Asian Fisheries Science **24** (2011):125-139

ISSN 0116-6514

Asian Fisheries Science
The Journal of the Asian Fisheries Society

Population Assessment and Evaluation of the Recovery of the Sea Cucumber *Actinopyga mauritiana* (Echinodermata: Holothuroidea) in the Commonwealth of the Northern Mariana Islands.

MICHAEL S. TRIANNI[1,2,*] and MICHAEL C. TENORIO[1]

[1]Commonwealth of the Northern Mariana Islands Division of Fish and Wildlife
P.O. Box 10007 Saipan, MP 96950
[2]National Marine Fisheries Service Pacific Islands Fisheries Science Center, Saipan

Abstract

A survey on Saipan in the Commonwealth of the Northern Mariana Islands (CNMI) was undertaken in 2006 to determine the recovery of surf redfish (*Actinopyga mauritiana)* in areas harvested in 1996 and 1997, and which were subsequently protected through a CNMI wide moratorium soon after. Surf redfish populations increased from an estimated number of 32,977 in 1997 to 220,578 in 2006, with densities increasing in all management units, from a 1997 low of $0.0 \cdot 100\ m^{-2}$ to a 2006 high of $11.8 \cdot 100\ m^{-2}$. Most significant areas of density increase were in the back-reef aspects of defined management units. Size structure indicated a fully recovered population, though Monte Carlo simulations of the discrete logistic model using varying initial population size, growth rates and annual harvest levels did indicate that surf redfish populations in the Saipan management unit area could become unstable above a projected annual harvest of 40,000 a year. Understanding population growth rates of sea cucumber stocks is essential to the development of sustainable management regimes, and subsequently, there is a need to resurvey harvested sea cucumber populations at regular intervals.

Introduction

The demand from the Orient for dried sea cucumber or "bêche-de-mer" has increased over the past 20 years and with it an increase in sea cucumber exploitation throughout the tropical and temperate Indo-Pacific Region, often resulting in overexploitation of many stocks (Conand and Byrne, 1993; Bruckner et al. 2003; Clarke, 2004: Kinch et al. 2008; Toral-Granda et al. 2008; Purcell, 2010).

The sea cucumber fishery in the CNMI operated from 1995 to 1997 and targeted the surf redfish (*Actinopyga mauritiana*, Holothuridae) (Trianni, 2002; Trianni, 2003). The fishery first commenced operations on Rota where it was poorly regulated, though stringent management

[*]Corresponding author. E-mail address: mstdfw@yahoo.com

measures were enacted prior to the fishery moving to Saipan (Trianni, 2003).These measures included the creation of two no-take reserves and the designation of specific management units for monitoring harvests (Figure 1). Despite these measures the Saipan fishery was halted in 1997 due to rapidly declining catch rates (Trianni, 2003).

Extension of the fishery to Tinian was sought in 1997, triggering a pre-harvest survey of resources that resulted in the establishment of a quota that was deemed unprofitable by the harvest company, leading to fishery cessation (Trianni and Bryan, 2004). In 1999 a CNMI law was passed that placed a ten-year moratorium on the harvest of sea cucumbers. In 2006 a re-survey was undertaken in the five Saipan management units harvested during the 1996/97 fishery to evaluate population recovery.

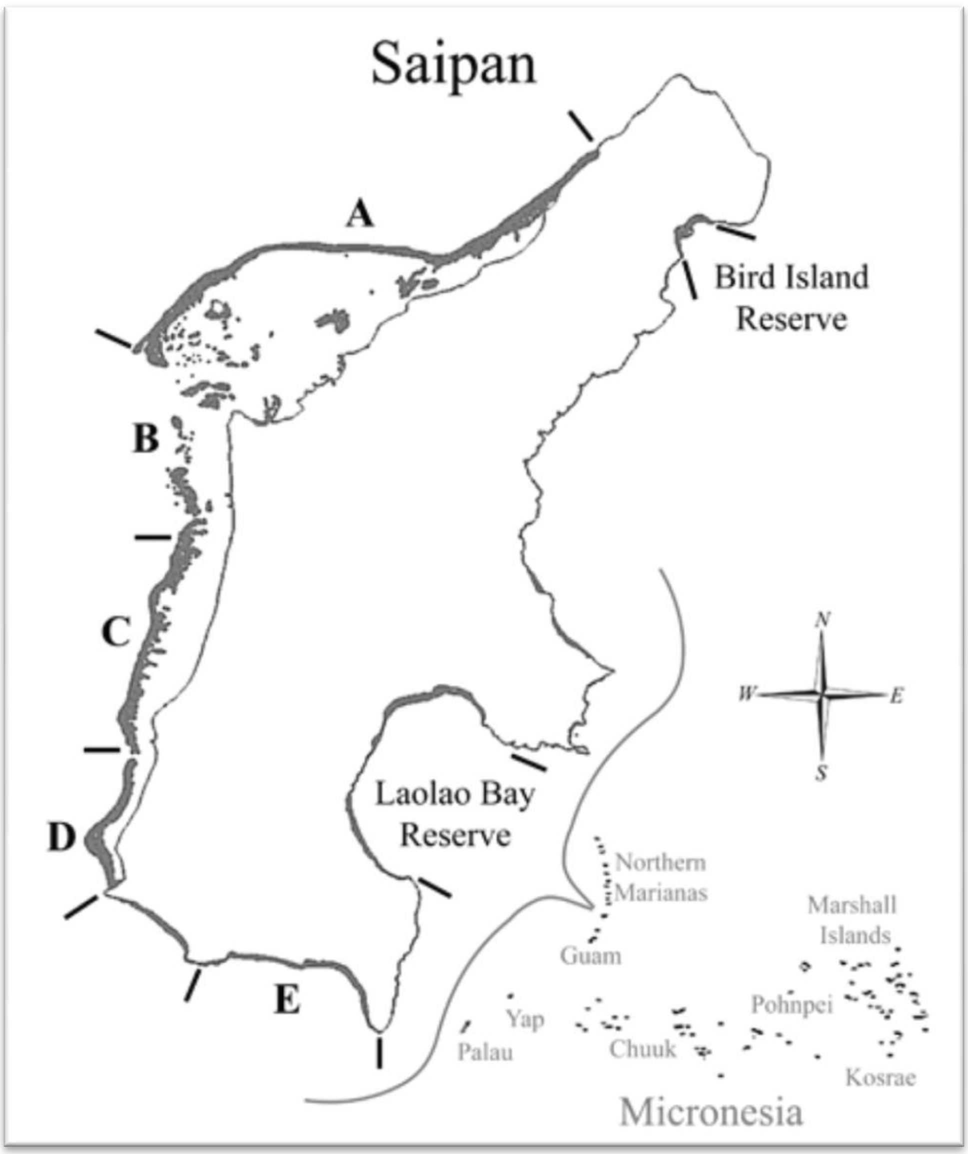

Fig. 1. Map of the island of Saipan, Commonwealth of the Northern Mariana Islands, showing management units, sea cucumber reserves and relative location in Micronesia.

This paper evaluates the 2006 status of surf redfish resources in the five management units that were harvested during the 1996-97 Saipan fishery, provides baseline biological information and population status for the surf redfish in the Saipan management units, and provides suggestions for future management of sea cucumber resources.

Methods

Sampling Design and Biological Data

Distinct management units identified prior to the Saipan sea cucumber fishery were subsequently used as statistical strata during the 2006 survey for the surf redfish (Fig. 1) (Trianni, 2003), and were divided into three categories. Back-reef (BR) areas were demarcated from the shoreward extent of continuous hard bottom impacted by wave energy to the crest of the barrier reef. Reef-slope (RS) areas consisted of the area from the outer slope of the barrier reef crest to a depth of 6 m. Patch-reef networks (PR) were limited to management unit B only, and was subsequently treated as a single stratum.

Sample size was determined using mean and variance estimates from samples in un-exploited populations obtained during the 1997 Tinian survey, by the formula (Andrew and Mapstone, 1987):

$$n = [s/(p \times m)]^2$$

Where n = sample size, p = desired precision, m = sample mean, s = standard deviation of sample mean. The number of samples required for varying levels of precision was calculated to identify sample sizes that would result in precision levels of at least 0.20. Sample size was proportionally allocated within each management unit using GIS, and further allocated into the BR and RS strata, with the exception of the PR management unit.

The circle plot method (Amesbury and Kerr, 1996) employed in the 1997 Tinian survey was used in order to standardize sampling methods for sea cucumbers in the CNMI. A 5.64 m rope was attached to a weight, stretched and moved in a circular manner around the weight to delimit an area of 100 m^2. Sample positions were randomly selected using a GIS software algorithm and accessed using hand held global positioning systems, and sampling was conducted at low tide in the BR strata, and as weather permitted in the RS and PR strata. Sampling occurred from April through July 2006, corresponding to the same time period of the 1997 post-harvest survey, which took place from April through May. One sampler deployed the circle plot while one to two samplers followed, collecting surf redfish which were measured for length from mouth to anus along the curvature of the back, and wet weight using a spring scale graduated in grams. Once sampling was complete specimens were returned live back onto the reef. Surf redfish weight was subsequently regressed on length.

Population Estimation

The overall population estimate was generated from the stratified random sample mean (Cochran, 1977) by:

$$\bar{y}_{st} = \sum_{h=1}^{L} W_h \bar{y}_h$$

where W_h= stratum weight and $\bar{y}_h$= stratum mean. The overall estimate of variance was determined using:

$$V(\bar{y}_{st}) = \sum W_h^2 \left(\frac{s_h^2}{n_h}\right)\left(\frac{N_h - n_h}{N_h}\right)$$

where s_h^2=strata sample variance; n_h = sample size; N_h = stratum size.

The estimate of total population size was then calculated using:

$$\hat{Y} = N(\bar{y}_{st})$$

where N = size of all strata.

95% bounds on the error of estimation were computed using:

$$B = \pm 2\sqrt{N^2 V(\bar{y}_{st})}$$

Following population estimation a discrete logistic model using Microsoft Excel® was iteratively fitted to survey population estimates in each management unit from the 1997 post-harvest survey and the 2006 re-survey to approximate growth rates between the two periods. The logistic model takes the form:

$$N_{t+1} = N_t + rN_t\left(1 - \frac{N_t}{K}\right)$$

where r = growth rate, K = carrying capacity, N_t = population estimate at time t. The mean population estimate from each stratum was used as the estimate of carrying capacity in the determination of growth rate.

Management Options

Following estimation of growth rates, a Monte Carlo simulation (Hilborn and Mangel, 1997; Haddon, 2001) of the logistic model was used to estimate the impact of varying annual harvest level from the management unit area over a 25-year time span, at estimated total population growth rate *r* with normal standard deviation (σ), ranging from 0.05 to 0.5, and initial population size ranging within the 95% confidence interval of the estimated population size.

$$N_{t+1} = N_t + rN_t\left(1 - \frac{N_t}{K}\right) - C_t$$

where C_t = annual harvest level.

The model was simulated 1,000 times for various combinations of σ, harvest level and initial population size, with the percentage of extinction (population going to zero within 25-year span) and coefficient of variation (CV) in population mean size documented per combination. This simulation approach was used to provide management guidelines on the potential of future harvest for this species on Saipan.

Results

Sampling Design & Biological Data

A total of 522 samples, proportionally allocated by management unit size, were taken during the 2006 survey. Estimated precision over sample size based on mean and variance data from the Tinian Survey in 1997 are illustrated in Fig. 2. The precision of the sample size taken was estimated at 6.3% using the Tinian data, and at 8.8% from the 2006 data.

Average length and weight of surf redfish from each management unit are shown in Fig. 3. The highest number of measurements recorded was from management unit A_{BR}, 895 and 893, and the lowest number from E_{RS}, 10 and 9. For management units where more than 200 individuals were measured, the stratum C_{RS} surf redfish had the highest average length, 23.8 cm, and the highest average weight, 599 g. In general, surf redfish from the RS strata were heavier than those from the BR strata, except in management unit D. There was no apparent pattern regarding length between RS & BR. The regression of weight on length resulted in a moderate fit; R^2=0.65 (Fig. 4).

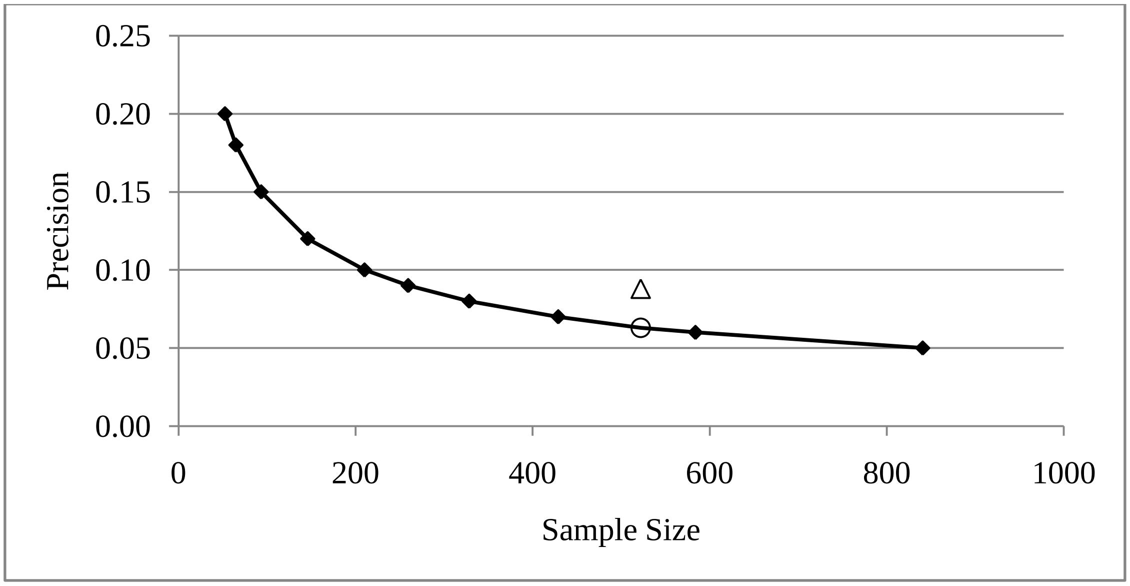

Fig. 2. Graph of estimated precision versus sample size generated from data collected during the 1997 Tinian sea cucumber survey (Trianni and Bryan, 2004). Open circle indicates chosen sample size of 522 with estimated precision of 6.3% for the 2006 re-survey. Open triangle indicates actual precision from the 2006 re-survey of 8.8%.

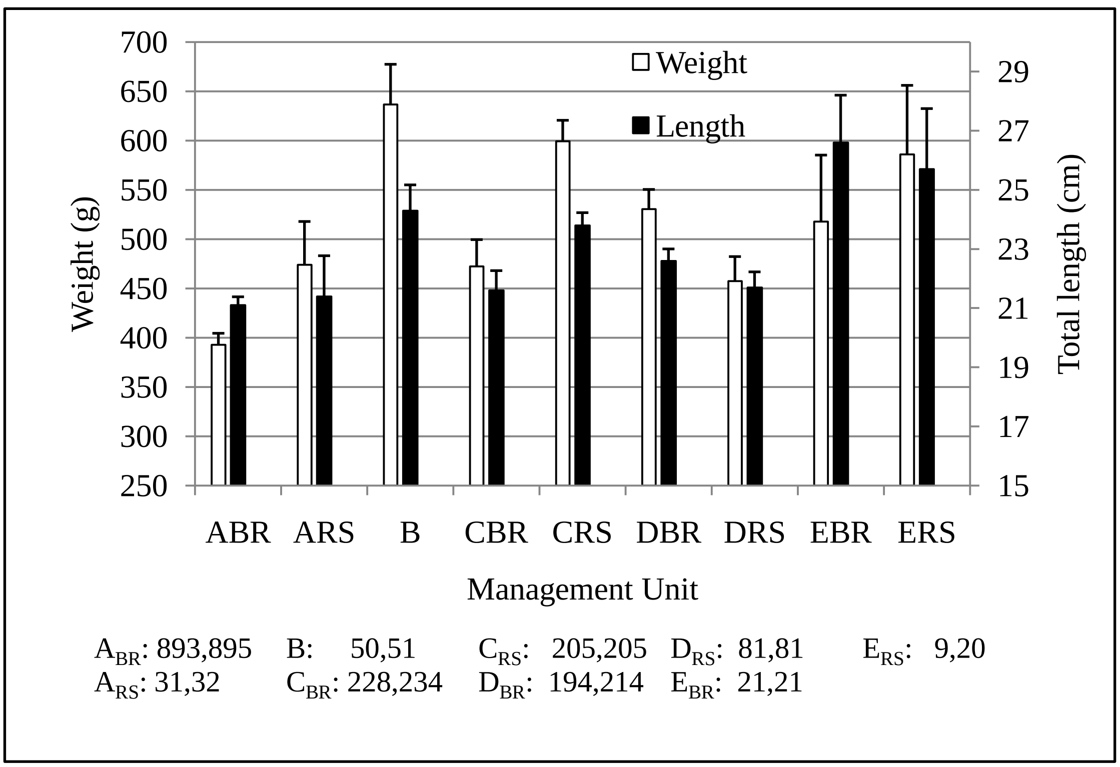

Fig. 3. Mean weight and length per management unit stratum for surf redfish on Saipan. Numbers at bottom of graph indicate sample size for weight, length.

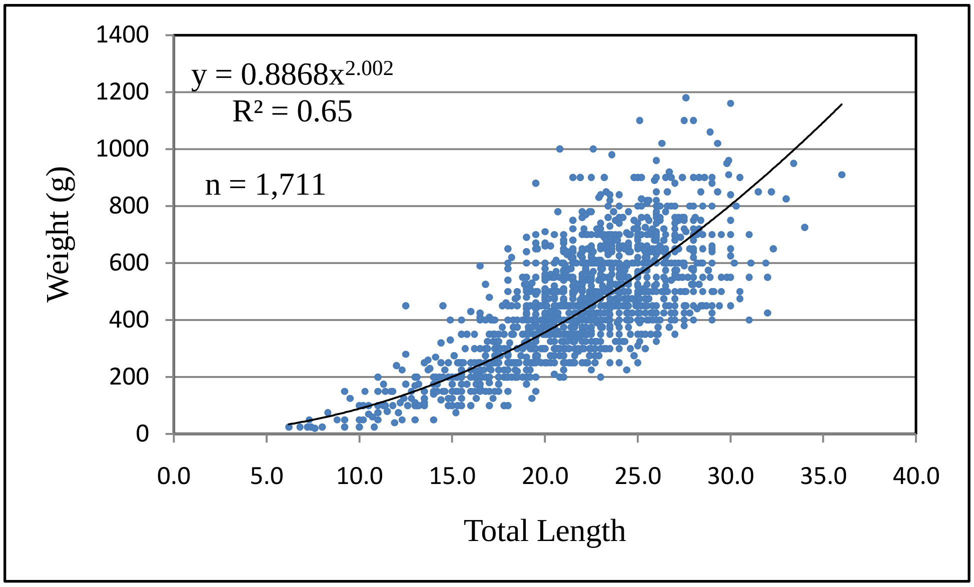

Fig. 4. Regression of weight on length for surf redfish, *Actinopyg mauritiana*, from management units on Saipan.

Length and weight-frequency plots along with estimates of length and weight at maturity are depicted in Fig. 5. Conand (1989) estimated the size at maturity for surf redfish at 22.0 cm wet length and 370 g wet weight. For both length and weight more surf redfish sampled on the RS strata, compared to the BR strata, had sizes that were larger than the sizes at maturity estimated by Conand (1989). Surf redfish samples from the PR indicated that 75% were larger than the length at maturity, and 98% were above weight at maturity.

Population Estimation

The stratified random sampling estimate of surf redfish abundance from the 2006 survey was 220,578 animals, with a 95% confidence interval of 35,796. This compares to the 1997 post-harvest survey abundance estimate of 32,977(Trianni, 2003), representing a significant increase in estimated population size between periods. Estimated remaining surf redfish from the 1997 survey, 32,977, when added to the estimated number of surf redfish reported harvested by the fishing company, 156,388, resulted in an initial population estimate of 189,365, comparable to the lower bounds of estimate from the 2006 survey, 186,249. Additionally, depletion model estimates of initial population size from the 1996/7 fishery averaged 172,457, slightly below the lower bounds from the 2006 survey (Trianni, 2003). The mean densities per 100 m^2 sample per habitat per survey are presented in Table 1. The largest increases in surf redfish density occurred in management units A_{BR},C_{BR}, C_{RS}, and D_{BR}.

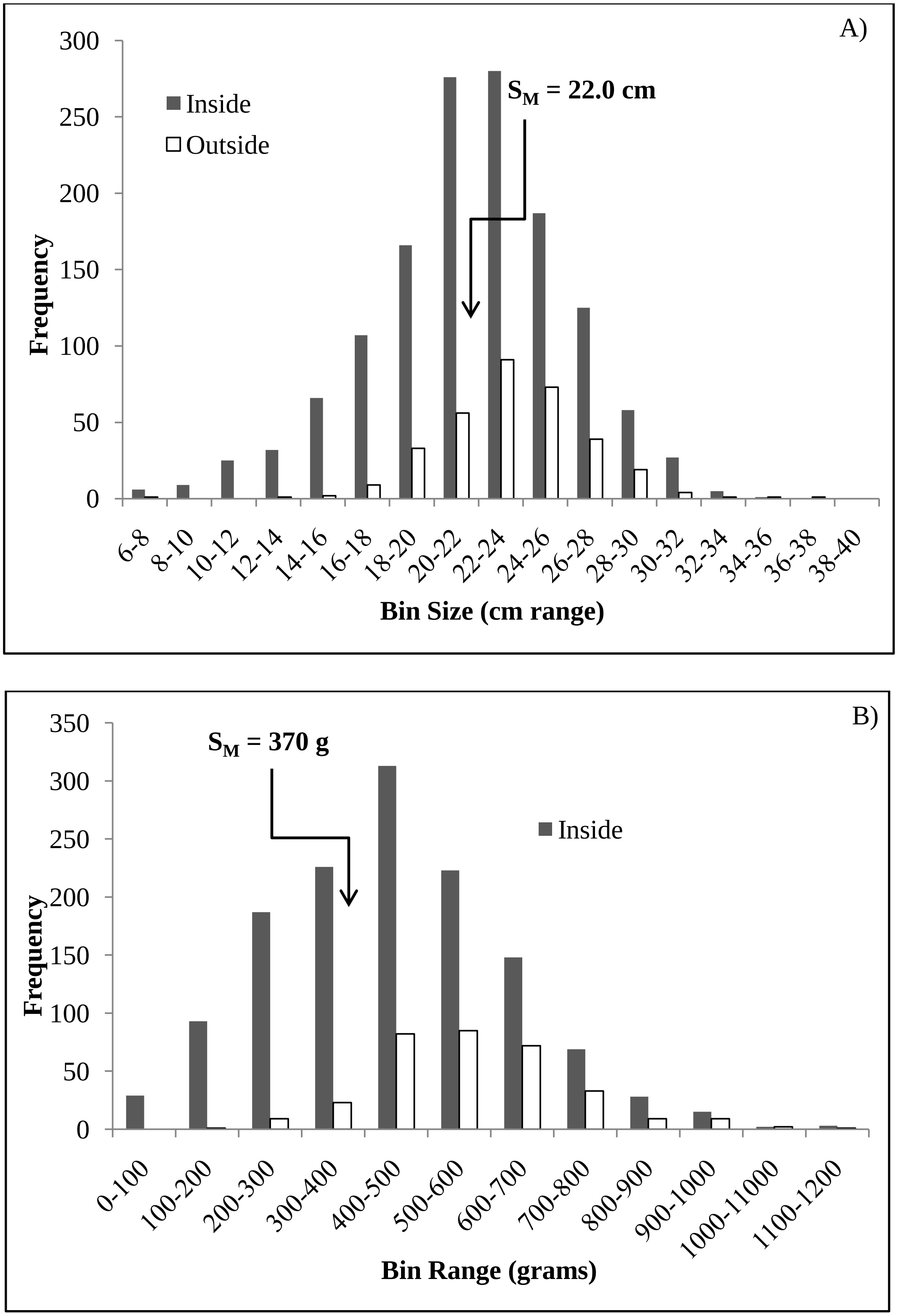

Fig. 5. Length (A) and weight (B) frequency histograms with size at maturity for the surf redfish, *Actinopyga mauritiana*, collected from management units on Saipan. The S_M indicates the relative position of size at maturity for both length and weight for animals found inside (back reef to reef crest) and outside (reef slope to 6 m) the barrier reef.

The iterative fit of the discrete logistic model to management unit data points from the 1997 post-harvest survey and the 2006 survey resulted in rates of growth ranging from 0.8 to 1.02 (Table 2).The density dependent discrete logistic model was not directly applicable to stratum D_{BR} as the 1997 survey estimate (model initial population size) was "0". A linear regression of estimated growth rate on post-harvest survey density did not detect a trend ($R^2 = 11^{\%}$), indicating that density dependence within the harvested strata may not have been a significant factor in surf redfish recovery.

Table 1. Surf redfish habitat area, sample size and density·100 m^{-2} from the 2006 survey with 95% confidence intervals, and density·100 m^{-2} from the 1997 post-harvest survey.

Habitat	Area (km^2)	n	Density·100 m^{-2}	95% CI	1997 Survey·100 m^{-2}
A_{BR}	1.16	109	11.8	(9.1,14.6)	1.2
A_{RS}	1.74	123	0.3	(0.2,0.4)	0.2
B	0.51	51	1.1	(0.1,2.0)	0.6
C_{BR}	0.45	64	4.3	(2.9,5.7)	0.1
C_{RS}	0.41	66	3.3	(2.4,4.2)	0.1
D_{BR}	0.36	38	7.4	(3.7,11.1)	0.0
D_{RS}	0.34	46	2.2	(0.7,3.6)	1.0
E_{BR}	0.22	14	1.9	(0.8,3.00	0.7
E_{RS}	0.22	11	0.7	(0.0,1.7)	0.8
Total	**5.41**	**522**			

Table 2. Growth estimates per habitat for surf redfish in management units on Saipan.

Unit	*r*
A_{BR}	0.93
A_{RS}	0.85
B	0.94
C_{BR}	1.02
C_{RS}	0.99
D_{BR}	NA
D_{RS}	0.90
E_{BR}	0.88
E_{RS}	0.80
Overall	**0.95**

Management Options

The simulation of the discrete logistic model used the overall growth rate estimate of 0.95 as the mean with normal standard deviation, σ, ranging from 0.05 to 0.5. Growth estimates were constrained to a lower limit of 0.1, to ensure a positive growth rate. The estimate of *K* was set at the 2006 population estimate, 220,578 animals, with initial population size varying within the 95%

confidence limits of that estimate. Annual harvest was evaluated over a range from 35,000 to 55,000 animals per year, at increments of 5,000, over a 25 year-period. A total of 1,000 estimates for each combination of harvest level and σ were conducted, with levels of harvest compared with percentage of extinction within the 25-year period, CV of the mean value of harvest, and standard deviation (Fig. 6). Harvest levels of 50,000 and above resulted in population instability, especially as growth became more variable. The CV for population mean size increased steadily as growth variability increased, notably for harvest levels of 40,000 animals and above, though significantly for harvest levels 45,000 animals and above.

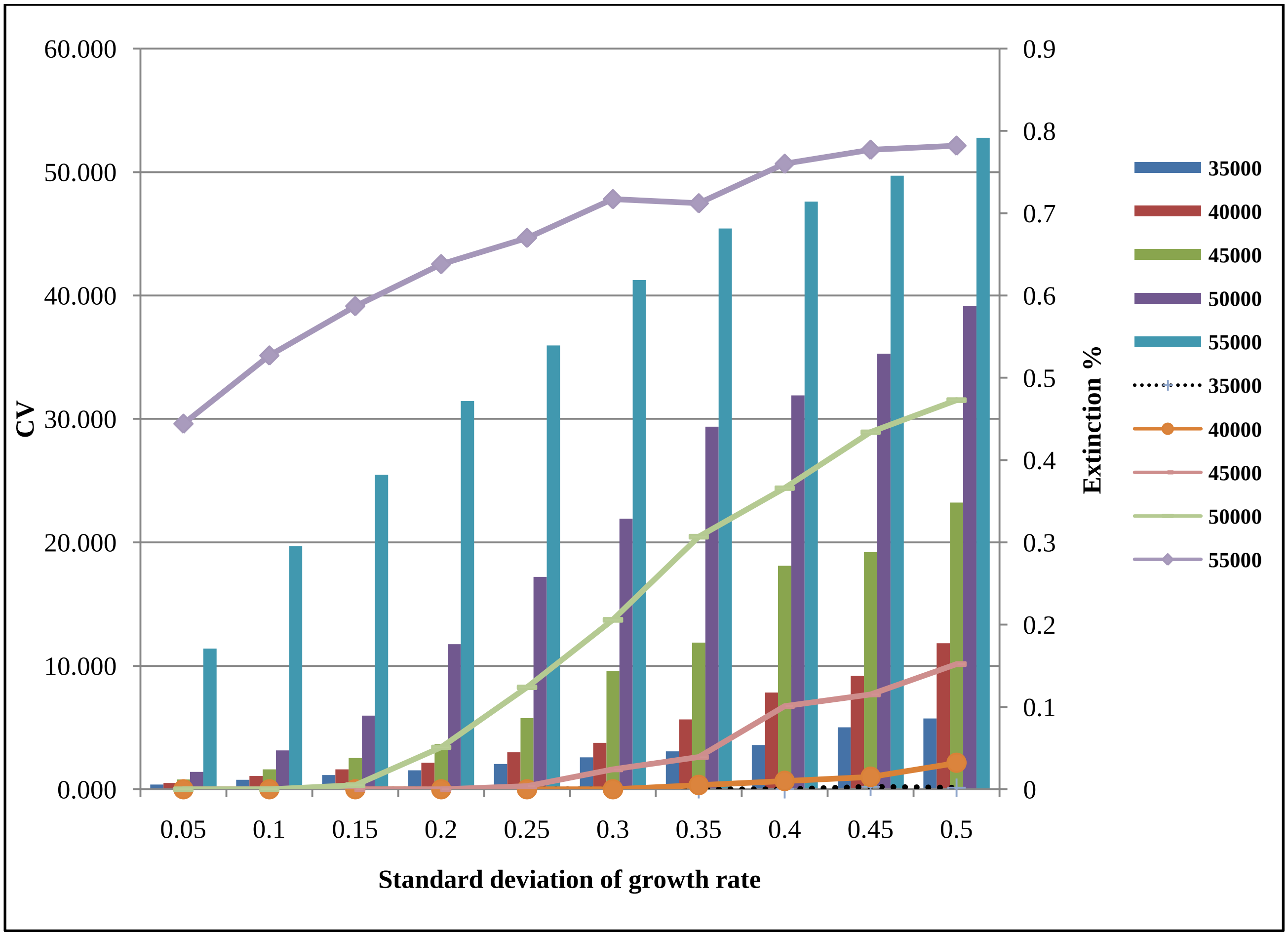

Fig. 6. Monte Carlo simulations of coefficient of variation (bars) and extinction percentage (lines) against standard deviation of growth rate from varying levels of annual harvest.

Discussion

The sample size in this study was based upon previous survey data from an un-exploited surf redfish population on Tinian. As the Saipan management units had not been harvested since 1997, the estimated precision based upon the Tinian survey data was similar to the precision calculated from the Saipan survey data, illustrating the importance of using estimates of mean and variance for sample size estimation from populations under similar harvest pressure.

The length and weight frequency histograms further demonstrated the recovery by illustrating broad size frequency distributions, indicating although surf redfish were not collected for microscopic maturation examination, the majority of sampled individuals were above published length and wet weight maturity sizes. These data are the first to document the size structure of a recovered sea cucumber population.

The 2006 population estimate of surf redfish of 220,578 animals was 16% greater than the estimated number at the commencement of the 1996/7 fishery, 189,365, that was based on the number harvested plus the number estimated to be remaining from the 1997 post-harvest survey. The population estimate discrepancy between periods could have been due to any or all of the following factors:

1) Low population levels observed from the 1997 post-harvest survey resulted in a lower probability of observer detection during that survey, and greater sampling variance.
2) The harvest company underreported sea cucumber landings during the fishery,
3) Due to depressed population levels, high recruitment levels occurred following the fishery.

The surf redfish density estimates from the 2006 survey fall within or are greater than other published density ranges for this species (Preston, 1993; Dalzell et al. 1996, Trianni and Bryan, 2004; Ahmed and Lawrence, 2007; Kinch et al. 2008). As noted, not all of Saipan was open to sea cucumber exploitation in 1996/7, and at the commencement of that fishery two no-take reserves for sea cucumber were established, one at LaoLao Bay and the other at Bird Island (Fig. 1). The highest density recorded during the 1997 post-harvest survey was $1.2^{\cdot}100\ m^{-2}$ surf redfish in management subunit A_{BR}, with the lowest at $0.0^{\cdot}\ m^{-2}$ in subunit D_{BR} (Table 1). In addition, the 1997 post-harvest survey revealed that over 25,000 surf redfish were estimated to remain in management unit A. The presence of two no-take reserves on Saipan, spatial and temporal limitations on the Saipan harvest, estimated surf redfish number in management unit A post-harvest, and un-exploited populations on Tinian most likely enhanced species recovery in the Saipan management units. Unfortunately, the recovery of the management unit populations was not tracked over time, thus impeding the elucidation of the actual population growth rate processes and preventing insights into the density-dependent nature of sea cucumber population carrying capacity and stability.

The ‘Allee effect’ correlates reproductive success with population size, suggesting that a minimum threshold, the ‘Allee Threshold’ (Berec et al. 2007) may be required for positive population growth (Stephens et al. 1999). Trianni and Bryan (2004) noted a lack of information pertaining to sea cucumber species density levels sufficient to ensure reproductive and recruitment success. Bell et al. (2008) also noted a lack of knowledge regarding sea cucumber Allee effect thresholds, and provided options for sustainably managing and recovering harvested sea cucumber populations. Friedman et al. (2010) found inconsistent recovery of sea cucumber populations provided protection following varying harvest regimes as some high valued species such as the black teatfish, *Holothuria whitm*aei, evidenced a lack of recovery capability when reduced to very low density levels (Uthicke et al. 2004; Friedman, 2010), while other high valued (white teatfish, *Holothuria fuscogilva*), medium valued (greenfish, *Stichopus chloronotus*) and low valued (amberfish, *Thelenota anax*) species demonstrated recovery, perhaps tied to the biology, behavior, and habitat requirements of the species (Friedman, 2010). Interestingly, Friedman et al. (2010) found the recovery of the surf redfish to be variable.

The results indicate that juvenile recruitment in surf redfish may not be linked to local adult density. This is not unexpected as the five week planktotrophic larval stage would allow ample time for dispersal (Richmond et al. 1996). The larval stage of surf redfish, as with other sea cucumber species, is an important component of effective management, but one that may not need to be addressed as a top priority when producing a management plan, as emphasis should be placed on adequate spatial and temporal restrictions on harvesting the adult, sexually mature populations.

The Monte Carlo simulation of harvest levels against varying growth rates for the surf redfish provided some interesting results. The logistic model indicates surf redfish populations in the management units can become increasingly unstable above an annual harvest level of 45,000 animals (Fig. 5). The only level of harvest that appeared to have a minimal influence on CV and extinction percentages was 35,000 animals, which resulted in extremely low extinction percentages (maximum extinction rate of 0.003 @ $\sigma = 0.5$), and CV estimates below 5% for all combinations of harvest level and σ. These simulations suggest that it would be imprudent to harvest this species at levels above 35,000 a year in the management unit area.

Sea cucumber prices have increased considerably over the past decade due to increases in demand from the growing Asian middle class (Clarke, 2004; Purcell, 2010) and consequent decreases in available stocks due to past overharvest (Uthicke and Conand, 2005; Kinch et al. 2008; Friedman et al. 2010). Given unknown influences of sea cucumber harvest on broader ecosystem functioning (Friedman et al. 2008), as well as the direct physical impacts on barrier reef habitats from harvesting of surf redfish, a cost-benefit analysis would appear instrumental to prudent management and should be done prior to future sea cucumber harvest on Saipan. Of the 15 islands in the CNMI only Saipan, Tinian and Rota offer habitats that can sustain moderate to high ambient densities of surf redfish as the remaining islands are characterized by steeply profiled, fringing reef habitat.

Tracking harvested sea cucumber populations over time can provide valuable insight into recovery rates, and such information is essential if long-term sustainable harvesting of sea cucumber populations is to be realized.

Conclusion

Although this study did not explain sea cucumber Allee threshold levels, it indicates that surf redfish populations can recover from over-exploitation, given spatial and temporal restrictions on harvest. Although there are few follow-up surveys for most sea cucumber fisheries (Uthicke et al. 2004; Ahmed and Lawrence, 2007; Friedman et al. 2010), such studies are essential to advancing the knowledge of fishery influences on sea cucumber populations by providing population growth and recovery rates which can enhance long-term sustainable management strategies.

Acknowledgements

This work was fully funded by the US Fish and Wildlife Service State Wildlife Grant. The authors wish to acknowledge the contributions of the following Division of Fish and Wildlife employees who contributed in data collection and processing; Anthony Flores, Rudy Pangelinan, Juan Kapeilo, Roxxon Kani, Steve McKagan and the late Jacinto Taman. Dierdre McClarin, formerly of the CNMI Coastal Resource Management Office, provided geographical information system assistance. Comments from two anonymous reviewers greatly improved the manuscript.

References

Ahmed M.I. and A.J. Lawrence. 2007. The status of commercial sea cucumbers from Egypt's northern Red Sea Coast. SPC Bêche-de-Mer Information Bulletin 26:14–18.

Amesbury, S.S. and A.M. Kerr. 1996. Data collection methods for bêche-de-mer resource management in Micronesia. In: Suggestions for the Management of Sea Cucumber Resources in Micronesia (ed. R.H. Richmond). University of Guam Marine Laboratory Technical Report No. 101. 75 pp.

Andrew, N.L. and B.D. Mapstone. 1987. Sampling and the description of spatial pattern in marine ecology. Oceanography and Marine Biology: An Annual Review 25:39-90.

Bell, J.D., S.W. Purcell and W.J. Nash. 2008. Restoring small-scale fisheries for tropical sea cucumbers. Ocean and Coastal Management 51:589-593.

Berec, L., E. Angulo and F. Courchamp. 2007. Multiple Allee effects and population management. Trends in Ecology and Evolution 22(4):185-191. doi:10.1016/j.tree.2006.12.002.

Bruckner, A., K. Johnson and J. Field. 2003. Conservation strategies for sea cucumbers: Can a CITES Appendix II promote international trade? SPC Bêche-de-Mer Information Bulletin 18:24–33.

Clarke, S. 2004. Understanding pressures on fishery resources through trade statistics: a pilot study of four products in the Chinese dried seafood market. Fish and Fisheries 5:53-74.

Cochran, W.G. 1977. Sampling techniques. 3rd ed. John Wiley & Sons, New York. 428 pp.

Conand, C. 1989. Les Holothuries Aspidochirote du Lagon de Nouvelle-Caledonie: Biologie, Ecologie et Exploitation. Ph.D thesis, University of Western Brittany, Brest, France. 393 pp.

Conand, C. and M. Byrne. 1993. A review of recent developments in the world sea cucumber fisheries. Marine Fisheries Review 55:1-13.

Dalzell, P., T.J.H. Adams and N.V.C. Polunin. 1996. Coastal Fisheries in the Pacific Islands. Oceanography and Marine Biology: An Annual Review 34:395-531.

Friedman, K., E. Roperti and A. Tafileichi. 2008. Development of a management plan for Yaps sea cucumber fishery. SPC Bêche-de-Mer Information Bulletin 28:7–13.

Friedman, K., H. Eriksson, E. Tardy and K. Pakoa. 2010. Management of sea cucumber stocks: Patternsof vulnerability and recovery of sea cucumber stocks impacted by fishing. Fish and Fisheries. DOI: 10.1111/j.1467-2979.2010.00384.x

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman & Hall/CRC. 406 pp.

Hilborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press. 315 pp.

Kinch, J., S. Purcell, S. Uthicke and K. Friedman. 2008. Population status, fisheries and trade of sea cucumbers in the Western Pacific. In: Sea Cucumbers: A Global Review of Fisheries and Trade (ed. V. Toral-Granda, A. Lovatelli and M. Vasconcellos), pp. 7-15. FAO Fisheries Technical Paper No. 516. Rome: Food and Agriculture Organisation.

Preston, G.L. 1993. Bêche-de-mer. In: Nearshore marine resources of the South Pacific (ed. A. Wright and L. Hill), pp. 371-407. Suva: Institute of Pacific Studies, Honiara: Forum Fisheries Agency and Halifax: International Centre for Ocean Development.

Purcell, S.W. 2010. Managing sea cucumber fisheries with an ecosystem approach. In: FAO Fisheries and Aquaculture (ed. A. Lovatelli , M. Vasconcellos and Y. Yimin). Technical Paper No. 520. Rome, FAO. 157 pp.

Richmond, R., D. Hopper and P. Martinez. 1996. The biology and ecology of sea cucumbers.. In: Suggestions for the Management of Sea Cucumber Resources in Micronesia (ed. R.H. Richmond), pp. 7-31. University of Guam Marine Laboratory Technical Report No. 101.

Stephens, P.A., W.J. Sutherland and R.P. Freckleton. 1999. What is the Allee effect? (summary). Oikos 8:185–190.

Toral-Granda, V., A. Lovatelli and M. Vasconcellos (eds).2008. Sea Cucumbers – A Global Review of Fisheries and Trade. FAO Fisheries and Aquaculture Technical Paper No. 516, FAO, Rome. 317 pp.

Trianni, M.S. 2002. Summary of data collected from the sea cucumber fishery on Rota, Commonwealth of the Northern Mariana Islands. Bêche-de-Mer Information Bulletin. 16:5-11.

Trianni, M.S. 2003. Evaluation of the resource following the sea cucumber fishery of Saipan, Northern Mariana Islands. Proceedings 9th International Coral Reef Symposium, Bali, Indonesia. pp. 829-835.

Trianni, M.S. and P.G. Bryan. 2004. Survey and estimates of commercially viable populations of the sea cucumber *Actinopyga mauritiana* (Echinodermata: Holothuroidea), on Tinian Island, Commonwealth of the Northern Mariana Islands. Pacific Science 58:91-98.

Uthicke, S. and C. Conand. 2005. Local examples of beche-de-mer overfishing: An initial summary and request for information. SPC Bêche-de-mer Information Bulletin 21:9–14.

Uthicke, S., D. Welch and J.A.H. Benzie. 2004. Slow growth and lack of recovery in overfished holothurians on the Great Barrier Reef: Evidence from DNA fingerprints and repeated large-scale surveys. Conservation Biology 18:1395–1404.

Received: 6/3/2009; Accepted: 29.3.2011(MS09-13)