Application of Biological Knowledge to the Management of the Virgin Islands Conch Fishery

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ABSTRACT

Management of Virgin Islands queen conch resources has become a priority. Management information was developed through estimation of population dynamic features. Growth was estimated by analysis of size frequency distributions and found to be similar to information in the literature. Natural and fishery mortality rates were estimated and combined with weight-length information in an analysis of yield per recruit. These results indicate that maximum yield per recruit is obtained at age of first harvest between 3 and 5 years of age.

Stock abundance was assessed using a diver tow with an underwater sled. Total sustainable yield was estimated and found to be approximately equal to the 1978-79 annual harvest for St. Croix.

The queen conch *(Strombus gigas)*, a marine snail inhabiting the Caribbean seabed, has long been an important resource for both its dietary and economic value. Research efforts in the region have provided significant insight into much of the life history, growth and biology of the species (Berg, 1975; 1976; Randall, 1964; Brownell and Stevely, 1981). These authors have described problems of decreasing landings in many areas, presumably attributable to intense fishing pressure.

Much of the recent work done on *S. gigas* has been structured towards the information needs of the aquacultural biologist and in development of aquaculture and stock replenishment plans. This information is needed, as aquaculture appears to hold the promise of restocking many of the once productive areas. However, resource managers must face problems of managing this fishery until these current potential restocking schemes become available.

The present study conducted in the U.S. Virgin Islands concentrated on developing information for current management needs. In this effort growth rates for both juvenile and adult conch, mortality (natural and fishing) rates, and estimations of standing stock of the shelf areas were obtained. Utilizing this information a maximum sustainable yield (MSY) was calculated and harvest sizes were calculated to optimize yield-per-recruit functions. These data will hopefully be useful outside of the Virgin Islands area.

METHODS

Growth and Mortality

Queen conch were collected from two areas off St. Thomas, U.S. Virgin Islands. Three hundred thirty-four animals were collected between Great St. James and Little St. James Islands off St. Thomas during September, 1981 (Fig. 1). Measurements on length, width, lip thickness, total weight and meat weight were taken. In October 1981, 191 conch were collected near Turtle Back Rock off the north side of St. Thomas. The area between the St. James Islands is relatively shallow (3 to 12 m) and has a sheltered anchorage. This area has been subject to heavy fishing pressure for many years. The area near Turtle Back Rock is deeper (17 to 22 m) and not as calm. Because it is accessible only by SCUBA diving, there has been only minimal fishing pressure in this area.

Shell length size-frequency distributions of juvenile conch were analyzed by probit analysis (Harding, 1949) for the presence of size classes. Shell length is not an

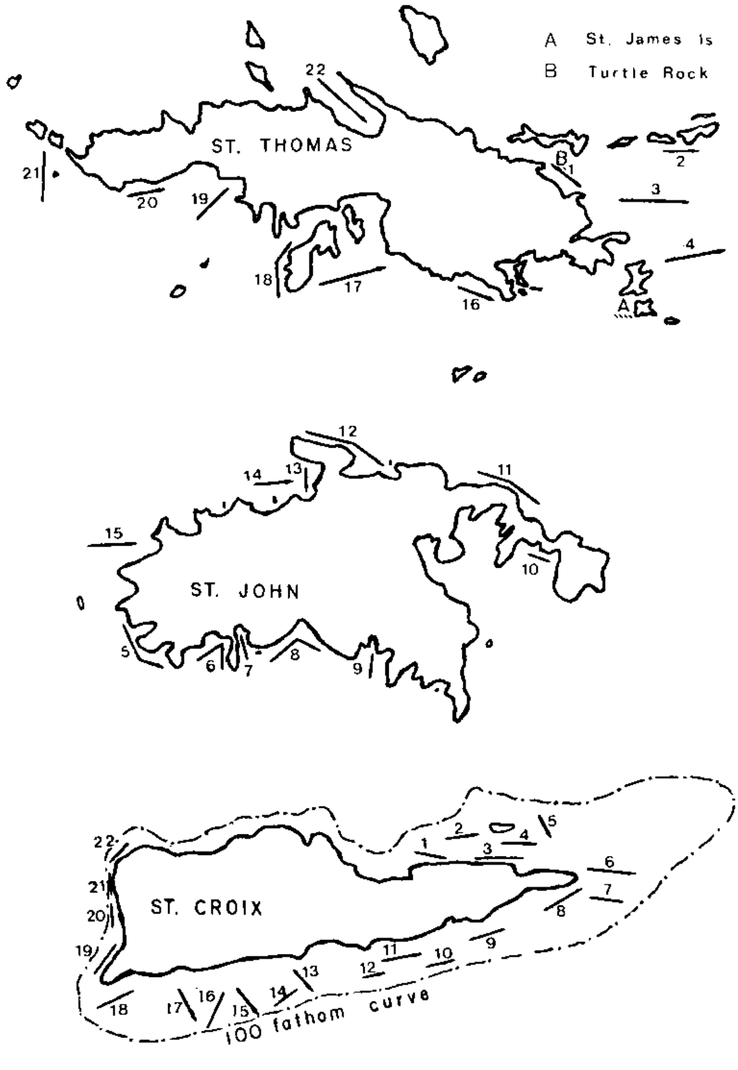


Figure 1. Study areas around the U.S. Virgin Islands (Numbers indicate towing transects).

appropriate measurement for adult conch. Randall (1964) showed that maximum shell length is obtained at or before sexual maturity, and that growth energy is then devoted to the formation of a flaring shell lip and its subsequent thickening. Therefore, measurements of shell lip thickness were taken from all adult conch, and size frequency distribution was again analyzed by probit analysis for the presence of size classes. Hesse (1976) found that shell lip thickness was related to growth for adult conch from the Caicos Islands. These analyses provided indications of size classes and numbers of individuals in each of the size classes. The size classes were "aged" by comparison with Berg's (1976) study of conch growth. The size class frequencies were used to calculate between year class mortality. Natural mortality *(M)* was estimated from size classes that were smaller than harvestable size. Fishing mortality *(F)* was estimated as the difference between total mortality *(Z)* and *(M)*.

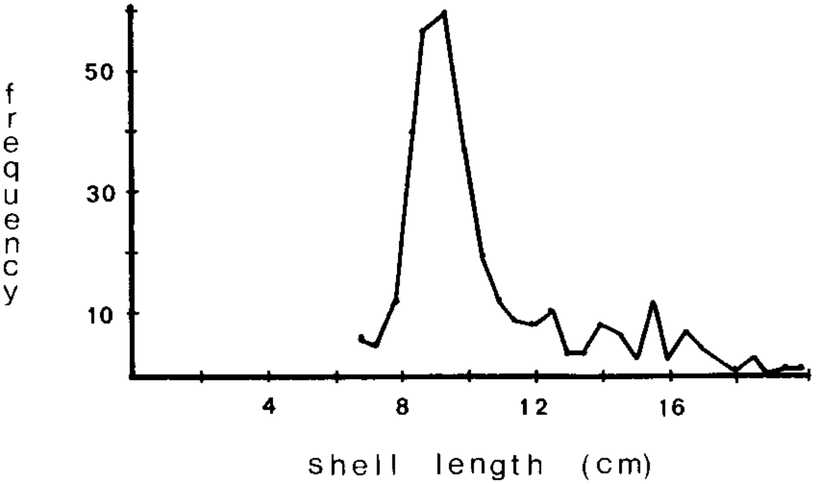
Stock Assessment

Stock abundance was assessed by a random transect method. Conch were counted during tows of an underwater sled. The study was carried out around St. Thomas, St. John and St. Croix. Data on depth of bottom, depth of sled, type of bottom, time over each bottom type and number of adult conchs counted was recorded during each transect. This information was used to describe preferred habitat and to estimate potential yield on the shelf areas around the Virgin Islands.

The area surveyed underneath the sled was determined by towing in an area of known depths to determine the angle of vision between two support bars on the bottom of the sled. This angle was determined to be 59 degrees. Knowing this angle, the depth of water and the depth of the sled, the visual path width could be calculated by the equation:

$$P = 2(\tan 1/2 <)(H) \quad (1)$$

where P = visual path width and H = sled height from bottom.



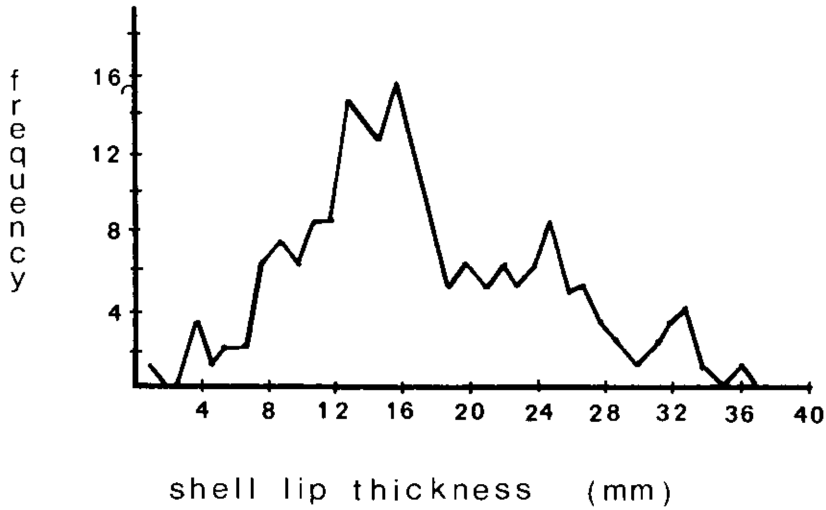


Figure 2. Size frequency of *Strombus gigas;* shell length (cm) of Juvenile *S. gigas;* shell lip thickness (mm) of adult *S. gigas.*

A hand bearing compass was used to plot the beginning and ending points of the tows and calculate the linear distance. The area surveyed was calculated by multiplying the path width (P) times the linear distance.

Table 1. Calculated lengths of Queen Conch at 1, 2 and 3 years of age

Lengths (cm) and years			Method of calculation (geographic location)	Reference
1	2	3		
8.8	12.6	18.0	Size frequency distribution of natural population (Puerto Rico)	Berg (1976)
7.6	12.8	18.0	Size frequency distribution of natural population (Venezuela)	Brownell (1977)
9.0	12.6	15.7	Size frequency distribution of natural population (St. Thomas)	Wood and Olsen (this paper)
10.8	17.0	20.5	Von Bertalanffy growth curve analysis of Randall's 1964 tag/recapture data (St. John, U.S.V.I.)	Berg (1976) Brownell, et al. (1977)
No Data	17.0	18.6	Von Bertalanffy growth curve analysis of nine populations using tag/recapture data (Cuba)	Alcolado (1976)

(Source: Brownell and Stevely (1981))

RESULTS

Growth

The size frequency distributions (Fig. 2) indicated the presence of three size classes in the juvenile conch and four size classes for adult conch. The size classes which were calculated by probit analysis were consistent with the results of other studies (Table 1). The size class mean for the third size group may be somewhat smaller than other estimates due to very heavy fishing pressure in the area where the sample was taken.

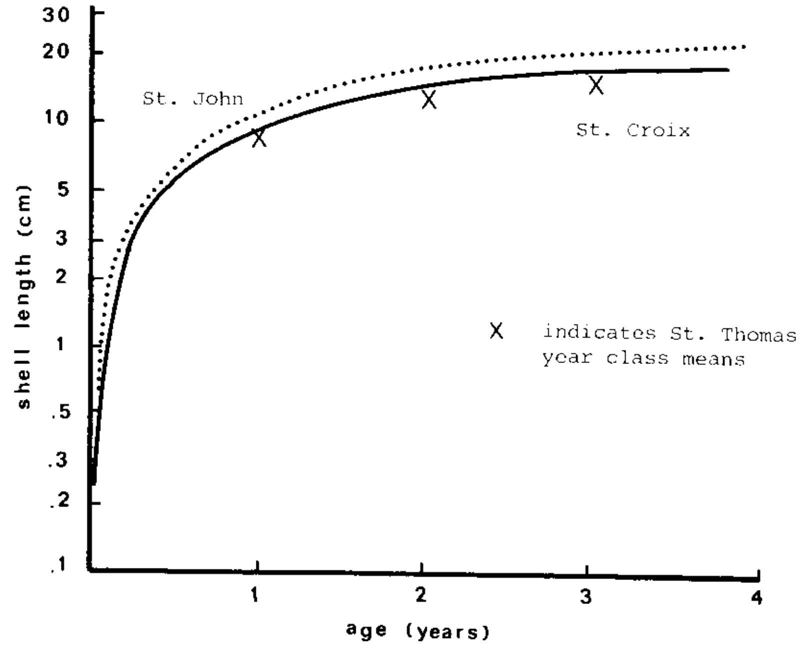


Figure 3. Size class means fitted to von Bertalanffy growth curve (from Berg, 1976).

The size class means were fitted to the von Bertalanffy curve (Fig. 3) shown in Berg (1976). The growth parameters derived by Berg were used in this paper, as they were felt to best describe the growth of *S. gigas* in the Virgin Islands. The von Bertalanffy equation:

$$L_t = L_\infty (1 - e^{-k(t-t_0)}) \quad (2)$$

where L_∞ = asymptotic shell length, L_t = shell length at time, k = Brody growth coefficient, t_o = time at which shell length equals zero, and e = base of natural log.

$$L_\infty = 26.0,\ k = 0.515,\ t_o = 0$$

To relate the growth of juvenile animals where shell length was used as the growth unit and the growth of adult animals where shell lip thickness was used, a conversion was made to marketable meat weight. The conversion was made through a series of regressions which described these relationships.

For shell length and total weight:

$$W = aL^b \quad (3)$$

where W = total weight (gm), L = shell length (cm), a = intercept and b = slope.

$$W = .0164\ L^{3.713}$$

This relationship was significant at the 0.01% level (N = 514, r = 0.98).

The relationship between shell lip thickness (mm) and total weight is described by:

$$W = 885\ L^{0.256}$$

This relationship was significant at the 0.01% level (N = 135, r = 0.52).

The relationship between total weight *(TW)* and marketable weight *(MW)* is best described by the linear equation:

$$MW = 6.465 + 0.077\ (TW) \quad (4)$$

Table 2. Calculations of mortality from size frequency data

Age	$\bar{X}$ Shell Length (cm)	SD	Size Class (No.)	Z
1	9.0*	.6	114.6	
				.188
2	12.5*	1.7	94.8	
				.042
3	15.7*	1.5	91.0	
				1.8
4	11.5+	3.7	74	
				.72
5	19.1+	2.9	36	
				.217
6	26.2+	2.3	29	
				1.42
7	32.2+	1.0	7	

*Mean shell lengths
+Mean thickness of shell lip
Mean mortality of year classes 1-2, 2-3, 4-5, and 5-6 = 0.292, SD = .295.

This relationship was significant at the 0.01% level ($N = 102$, $r = 0.95$).

Using these regressions the parameter W_∞ (the maximum marketable meat weight) was found to equal 231.6 g.

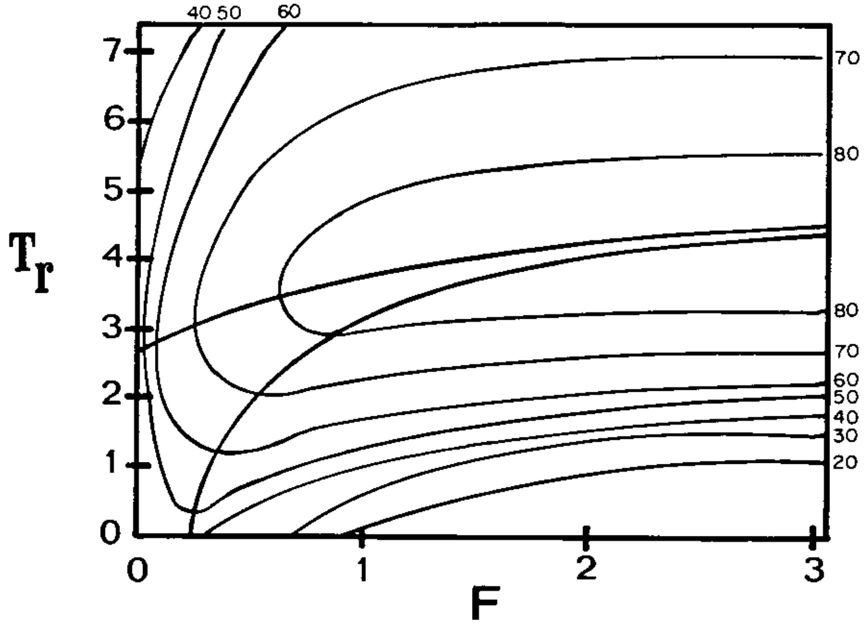


Figure 4. Yield isopleth diagram for queen conch, yields shown in grams of yield per recruit. Line a-a is the locus of the maximum yield for any given rate of fishing (f). Line b-b is the locus of best yields for a given recruitment age (t_r).

Mortality

Annual total mortality rates (Z) were estimated from the equation

$$N_t = N_{t-1} (e^{Z}) \qquad (5)$$

where: *N* is the number of individuals surviving from time t–1 to t.

The method employed is outlined in Olsen and Koblick (1975). Summarized, it consists of deriving size class means and standard deviations from a polymodal frequency distribution by probit analysis. A z score is derived and the number of individuals is then calculated using a table of normal probabilities and the frequency of individuals in the modal size class.

This technique provided an estimate of 299 individuals for size classes one to three as compared with 332 (or within 10%) in the actual sample. For size classes four to seven based on shell lip thickness this technique provided an estimate of 146 individuals as compared with an actual 186 (within 20%) in the actual sample. Table 2 summarizes the mortality rates for each size class.

The interval between size classes was assumed to be one year. This assumption was based on the fit of these size classes to Berg's (1976) growth curve for conch in the Virgin Islands. Mortality (Z) was then calculated from the equation

$$Z = (L_n(N_i/N_{i-1}))/t \qquad (6)$$

where: *N* is the number of individuals estimated in i and i–1 size classes and t is the interval in years between those classes.

The mortality in the first 2 year-classes are assumed to be natural *(M)*, as they are too small for harvest. The mortality is very high after the 3rd year-class due to heavy fishing pressure. In a sample of 334 queen conch from St. James only two had reached the flared lip stage. The average mortality for the first 2 year-classes is 0.115. If this represents natural mortality for this area, then the fishing mortality *(F)* would equal 1.685. For the purposes of this paper and the yield-per-recruit analysis the natural mortality was considered to range 0.12. The total mortality rates for the Turtle Back Rock population ranged between 0.22 and 1.42 with an average of 0.79 (SD = 0.60).

Fishing mortality *(F)* was estimated by subtracting the estimate of *M* (0.115) from total mortality for the largest size class of the St. James population (1.800). Fishing mortality *(F)* was estimated at 1.69. At Turtle Back Rock fishing mortality was estimated at 0.67.

Yield-per-recruit was calculated after Ricker (1978) from the equation:

$$Y = FN_0e^{-Mr}W_\infty\left(\frac{1}{Z} - \frac{3e^{-Kr}}{Z+K} + \frac{3e^{-2Kr}}{Z+2K} - \frac{e^{-3Kr}}{Z+3K}\right) \qquad (7)$$

where: t_r = age at recruitment to the gear, t_0 = theoretical age at length "O", F = instantaneous rate of fishing mortality (assumed to range between 0 and 3.0 in the Virgin Islands), N_0 = hypothetical number of individuals that reach hypothetical age 0 annually (in this analysis $N_0 = 1$), M = instantaneous rate of natural mortality (assumed at 0.12 from the current study), W_∞ = asymptotic weight, K = growth coefficient from von Bertalanffy growth equation, $r = t_r - t_0$, Z = F + M and Y = yield in weight.

Parameters t_0 and K are derived from the von Bertalanffy (1938) growth equation (Berg, 1976), and W_∞ is estimated as the meat weight corresponding to the asympotic length based on a length-weight regression.

Figure 4 shows a yield isopleth diagram for *S. gigas*. Using an assumed natural mortality rate of M = 0.12, there is a sharp increase in yield at low fishing pressures. Thereafter, increases in yield are more gradual. When *F* is approximately equal to 0.8, the yield isopleths are nearly parallel, and the addition of additional fishing pressure for any given harvest size has little effect on the yield function.

The effect of increasing harvest size (T_r in the present discussion) at Virgin Islands fishing pressures also provides significant increases in available yield at values of T_r less than 3 years. After this age, increases in yield accumulated gradually until T_r is equal to 5 years when the yield function gradually decays.

These results indicate that at the most probable levels of fishing pressure maximum yield/recruit obtains at T_r between 3.0 and 5.1 years, or just during and after the time that the animals are becoming reproductive. At an earlier T_r of approximately 2 to 2.5 years, 87% of the maximum yield can still be harvested.

Table 3. Density of Queen Conch from predominant community types in the U.S. Virgin Islands

TERRAIN	COMMUNITY TYPE							
	ALGAL PLAIN		CORAL		SAND		GRASS	
Community	STT-STJ	STX	STT-STJ	STX	STT-STJ	STX	STT-STJ	STX
No. of Transects	36	27	22	19	21	14	23	12
Area Surveyed (Ha)	9.8	7.3	3.8	4.7	3.3	3.2	4.3	2.6
Density (conch/Ha)	9.31	10.15	10.58	7.79	9.31	5.76	6.47	2.40
Standard Deviation	9.65	8.88	10.34	6.24	6.32	4.20	7.37	3.17

Estimations of standing stock were made during 22 tows around St. Thomas-St. John and 22 around St. Croix (Fig. 1). Each different bottom type as it was passed over by the sled was called a transect. Therefore, each tow could have more than one transect. The average length of the tows was 1 nautical mile. The density of adult queen conch for the varying bottom types is shown in Table 3. The average weighted density for the St. Thomas shelf is 9.7 conch/ha and for St. Croix is 7.6 conch/ha.

Total standing stock was estimated by assuming that the abundance of the bottom types surveyed was representative of their abundance on the shelf.

Using the area surveyed of each bottom type as the basis for weighting for these standing stocks provided results similar to the Caribbean Fishery Management Council (1981) who estimated that on the Puerto Rico-Virgin Islands shelf that 20% of the shelf is hard bottom. In our sample 18% of the area sampled was coral. In St. Croix the shelf appears to have a higher percentage of hard bottom which was supported by our survey where 30% was coral.

In determining the standing stock of the shelf area these average densities were used. The shelf area around St. Thomas-St. John is 162,925 ha and 34,300 ha around St. Croix. The standing stock of *S. gigas* on the St. Thomas-St. John shelf is estimated at 1,580,372 individuals, and around St. Croix at 260,680 individuals. In order to determine MSY these adult conch were assumed to be an average of 5-year-olds. Using the natural mortality rates of $M = 0.115$ back calculations were made to give the number of recruits at 3.1 years of age where the maximum yield was shown to occur. This back calculation produced the numbers 1,966,313 individual recruits on the St. Thomas-St. John shelf and 324,340 individuals on the St. Croix shelf. Using the Beverton and Holt yield-per-recruit equation with these numbers of recruits as MSY in pounds of conch can be calculated. When recruiting conch into the fishery at approximately 3.1 years of age and if the fishing pressure is kept at a level of between $f = 1.5$ to $f = 2.0$, then the calculated MSY for the St. Thomas shelf is 364,000 pounds annually and for the St. Croix shelf MSY is 60,000 pounds.

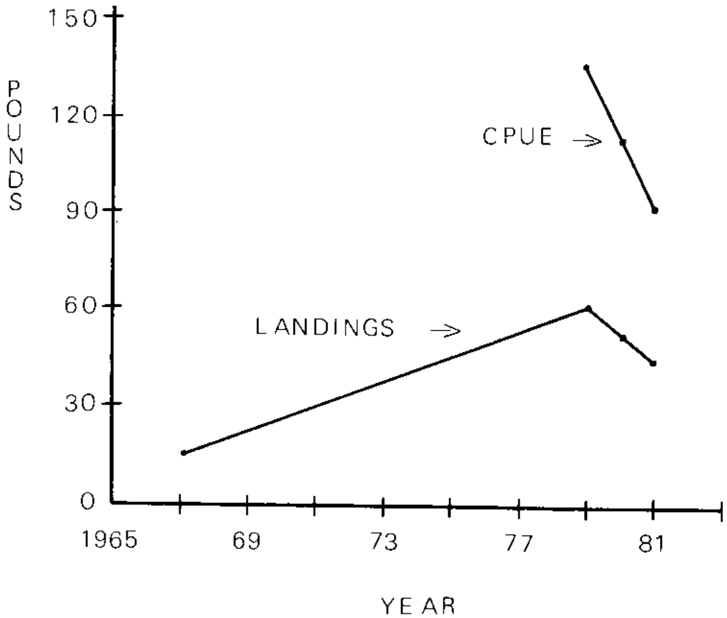


Figure 5. Landings and catch per unit effort (CPUE) for St. Croix, U.S.V.I. (Landings in thousands of lbs; CPUE is the average catch (pounds) per fishing trip).

Landings

On St. Croix where there is a directed fishery for *S. gigas* and most of the shelf is accessible by small boat the resource is highly exploited. In 1978-79 the conch catch in St. Croix was estimated at 59,000 pounds, or about equal to the MSY figure. The resources in St. Thomas are spread out over a deeper shelf area and although there appears to be a large harvestable resource, most of it is protected by deeper water and distance from shore. Figure 5 shows the landings and catch-per-unit effort for St. Croix over the past 3 years. Both the landings and the CPUE have been steadily decreasing, which could indicate that the fishery is being overexploited. Data limitations prevent more definitive statements.

SUMMARY AND DISCUSSION

The population dynamics of queen conch in the Virgin Islands suggest several directions for resource management. Analysis of size frequency distributions provide estimates of growth which are consistent with information throughout the literature. Estimates of fishery and natural mortality rates provide an estimate of $M = 0.115$. If natural mortality is underestimated, a revision of the yield/recruit analysis would suggest harvest at a smaller size in order to maximize yield/recruit. Additionally, the absolute value of the maximum yield would decrease. An alternate yield-per-recruit (at $M = 0.3$) would require harvest beginning with 2-year-old animals until age 3.5.

The current analysis suggests that maximum yield/recruit may be obtained by harvesting *S. gigas* at between 3 and 5 years of age. This coincides, unfortunately, with the onset of reproductivity.

Virgin Islands conch resources provide a model of the difficulty of managing this resource. Substantial reserves of conch are available in the deep waters of the shelf. In St. Croix the major portion of the shelf is shallow enough to allow exploitation of the resource. As a result, harvest has approached or exceeded sustainable yield for the last 3 years. Additionally, both total landings and catch-per-unit effort have declined during the last 3 years. In other words, there is every indication of a current need for some sort of regulatory management.

ACKNOWLEDGMENTS

The following project staff contributed to these studies: J. LaPlace, K. Turbe, L. McLain, W. Tobias, D. Olsen and K. Brown.

The preparation of this report was funded in part through financial assistance provided by the Commercial Fisheries and Development Act (PL 88-309) administered by the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

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