# ANALYSIS OF CATCH AND EFFORT DATA FOR THE SPINY LOBSTER, PANULIRUS MARGINATUS, AT NECKER ISLAND

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## INTRODUCTION

Commercial spiny lobster, Panulirus marginatus, fishing began on a regular basis off Necker Island in the Northwestern Hawaiian Islands in November 1976. Seven commercial fishing vessels from Honolulu reported lobster catches during the period November 1976 through April 1979. Some of these vessels trapped in the area frequently while others trapped only occasionally.

This report analyzes and summarizes commercial and research data for the P. marginatus fishery off Necker Island during the period from November 1976 through April 1979. The commercial data consist of monthly totals of the number of legal lobsters[1] caught and the effort expended (Table 1). These data were collected by National Marine Fisheries Service observers aboard commercial vessels or were reported in catch reports submitted by the vessels' owners. The unit of effort is measured as one baited trap fished on the lobster ground for one night, henceforth referred to as a trap night. The research data consist of total number and effort, as well as length and sex observations, for lobsters caught at sampling sites from the RV Townsend Cromwell.

The island of Necker is surrounded by a large bank (Figure 1). The commercial catch by position indicates that the fishermen have primarily trapped in the northwest region of this bank, indicated as Region I in Figure 1. There were 90,368 legal lobsters trapped in Region I from January 1977 through April 1979; only 17,470 legal lobsters were trapped on the rest of the bank (Region II) during the same period (Table 2). The catch per unit effort (CPUE) in Region II (Figure 2) shows considerable variation, and some of the more recent values for CPUE approach those for Region I (Figure 3). However, because of the lack of a longer series of catch and effort data for Region II, this report will focus only on Region I. By isolating Region I for study, we are making the assumption that the lobster population in this region is closed. This may not be an unreasonable assumption for adult lobsters because tagging experiments indicate minimal migration (Uchiyama[2]). However, in the case of larval recruitment this may not be the case and for the long term, the assumption of a closed population in Region I may not be valid.

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[1]A legal lobster is defined as a lobster with a carapace length equal to or exceeding 8.25 cm.

[2]J. H. Uchiyama. Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, Honolulu, HI 96812. Personal communication, June 1979.

## RELATIVE ABUNDANCE

Catch per unit of effort provides a measure of relative abundance. Changes in CPUE over time can result from changes in population structure and size, as well as changes in fishery methods and gear. In the case of the lobster fishery at Necker between November 1976 and April 1979, the changes in fishing methods and gear have been minimal. A graph of CPUE for legal lobsters from Region I on a monthly basis is presented in Figure 3. Considerable month-to-month variation as well as a declining trend is apparent.

One reason for some of the month-to-month variation in CPUE is that the monthly CPUE is computed by pooling the catch and effort for all the vessels reporting trips to Necker during the month. These vessels are not always the same vessels but a subset of the seven commercial vessels which comprise the fleet.

Catch per unit effort computed on an annual basis has declined each year from 1977 to 1979, although the 1979 figure should be treated with caution because it is based on only an effort of 1,616 trap nights and may change when more 1979 data are available (Table 2).

A regression of CPUE against month, weighted by effort, indicates that at the 5% level the decreasing trend in CPUE for 1977 is significant while the trend in 1978 is not significant. The CPUE for January 1977 and January 1978 represents a sharp increase from the preceding and following months indicating a possible seasonal trend which should be examined as more data become available.

The percentage of legal lobsters in the total lobster catch provides an index of the proportion of legal lobsters in the population to the total lobster population. A decrease in this index could mean that the number of legal lobsters in the population has been reduced and/or the number of sublegal lobsters in the population has increased due to increased reproduction, survival, or immigration. We found that the percentage of legal lobsters in the catch for the RV Townsend Cromwell decreased from 54.2% in November 1976 to 23% in May 1979 (Table 3).

## POPULATION ESTIMATES

The primary approach we selected to estimate population size was a method proposed by Allen (1966) (see Appendix 1). Basically, this method consists of a least squares procedure which estimates population size and catchability by minimizing the sum of squares between the actual catch and the predicted catch based on effort.

We used the monthly commercial catch and effort data from November 1976 through April 1979 to estimate population size and catachability. Allen's model assumes natural mortality and recruitment operate in the population. In its most general form, this model assumes that the rate

of natural mortality is constant while recruitment may vary over time. This most general form requires that the user supplies estimates of the natural mortality rate and the recruitment rates. We do not have any size and age data which might allow us to estimate these parameters and consequently, we used a simplified version of Allen's model. We assumed that the ratio of the rate of natural mortality to the recruitment rate ($e^{-M}/1-W_i$) in Appendix 1 is constant. Given effort, we then estimated this constant as the value which gave the best fit of predicted catch to actual catch. We feel the assumption that the ratio, rate of natural mortality to recruitment rate into the fishery is constant, may not be too unreasonable for the 2-year period of our study. If it takes six or more years for a lobster to grow from larval stage to legal size, and if the majority of the mortality occurs during the early years of life, then, even an intense reduction of the population of legal lobsters in 1977 will not have a major effect on the ratio of natural mortality rate to recruitment rate until 6 years later.

The plots of actual monthly catch and predicted monthly catch estimated by Allen's method are presented in Figure 4. The fit of the model to the data is good. Based on this method, we estimate that there were 132,406 legal lobsters in Region I at the beginning of November 1976. This number declined to 68,571 legal lobsters by April 1979. A plot of the monthly estimated population size is given in Figure 5. As could be expected from the catch and CPUE data, the population size of legal lobsters dropped severely during 1977 and decreased very slowly during 1978.

As an independent check on the results obtained by Allen's method, we used two additional population estimation methods which were based on completely different assumptions--Delury's method and Leslie's method (Ricker 1958). Both of these methods are used to estimate population size and catchability in situations where there has been intensive fishing of a closed population over a short period of time. Since these methods apply to fishing over a short period of time, they assume that natural mortality and recruitment are negligible (Appendix 2).

We noticed from Table 1 that trapping was very intense from May through August 1977. We used these data to estimate the population size of legal lobsters at the beginning of May 1977 and the catchability by Leslie's and Delury's methods. The estimated population size and catchability obtained from Leslie's method and Delury's method are in agreement with the estimates obtained by Allen's method (Table 4).

## CONCLUSION

The decline in CPUE from 3.95 in 1977 to 3.12 in 1978 strongly suggests that a population size of 65,676 legal lobsters is not sustainable with a CPUE of 3.90. This is further supported by the decline in the percentage of legal lobsters per trap from the Cromwell sampling data. The fact that we do not reject the hypothesis that CPUE did not

decline during 1978, based on the test of the slope of the regression line, suggests that a yield of 21,201 legal lobsters per year may be sustainable with a CPUE of about 3.00. However, if the preliminary indications we have for 1979 are supported with additional data, then, even 20,000 legal lobsters per year would exceed the annual MSY. We can use the result of Allen's model to compute the surplus production which can be harvested without reducing the population size. This value is obtained by multiplying the population size of legal lobsters by the ratio of the natural mortality rate to the recruitment rate for legal lobsters and subtracting the initial population size. We estimated the population size at the beginning of 1979 to be 67,766 legal lobsters and the ratio of the monthly rate of natural mortality to recruitment to be 1.0116. Consequently for 1979, we estimate that slightly over 10,000 legal lobsters can be harvested for the year without reducing the population size of legals. Thus, based on the data presented here, the annual surplus production of legal lobsters in 1979 is estimated to be between 10,000 and 21,000.

It should be noted that we are observing only the short-term effects of exploitation on a previously unexploited population. The long-term population trends as a result of continued exploitation may differ substantially from the results we are now observing.

## LITERATURE CITED

ALLEN, K. R.
1966. Some methods for estimating exploited populations. J. Fish. Res. Board Can. 23:1553-1574.

RICKER, W. E.
1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Board Can. Bull. 119, 300 p.

## Appendix 1

## Allen's Population Estimation Procedure

A method developed by Allen (1966) was used to estimate population size at time t ($N_t$), catchability (q) given effort at time t ($X_t$) and catch ($C_t$). M is the natural mortality and $W_i$ is the proportion of the new recruits in the exploited stock for the $i^{th}$ season. The essential relationships of this model are given below:

Year 1 Initial population $= N_1$

Survival to beginning of next season $= (N_1 - C_1)e^{-M}$

Expected catch $= \left(N_1 - \frac{C_1}{2}\right) qX_1$

Year 2 Initial population = $N_2$ $= \frac{(N_1 - C_1)e^{-M}}{1 - W_2}$

Survival to beginning of next season $= \left[\frac{(N_1 - C_1)e^{-M}}{1 - W_2} - C_2\right] e^{-M}$

Expected catch $= \left[\frac{(N_1 - C_1)e^{-M}}{1 - W_2} - \frac{C_2}{2}\right] qX_2$

Continuing in this way we can show that at the beginning of year t the population equals

$$N_t = \frac{e^{-(t-1)M}}{\prod_{i=2}^{t}(1-W_i)} \left[ N_1 - C_1 - \frac{C_2(1 - W_2)}{e^{-M}} \cdots \frac{C_i \prod_{j=2}^{i}(1-W_j)}{e^{-(i-1)M}} \cdots \frac{C_{t-1} \prod_{j=2}^{t-1}(1-W_j)}{e^{-(t-2)M}} \right]$$

$$= A_t[N_t - f(C)_{t-1}],$$

where

$$A = \frac{e^{-(t-1)M}}{\prod_{i=2}^{t} (1 - W_i)}$$

and

$$f(C)_{t-1} = C_1 + \sum_{i=2}^{t-1} \frac{C_i}{A_i} .$$

Appendix 2

Three Population Estimation Procedures

1) Allen's Method.--Estimates population size and catchability by minimizing sums of squares of differences between actual catch and predicted catch given effort. Model incorporates recruitment and natural mortality.

2) Delury's Method.--Estimates population size and catchability by fitting equation

$$\text{Ln}\,(C_t/f_t) = \text{Ln}\,(qN) - qE_t,$$

where $C_t$ = catch at time t, $f_t$ = effort at time t, $E_t$ = cumulative effort up to time t, and q = catchability. Model assumes no recruitment or natural mortality.

3) Leslie's Method.--Estimates population size and catchability by fitting equation

$$C_t/f_t = qN - qK_t$$

where $K_t$ = cumulative catch up to time t. Model assumes no recruitment or natural mortality.

Table 1.--Catch (No.) and effort (trap night) of legal lobsters at Necker Island.

| | Region I | | Region II | | Total | |
|---|---|---|---|---|---|---|
| Date | Catch | Effort | Catch | Effort | Catch | Effort |
| 1976 | | | | | | |
| Oct. | 107 | 73 | -- | -- | 107 | 73 |
| Nov. | 616 | 156 | -- | -- | 616 | 156 |
| Dec. | 984 | 276 | -- | -- | 984 | 276 |
| 1977 | | | | | | |
| Jan. | 10,030 | 1,656 | 1,599 | 1,081 | 11,629 | 2,737 |
| Feb. | -- | -- | -- | -- | -- | -- |
| Mar. | -- | -- | -- | -- | -- | -- |
| Apr. | -- | -- | -- | -- | -- | -- |
| May | 15,588 | 3,480 | 67 | 53 | 15,655 | 3,533 |
| June | 7,132 | 1,936 | 461 | 122 | 7,593 | 2,058 |
| July | 9,727 | 2,447 | 24 | 75 | 9,751 | 2,522 |
| Aug. | 5,404 | 1,832 | 678 | 534 | 6,082 | 2,366 |
| Sept. | 10,524 | 2,944 | 293 | 120 | 10,817 | 3,064 |
| Oct. | 2,901 | 916 | 58 | 120 | 2,959 | 1,036 |
| Nov. | 1,885 | 600 | -- | -- | 1,885 | 600 |
| Dec. | 2,485 | 824 | -- | -- | 2,485 | 824 |
| 1978 | | | | | | |
| Jan. | 1,314 | 254 | 203 | 92 | 1,517 | 372 |
| Feb. | 978 | 300 | -- | -- | 978 | 300 |
| Mar. | 3,687 | 1,482 | 54 | 60 | 3,741 | 1,600 |
| Apr. | 3,022 | 719 | 398 | 112 | 3,420 | 831 |

Table 1.--Continued.

| Date | Region I Catch | Region I Effort | Region II Catch | Region II Effort | Total Catch | Total Effort |
|---|---|---|---|---|---|---|
| 1978 | | | | | | |
| May | 3,160 | 687 | -- | -- | 3,160 | [1]687 |
| June | 2,940 | 1,260 | -- | -- | 3,849 | 1,724 |
| July | 2,167 | 603 | -- | -- | 2,167 | 603 |
| Aug. | 2,014 | 585 | -- | -- | 2,014 | 585 |
| Sept. | 202 | 246 | -- | -- | 202 | 246 |
| Oct. | 1,574 | 606 | 1,373 | 401 | 2,947 | 1,007 |
| Nov. | 116 | 56 | 5,222 | 2,349 | 5,338 | 2,405 |
| Dec. | -- | -- | 7,040 | 3,139 | 7,040 | 3,139 |
| 1979 | | | | | | |
| Mar. | 1,563 | 658 | -- | -- | 1,563 | 658 |
| Apr. | 1,925 | 958 | -- | -- | 1,925 | 958 |

[1]Two stations with no positions.

Table 2.--Catch (No.) and effort (trap night) data for legal lobsters, Necker Island.

| Year | Catch | Effort | C/E |
|---|---|---|---|
| | Region I | | |
| 1977 | 65,676 | 16,635 | 3.95 |
| 1978 | 21,201 | 6,798 | 3.12 |
| 1979 (1/1-5/1) | 3,491 | 1,616 | 2.16 |
| | Region II | | |
| 1977 | 3,180 | 2,105 | 1.51 |
| 1978 | 14,290 | 6,153 | 2.32 |
| | Combined (Regions I and II) | | |
| 1977 | 68,856 | 18,740 | 3.67 |
| 1978 | 35,491 | 12,951 | 2.74 |

Table 3.--Townsend Cromwell sampling.

| Date | Effort (Trap night) | Percent legals in catch |
|---|---|---|
| | Region I | |
| Oct.-Nov. 1976 | 145 | 54.2 |
| May 1977 | 32 | 40.0 |
| Oct. 1977 | 116 | 42.0 |
| Mar. 1978 | 57 | 35.0 |
| Oct.-Nov. 1978 | 104 | 37.1 |
| May 1979 | 48 | 22.8 |
| | Region II | |
| Sept.-Oct. 1977 | 234 | 62.6 |
| Mar. 1978 | 61 | 81.0 |
| Oct. 1978 | 52 | 67.0 |

Table 4.--A comparison of three population estimation methods.

| | Leslie | Delury | Allen |
|---|---|---|---|
| $N_{May}$ | 127,000 | 163,000 | 125,000 |
| q | $3.58 \times 10^{-5}$ | $2.40 \times 10^{-5}$ | $3.94 \times 10^{-5}$ |

$N_{May}$ is an estimate of the number of legal lobsters in Region I beginning May 1977.

q is the catchability coefficient.

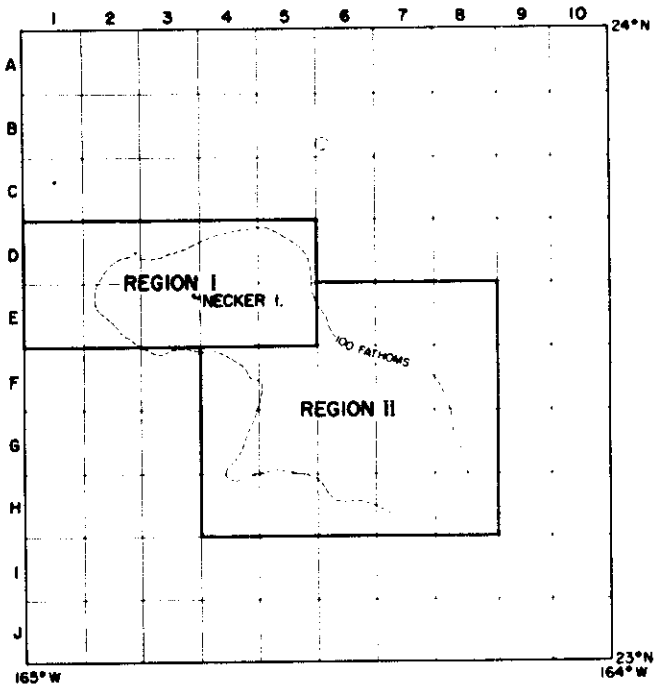


Figure 1.--Necker Bank.

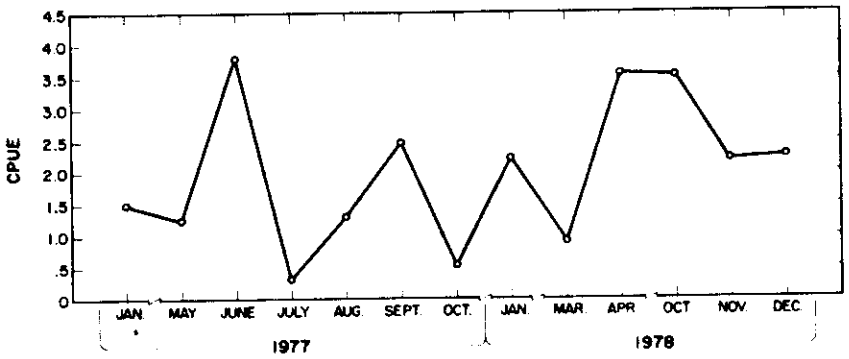


Figure 2.--Catch per unit effort for legal lobsters from Region II at Necker Bank.

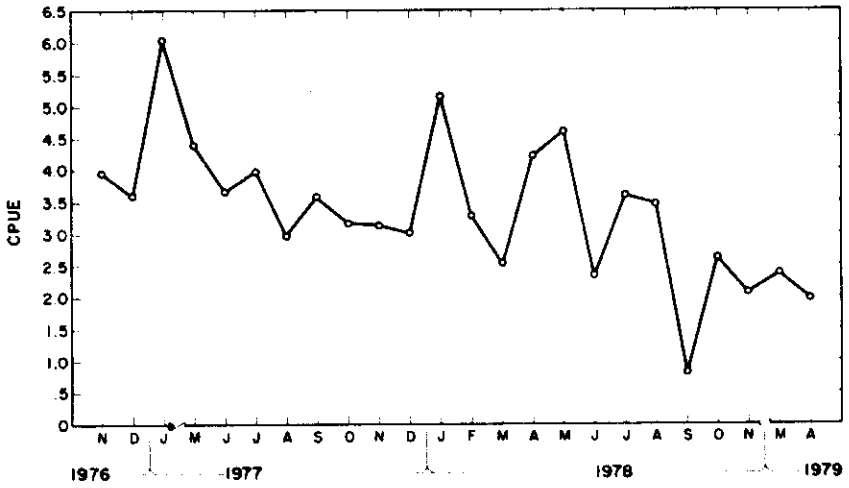


Figure 3.--Catch per unit effort for legal lobsters from Region I at Necker Bank.

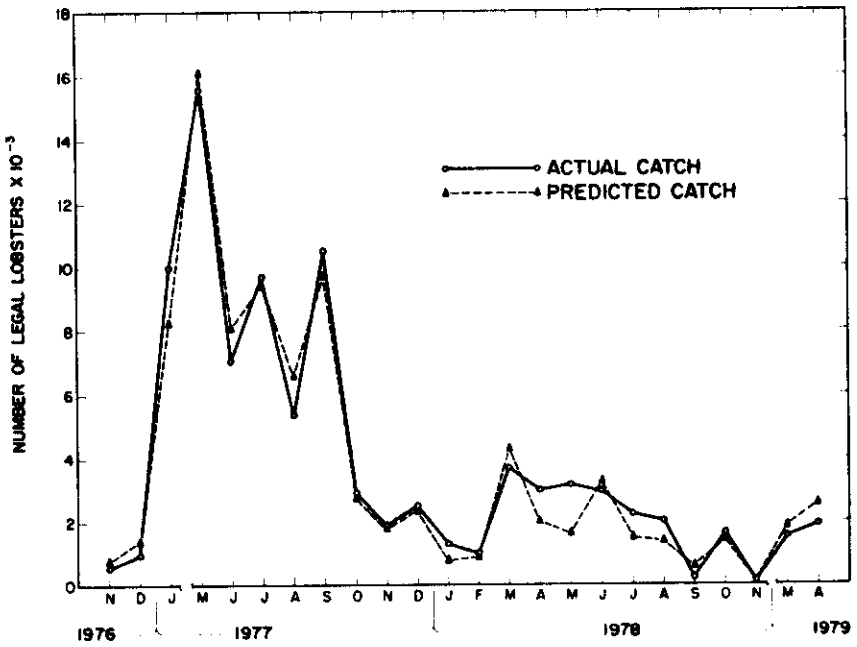


Figure 4.--Predicted versus actual catch of legal lobsters from Region I.

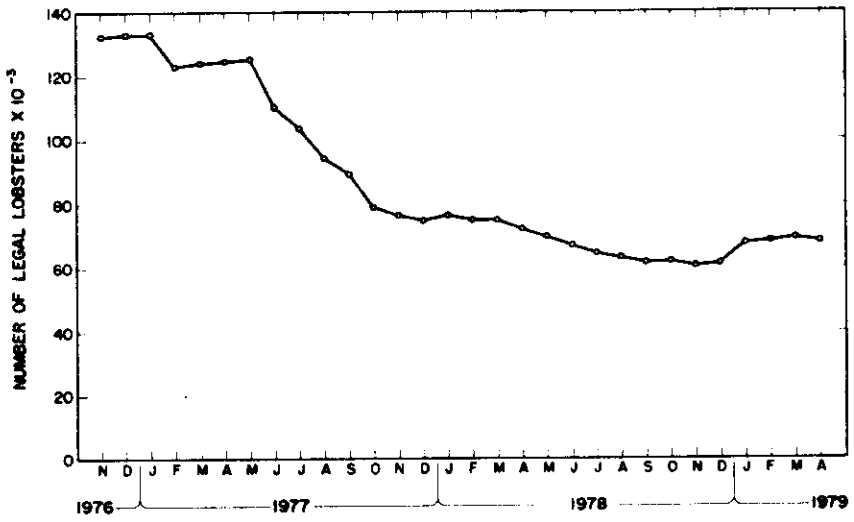


Figure 5.--Estimated population size of legal lobsters in Region I.