

# FINAL REPORT

## ASSESSMENT OF THE CAPE VERDE SPINY LOBSTER (*Palinurus charlestoni*) RESOURCE AND FISHERY IN THE WATERS SURROUNDING CAPE VERDE

Joseph DeAlteris  
DeAlteris Associates Inc  
PO Box 366  
Onancock, VA USA

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### EXECUTIVE SUMMARY

The spiny lobster (*Palinurus charlestoni*) fishery in Cape Verde has experienced substantially decreased landings in the last 25 years. The catch per unit effort (CPUE) has also decreased markedly in same period, indicating a decline in the relative abundance of the fishable biomass to about 5% of the biomass in the 1980s. Examination of the carapace length relative frequency distribution from the 1990s thru 2014 indicates no change in the size frequency distribution of the lobsters in the catch, suggesting that there has been no change in the catchability or size selectivity of the traps used in the fishery, and that the resource was probably overfished at the time of the first sampling of the size distribution in early 1990s. The results of the various surplus production models implemented in this study estimate that MSY for pink lobster is between 33 and 45 mt. The equilibrium model estimate a wide range of values as to the level of effort required to achieve MSY, ranging from 29 to 69 thousand trap hauls. The non-equilibrium models agree that the pink lobster stock is severely overfished, that the current 2014 stock level is less than 20 mt, and that  $B_{MSY}$  is between 202 and 352 mt. Before the resource can ever produce MSY, the stock must be rebuilt. It is recommended that management dramatically limit landings or close the fishery for several years to allow for stock rebuilding. If the fishery were closed, the status of the resource in subsequent years could be monitored with a limited trap survey or experimental fishery.

## INTRODUCTION

The deep water spiny lobster or pink lobster (*Palinurus charlestoni*) is a valuable fishery in Cape Verde, as it provides export income to the nation. Current landings in 2014 are considerably less than the landings in the early 1990s. The Catch per Unit Effort (CPUE, kg/trap haul) is also much less than the CPUE in the 1980s. The fishery is reported to have started in the 1960s by French fishing vessels, and these vessels were replaced in 1975 by Cape Verdean vessels. There are currently four vessels licensed to fish for pink lobster in Cape Verde. There is a currently a closed season that prohibits harvest from 1 July to 31 November. The current minimum size of pink lobster that can be landed is 11 cm carapace length. Female pink lobsters are 50% mature at carapace lengths ranging from 8 to 13 cm depending on the habitat area.

There is a clear need for a stock assessment that will support rational management of this valuable resource. This effort was initiated with a mission by Joseph DeAlteris and Richard Allen to Cape Verde in September of 2014 to collect data, and to meet with representatives of the fishery. The summaries of the meetings are presented in the Appendix to this report. Richard Allen is conducting a bio-economic analysis of the pink lobster fishery that will complement this stock assessment.

The purpose of this report is to present:

- Summary previously published reports on the pink lobster fishery and resource
- Results of the development of a time series of landings and Catch per Unit Effort for the fishery for the last 30+ years
- Results of analyses of length frequency distributions of pink lobsters sampled at sea over the last 25 years.
- Results of seasonal depletion analyses to provide point estimates of the minimal fishable biomass
- Results of stock assessment models used to estimate the trajectory of stock biomass and fishing mortality of the last 25 years.
- Summary and stock management advice

## SUMMARY OF PREVIOUS PUBLISHED REPORTS

There has been a long history of scientific investigations conducted by INDP dating from the early 1990s to the present that provide a wealth of biological information and catch data on the fishery.

Carvalho in 1992 reported on the results of an experimental fishery from April 1991 to April 1992. During this study, INDP sampled about 10,000 at sea, recording carapace length, sex, presence of eggs, etc., and these data are available in the INDP biological data base for lobster. The data will be useful for a comparison of size distributions of the lobsters captured by the fishery over the last 25 years. He also presents INDP landings data for the period 1981 to 1990. The report compares the catch rates (CPUE) and size distributions of the catches for Cape Verdean and French traps on an island by island basis.

Dias in 1992 also reported on the results of his studies of the pink lobster fishery. He reports landings by month within years for the period 1982 to 1989. He also provides data on effort (number of traps) and reports CPUE by month for the 87/88 and 88/89 fishing seasons. These data may be useful for a depletion analysis that will provide point estimates of minimum abundance. He also reported on his analysis of the biological (life history) characteristics of the pink lobster.

Eide in 1996 provided an excellent description of the fishery and the resource at the inception of the fishery. Later in 1999 Eide et al. describes a bio-economic model for the fishery that recommended limitation on effort so as to maximize profit. This report has both landing and effort data for the period 1987/1988 to 1995/1996. The results of his analyses suggest a Maximum Sustainable Yield (MSY) of 55-75 mt, and a Maximum Economic Yield (MEY) of 25-50 mt.

Schwarz in 1999 provides an analysis of commercial fishery data collected for the period 1995/1996 to 1998 to 1999. The data presented includes landings and effort on an annual basis, CPUE by month for the four fishing seasons, and catch-effort data by island and fishing vessel. The CPUE data may be useful for a depletion analyses.

Medina et al. in 2000 apply a global, equilibrium surplus production model to the catch and effort data for the period 1987/1988 to 1998/1999, and suggest that the resource was over-exploited and the effort should be reduced. They estimate MSY at about 40-44 mt.

Finally, Tariche-Pastor in 2012 studied the biological characteristics of the resource, and suggested a management strategy that would address the resource on a regional basis as she believed that there were distinct groups or sub-stocks of pink lobster in Cape Verde based on the geography of the archipelago and the morphological characteristics of the animals in each region. Her thesis report also presents INDP landings data for the period from the 1980s to 2014.

## RESULTS OF THE DEVELOPMENT OF A TIME SERIES OF LANDINGS AND CATCH PER UNIT EFFORT

To supplement the published data with more recent data from INDP files on landings and effort, Tatiana Cabral of INDP summarized original trip landings reports on an annual basis. These data were then used to calculate Catch per Unit Effort (CPUE). A comparison of all the data available on landings indicates some discrepancies in the actual values of the reported landings on a year to year basis, but the trend remains unmistakable (Figure 1 and Table 1). In the mid-1980s landings were about 20-50 mt, then increased dramatically and peaked at 80-100+ mt in the early 1990s, then decreased steadily to about 10 mt into the 2000s, and finally in the period 2011/2012-2013/2014 landings increased to about 20 mt. While there are many reports of landings for the period prior to 2000, there are only two sources of data for the period 2000-2010. In summary, landings have declined substantially from the peak in the early 1990s.

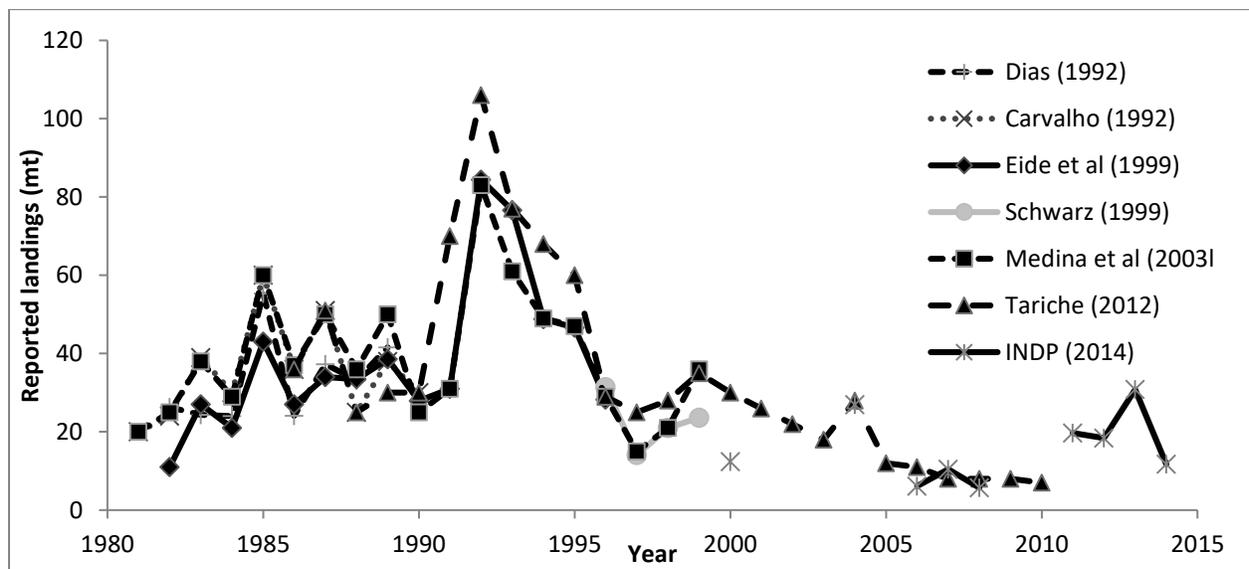


Figure 1. Reported landings of pink lobster in Cape Verde from all available sources. The landings are expressed in MT, and the years reflect the second calendar year of the fishing season, (Nov 2014-May 2014 is expressed as 2014).

The results of the analysis of CPUE data provide an explanation for the decrease in landings (Figure 2 and Table 2). Dias (1992) reported mean CPUE levels of 16.7 and 16.6 kg/trap-haul for 1987/1988 and the 1988/1989 fishing seasons. While the reports appear legitimate, they are so much higher than other values reported, they are not included in the analyses described in this report. Annual average CPUE (kg/trap haul) was the highest (about 4 kg/trap-haul) at the

beginning of the time series (late 1980s), and declined to between 1 to 2 kg/trap-haul in the late 1990s. CPUE reported by INDP in the post-2000 period is about 0.2 kg/trap.

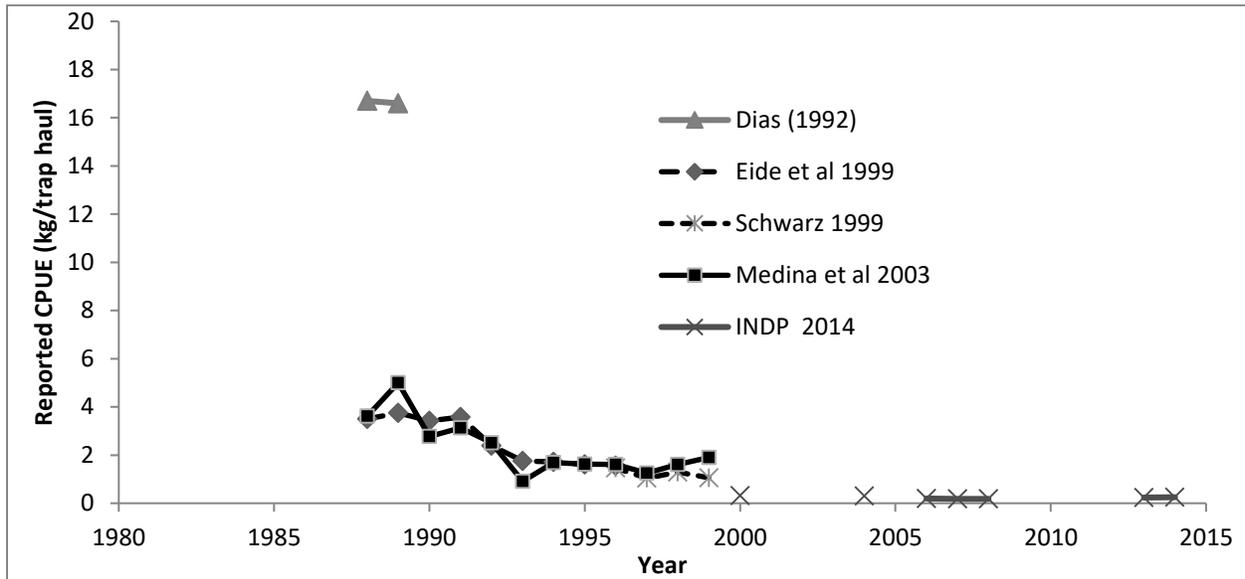


Figure 2. Reported values of Catch per Unit Effort (CPUE) expressed as kg/trap-haul.

The average landings and CPUE that is used in the remaining analyses in this report are presented in Figure 3. Note that the extremely high values of CPUE reported by Dias were excluded from the estimation of the average time series, as they are believed to not be representative of the entire fishery. Assuming CPUE is a reliable index of relative abundance, it appears that the stock has declined to about 5% of the abundance that it had in the late 1980s. There appears to a discontinuity in the CPUE record in the 1999/2000 fishing season that is difficult to reconcile. Discussions with the fishery representatives indicate that there was a transition from fishing few, large traps individually to fishing many, smaller traps with 20-50 traps attached to a long line (“casadas”). In the early days of the fishery, it was reported that a single boat hauled 50-100 large traps per day, and in the post 2000 period, a single boat fishes 300-400 smaller traps per day. It was reported that this transition began about 1995, and was complete by 2000. The fishery representatives indicated that the “casadas” allowed them to fish more traps, so as to be able to maintain total catch in light of decreased CPUE on an individual trap basis. As the transition was gradual, it is hard to believe that some fishermen transitioned to a less efficient trap, or one the only captured smaller lobsters, just to be able to fish more traps. So, with no clear reason to justify any change is trap capture efficiency, the remaining analyses will consider the trap catchability to remain constant over the period of available data.

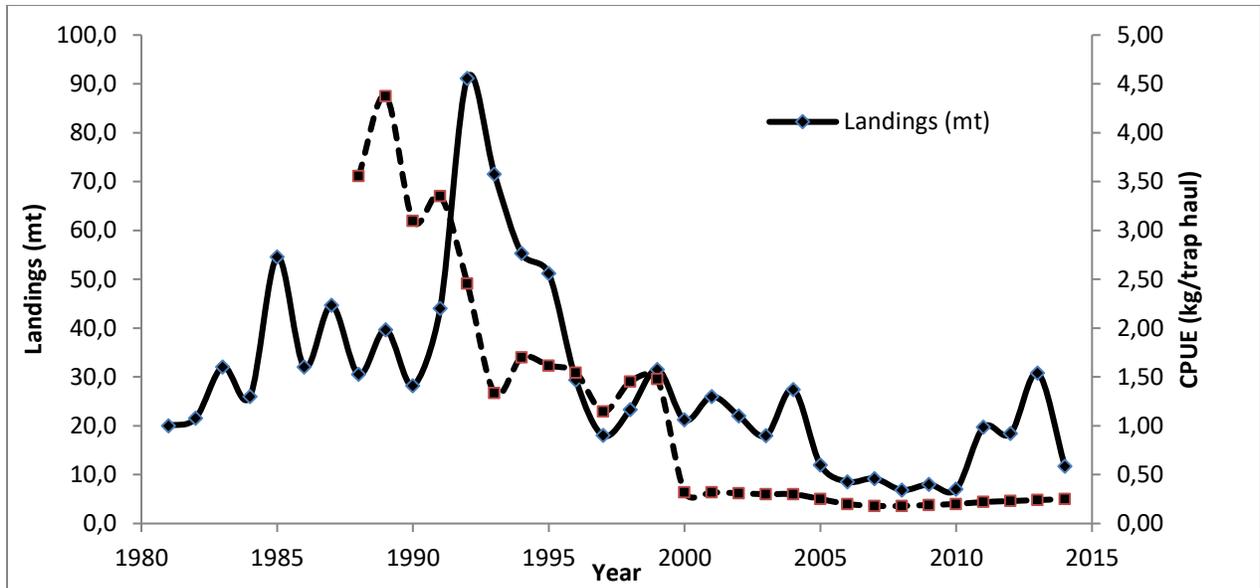


Figure 3. Average estimated landings (mt) and CPUE (kg/trap-haul) for the Cape Verde pink lobster fishery.

RESULTS OF THE ANALYSIS OF LENGTH FREQUENCY DISTRIBUTIONS OF PINK LOBSTERS CAPTURED IN TRAPS IN THE CAPE VERDE FISHERY

To investigate possible changes in the size distribution of pink lobsters captured by the traps in the fishery that would possibly be indicative of a change in the traps catchability, and / or a change in the size distribution of the fishable resource of pink lobsters indicative possibly indicative of overfishing, available data from the INDP biological database was analyzed, and plotted for comparison purposes. Unfortunately, the data base was not complete over the history of the fishery, and the sample size varied substantially for the fishing seasons that data was available for (Table 3). The first season of available data is for 1991-1992, and almost 10,000 were sampled, for several years there are only 200+ lobsters in the sample, and some fishing season the sampling was not representative of the entire fishing season. The plot of the relative distribution of carapace lengths (CL) for the pink lobsters sampled in the catch is shown in Figure 4.

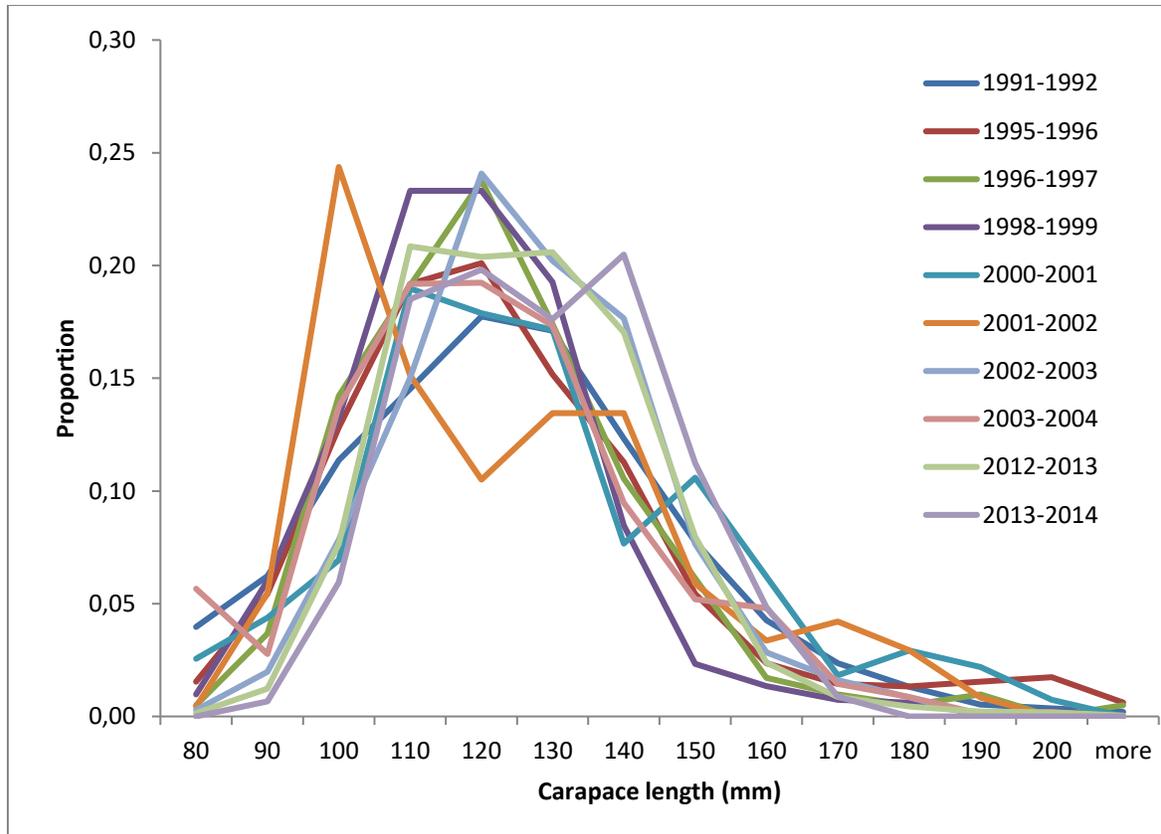


Figure 4. Plot of the Carapace Length (CL) relative frequency distribution for fishing seasons from 1991-1992 to 2013-2014.

Examination of the carapace length distributions (Figure 4) reveals no clear change in the size frequency distributions of the lobsters captured in the fishery over the 20+ years of available data. The data also indicate that there is a substantial portion of the catch that is less than the current minimum size, a carapace length of 110 mm (11 cm). These sub-legal lobsters, if discarded, represent the future recruits to the fishery for legal sized lobsters. Additionally, as pink lobsters are only 50% mature at carapace lengths of 8-13 cm, most of the sublegal females that are captured, are not mature. The 2001-2002 distribution is anomalous with the mode of the distribution 20 mm less than the previous and subsequent distributions. This anomalous distribution is based on a very small sample, that was taken at the end of the fishing season. In general, there appears to be no loss of larger lobsters in the catch that would be indicative of either an increase in fishing mortality or a change in the catchability (catch efficiency / selectivity) of the traps. Note that there are no carapace frequency data available for the 1980s, and in fact the first available data coincides with the dramatic increase in landings in the early 1990s. Therefore, the resource may have already

experienced a substantial change in the size frequency distribution prior to the beginning of sampling.

### RESULTS OF SEASONAL DEPLETION ANALYSES TO PROVIDE POINT ESTIMATES OF MINIMAL POPULATION SIZE

The Leslie depletion model can be used to estimate the efficiency of a fishing gear or to estimate the population size from a closed system. The methodology is described in Ricker (1975) and has been reviewed by Hilborn and Walters (1992). Parkes et al. (1996) used this methodology to estimate the abundance of the Patagonian toothfish off South Georgia Island, and on the Pacific coast of Chile.

The theory defines  $q$ , as the catchability or efficiency of the fishing gear,  $P_0$  as the initial population size, and  $K_t$ , as the cumulative catch, is  $\sum(C_1 + C_2 + C_i)$ . The population available for each subsequent sample (t) is  $P_0 - K_t$  and the catch per unit effort(t) is  $C_t = q*(P_0 - K_t) = q*P_0 - q*K_t$ . Finally the slope of the catch per unit effort,  $C_t$ , versus the cumulative catch,  $K_t$  is  $q$ , the catchability.

Previous investigators of pink lobster in Cape Verde have reported monthly catch and CPUE data in particular seasons that indicate a substantial decline in catch over the fishing season. These data can be used to make an estimate of the minimum abundance of pink lobsters at the beginning of the season.

Dias (1992) presented monthly catch data for the fishing season 1987/1988 and 1988/1989 that were analyzed in this study with a Leslie Depletion Model (Figure 5 and 6). The results of these analyses indicated minimum population abundances at the start of the 1987/1988 and 1988/1989 seasons of 100 and 73 mt, respectively. It is interesting to note that the catch per unit effort rates reported by Dias (1992) are extremely high, and were not used in the average CPUE time series.

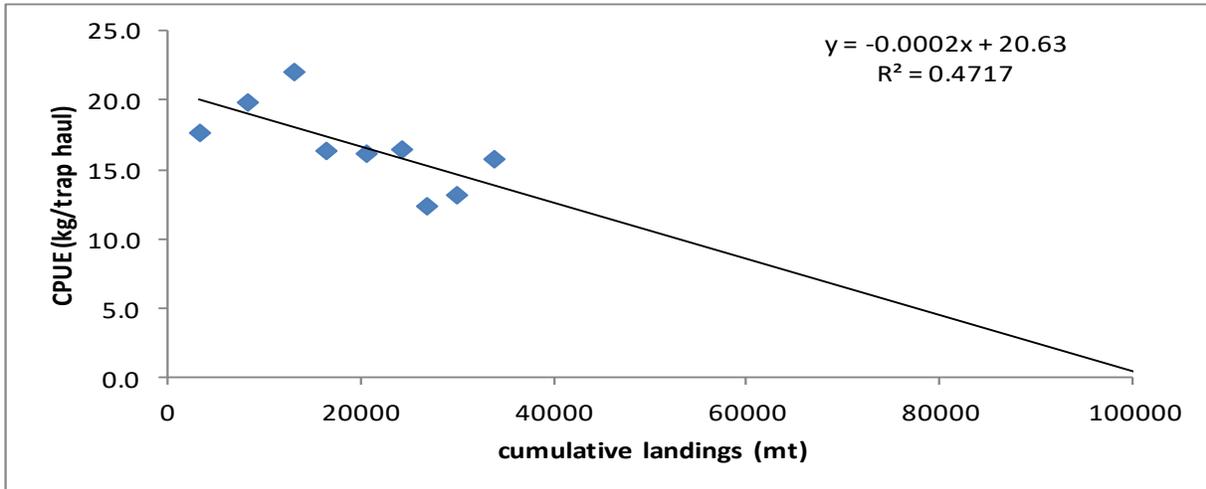


Figure 5. The results of a Leslie Depletion Model applied to 1987/1988 pink lobster catch data.

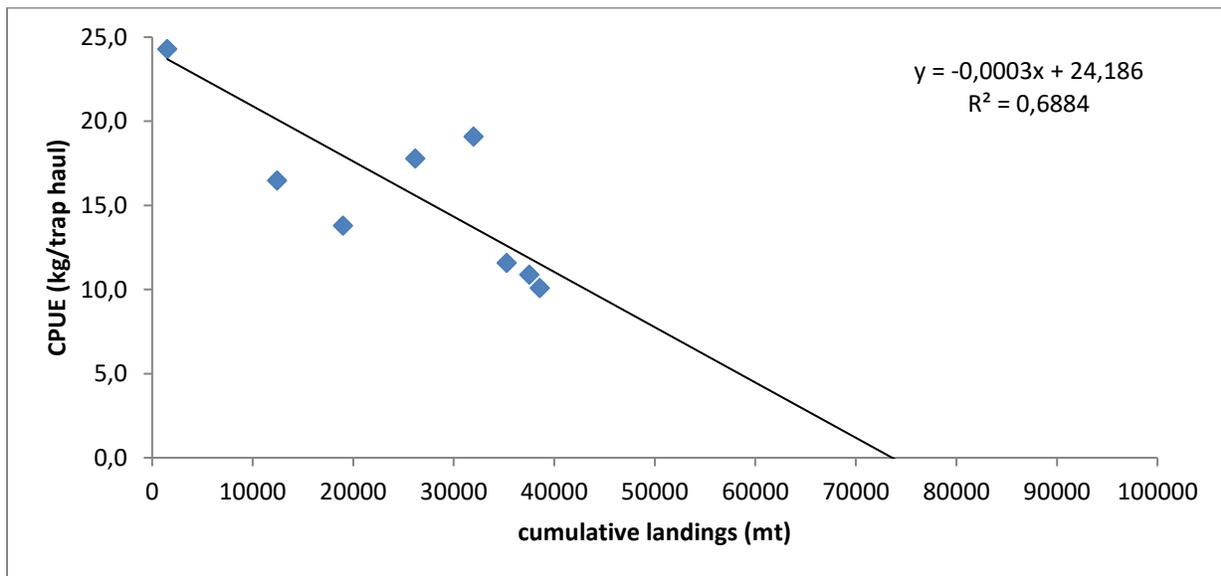


Figure 6. The results of a Leslie Depletion Model applied to 1988/1989 pink lobster catch data.

Schwarz (1999) presented monthly catch data for the fishing season 1995-1996 and 1998/1999 that were also analyzed in this study with a Leslie Depletion Model (Figure 7 and 8). The results of these analyses indicated minimum population abundances at the start of the 1995/1996 and 1998/1999 seasons of 58 and 21 mt, respectively.

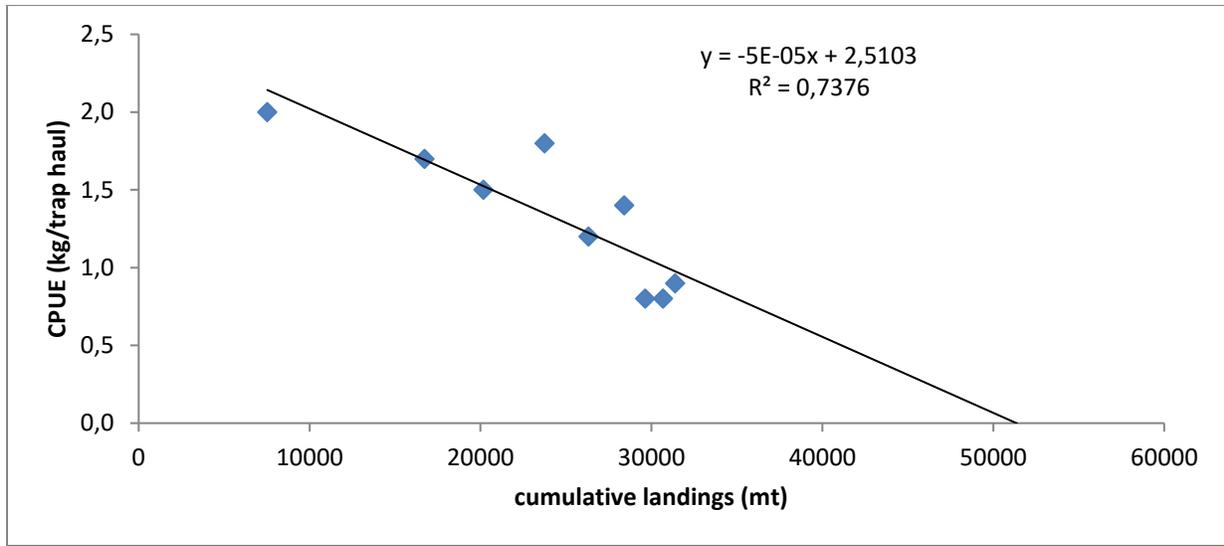


Figure 7. The results of a Leslie Depletion Model applied to 1995/1996 pink lobster catch data.

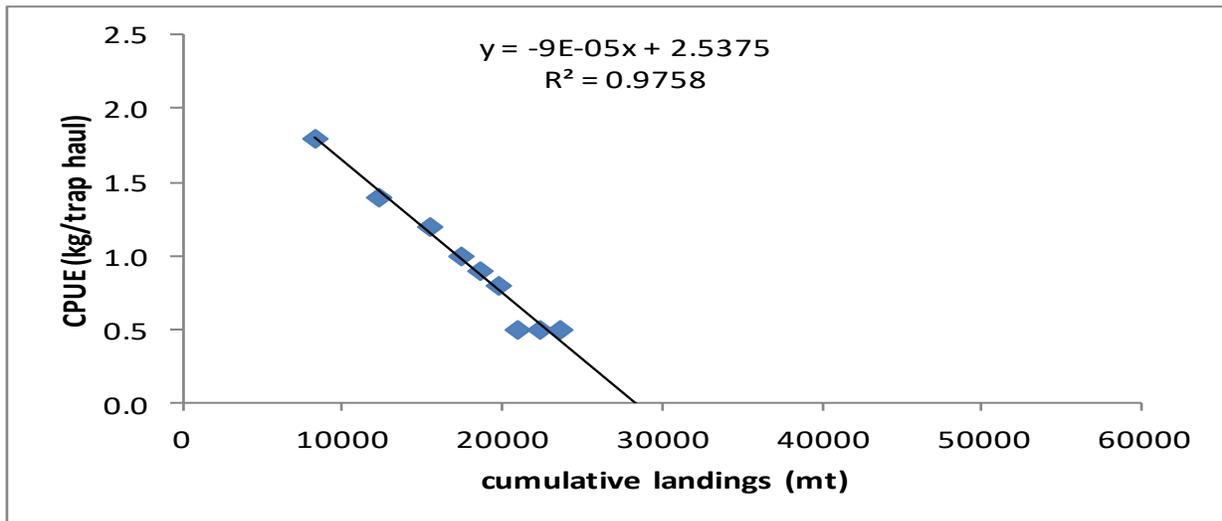


Figure 8. The results of a Leslie Depletion Model applied to 1998/1999 pink lobster catch data.

The results of the depletion analyses (minimum abundance estimates) will be compared to the abundance estimates resulting for the non-equilibrium, surplus production models that will be presented in the next chapter of this report. However, it is interesting to note that these data reinforce the notion of a limited abundance of pink lobsters in Cape Verdean water, in that in a given season catch rates decline by a factor of 2 to 4.

## RESULTS OF THE SURPLUS PRODUCTION STOCK ASSESSMENT MODELS USED TO ESTIMATE THE TRAJECTORY OF STOCK BIOMASS AND FISHING MORTALITY

### Background on Surplus Production Models

Surplus production models utilize data on catch (yield), stock abundance, and fishing effort or mortality to estimate the Maximum Sustainable Yield (MSY) at particular levels of stock abundance ( $B_{MSY}$ ) and fishing effort or mortality ( $F_{MSY}$ ). The models are conceptually simple, may be based on assumed equilibrium or non-equilibrium conditions for the stock. The models provide both target and threshold/limit reference points, overfishing reference points and inputs to bio-economic models. The models are using catch data and CPUE to investigate the stock dynamics of the fishable biomass. These models do not estimate the biomass of the resource not available to the fishery, that is both animals too small and too large to be captured by the fishing gear used in the fishery.

The Schaefer equilibrium surplus production model is represented by a quadratic, parabolic function, where yield or catch is related to the effort required to produce that yield. The surplus production model is derived from the density dependent population growth model by replacing population number ( $N$ ) with biomass ( $B$ ):

$$\frac{dB}{dt} = (\alpha - \beta B)B - FB,$$

where  $\alpha$  is the difference in the initial birth and death rates

$\beta$  is the difference in the density dependent birth and death rates

$F$  is fishing mortality

At equilibrium  $\frac{dB}{dt} = 0$ , and substituting fishing effort ( $f$ ) for  $F$  assuming catchability is constant (based on  $F = fq$ ) results in the generalized Schaefer Model (1954):

$$Y = (a - bf)f = af - bf^2,$$

where  $a$  is the ratio of  $\alpha/\beta$

$b$  is inverse of  $\beta$  or  $1/\beta$

This model has the parabolic or dome shaped form that relates yield ( $Y$ ) to fishing effort ( $f$ ). The level of effort required to achieve Maximum Sustainable Yield ( $MSY$ ) is determined by taking the derivative of the function and setting it equal to zero, and solving for  $f$ .

$$f_{MSY} = \frac{a}{2b}$$

MSY is then determined by substituting  $f_{MSY}$  back into the original equation:

$$Y_{MSY} = \frac{2a^2b}{4b^2} - \frac{a^2b}{4b^2} = \frac{a^2b}{4b^2} = \frac{a^2}{4b}$$

Note that the  $MSY$  occurs at the point of maximum growth (one-half carrying capacity).

The parameters  $a$  and  $b$  of the Schaefer model are initially estimated by linearizing the function:

$$Y/f = a - bf,$$

and using linear regression on CPUE  $\left(\frac{Y}{f}\right)$  versus effort ( $f$ ). Non-linear, best-fit estimation of the parameters is accomplished using Solver in *Microsoft Excel*, with parameter starting values from the linearized estimation.

An alternative model for fitting the relationship between catch and effort was introduced by Fox in 1970 which assumes that a stock would respond to intense fishing by maximizing productivity thus the yield would never reach zero. This model also assumes that CPUE would decline as effort increases and provides an estimate of the  $MSY$  usually close to the Schaefer model. The Fox model has the form:

$$Y = fe^{(c-df)}.$$

This model is linearized to:

$$\ln\left(\frac{Y}{f}\right) = c - df.$$

$MSY$  for the Fox model is estimated by again taking the derivative of the function, setting it equal to zero to solve for  $f$  at  $MSY$ , and finally, substituting that back into the original equation:

$$f_{MSY} = 1/d$$

$$Y_{MSY} = \left(\frac{1}{d}\right)e^{(c-1)}.$$

These models were fit to the annual catch and standardized total effort data using non-linear least squares regression. These models have a parabolic or dome shaped form that relates yield ( $Y$ ) to fishing effort ( $f$ ), and  $MSY$  was estimated at the point of zero slope in the function. The limitation of the equilibrium model is that it overestimates  $MSY$  and  $f_{MSY}$  for several reasons (Hilborn and Walters, 1992).

The Graham-Schaefer model in the form of a differential equation also can be used to describe the dynamic behavior of stock biomass in non-equilibrium:

$$dB/dt = rB\left(1 - \frac{B}{K}\right) - C$$

where  $B$  is stock biomass,

$C$  is catch,

$r$  is the intrinsic rate of stock growth, and

$K$  is the unfished stock size at carrying capacity.

The catch ( $C$ ) is assumed to be proportional to stock size:

$$C = FB = qfB$$

where  $C$  is catch,  
 $F$  is fishing mortality,  
 $B$  is biomass,  
 $q$  is catchability coefficient, and  
 $f$  is fishing effort.

Rearranging this equation:

$$CPUE = C/f = qB.$$

The catch per unit effort ( $C/f$  or CPUE) is directly proportional to stock abundance, through  $q$ , the catchability coefficient. This equation describes an “observation model” that may result from a fishery or survey CPUE, and it assumes that CPUE declines linearly with increasing effort.

In the discrete-time form the previous differential equation describing the stock biomass time series can be rewritten (Walters and Hilborn 1976):

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K}\right) - C_t$$

where  $B_{t+1}$  is the stock biomass in year  $t+1$ ,  
 $B_t$  is the stock biomass in year  $t$ ,  
 $C_t$  is the catch in year  $t$ ,  
 $K$  is the unfished stock biomass at carrying capacity, and  
 $r$  is the intrinsic rate of stock growth.

The Graham-Schaefer model is symmetrical, and therefore surplus production is maximized at  $\frac{1}{2} K$ . The term  $\left(1 - \frac{B_t}{K}\right)$  provides density dependent feedback into the model, and thus modulates stock growth at high stock biomass. As  $B_t$  approaches  $K$  (high biomass), the term approaches 0, and stock growth is zero. As  $B_t$  approaches 0 (low biomass), the term approaches 1, and the rate of stock growth is maximized at the intrinsic growth rate,  $r$ . At any biomass less than  $K$ , the stock is growing. A catch that matches the potential stock growth or the surplus production will leave the stock at the same biomass level in year  $t+1$  as it was in year  $t$ . Catch rates in excess of stock biomass surplus production result in stock decline. Conversely, catch rates less than stock biomass surplus production result in stock expansion.

An alternative surplus production model is the Fox formulation, which again relates catch to effort or CPUE to effort in the equilibrium form, or uses catch and an index of abundance (CPUE) in the discrete time form to generate a trajectory of stock biomass. The Fox model in the discrete time form is:

$$B_{t+1} = B_t + rB_t \ln(K / B_t) - C_t$$

The Fox model is dome shaped, but maximizes surplus production at less than ½ of K, carrying capacity, whereas the Schaefer model is symmetric and maximizes surplus production at exactly ½ of K.

These models were fit to the landings or catch data and the observed CPUE index, where the sum of the squared differences between the observed and predicted CPUE indices was minimized using a least squares method, while adjusting values of  $r$ ,  $K$  and  $B_0$  using Excel's SOLVER function. There are alternative methods for fitting the model that allow for the incorporation of uncertainty into the estimated parameters that include maximum likelihood and Bayesian methods. The reference points  $MSY$ ,  $B_{MSY}$  and  $F_{MSY}$  were all derived from the final estimates of  $r$  and  $K$ , and because of the different forms of the Schaefer and Fox models, the estimation of these reference point required different equations:

Reference Point	Schaefer Model	Fox Model
$B_{MSY}$	$=K/2$	$=0.368*K$
$MSY$	$=(r*K)/4$	$=r*B_{MSY}*ln(K/B_{MSY})$
$F_{MSY}$	$=r/2$	$=MSY/B_{MSY}$

Some of the reference points that result for surplus production models include:

- $MSY$  is the maximum sustainable yield from the stock under the average productivity conditions during the time period covered by the data,
- $f_{MSY}$  or  $F_{MSY}$  is the fishing effort or level of exploitation required to produce  $MSY$ ,  $f_{MSY}$  or  $F_{MSY}$  is considered a limit or threshold reference point, and fishing at levels greater than  $f_{MSY}$  or  $F_{MSY}$  result in generalized overfishing that is likely to reduce the stock size. The target level of fishing mortality is usually 80-90% of  $F_{MSY}$ .
- $B_{MSY}$  is the biomass level that allows for the production of  $MSY$ .  $B_{MSY}$  is considered a limit reference point, and biomass levels less than  $B_{MSY}$  refer to depressed stocks that have lower surplus production than stocks at  $B_{MSY}$ . Because stock biomass is expected to fluctuate naturally, fishery management plans generally set a threshold or limit biomass level below which a stock is considered overfished, often ½  $B_{MSY}$ . Higher thresholds are more precautionary and are likely to require less corrective action if they are exceeded.

Harvest control rules are pre-agreed upon protocols that control fishing mortality with respect to stock status and the limit/threshold reference points. They also allow for the illustration of the trajectory or the past, present or future status of the resource and the intensity of fishing relative to pre-established reference points. The control rules may incorporate minimum

biomass and maximum fishing mortality thresholds, as well as targets for these parameters, and rebuilding horizons for overfished stocks that include biomass and fishing mortality schedules. Control rules may also specify harvest strategies to achieve maximum sustainable yield (MSY) from the stock under prevailing ecological and environmental conditions. Optimum yield (OY) incorporates economic and social considerations as well as stock dynamics. Optimum yield from a fishery stock will be sustainably achieved when existing biomass exceeds  $B_{MSY}$  ( $B/B_{MSY} \geq 1$ ) and when fishing mortality is less than  $F_{MSY}$  ( $F/F_{MSY} \leq 1$ ). Maximum economic yield (MEY) is the catch that maximizes the difference between the revenue from the catch and the cost of making the catch. In artisanal fisheries where costs other than labor are minimal and there are few alternative employment opportunities, maximum economic yield is approximately equal to maximum sustainable yield.

## Results

The results of the Schaefer equilibrium surplus production model using the linearized form of CPUE versus effort indicates a significant decline in CPUE as a function of increasing effort (Figure 9), and that is a requirement for a surplus production model. The results of the non-linear analysis of catch versus effort for the Schaefer equilibrium surplus production model suggest that MSY for pink lobster is about 33.2 mt and that can be achieved at about 68,930 trap hauls of effort (Figure 10). The results of the Fox equilibrium surplus production model using the linearized form of  $\ln(\text{CPUE})$  versus effort indicates a significant decline in  $\ln(\text{CPUE})$  as a function of increasing effort (Figure 11). The results of the non-linear analysis of catch versus effort for the Fox equilibrium surplus production model suggest that MSY for pink lobster is about 35.3 mt and that can be achieved at about 29,422 trap-hauls of effort (Figure 12).

The results of the Schaefer and Fox non-equilibrium, surplus production or biomass dynamic models using fishery CPUE indices indicate that *MSY* is approximately 38 and 45 mt, respectively. The results of the Schaefer model fit with the individual indices are shown in Figure 13, and the trajectory of harvest control rule suggests that in 1988 the stock was not overfished ( $B/B_{MSY} > 0.5$ ) and that overfishing ( $F/F_{MSY} < 1$ ) was not occurring. However that situation changed rapidly in the early 1990s, and the stock was both overfished and overfishing was occurring. By 2014 the stock biomass is estimated to be at a record low level, and the fishery is overfishing at a record high level (Figure 14). The results of the Fox model fit with the individual indices are shown in Figure 15, and the trajectory of harvest control rule suggests that in 1988 the stock was not overfished ( $B/B_{MSY} > 0.5$ ) but that overfishing ( $F/F_{MSY} > 1$ ) was occurring. With continued overfishing, the stock became overfished by the early 1990s, and by 2014 the stock biomass is estimated to be at a record low level, and the fishery is overfishing at a record high level (Figure 16).

The results of the equilibrium and non-equilibrium surplus production models are summarized in terms of estimated parameters in Table 4. In summary the various forms of the surplus production models implemented in this study estimate that MSY for pink lobster is between 33 and 45 mt. The equilibrium model estimate a wide range of values as to the level of effort required to achieve MSY, ranging from 29 to 69 thousand trap hauls. The non-equilibrium models agree that the pink lobster stock is severely overfished, that the current 2014 stock level is less than 20 mt, and that  $B_{MSY}$  is between 202 and 352 mt. Before the resource can ever produce MSY, the stock must be rebuilt.

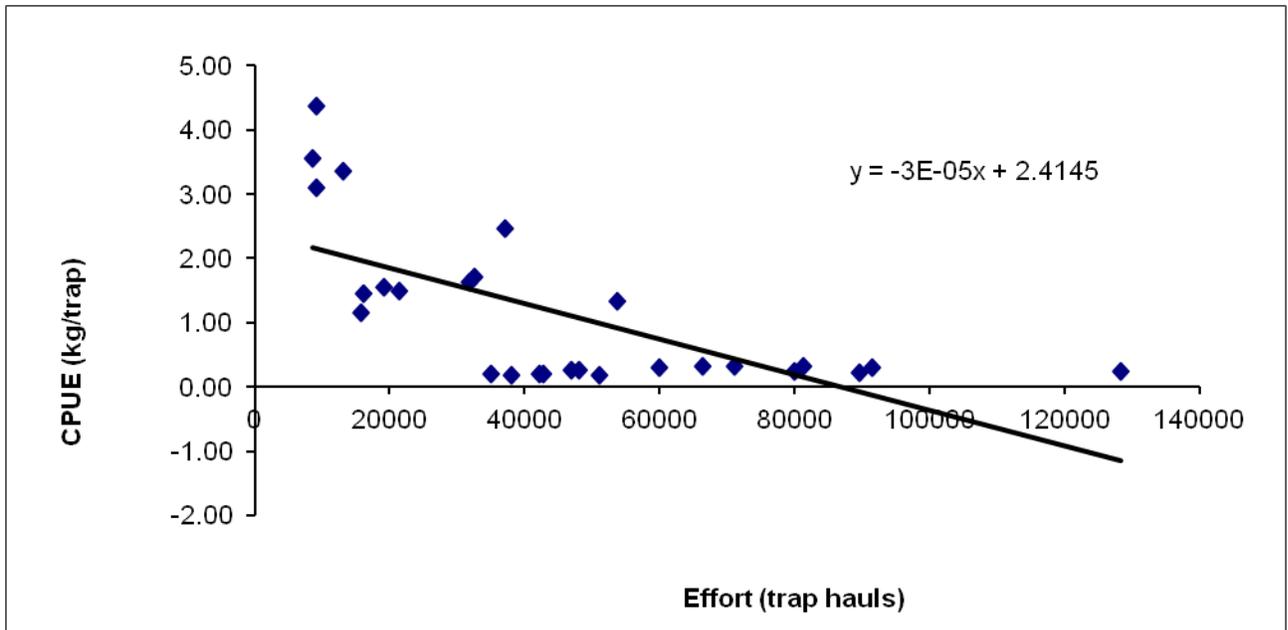


Figure 9. Schaefer surplus production model plot of CPUE vs. Effort

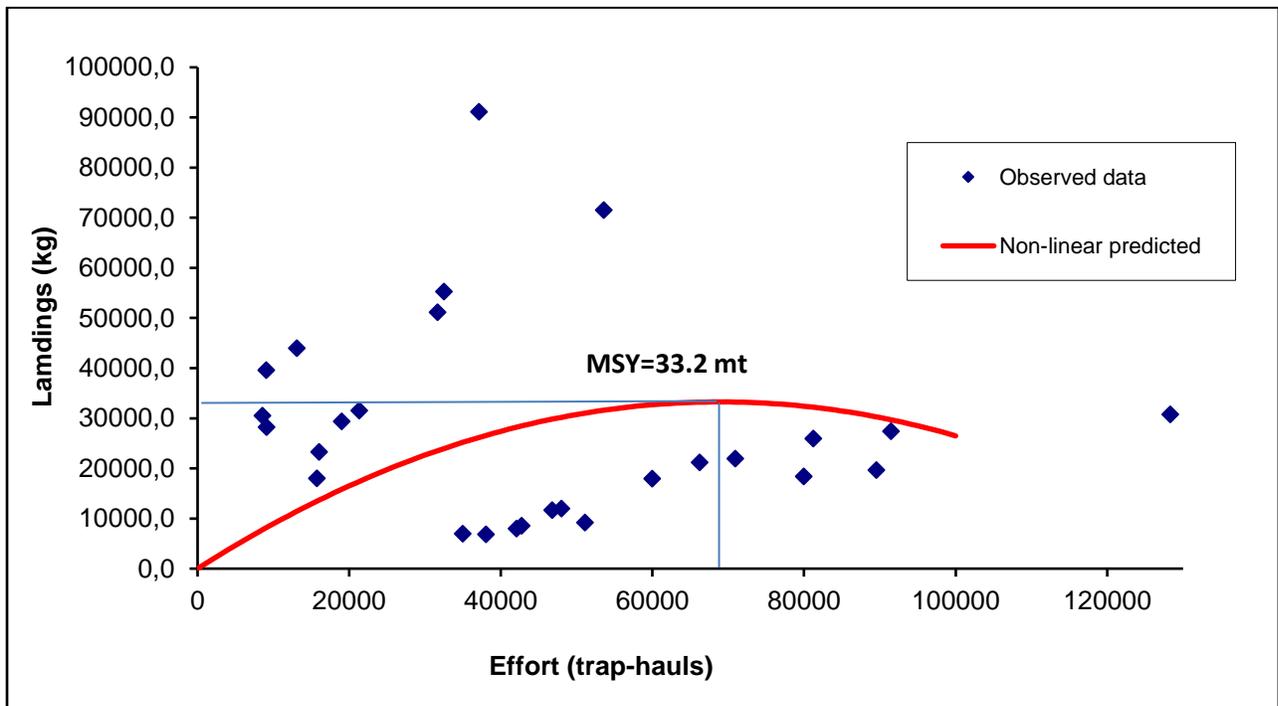


Figure 10. Results of equilibrium Schaefer surplus production model

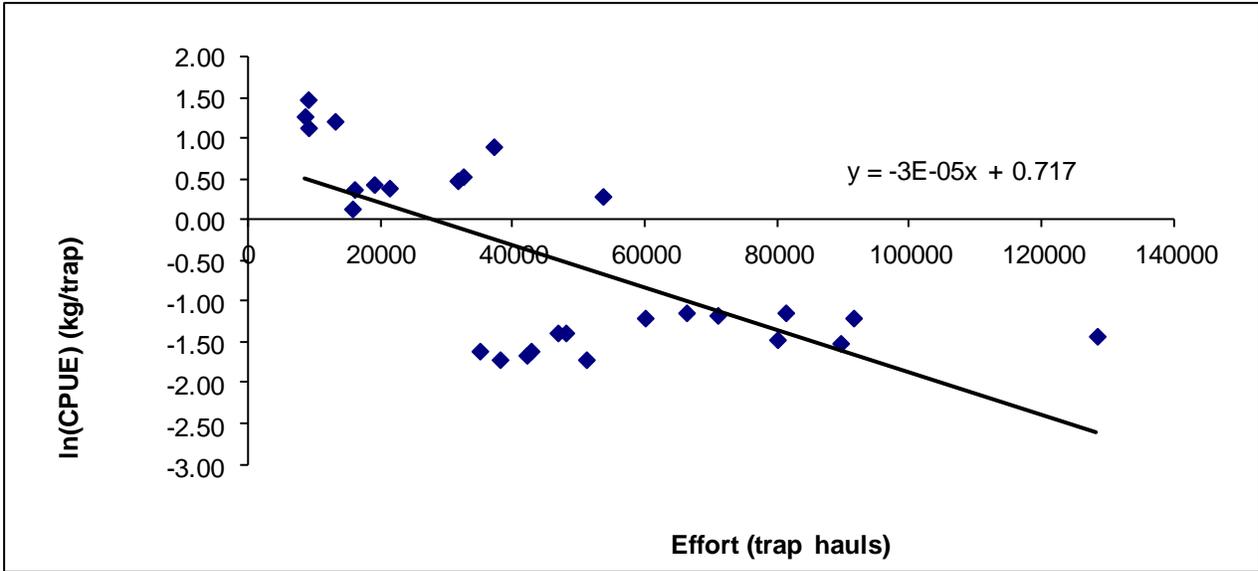


Figure 11. Fox surplus production model plot of Ln (CPUE) vs. Effort

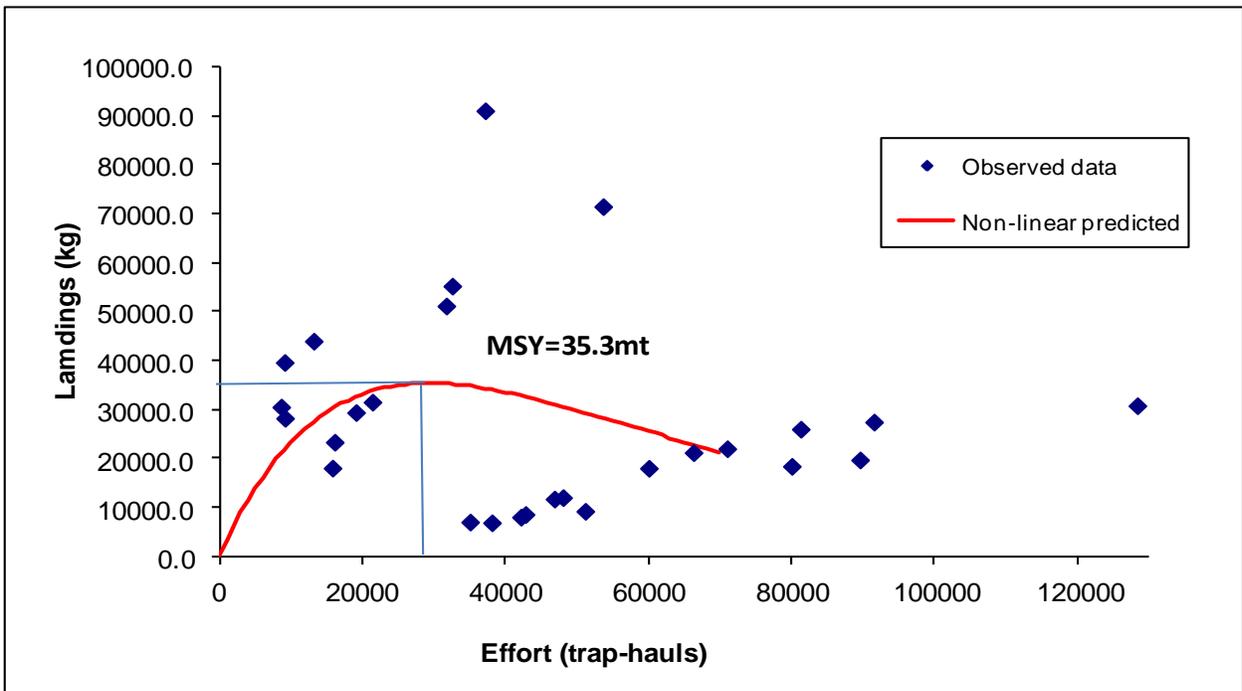


Figure 12. Results of equilibrium Fox surplus production model

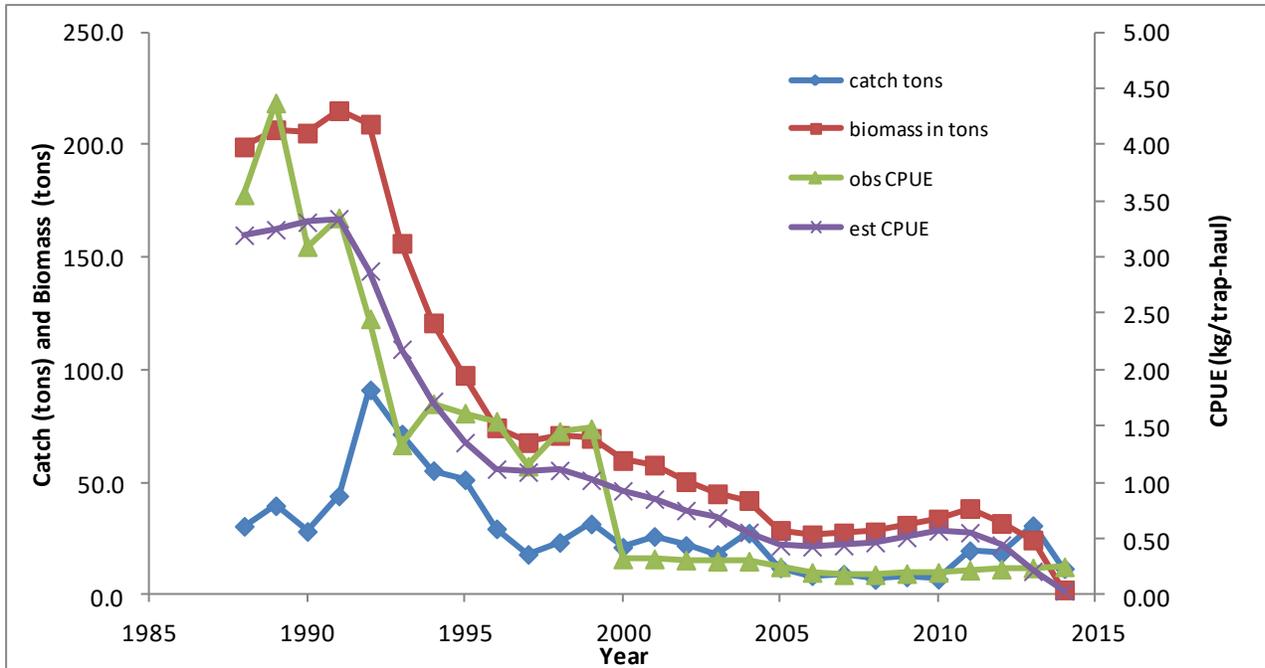


Figure 13. Results of Schaefer non-equilibrium, biomass dynamic model analysis for pink lobster

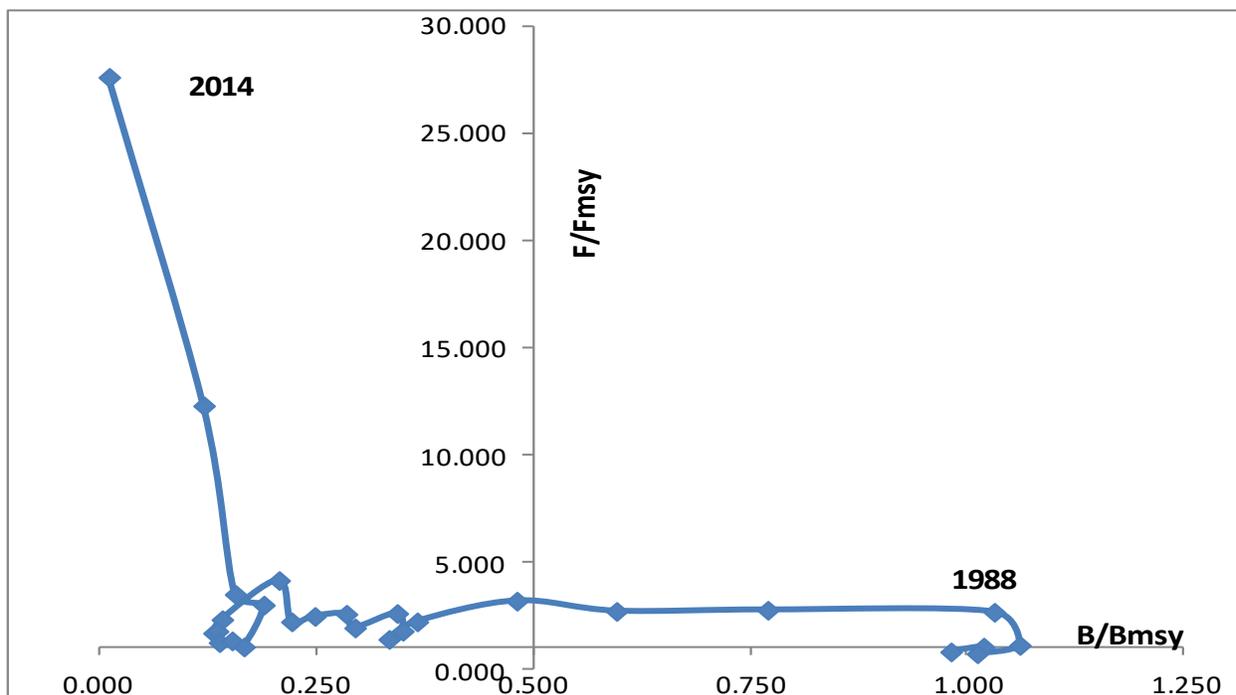


Figure 14. Results of Schaefer non-equilibrium, biomass dynamic model analysis for pink lobster in the form of a harvest control rule.

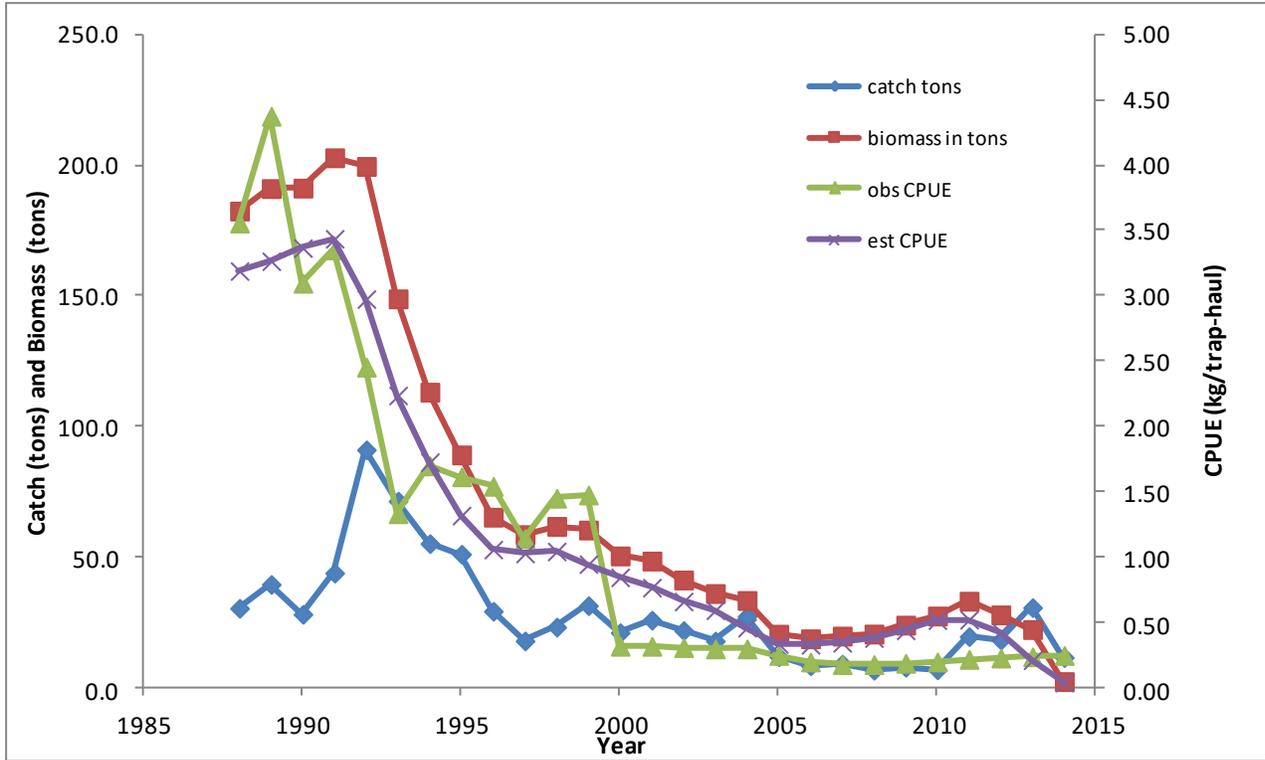


Figure 15. Results of Fox non-equilibrium, biomass dynamic model analysis for pink lobster

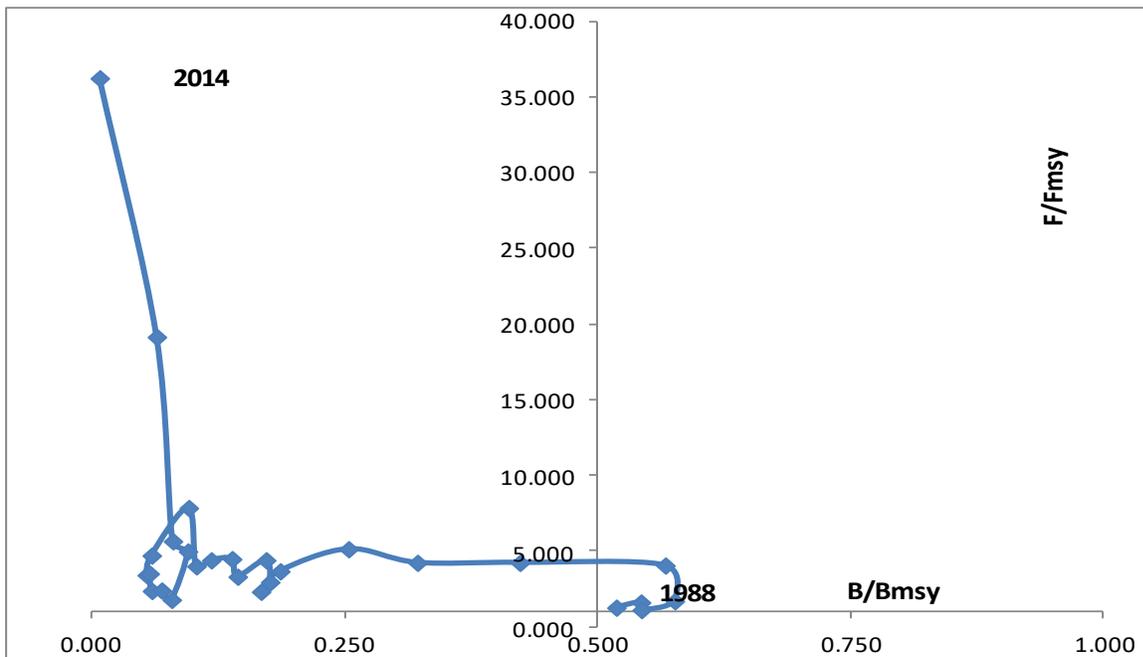


Figure 16. Results of Fox non-equilibrium, biomass dynamic model analysis for pink lobster in the form of a harvest control rule.

## SUMMARY AND MANAGEMENT ADVICE

The evaluation of the time series of landings indicate that in the mid-1980s landings were about 20-50 mt, then increased dramatically and peaked at 80-100+ mt in the early 1990s, the decreased steadily to about 10 mt into the 2000s, and finally in the period 2011/2012-2013/2014 landings increased to about 20 mt. The complementary analysis of the CPUE time series indicates that the annual average CPUE (kg/trap haul) was the highest (about 4 kg/trap-haul) at the beginning of the time series (late 1980s), and declined to between 1 to 2 kg/trap-haul in the late 1990s. CPUE reported in the INDP data for the post-2000 period is about 0.2 kg/trap. Assuming CPUE is a reliable index of relative abundance, it appears that the stock has declined to about 5% of the abundance that it had in the late 1980s.

The results of the depletion analyses indicate minimum fishable biomass estimates of 100, 73, 51 and 28 mt for 87/88, 89/89, 95/96, and 98/99 fishing seasons. These estimates compare reasonably well to the results of the Fox non-equilibrium surplus production model that estimate fishable biomass levels of 190, 182, 89, and 62 mt for the same seasons, respectively. The depletion analyses underestimate the total biomass at the start of the season, as expected because the catch data used in the analyses may not have represented the total catch from the fishery. The results of the depletion analysis also indicate a strong seasonal decline in CPUE by a factor of 2-4 that suggests both a relatively low fishable biomass compared to the catch, and a reasonable annual recruitment of new lobsters into the fishery.

The evaluation of the carapace length distributions indicated no clear change in the size frequency distributions of the lobsters captured in the fishery over the 20+ years of available data. The data also indicate that a substantial portion of the catch is less than the current minimum legal size, a carapace length of 11 cm. This suggests that it is important for fishermen to respect and management to enforce the current minimum size, as these lobsters represent the future spawning biomass and recruits to the fishery in the future. As noted previously, most of the sub-legal lobsters are immature, and they should be given the opportunity to spawn once prior to being landed. This fishery appears to be a classic "recruitment-based fishery", with a very small standing stock above the minimum size. Because the catch consists of many lobsters that were undersize in the previous year and grow into the legal size during the fishing season, the catch can actually exceed the standing stock biomass of legal lobsters at any point in time. This dependence on new recruits creates instability in the fishery because reproductive success varies from year to year. A fishery with a large standing stock can withstand a few years of poor reproduction while still providing a catch and a chance for good reproduction when environmental conditions are favorable. A "recruitment-based fishery" that suffers a few years of poor reproduction will have little to catch and a small spawning stock biomass to take

advantage of favorable environmental conditions when they occur. The suite of length frequency distributions also indicate that there is no loss of larger lobsters in the catch in recent years that would be indicative of either an increase in fishing mortality or a change in the catchability (catch efficiency / selectivity) of the traps. However because there are no carapace frequency data available for the 1980s, and in fact the first available data coincides with the dramatic increase in landings in the early 1990s, the resource may have already experienced a substantial change in the size frequency distribution prior to the beginning of sampling.

The various forms of the surplus production models implemented in this study estimate that MSY for pink lobster is between 33 and 45 mt. The equilibrium model estimate a wide range of values as to the level of effort required to achieve MSY, ranging from 29 to 69 thousand trap hauls. The non-equilibrium models agree that the pink lobster stock is severely overfished, that the current 2014 stock level is less than 20 mt, and that  $B_{MSY}$  is between 202 and 352 mt. Before the resource can ever produce MSY, the stock must be rebuilt.

As noted in the beginning of this report there is a complementary bio-economic analysis being conducted by Richard Allen. One goal of the analysis is to provide advice on levels of catch and effort that will maximize the profits for the fishery, and the economic benefits for the harvest of the resource to the people of Cape Verde. It should not be assumed that the level of catch or effort estimated in this study to produce MSY, will maximize profits or economic benefit. However, given the current state of the resource, it is clear that the stock must be rebuilt, and to achieve this goal, the fishery landings should be substantially reduced, or the fishery should be closed for some period to allow for stock re-building. The non-equilibrium models developed in this analysis suggest that it will take more than 20 years to rebuild the pink lobster stock to  $B_{MSY}$  levels if the fishery were closed. Clearly this is a long time, but it reflects the severe depressed state of the resource, and the relatively slow population growth associated with most deep water species. It is recommended that the status of the resource be evaluated in subsequent years and this can be done with either a very limited experimental fishery, or if there were a complete closure, with a limited trap survey to monitor stock rebuilding.

It is possible that there is a stock of larger, reproductive lobsters that are not accounted for in this study, as they are too large to be susceptible to capture. If those lobsters exist, this could reduce the stock rebuilding time. If they do exist, these animals could be the reproductive stock that has sustained the fishery for the last 15 years, and certainly, if they exist, they should be protected and not be captured, as they are vital to the future of the stock re-building effort.

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Table 1. Reported landings of pink lobster in Cape Verde expressed in metric tons (mt)

Season	Year	Carvalho,92	Diaz,92	Schwarz,99	Eide,99	Tariche,14	Medina,03	INDP,14	AVERAGE
80-81	1981	20.0					20.0		20.0
81-82	1982	24.0	26.3		11.0		25.0		21.6
82-83	1983	39.0	24.3		27.0		38.0		32.1
83-84	1984	30.0	24.0		21.0		29.0		26.0
84-85	1985	60.0	55.3		43.0		60.0		54.6
85-86	1986	36.0	24.1		27.0	36.0	37.0		32.0
86-87	1987	51.0	37.3		34.0	51.0	50.0		44.7
87-88	1988	25.0	33.2		33.4	25.0	36.0		30.5
88-89	1989	38.0	41.6		38.6	30.0	50.0		39.6
89-90	1990	30.0			27.9	30.0	25.0		28.2
90-91	1991				31.0	70.0	31.0		44.0
91-92	1992				84.4	106.0	83.0		91.1
92-93	1993				76.6	77.0	61.0		71.5
93-94	1994				48.8	68.0	49.0		55.3
94-95	1995				46.6	60.0	47.0		51.2
95-96	1996			31.4	28.2	29.0	29.0		29.4
96-97	1997			14.1		25.0	15.0		18.0
97-98	1998			21.0		28.0	21.0		23.3
98-99	1999			23.6		35.0	36.0		31.5
99-00	2000					30.0		12.4	21.2
00-01	2001					26.0			26.0
01-02	2002					22.0			22.0
02-03	2003					18.0			18.0
03-04	2004					28.0		26.9	27.5
04-05	2005					12.0			12.0
05-06	2006					11.0		6.1	8.6
06-07	2007					8.0		10.4	9.2
07-08	2008					8.0		5.7	6.9
08-09	2009					8.0			8.0
09-10	2010					7.0			7.0
10-11	2011							19.7	19.7
11-12	2012							18.4	18.4
12-13	2013							30.8	30.8
13-14	2014							11.7	11.7

Table 2. Reported values of Catch per unit effort (CPUE) expressed as kg/trap-haul. The average values in italics were interpolated between known values. The extremely high values of CPUE reported by Dias were excluded from the estimation of the average time series, as they are believed to not be representative of the entire fishery.

Season	Year	Dias,92	Schwarz,99	Eide,99	Medina,03	INDP,14	AVERAGE
80-81	1981						
81-82	1982						
82-83	1983						
83-84	1984						
84-85	1985						
85-86	1986						
86-87	1987						
87-88	1988	16.7		3.50	3.62		3.56
88-89	1989	16.6		3.75	5.00		4.37
89-90	1990			3.42	2.78		3.10
90-91	1991			3.57	3.13		3.35
91-92	1992			2.40	2.52		2.46
92-93	1993			1.76	0.91		1.33
93-94	1994			1.71	1.69		1.70
94-95	1995			1.61	1.62		1.62
95-96	1996		1.46	1.56	1.61		1.54
96-97	1997		1.04		1.25		1.15
97-98	1998		1.29		1.62		1.45
98-99	1999		1.06		1.89		1.48
99-00	2000					0.32	0.32
00-01	2001						<i>0.32</i>
01-02	2002						<i>0.31</i>
02-03	2003						<i>0.30</i>
03-04	2004					0.30	0.30
04-05	2005						<i>0.25</i>
05-06	2006					0.20	0.20
06-07	2007					0.18	0.18
07-08	2008					0.18	0.18
08-09	2009						<i>0.19</i>
09-10	2010						<i>0.20</i>
10-11	2011						<i>0.22</i>
11-12	2012						<i>0.23</i>
12-13	2013					0.24	0.24
13-14	2014					0.25	0.25

**Table 3.** Relative proportions of the observed carapace length size frequency distributions of pink lobsters captured in the fishery. Note the substantial differences in the sample sizes on a seasonal basis.

CL (mm)	1991-1992	1995-1996	1996-1997	1998-1999	2000-2001	2001-2002	2002-2003	2003-2004	2012-2013	2013-2014
80	0.04	0.02	0.00	0.01	0.03	0.00	0.00	0.06	0.00	0.00
90	0.06	0.05	0.04	0.06	0.04	0.05	0.02	0.03	0.01	0.01
100	0.11	0.13	0.14	0.13	0.07	0.24	0.08	0.14	0.08	0.06
110	0.15	0.19	0.19	0.23	0.19	0.15	0.15	0.19	0.21	0.19
120	0.18	0.20	0.24	0.23	0.18	0.11	0.24	0.19	0.20	0.20
130	0.17	0.15	0.17	0.19	0.17	0.13	0.20	0.17	0.21	0.18
140	0.12	0.11	0.11	0.08	0.08	0.13	0.18	0.09	0.17	0.20
150	0.08	0.05	0.06	0.02	0.11	0.06	0.08	0.05	0.08	0.11
160	0.04	0.02	0.02	0.01	0.06	0.03	0.03	0.05	0.02	0.05
170	0.02	0.01	0.01	0.01	0.02	0.04	0.02	0.01	0.01	0.01
180	0.01	0.01	0.00	0.01	0.03	0.03	0.01	0.01	0.00	0.00
190	0.01	0.02	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00
200	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
more	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
sample size	9457	975	408	815	274	238	1059	1731	2758	454

**Table 4.** Summary of the results of the surplus production assessment models

Equilibrium surplus production models

	a	b	MSY (mt)	f <sub>MSY</sub> (trap hauls)
Schaefer	0.965	0.0000007	33.2	68,930

	c	d	MSY (mt)	f <sub>MSY</sub> (trap hauls)
Fox	1.18	3.399E-05	35.3	29,422

Non-equilibrium surplus production models

	r	K (mt)	MSY (mt)	B <sub>MSY</sub> (mt)	F <sub>MSY</sub>
Schaefer	0.37	406	38.2	202	0.19
Fox	0.13	954	45.5	352	0.13

## APPENDIX: SUMMARIES OF MEETINGS WITH INDP STAFF AND FISHERY REPRESENTATIVES

### Notes on meeting at INDP with Atlantic Tuna on 16 September 2014

Participants: Rui Manuel Vera-Cruz, Director of Atlantic Tuna, [rui.veracruz@atlantictuna.com](mailto:rui.veracruz@atlantictuna.com), and Capt. Armando Filipe Cardoso, Fishing Master, Movel: 9916440, Fix: 2324571

Captain Cardoso has been in the pink lobster fishery since 1979. He owned and operated the FV Pixita, until recently, and for the last two years he has run the FV Praia Grande for Atlantic Tuna.

Vessels: There are four vessels permitted in the fishery, and the season is now 7 months (Dec-Jun). At the inception of the fishery, the season was 12 months. Then it was closed from August to September, re-opening in October. Later it was closed from July to October, and open from November to June. The closed season is related to the breeding season (high peak in the summer). The size of the vessels has increased, now most are more than 20 meters. While four vessels are permitted, not all four fish every year, and even if four vessels start the year, not all four vessels fish the entire season.

Landings: Captain Cardoso agreed with the trend in landings from 1980 to present, as shown in my figure (attached) of historical landings. He specifically noted that in the period 2000 to 2009 he alone landed about 15 mt annually, note that this suggests the Tariche report of landings of about 30 tons in 2000 decreasing to 10 tons in 2010 may be in error? Titino suggested that the peak in landings in 1992 may be related to an INDP survey of the resource that lasted an entire year? Captain Cardoso noted that he believes that there is a two year cycle or period of recovery for an area once it has been fished down.

Traps: Prior to 1996, the fishery used larger traps, fished as singles. These larger traps up to 1.9 meters in length, and therefore had greater volume and larger funnels, so it was suggested that they captured larger lobsters. In 1996 to 1997 there was a transition in the fleet to fishing smaller traps, on a main line, with 50 traps on gangions separated by a distance of 20 meters. These smaller traps are alleged to exclude larger lobsters. Captain Cardoso indicated he believes that the larger lobsters are out there, just not captured due to the small funnel, and he cited an example that last month he captured a 3.5 kg lobster outside the trap hanging on to the webbing. I will check the size distributions of lobsters landed from past publications to investigate if there is a noted difference in the proportion of large lobsters in the catch before and after 1997/1997. Mr. Vera-Cruz indicated that the export market demands 1.5 to 2.0 kg lobsters. If too

big then the price per kg is less, and if too small, then again the price per kg is less. In the early days of the fishery there were no limits on trap number, but today, some boats are limited to 350 traps, others 300 traps.

CPUE: Captain Cardoso and Mr. Vera-Cruz agreed with the declining CPUE trend, as illustrated in my figure. Captain Cardoso reported that in the early days of the fishery (1980s), the catches of lobsters per trap haul were as high as 90-100 lobsters per trap. However, they report that the current level of CPUE 0.2 kg per trap. My figure illustrates a steady decline from more than 5.0 kg/trap haul trap haul in 1988 to about 1.0-1.5 kg/trap in 1993, and then remained at about 1.5 kg/trap until 1999. While we have no data for the period, 2000 to 2012, captain Cardoso indicated that he estimated his average annual CPUE was 0.7 kg/trap, based on an average annual catch of 15 mt (15,000 kg), fishing 7 months a year, making 3 trips per month, with the average trip being 5-6 days, and hauling 300-400 traps per day. These data suggest a range of CPUE of 0.3-0.5 kg/trap for the period. The reported CPUE on the bio-economic sheets for the last two years was 0.2 kg/trap haul. Captain Cardoso suggested that the CPUE was kg/trap 0.5-0.8 back in the years 2000-2010; and he agrees with the current CPUE of 0.2. The current INDP survey of the lobster resource conducted in August of 2014 resulted in a CPUE of 0.2 kg/trap, From the values of loss/dead reported, it appears to me that the CPUE may be 0.3 to 0.4 kg/trap, but probably not 0.5-0.8 kg/trap.

Notes on our meeting at INDP on 17 September 2014:

Participants: Anibal Medina, Tatiana Cabral, Albertino Martins and Sandra Correia.

Data Collection and Review: We meet first with Captain Cardoso to confirm a number of questions resulting from the previous day's meeting. First, we wanted to resolve the date that the lobster industry shifted from fishing individual traps to trawls (Cacada or Lances) that include 50 traps per mainline. Initially it was indicated that the transition occurred in the 96/97 season, but data presented in Schwarz (1999) it appears that the industry was setting and hauling about 50 traps per day, through the 98/99 season. This suggests that the lobster fishing industry had not as yet shifted to the smaller traps and hauling 300 traps. Additionally, we found in the INDP daily fishing reports from 1997 and 1998 that even Captain Cardoso reported hauling about 50 traps per day. We also found INPD data for the period 2012-2014 that includes the number of days fishing and the traps fished per day on a trip by trip basis. Thus, it appears that the data void with respect to landings and effort needed to estimate CPUE is for the period 2000 to 2009. INDP staff have offered to search out this data, as it appears that there were trip records submitted by fishermen. The data that we need on a trip by trip basis is: date landed, vessel name, days fishing, traps hauled per day, lobster captured (kg), bycatch

captured (kg). We will use this data to estimate, total catch (lobsters and bycatch) and effort (days fishing and traps hauled) by year, and then estimate lobster CPUE by year. Richard Allen and I will prepare and submit a draft data spreadsheet tomorrow for the recording of this data for the period 2000-2009.

Length and weight frequency distributions: We have identified the following data:

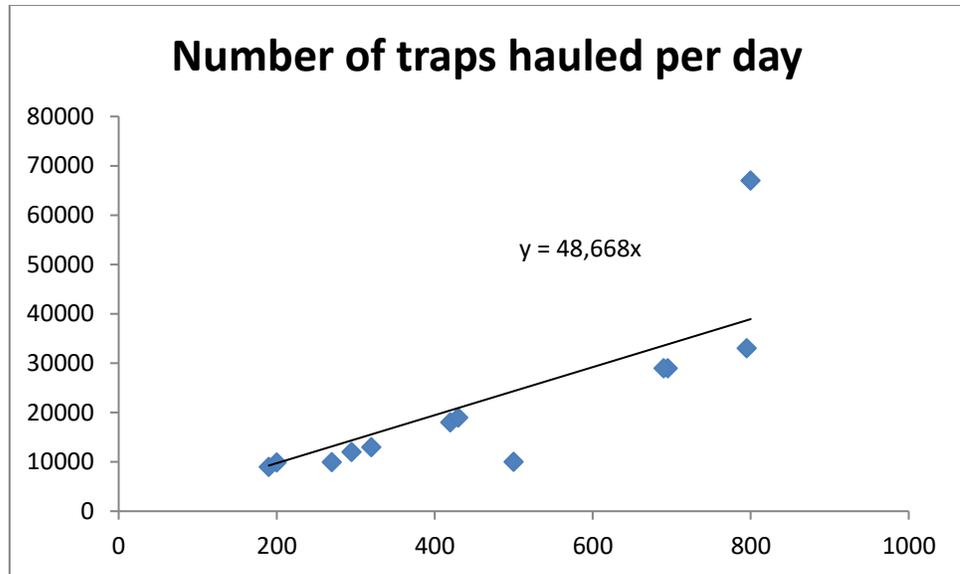
Lobster database from 1991 to 2004. About 10000 records, but one half are from the 1991-1992 INDP project. I believe that these data are of landed lobsters? (2003-2004 include biological, economical, landed, , days of fishing and traps per fishing trip)

- BD Amostragens 2012-2014; these are complete data: biological, landings, days of fishing and traps per fishing trip.
- The results of the August 2014 lobster survey. These data are only partially available now, but will be completely entered in a few days, and they are the results of sea sampling, so we will be able to identify the number and weight of undersize lobster that would not be landed?? yes

With these data I intend to investigate changes in the size and weight frequency distributions that can be attributed to fishing removals, changes in the trap selectivity (recall that the older larger traps are alleged to take larger lobster, and the newer smaller traps do not capture the larger lobsters.), and finally the abundance of undersize or pre-recruits to the fishery based on the 2014 sea sampling or survey data.

CPUE data: We have confirmed that the monthly CPUE data presented in Dias (1992) for the period 87/88 and 88/89 is good data on catch of lobsters (kg) per trap haul. These data indicate average annual catches of about 15kg/trap haul for these fishing seasons. The CPUE for the period 88/89 start at 24.3 kg/trap in Oct 88 and end at 10.1 kg/trap in June 89. I will use these data and similar monthly data available in the published report of Schwarz (1999) to obtain point estimates of total fishable biomass using a depletion methodology. The results of these analyses will provide point estimate of the minimum population biomass.

Traps fished per day analysis: I have already used the Medina (2003) data on annual effort (traps fished and days fishing) to estimate the average traps fished per day. This analysis covers the period (1988-1999). The results suggest that the average was 49 traps per day, again suggesting that these were all larger traps, fished as singles.



I will add the Schwarz data for the period (1995-1999) that compares individual boat data for each year, and includes: days fishing, trap hauled, total lobsters captured, catch per trap haul. Preliminary review of this data suggests 50 traps per day fished.

Landing or Fishing Year	Landing or Fishing Month	Landing or Fishing Day	Fishing Vessel Name	Day or Days Fishing	Traps Fished/Day	Lobster Captured (kg)	Bycatch Captured (kg)

Notes on our meeting at INDP on 18 September 2014:

Participants: Anibal Medina, Tatiana Cabral, Albertino Martins and Pericles Augusto Rosario Martins (periclesamartins@yahoo.com) , a former fisheries technologist at INDP.

Discussion of traps used in the fishery (old Cape Verdean, French, Portuguese, and new Cape Verdean):

1. Old CV traps were half round traps, about 2 meter in length, 1.5 meters wide, 0.75 meters high, with two funnels on both sides of the tops. The traps were made of steel rebar, and covered in webbing. The funnels were plastic buckets with the bottom cut out, and sewn into the webbing.

2. The new CV traps were smaller, but identical design to the larger CV traps, the length was about 1 meter, the width was 0.7 meters, and the height was 0.5 meters. There was only a single funnel in the top with the webbing, and it was a slightly smaller plastic bucket with the bottom cut out. These traps were introduced into the fishery in the late 1990s, and the transition was complete by 2000.
3. The French traps were cylindrical traps, made of wood, with webbing at the ends, and a single funnel in the top. The dimensions were 1.0 meters by 0.5 meters. The traps were ballasted with bricks, but must have rolled on the bottom.
4. The Portuguese traps were the same as the smaller, new CV traps.
5. Other inshore traps are smaller plastic, stackable, square traps, that were used in the green lobster, about 0.8 meters on a side, with an opening in the top, but no funnel.

Notes on our meeting in Sal on 19 September 2014:

Participants: Anibal Medina, Tatiana Cabral, Capt. Nelson Santos of Sal, Carlos Figueiredo of FV Luta de Pescador, and Nelson Andrade, the INDP landings reporter.

Discussion with Capt. Nelson Santos, rents his boat from the government. He fishes for lobster for about 7 months, 4 trips per month (excepting holiday, Christmas and Carnival), so about 25 trips per year. Each trip is 5 fishing days. He has license for 500 traps, and hauls 220-250 per day, so each trap has a 2 day soak, finds that he has a better catch after two days, perhaps 1.5 times greater than a 1 day soak. He suggests that we use 220-250 traps per day as his average hauling rate per day. His average catch is 250 gr. per trap, or 0.25 kg/ trap haul.

He started fishing for lobster in 1995, about 20 years ago. He has always used trawls (cacadas or lances) of traps, initially 25 per trawl, now 50 per trawl, about 20 meters apart. In the last decade his landings have averaged 7-9 mt annually. My estimate of his landings is 250 kg per trap x 250 traps per day x 125 days per year (25 trips x 5 days fishing) = about 60 kg per day, or 300 kg/trip, or 7.5 mt per fishing season.

General comments by captain Santos is that the statistics are in error, as they underestimate the total landings. He suggests that there was considerable illegal and unreported fishing in the 1970s and 1980s, especially by Portuguese boat using tangle nets on the bottom. He believes that there are still boats coming from Portugal with

1000 traps, dropping them in the ocean, but declaring 400 traps as on their license (FV Condor??). However, Capt Santos agrees with the trend as indicated in the CPUE.

Discussion with Nelson Andrade, INDP Sal landings recorder.

In response to question about landings data for lobster from Sal, he indicates that he collected that data on landings, effort, and biological data through 2009, when the processing/exporting plant in Sal closed, and the operation was shifted to Mindelo. Since 2009, only Mindelo is authorized to export to the EU, not Sal. Nelson indicates that he sent the data to Oksana at INDP. I will contact Oksana to enquire as to the process at INDP for data flow. Where did she submit the data, where are the reports? Why is no data available from the data base? Additionally where did she get the annual landings data that she has in her thesis?

Discussion with Carlos Figueiredo. FV Luta de Pescador.

He manages a 28 meter vessel. He has been fishing in Cape Verde for 20 years, 1995-2015. Best catch of lobster was in 2011. He notes no trend in catches over the last decade, both up and down. His license is for 400 traps, and he fishes about 240-300 per day. He only fishes for the first 3 months of the fishing season, when catch rates are high and prices for export are high. Will not fish for lobster next year, and the price is too low due to Mauritania is flooding the market with high catches and therefore a low price to the boat. Price has dropped for \$55 Euro per kg to \$18-27 Euro due to competition from Mauritania.

Carlos reports that his average seasonal landings in the last decade is 8-10 mt, but again his best season was 2011 when he landed 11 mt. He indicates that he has no idea as to his average CPUE? He reports weekly trip landings as follows: 2200 kg as good, 1500 kg as average, and 800 kg as poor.

My estimate of his seasonal CPUE, given the effort he reports and the seasonal landings based on 275 traps hauled per day is as follows: Something is inconsistent check, contact Carlos through Tatiana???

Good 2200 kg for 5 days, and 10 trips per season is 22 mt and 1.6 kg/trap

Average 1500 kg for 5 days, and 10 trip per season is 15 mt or 1.1 kg/trap

Poor 800 kg for 5 days and 10 trips per season is 8 mt or 0.6 kg/trip.

Carlos notes that the fishery has evolved to better gear, more traps, but less catch. This suggests to him that there are "less lobsters". He notes that there are high catches in

Oct and Nov, mostly egged females, that were scrubbed. Now, that season is closed to stop that problem. He suggests that those lobsters are not available today, as a possible explanation for the lower catches. But now in the open season those lobsters are without eggs, so they can be caught legally, so this does not make sense.

Carlos suggests that the fishery be closed to allow the stock to rebuild, especially while the prices are low due to the competing lobsters from Mauritania are abundant and flooding the market. He believes that soon the Mauritanian lobsters will be caught up, and then there will be demand to CV pink lobsters at the traditionally higher price.