsters at time t-1 (the previous time period), adjusted for natural mortality, fishing mortality, and recruitment. The Council decided to accept a 10% risk of overfishing in any given year, and because of a perceived high rate of discard mortality, require fishermen to retain and land all lobsters caught (a retain-all retention policy). Results from population modelling showed that with a mandatory retain-all policy and associated 10%

risk of overfishing, the population could sustain a long-term harvest rate of 13%. At a later date, the Council adopted an optional retain-all policy but left the harvest rate unchanged (WPRFMC, 1995).

Using equation (1) to establish harvest guidelines assumes that no discarding of the catch occurs, i.e., that total catch equals the established harvest guideline. However, under Amendment 9 the retention of catch is optional, i.e., fishermen may choose to discard part of their catch. Given the high mortality likely associated with the current handling of decked lobsters by the NWHI commercial lobster fleet ($\approx$75% mortality) (DiNardo and Haight, 1996), and the presumed high predation mortality on discarded lobsters, it is assumed that all lobsters caught and discarded die. Thus, discarding is an additional source of mortality that needs to be assessed against the harvest guideline along with the retained catch.

ESTIMATION OF TOTAL CATCH AND DISCARDS

Commercial fishing during the 1996 fishing season was conducted primarily on banks surrounding Necker Island. The number of spiny lobsters discarded at Necker Island during the 1996 NWHI commercial lobster trap fishery was computed for each vessel using lobster tail width data from (1) the 1995 and 1996 NMFS-HL NWHI fishery-independent surveys, (2) an independent commercial lobster trap survey in 1995, and (3) NWHI commercial lobster trap landings in 1996. Vessel monitoring system (VMS) data from 1996 were also used. Vessel-specific estimates of the number of spiny lobsters discarded and 90% confidence intervals (CI) were summed to provide an estimate of total discards and associated 90% CI.

Sources of Data

The following is a brief description of the data sets used to estimate discards.

NMFS-HL NWHI Fishery Independent Trap Survey Data

A fishery-independent trap survey has been conducted annually since 1984 by the NMFS-HL to collect length frequency, sexual development, and distributional data from lobster stocks in the NWHI. The survey has also been used to evaluate the performance of commercial and research survey gear and to calibrate gear types. Fathom Plus black plastic traps with 1-inch by 2-inch mesh were introduced into the commercial fishery in the early 1980s and quickly replaced the California two-chambered wire trap to become the standard commercial gear.

These black plastic traps, minus any escape vents, were first used in the research survey in 1985 and since 1992 have been used exclusively.

The survey uses a fixed-site design stratified by depth. At each site, shallow (< 20 fathoms) and deep (> 20 fathoms) water stations are sampled. Ten strings of 8 traps each are set at the shallow station and two to four strings of 20 traps each are set at the deep station. Traps are fished overnight and baited with 1.5-2.0 pounds of cut up, previously frozen, mackerel. Species, tail width (TW), gender, and reproductive condition (berried or unberried) data are collected for each lobster caught, as well as the spatial position (latitude and longitude) of the catch (recorded at the string level).

1995 Commercial Fishery Data

In the 1995 commercial fishing season, the NMFS opened a limited fishery under an experimental permit which was issued to the single vessel that applied. To provide useful data for stock assessment the experimental permit stipulated that the vessel was required to expend a predetermined level of effort at each of the three major fishing areas in the NWHI (Necker Island, Maro Reef, and Gardner Pinnacles) and also carry a NMFS observer. For each decked lobster the observer collected data on species, gender, reproductive condition, and market category (legal or sublegal). In addition, 50 lobsters were randomly selected from each string; for each sampled lobster tail width and carapace length were measured, and reproductive condition was recorded. The observer also reported on daily fishing, sorting, and discard methods.

The vessel captain was also required to submit a daily logbook of catch and effort within 72 hours of returning to port.

1996 Commercial Fishery Data

The 1996 commercial fishery operated under the guidelines of Amendment 9 to the Crustaceans FMP, which allowed the retention of juvenile and berried lobsters. The harvest guideline for 1996 was set at 186,000 lobsters (spiny and slipper combined).

Vessel captains were required to report their daily retained catch to the NMFS Pacific Area Office (PAO) through daily call-ins. Captains were allowed to send their call-ins via the VMS, which was also used to record the vessel's position (latitude and longitude) every hour, and these data were sent to NMFS Enforcement for processing and analysis. In addition to daily call-ins, captains were also required to submit daily logbooks of catch and effort within 72 hours of returning to port.

A pilot shoreside monitoring program to sample commercial lobster landings was conducted in 1996 by the NMFS-HL. The

objectives of the program were to collect size structure data from the commercial fishery landings to (1) advance future stock assessments and methodologies and (2) assess the extent of lobster discarding during the 1996 commercial fishing season.

From each vessel approximately 500 measurements of tail width, tail weight, gender, and reproductive condition were collected at random from lots intercepted at wholesalers. Tail width-tail weight regressions, stratified by gender and reproductive condition, were computed. Another 900-3,500 measurements of tail weight, gender, and reproductive condition were collected from randomly selected lobster tails and tail widths estimated using the developed regressions.

Total Catch and Discard Estimation Procedures and Assumptions

To compute the number of discards, estimates of the expected total catch (reported landings + discards) are required. Vessel-specific estimation of total catch and number of discards involved the following five steps (Figure 1):

(1) A Necker Island spiny lobster selectivity curve was developed for commercial lobster pots using Necker Island research survey and commercial fishing "core area" (defined in the next section) data from 1995.

(2) For each vessel a 1996 Necker Island trappable spiny lobster population size distribution was estimated from 1996 Necker Island research survey core area and vessel-specific commercial fishing location data using a two-step process. In step one, an overall 1996 trappable spiny lobster population size distribution was estimated for the core area using all 1996 research survey tail width data. In step two, the trappable spiny lobster population size distributions were revised and vessel-specific trappable spiny lobster size distributions were developed using only those core-area data from the 1996 research survey that overlapped with each vessel's spatial distribution of commercial fishing effort in 1996. The commercial gear selectivity curve was applied to each vessel's estimated trappable population size distribution, and an expected commercial catch profile and retention curve developed. In this report, a catch profile is a size frequency polygon of percent catch and represents the percentage of tail width observations that fall into a specific width interval (e.g., 1.0 mm-2.0 mm). A retention curve is the cumulative of the size frequency polygon of percent catch and represents the percentage of tail width observations less than or equal to a specific tail width. Trappable spiny lobster population size distributions are size frequency polygons of percent catch based on data collected from the research survey and

are assumed to represent the size distribution of spiny lobsters in the population that are vulnerable to commercial fishing.

(3) For each vessel, observed 1996 Necker Island commercial landings profile and retention curves were developed based on shoreside monitoring data collected in 1996 and then scaled relative to the expected commercial catch retention curve.

(4) Increasing levels of catch, distributed according to each vessel's estimated 1996 Necker Island trappable lobster population size distribution, were applied to the vessel's 1996 scaled landing retention curve and landings were estimated. This procedure was continued until estimated landings equaled the vessels reported landings. The catch of lobsters satisfying this equality (estimated landings = reported landings) was assumed to be the vessel's estimated total catch.

(5) For each vessel the number of discards was estimated as the difference between estimated total catch and reported landings. The estimated numbers of discards at the vessel level were summed to provide an estimate of total discards.

This stepwise approach assumes that (1) the estimated 1995 commercial gear selectivity curve is applicable in 1996, (2) samples of the 1996 commercial lobster landings are unbiased, and (3) the research survey accurately profiles the trappable population.

Bootstrapping procedures were used to compute confidence limits for the vessel-specific discard estimates. The 1996 research survey and shoreside sampling length frequency data sets were resampled 1000 times (replicates) and a discard estimate computed for each replicate. Approximate upper and lower 90% confidence limits for the number of discards were computed as the 5th and 95th percentiles of the resulting bootstrap distribution (Efron 1982).

RESULTS

NMFS-HL NWHI Fishery Independent Trap Survey

Stations sampled at Necker Island during 1995 and 1996 are depicted in Figures 2 and 3. The bank surrounding Necker Island has been arbitrarily delineated into 7 statistical areas based on reported commercial fishing areas. Research sampling stations and effort were similar between years and generally limited to

statistical areas 2-4. In subsequent discussions, areas 2-4 are referred to as the "core area".

Spiny lobster tail width percent frequency distributions for 1995 and 1996 are shown in Figures 4 and 5 and are similar in shape. In 1995 the mean tail width was 47.9 mm and the coefficient of variation (CV) = 15.6, compared to a mean of 48.3 mm and CV = 14.5 in 1996. Areal differences in spiny lobster tail width are consistent between years (Figs. 6 and 7; Table 1). Spiny lobsters from area 4 are generally larger than spiny lobsters from areas 2 and 3, which appear to be similar in size. Mean tail width in area 4 was slightly larger in 1996 compared to 1995, but the CV was smaller.

1995 Commercial Fishery

Strings sampled at Necker Island during the 1995 commercial fishery are shown in Figure 8. Areal differences in spiny lobster mean tail width were observed (Table 2). Spiny lobsters from areas 4 and 5 were generally larger than spiny lobsters from areas 1 and 2 (Fig. 9). Spiny lobsters from area 3 were intermediate in size. The spiny lobster tail width percent frequency distribution for the core area is shown in Figure 10 (mean = 51.0; CV = 10.2).

1996 Commercial Fishery

During 1996, five commercial vessels participated in the fishery which lasted approximately 1 month. The reported total catch was 187,583 lobsters (88% spiny lobster) in 115,340 trap hauls, of which 2,341 spiny lobsters were reported to have been discarded. Approximately 93% of the reported fishing effort and 97% of the reported catch in 1996 occurred at Necker Island. Major fishing areas in 1996 were consistent with those observed at Necker Island in 1995 with minimal fishing effort occurring in statistical areas 6 and 7.

Spiny lobster sample statistics from the 1996 shoreside monitoring program are listed in Table 3. The total sample size from the pilot program (12,370 lobsters) represents approximately 7% of the reported 1996 spiny lobster commercial landings. Between-vessel differences in landed spiny lobster tail widths were observed (Fig. 11). Vessels A and B landed the smallest lobsters while vessels D and E landed the largest lobsters. Vessel C landed lobsters of intermediate size. The observed difference in sizes landed between vessels can be partially explained by fishing area and are consistent with areal differences in size observed in the 1995 commercial fishery and 1995 and 1996 research surveys.

Total Catch and Discard Estimates

The Necker Island spiny lobster selectivity curve developed from 1995 research survey and commercial fishing data is depicted in Figure 12. Differences in retention curves between the 5 vessels operating in 1996 were observed (Fig. 13), and these differences can be partially explained by fishing area. Vessels A and B had similar retention curves, and approximately 44% of all spiny lobsters landed by these two vessels had a tail width of a least 50 mm (former minimum legal size). Approximately 30% of all lobsters landed by vessel C had a tail width of at least 50 mm, 25% of all lobsters landed by vessel D had a tail width of at least 50 mm, and 12% of all lobsters landed by vessel E had a tail width of at least 50 mm.

Discard estimation was limited to those vessels (1) fishing exclusively in the core area and (2) for which VMS position data were available. To compute discards a trappable population size distribution was required, and these data were available for only the core area. Each vessel's trappable size distribution was refined by using only those data from the 1996 research survey that overlapped with the spatial distribution of commercial fishing effort in 1996. VMS position data from 1996 was used as a surrogate to delineate the spatial distribution of fishing effort.

Although vessels A, B, C, and D fished exclusively in the core area, VMS data was not available for vessel B. Total discards for vessels A, C, and D in the core area during the 1996 commercial fishing season was estimated at 16,537 spiny lobsters with an associated 90% confidence limit of 11,453-21,778 lobsters. The estimated discards are significantly greater than reported discards at both the vessel- and fleet-level (all vessels and all areas). Vessel-specific spiny lobster discard rates for the 3 vessels ranged from 8.6% to 20.4%, resulting in an overall weighted average discard rate of 16%.

While a fleet-wide estimate of the number of spiny lobster discarded during the 1996 fishing season could not be computed, a guesstimate of total discards is possible. Based on VMS data, vessels A and B and vessels C and E fished in similar areas. Assuming that the discards for vessels B and E can be approximated by weighting the estimated discards for vessels A (6,773) and C (3,186) by the ratio of reported total catch of vessels B and A and vessels E and C, respectively, a fleet-wide guesstimate of the number of spiny lobster discarded in the core area is 28,978 (16,537 + 9,162 + 3,279).

The VMS data were used as a surrogate for fishing location, which proved invaluable to the analyses. These data are generally not available to scientists at the NMFS-HL, but due to the sensitivity of the discarding issue they were provided. In

subsequent years fishing location data should be collected and used to advance our assessments and address management concerns.

VALIDITY OF ASSUMPTIONS

(1) The estimated 1995 commercial gear selectivity curve is applicable in 1996: There is no evidence to suggest that the estimated 1995 selectivity curve is not applicable in 1996. No modifications to the gear occurred between 1995 and 1996 that could affect selectivity. The areas fished in 1996 are the same as those fished in 1995, and the trappable population size distributions in 1995 and 1996 are similar. The 1995 commercial fishery data used to develop the selectivity curve was collected from an established NWHI lobster fisherman, who also participated in the 1996 commercial fishery.

(2) Samples of the 1996 commercial lobster landings are unbiased: Precaution was taken to ensure that samples collected from dealers participating in the shoreside monitoring program were random. At the dealers, bags containing 30-50 frozen lobster tails were randomly selected and each tail processed. The size of lobsters within a bag varied, which also added another level of randomization.

To assess the validity of this assumption, tail weight percent frequency distributions from the shoreside monitoring program and dealer packout slips were compared. These packout slips provide size-based metrics of the total weight of landed lobsters by two-ounce intervals for each vessel and represent an independent source of size-based data for comparative purposes.

For each vessel, the tail weight percent frequency distributions from shoreside sampling and dealer packout slips were similar, suggesting that the data collected at the wholesalers accurately reflected the actual distribution of landed sizes. Confidentiality of the dealer packout data precludes any further discussion of these data.

(3) The research survey accurately profiles the trappable population: The spatial distribution of sampling effort in the research survey is inconsistent with the spatial distribution of commercial fishing effort observed in 1996. For example, statistical areas 1 and 5 were fished heavily by the commercial fishery in 1996, yet no survey data were collected from these areas. Therefore, it is impossible for

the research survey data to accurately profile the Necker Island trappable population.

Even in those statistical areas sampled by the research survey, the efficacy of using survey data to accurately profile the trappable population is suspect. While there are no available data to effectively assess spatial heterogeneity within the population, such heterogeneity is believed to be significant and operating at scales very different from those addressed in the research survey. Qualitative data describing fishing strategy in the NWHI lobster fishery suggests that fishermen actually exploit this heterogeneity when setting gear.

The sensitivity of discard estimates to spatial heterogeneity is significant. For example, dropping one research survey station from the analysis resulted in the estimated number of discards for vessel A increasing from 6,773 to 31,000 lobsters. Similar sensitivity from adding or dropping a station was observed for vessels C and D. While the design of the research survey in 1997 will be modified to at least ensure consistency between the spatial distributions of sampling effort and commercial fishing effort, the ability of the research survey to accurately profile the trappable population will require further analysis.

ACCOUNTING FOR ADDITIONAL SOURCES OF MORTALITY

Our intent in this section is to provide a suite of possible solutions for accommodating all sources of mortality in the Amendment 9 harvest guideline system. In particular, (1) how do we ensure that discard mortality is accounted for in the harvest guideline formula and (2) given the identified data limitations and concerns surrounding estimation, what approaches can be used to reliably estimate the number of discards? Three possible approaches are outlined, however, the choice of a particular solution is deferred to the Council which is responsible for the management of the NWHI lobster fishery.

Modifications to the Amendment 9 Harvest Guideline Formula

Current parameterization of the Amendment 9 harvest guideline formula (equation (1)) assumes that no discarding of the catch occurs and that total catch equals the established harvest guideline. Under this assumption catch means total mortality due to fishing or total allowable catch. However, because the fishery presently operates under an optional retain-all policy, discarding occurs. Regardless of what numbers are

used to quantify discards (reported or estimated) this unchecked additional source of mortality (assuming that all discarded lobsters die) needs to be accounted for in the harvest guideline formula.

An additional source of mortality occurs when the reported catch exceeds the harvest guideline. During the fishing season, vessel captains are required to report their daily catch to the NMFS PAO through daily call-ins. Within a season the daily call-in data are used to develop a statistical model to forecast the closure date of the fishing season, and the closure date is provided to each vessel captain approximately 7 days prior to the effective date. As there is error associated with any forecast, the reported catch at the end of the fishing season may exceed the harvest guideline. In 1996 the reported catch was 187,583 lobsters and exceeded the established harvest guideline by 1,583 lobsters. This additional source of mortality, referred to as forecast error, does not need to be explicitly incorporated into the harvest guideline formula as long as this error is minimized. To minimize this error an efficient forecasting framework needs to be developed and this task is deferred to the NMFS PAO who is responsible for monitoring the harvest guideline.

There are three ways (options) to effectively incorporate discarding into the formula.

Option 1: Monitor Total Catch

This option treats the harvest guideline as it is presently defined: the total allowable catch of lobsters in the NWHI lobster fishery. Remember that the 13% harvest rate (r), as well as data used to compute exploitable population, assume a retain-all fishery. Discarding is therefore an additional source of mortality that needs to be assessed against the harvest guideline. Option 1 requires that the catch be monitored, not just the landings. The fishery ends when the total catch equals the harvest guideline. No modifications to the existing harvest guideline formula are required. The only way to effectively monitor the catch and provide accurate estimates of the number of discards is through the use of at-sea observers. Implementing this option would still require discarding and forecast error during the 1996 fishing season to be accounted for when estimating the 1997 harvest guideline.

Option 2: Reduce Total Allowable Catch to Account for Expected Discarding

Option 2 relies on annual estimates of the number discarded and incorporates these data into the harvest guideline formula. The harvest guideline in year t+1 (e.g., 1997) is adjusted to account for discards detected in year t (e.g., 1996) and the fishery ends when the retained catch equals the adjusted harvest

guideline. The adjustment to the harvest guideline is assumed to account for expected discards in year t+1 (retained catch + discards = unadjusted harvest guideline). Treating the discard parameters in the harvest guideline formula as constants, implies that the "pattern of discarding" (magnitude and type) is temporally invariant. Assuming that the parameters are dynamic would require annual estimates of the discard parameters, and could be estimated using the shoreside monitoring program, commercial fishing location data (e.g., VMS or modified logbook data), and expanded research surveys.

Estimates of the number of discards (16,537-28,978) and discard rate (16%) in this report would form the basis under option 2 for estimating the 1997 (and subsequent) harvest guideline(s). The modified harvest guideline formula can be expressed as:

$$HG_{t+1} = PHG_{t+1} * (1 - DR_t) ,$$

where HG = the harvest guideline, PHG = (r * N) = the provisional harvest guideline, r = harvest rate, N = the exploitable population, DR = the discard rate, and t is the year index.

Option 3: Phased Monitoring and Reduction in Total Allowable Catch

Option 3 is a combination of options 1 and 2 and is implemented in two phases. In phase 1, total catch is monitored and used to reliably evaluate discarding in the short-term (option 1). Estimates of the number discarded and discard rate from phase 1 form the basis of phase 2, and would be used to evaluate the harvest guideline adjustments in the long-term (option 2). One benefit from this approach is that the existing shoreside monitoring program can be optimized to compute more reliable estimates of discarding based on the sampling of similar vessels both at-sea and shoreside.

Treating discards as an additional source of uncertainty and accounting for this uncertainty by lowering the level of risk is not considered to be an option. As feasible procedures to effectively estimate the number discards are available, as well as provisional estimates of discarding, there is no reason to treat discarding as a source of uncertainty. Also, the Council decided on a 10% level of risk and any option considered should maintain the desired 10% risk. Lowering the risk level is contrary to what the Council adopted.

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Table 1.--Spiny lobster mean tail width (mm), sample size (N), and coefficient of variation (CV) statistics by year and area from research survey collected data.

Area	1995			1996		
	N	Mean tail width	CV	N	Mean tail width	CV
2	966	47.6	13.8	859	47.8	13.4
3	1,049	46.7	12.7	1,150	46.6	11.6
4	226	53.6	22.0	346	55.5	15.5

Table 2.--Area-specific spiny lobster mean tail width (mm) and legal, sublegal, and berried catches from observer data collected during the 1995 commercial fishery. Numbers in () represent percent.

Fishing area	N	Mean tail width (mm)	Number legal lobsters	Number sublegal lobsters	Number berried lobsters
1	1,758	48.7	399 (22.7)	891 (50.7)	468 (26.6)
2	2,666	49.8	786 (29.5)	1,208 (45.3)	672 (25.2)
3	859	50.7	301 (35.1)	324 (37.7)	234 (27.2)
4	2,278	52.6	1,010 (44.3)	521 (22.9)	747 (32.8)
5	3,569	53.2	1,511 (42.3)	530 (14.9)	1,528 (42.8)

Table 3.--Vessel-specific spiny lobster sample size (N), mean tail width (mm), coefficient of variation (CV), and quartiles from shoreside monitoring data collected during 1996.

Vessel	N	Mean tail width (mm)	CV	Quartiles (25% - 75%)
A	4464	51.85	9.31	48.39 - 54.94
B	1079	52.04	8.83	49.03 - 54.24
C	2111	53.71	9.79	49.99 - 56.89
D	374	55.53	11.70	50.35 - 59.93
E	4342	55.38	7.75	52.70 - 58.04

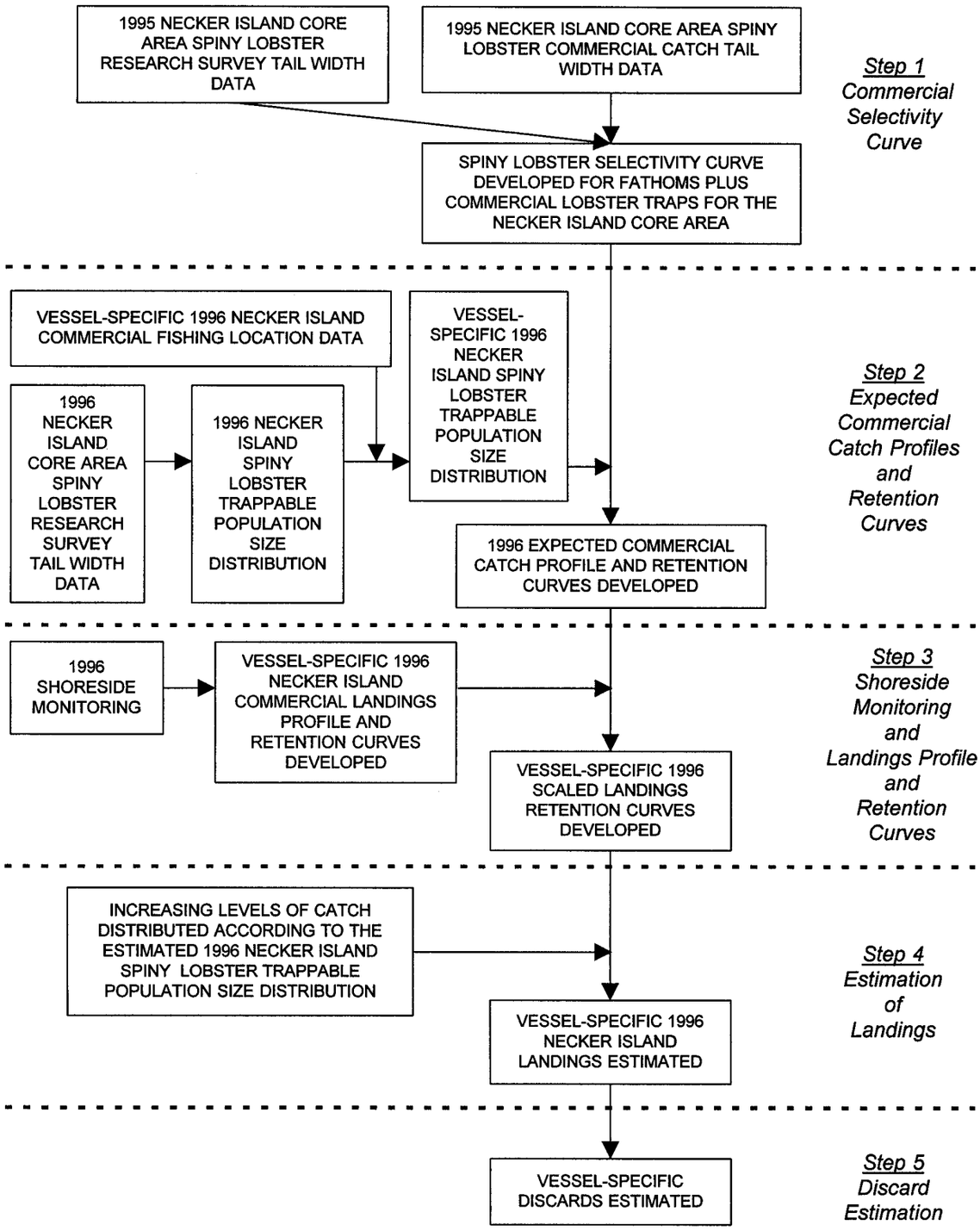


Figure 1.--Flow chart delineating the steps of the total catch and discard estimation procedures.

Figure 2.--The location of stations sampled at Necker Island during the 1995 research survey. Each station represents a string of 8 or 20 traps. The 7 statistical areas are arbitrarily delineated and based on reported commercial fishing areas.

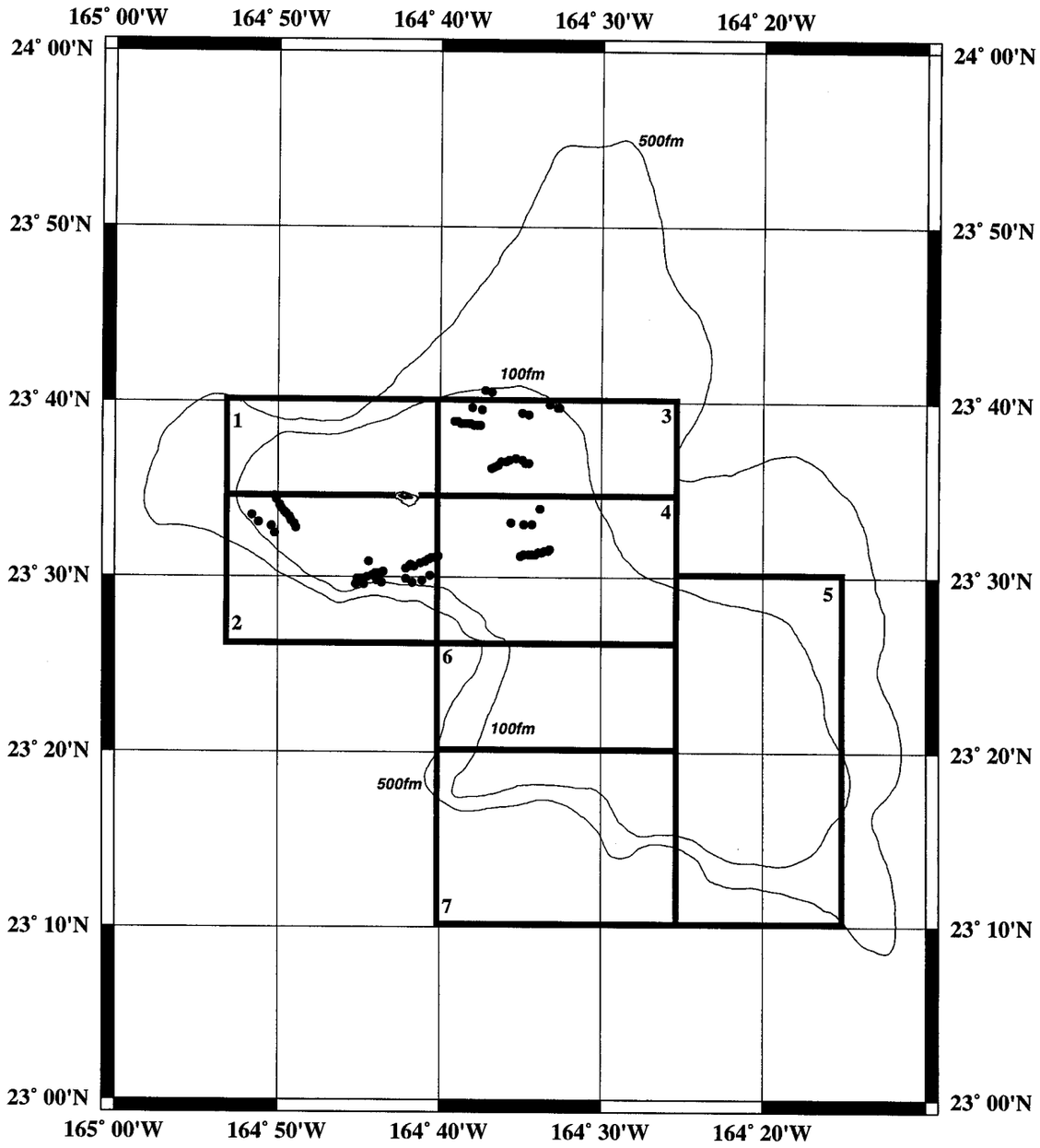
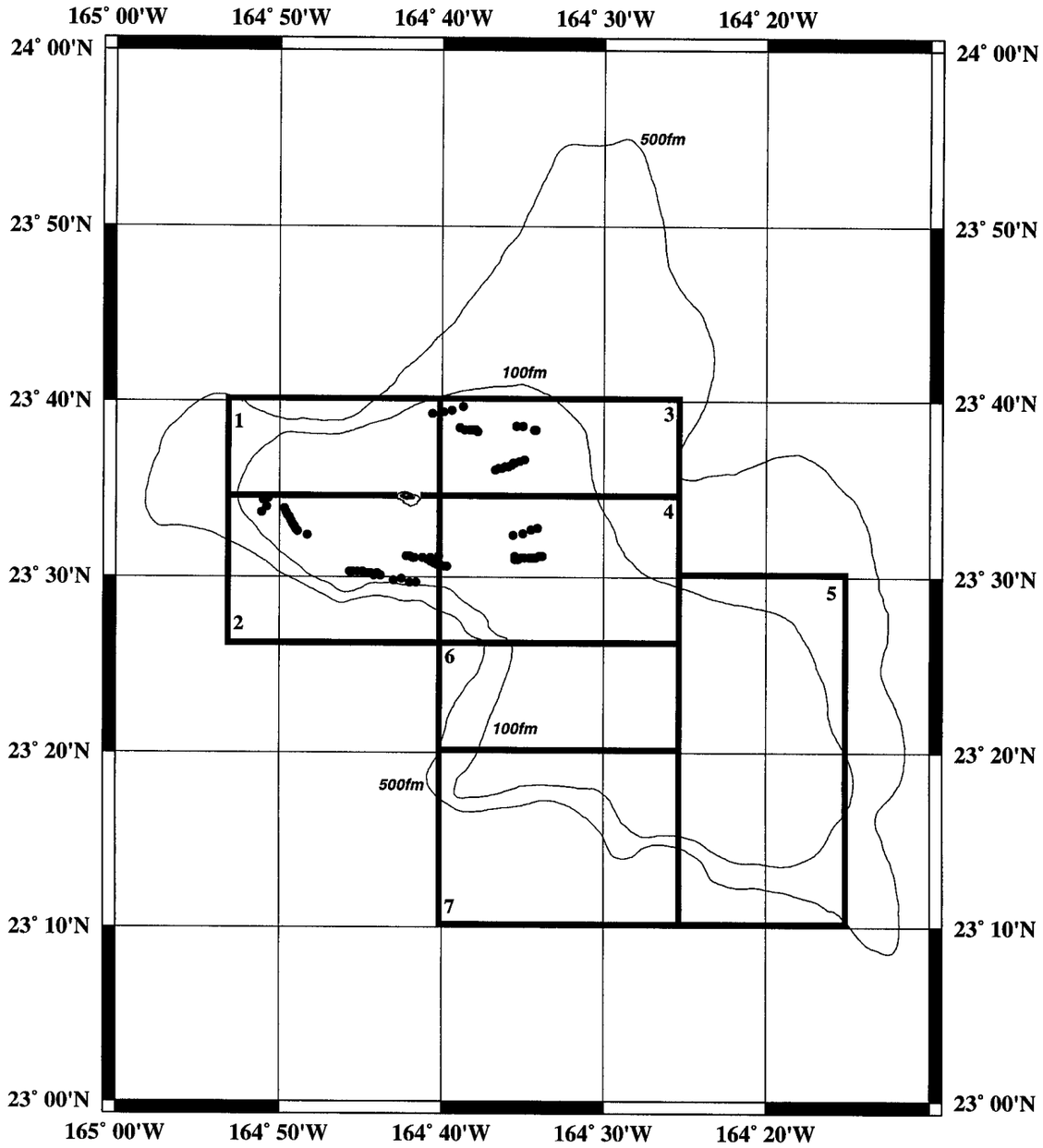


Figure 3.--The location of stations sampled at Necker Island during the 1996 research survey. Each station represents a string of 8 or 20 traps. The 7 statistical areas are arbitrarily delineated and based on reported commercial fishing areas.



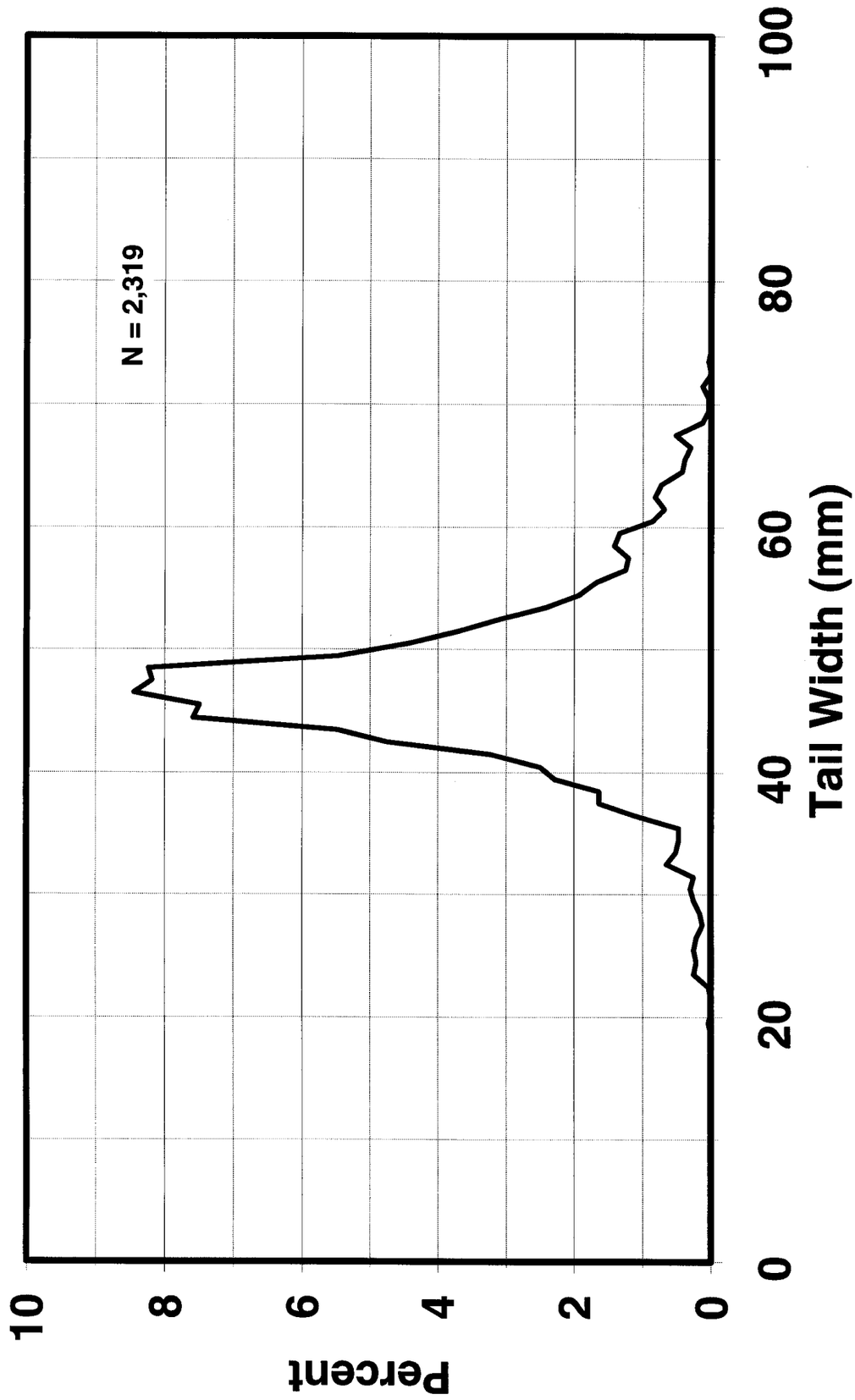


Figure 4.--The spiny lobster tail width percent frequency distribution based on 1995 research survey data.

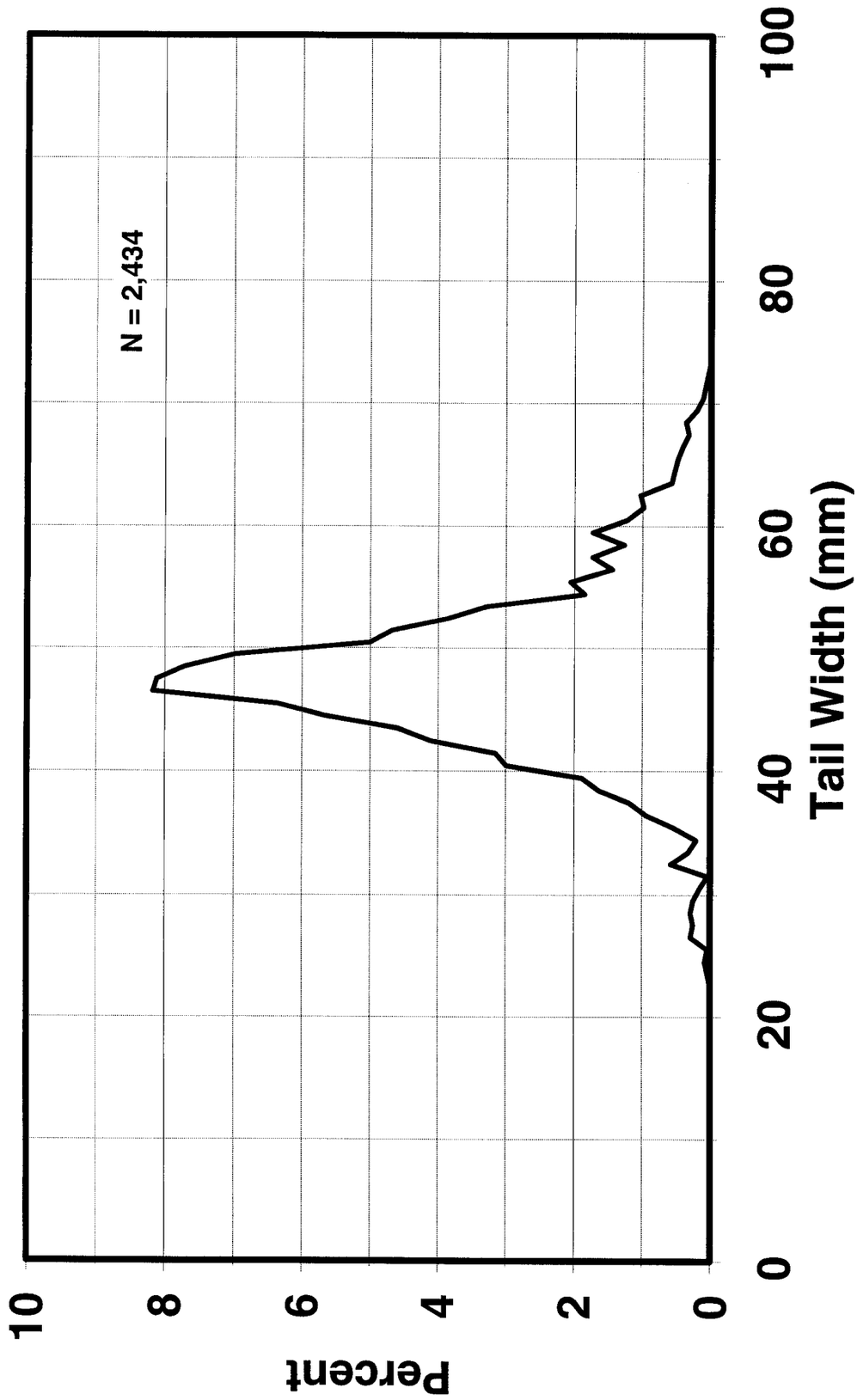


Figure 5.--The spiny lobster tail width percent frequency distribution based on 1996 research survey data.

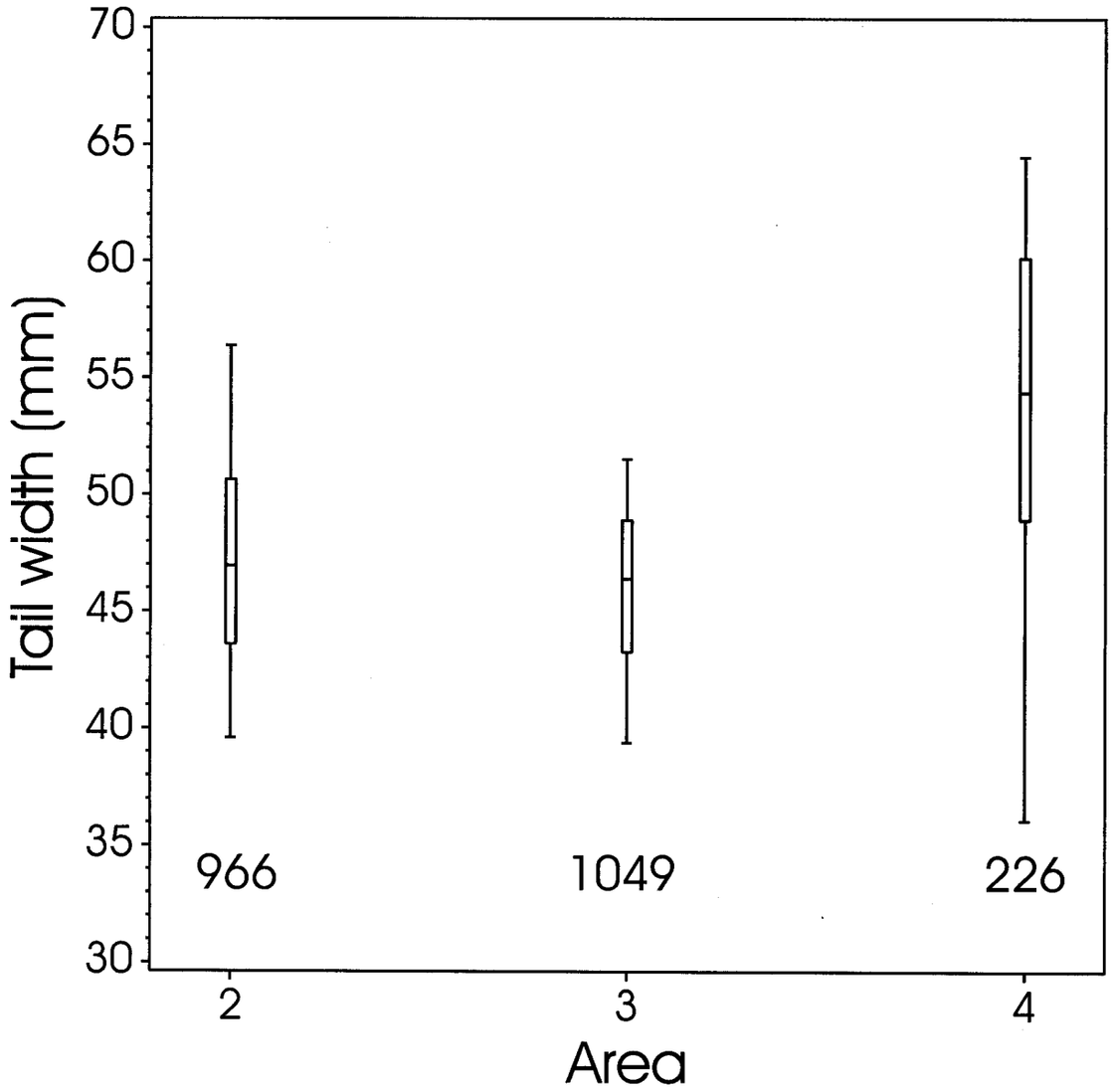


Figure 6.--Areal metrics of spiny lobster tail widths from the 1995 research survey. The bottom and top edges of the box are located at the sample 25th and 75th percentiles. The center horizontal line is drawn at the mean. The whisker ends are located at the sample 10th and 90th percentiles. Numbers above the x-axis represent sample size.

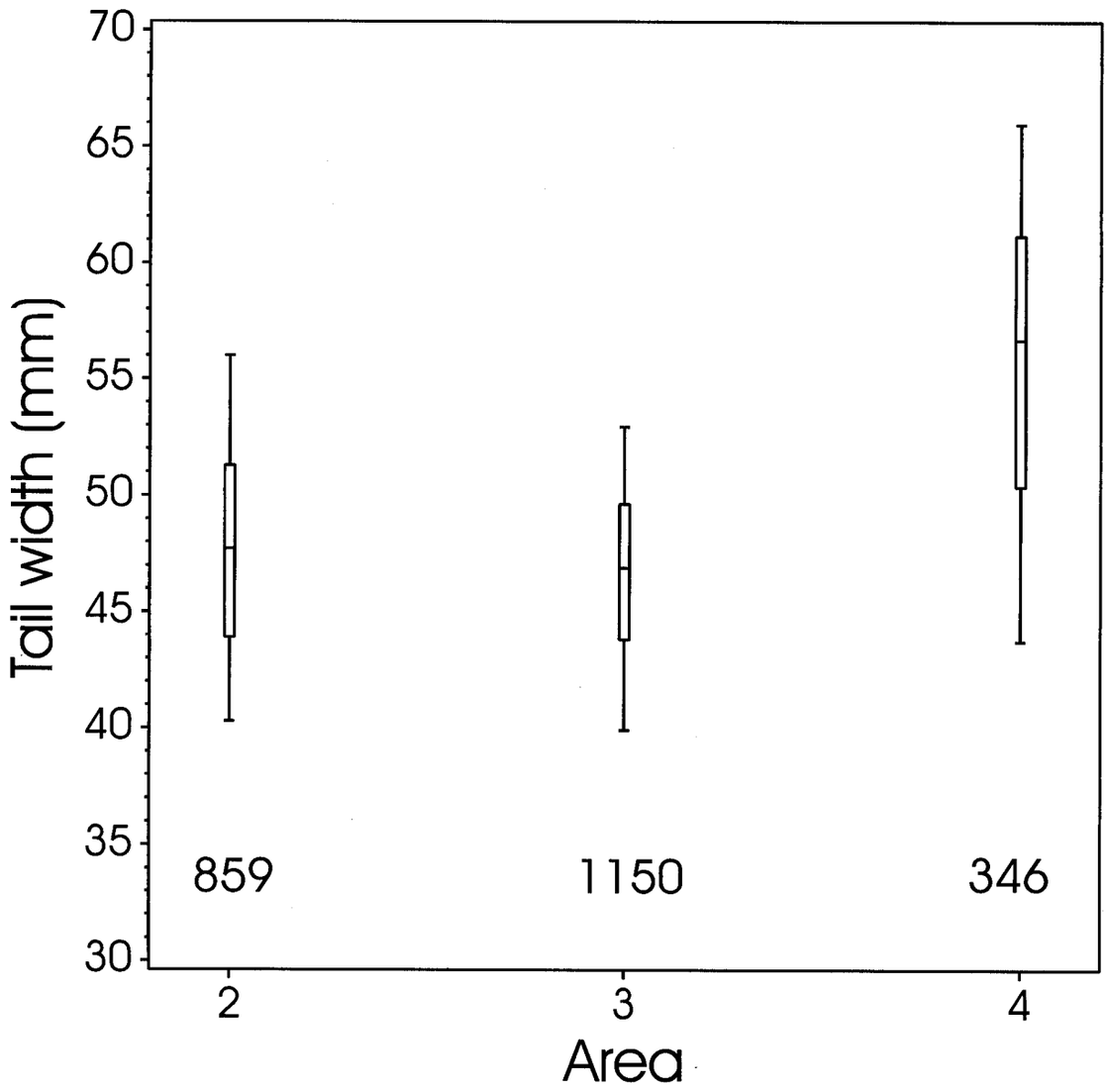
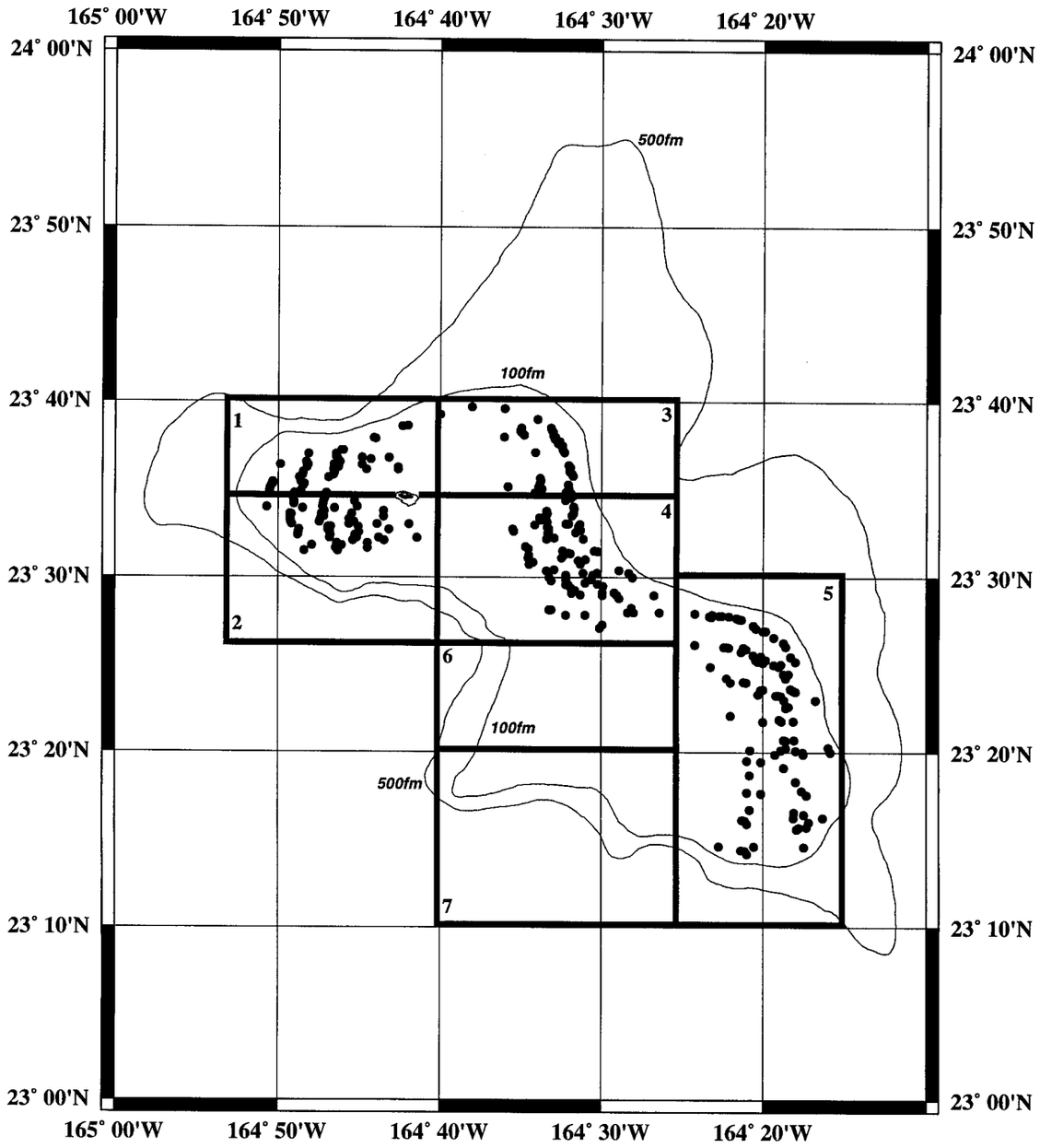


Figure 7.--Areal metrics of spiny lobster tail widths from data collected during the 1996 research survey. The bottom and top edges of the box are located at the sample 25th and 75th percentiles. The center horizontal line is drawn at the mean. The whisker ends are located at the sample 10th and 90th percentiles. Numbers above the x-axis represent sample size.

Figure 8.--The location of sampled strings during the 1995 Necker Island commercial fishery. The 7 statistical areas are arbitrarily delineated and based on reported commercial fishing areas.



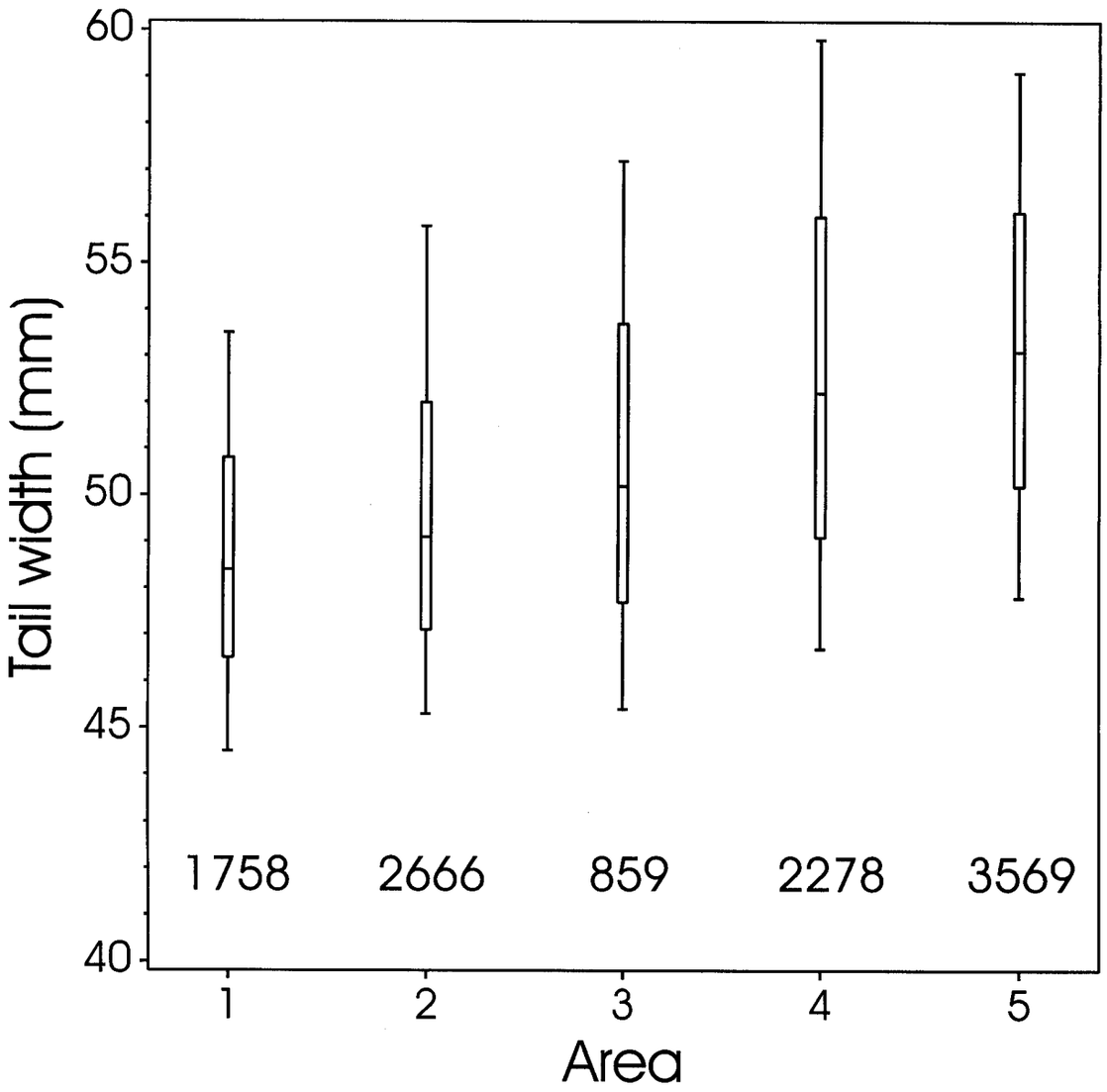


Figure 9.--Areal metrics of spiny lobster tail widths from data collected during the 1995 commercial fishery. The bottom and top edges of the box are located at the sample 25th and 75th percentiles. The center horizontal line is drawn at the mean. The whisker ends are located at the sample 10th and 90th percentiles. Numbers above the x-axis represent sample size.

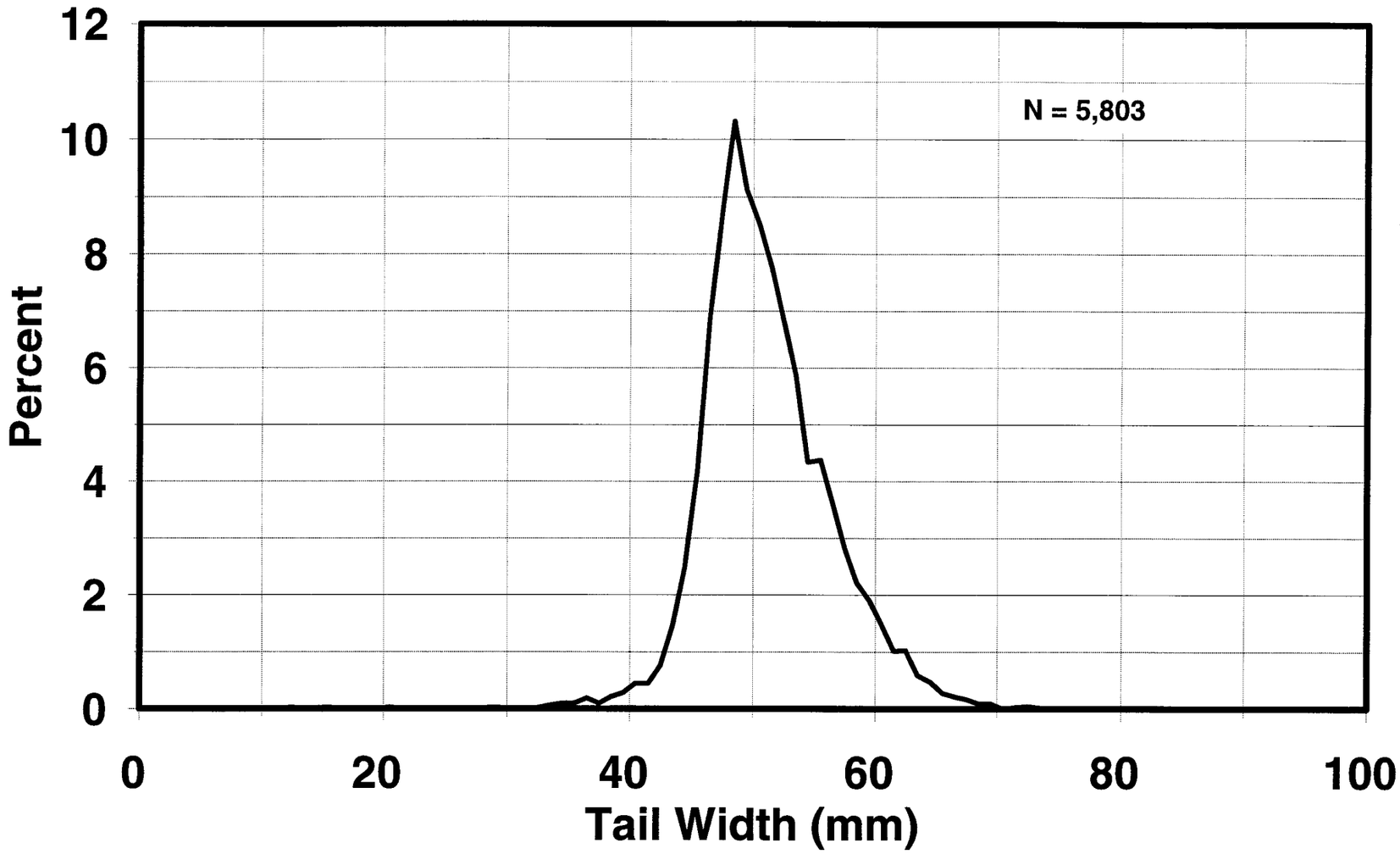


Figure 10.--The spiny lobster tail width percent frequency distribution based on 1995 Necker Island commercial fishing data collected in the core area.

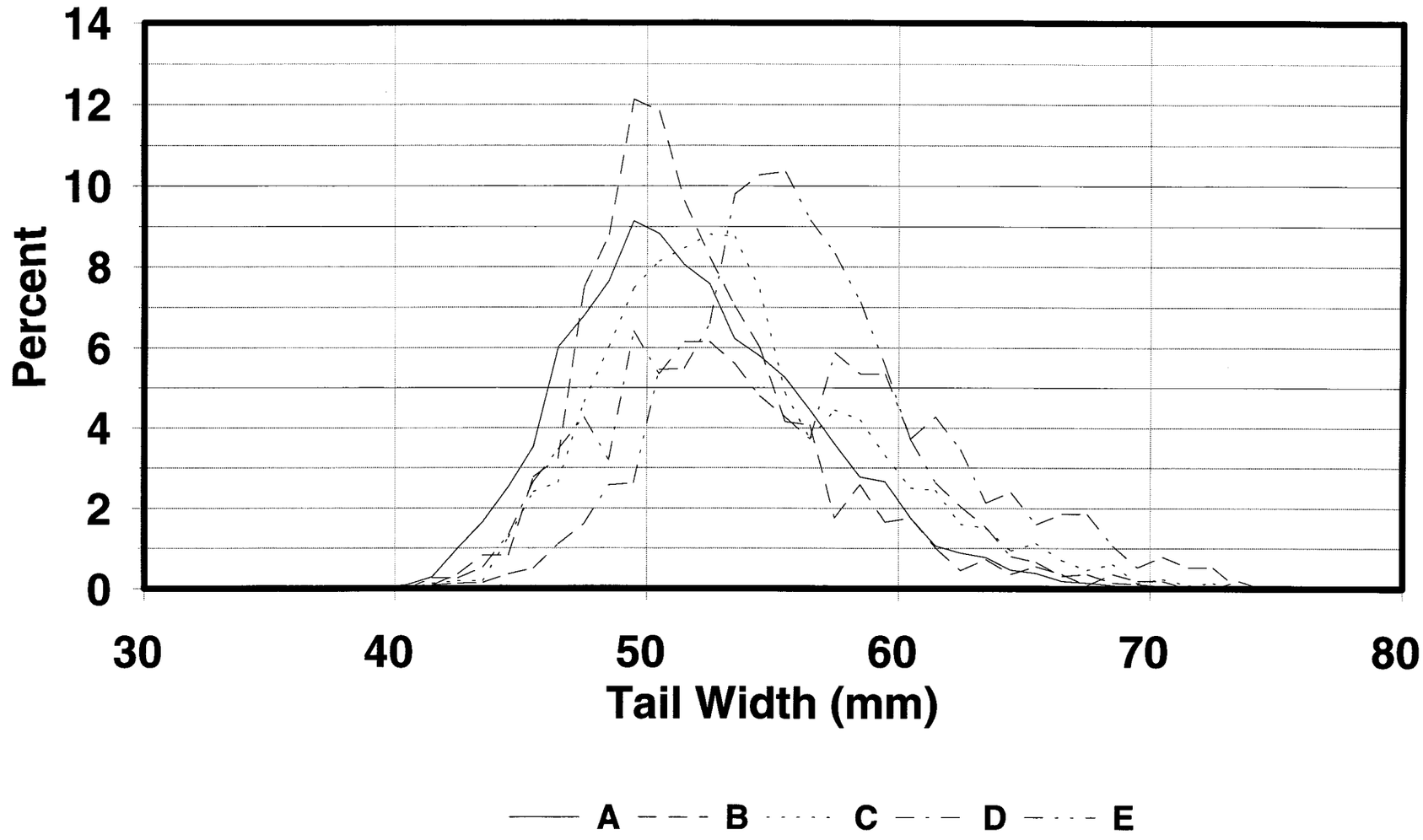


Figure 11.--Vessel-specific spiny lobster tail width percent frequency distributions based on data collected during the 1996 shoreside monitoring program.

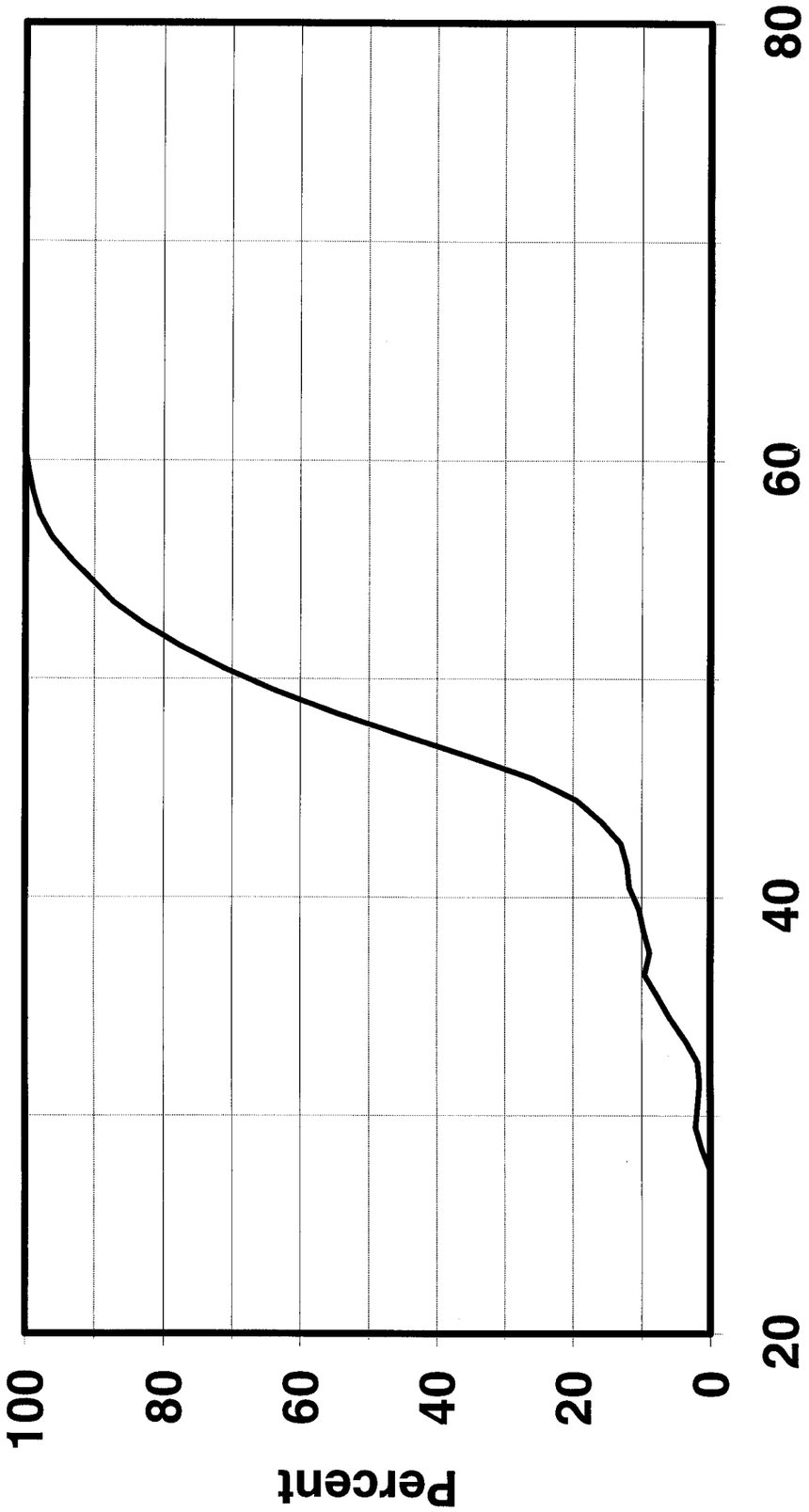


Figure 12.--The Necker Island spiny lobster commercial lobster pot selectivity curve.

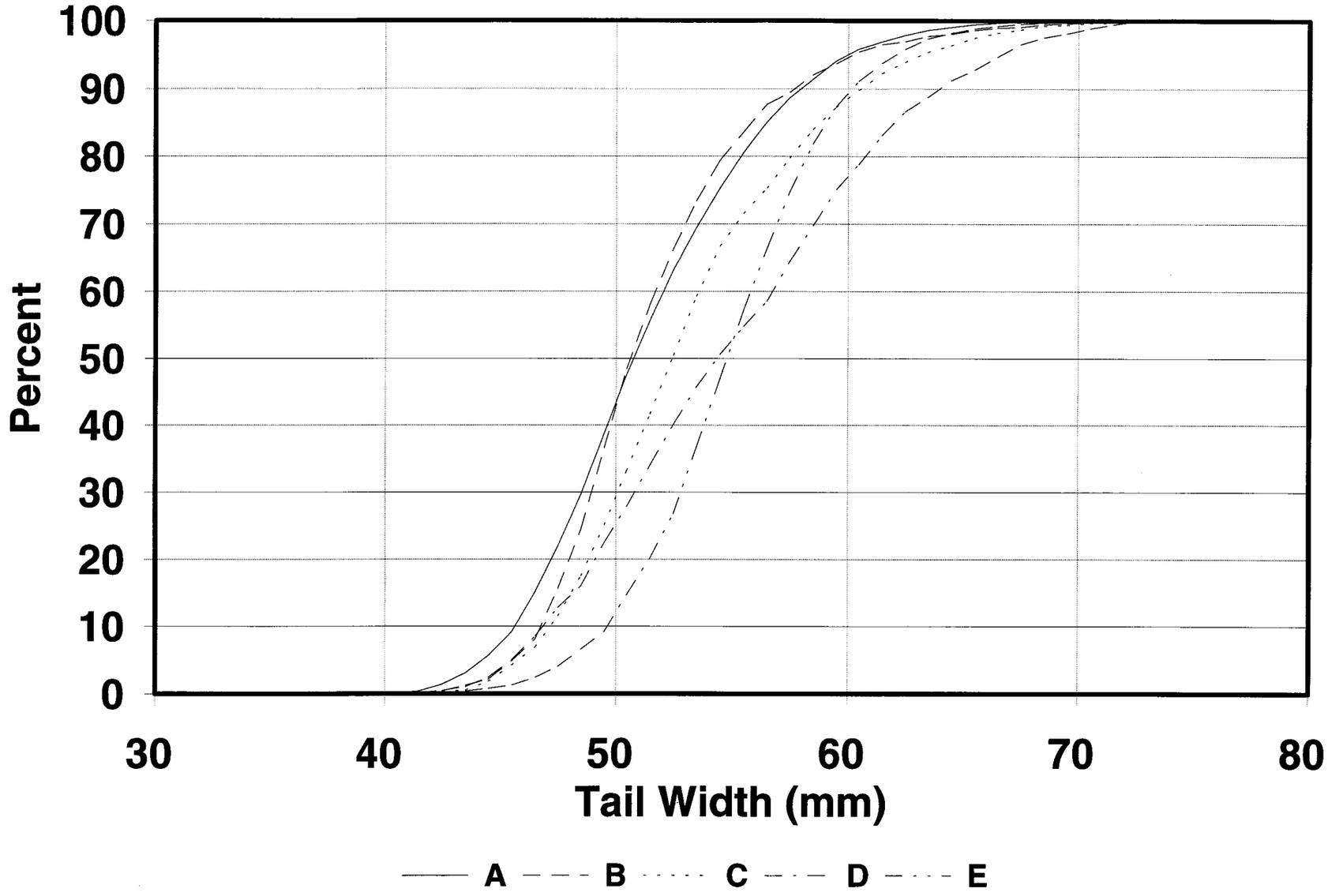


Figure 13.--Vessel-specific spiny lobster retention curves based on landing data collected during the 1996 shoreside sampling program.