2002 Estimates of Abundance and Potential Yield for the Pedro Bank Queen Conch Population

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Introduction

This project reports on a field research survey to determine, primarily, the size of the Queen Conch (*Strombus gigas*) population(s) on the Pedro bank. The Pedro Bank (Figure 1) is an offshore bank located south of Jamaica and supports the countries most important queen conch fishery (Smikle, 1996).

The conch fishery on the Pedro Bank began to grow in importance only since the mid 1980's. However by 1990 a large industrial scale fishery had developed (Mahon *et al.*, 1992). Since that time Jamaica has been considered the top producer of conch in the Caribbean, with mean annual export figures of 2045 MT (Chakallal and Cochrane, 1996). The Fisheries Division of Jamaica, recognizing very early the importance of this fishery and the need for its sustainability, prompted and implemented measures designed to allow scientifically sound management. These measures were quickly adopted and supported by the Industry and other stakeholders. One important tool was the use of a quota management system based on knowledge of the total allowable sustainable yield of conch from the Pedro Banks (Aiken et al., 1999). To date, Total allowable catches have been based on abundance surveys of the conch stocks on the Pedro Bank.

This research survey is the third in a series to determine stock size and potential sustainable yields from the Pedro Bank. The details of the first and second surveys can be seen in Appeldoorn (1995), and Tewfik and Appeldoorn (1998) respectively. Results of the first survey showed that at the time the mean densities (0-10 m, 89.09 conch/ha; 10-20 m, 144.46 conch/ha; 20-30 m, 276.97 conch/ha) of conch were 10 to 100 times that reported from other conch fishing areas. From these results mean maximum sustainable yield (MSY) was estimated to range from 1398 – 1818 MT (Appeldoorn, 1995).

The second survey (November 1997) found mean densities of conch to be: 0-10 m, 316 conch/ha and 10-20 m, 513 conch/ha. The observations of mean densities although on the same order of magnitude as the previous survey and probably higher, showed that densities of adult normal and stoned conch had decreased more than 50% in the 10-20 m depth zone where the majority of the industrial fishery takes place (Tewfik and Appeldoorn, 1998). There was no information regarding the 20-30 m depth zone as it was not covered during the survey. The impact that conch from this latter zone may have on the fishery was therefore not fully appreciated. Subsequently, MSY was estimated at 1366 MT.

The TAC for the 1998/99 fishing season was set at 1366 MT. For the 1999/2000 season there was no harvesting of conch due to a court injunction. The following year 2000/2001 a TAC of 946 MT was set. This latter harvest limit was set at such a low level because of the uncertainty arising from the impact of IUU fishing on the Pedro Bank conch populations. It is chiefly for this reason that the need for another survey in such short order has arisen.

Objectives

The purpose of this study is to gather the most current information on the Pedro Bank conch population(s) while incorporating the findings of earlier studies, to determine appropriate management measures for the resource. The following objectives are to be addressed:

- Estimates of population densities (number/ha) and abundance (population size)
- Description of population structure (size/age)
- Estimates of maximum sustainable yields

Methods

The Pedro Bank is described in Munro and Thompson (1973). A brief review of the characteristics of the Bank may also be found in Tewfik and Appeldoorn (1998). Essentially the Pedro Bank is a large submarine plateau that is approximately 70 km southwest of Jamaica in the region between latitude 16°42'N and 17°39'N and longitude 77°19'W and 79°02'W. The bank has, for depths less than 50 m where the edge drops away rapidly, an area of 8040 km^2, a maximum length of 168 km, a maximum width of 83 km in the west, a circumference of 590 km and a mean depth of 24.5 m. Dolan (1972) while characterizing the topology and sediment type on the Pedro Bank identified three distinct habitat types: Shallow reefs with irregular profiles that coincide with the shallowest areas; Reef areas which have a more regular profile than shallow reefs and are characterized by sandy bottom with frequent isolated patch reefs, and; Sand blanket which composes two thirds of the bank and is made up of carbonate, biogenic, and sand detritus.

As in the first abundance survey of 1994 (Appeldoorn, 1995), the Pedro Bank was stratified in to four zones defined primarily by management considerations. The first stratum is the Artisanal zone. Depths in this zone are generally less than 10 m and include all the emergent areas on the bank. This zone, fished exclusively by artisanal fishermen through free-lung diving, has the longest history of fishing. The second stratum covering the region of 10-20 m in depth is the area of focus of the industrial conch fishing vessels. The third stratum is defined as the area with depths between 20 and 30 m and is the practical depth limit of the survey due to diver safety considerations. Areas deeper than 30 m constitute the fourth stratum and will not be assessed.

Given the priority of opening the fishing season as early as possible, the first of two survey trips to the Pedro Bank was conducted May 5-14, 2002. This first trip focused on surveying the conch population in the 10-20 m depth zone. A total of 36 sample sites were assessed in this stratum. Sites are same as those of 94 & 97 survey (Figure 1). A second trip was conducted December 6-9, 2002 and focused on surveying conch in the 20-30 m depth zone. Only a total of 9 stations were assessed (7 in the 20-30 m zone, 2 in the 10-20 m zone) before mechanical difficulties forced termination of the cruise.

The visual surveys were conducted from the leased motor fishing vessel the M/V G.C. Gorton, owned by Mr. Norman Ramcharan. In both cruises, the M/V G.C. Gorton was supported by a smaller craft. Each station was surveyed by a team of 3-4 divers. Divers swam 3 x 100 m transects in each of the cardinal directions. Four to nine transects were completed per site, depending on dive conditions and available dive time. An average of four sites was completed per day between two dive teams.

Conch counted within each transect were categorized according to 6 size/age groups (Table 1). Divers also noted habitat type and maximum water depth.

Estimates of conch density were based on mean number of conch encountered over all transects completed at a site and extrapolated to one hectare (ha=10,000 m^2) for all size / age categories as well as total conch and the exploited stock. The latter is defined as the sum of all conch excluding small and medium juveniles. Total abundances of conch were calculated by multiplying density (conch/ha) in a given zone or stratum by the total area of that zone. For the 10-20 m stratum, the area was 201,700 ha, for the 20-30 m stratum the area was 370,000 ha. Computations of densities were done within a spreadsheet program (Excel). Confidence limits (95%) for all estimates were calculated by the bootstrap method using custom made software.

For comparative purposes, data were summarized for catch and catch per unit effort in years after 1997. These were added to previously calculated values as reported in Tewfik and Appeldoorn (1998) and CFMC/CFRAMP (1999). Catch Per Unit Effort (CPUE) data were only available for the 2001 season, and were calculated as kg/diver•hour. Catch data were taken as reported in export documents. These were checked against CITES permit documents for consistency and potential adjustment due to variations meat loss related to the degree of processing (see Tewfik and Appeldoorn 1998).

Results

A total of 36 stations were surveyed in the 10-20 m stratum between 5 May and 14 May 2002 (Table 2). Depths ranged from 50 to 80 ft (mean = 64 ft). The substratum was predominately sandy, occasionally with some algal cover. A few sites consisted of a hard pavement and rubble. Density estimates are also given in Table 2. Station densities ranged from 18.5 to 1704 conch/ha for all age classes, with a stratum mean of 287 conch/ha. Overall, total density was largely driven by the density of juveniles, with the highest correlation found with medium juveniles ($r^2 = 0.87$) (Figure 2). Nevertheless, a significant correlation also existed between total density and exploitable stock density ($r^2 = 0.61$) (Figure 3). An interesting observation was that the station with the highest juvenile and total densities was unique in being characterized as having a pavement-rubble bottom.

In the nine stations surveyed between December 6 and December 9, depths ranged from 75 to 100 ft in the 20-30 m depth stratum and 52 and 60 ft in the 10 – 20 m stratum

(Table 2). The substratum was variable among stations, but the majority consisted primarily of rubble-sand or pavement. Station densities in the 20 – 30 m stratum ranged from 83 to 648 conch/ha for all age classes, with an average total density of 350 conch/ha.

Table 3 presents the mean density and abundance estimates by age class and the bootstrap calculated 95% confidence limits. Confidence limits were generally plus/minus the magnitude of the mean. The mean exploitable stock density in the 10-20 m stratum was 138 conch/ha with 95% confidence limits of 92 – 180 conch/ha. Note that the two stations from this stratum sampled in December were not included in this analysis. For the 20-30 m stratum, the mean exploitable stock density was 245 conch/ha.

Table 4 gives the annual exports of conch since the time of the last survey (1997). These are assumed to equal the overall catch. The low export value shown for 2000 most likely resulted from catch in 1999 as there was no fishing during 2000. The one value of CPUE was 30.6 kg/diver•hour. This was based on a total of only 12 trips associated with a single processor.

Discussion

The conch densities in the 10-20 m stratum on Pedro Bank show an apparent increase in the abundance of larger conch compared to 1997 (Figure 4), with the density of exploitable conch increasing from 88 (1997) to 138 (2002) conch/ha, although the confidence limits on these are large. Juvenile recruitment was not as large as seen in 1997, but is substantially greater than observed in 1994. While only three estimates of recruitment represent an extremely small sample, the cumulative data are beginning to indicate the range of recruitment variability, with the results of 1997 being at the extreme high end, thus suggesting that normally lower levels of recruitment might be expected. This will have important implications when estimating the potential productivity of the system.

Generally, stations showing large densities in the present survey were not the same as those for 1997, both for juveniles and adults. This indicates that recruitment year to year is indeed patchy, but that locations vary over time so that the whole of the area potentially benefits from recruitment over the long term. The temporal variability in the location of the adults indicates the spatially dynamic nature of conch movements. These have an important implication for both the fishery and the interpretation of survey results. These dynamics insure that the survey results can be interpreted as random samples, even though the sampling stations have been located in the same general area in each survey. They also indicate that areas are repopulated after fishing so that the stock can be viewed as spatially mixed, at least over moderate spatial and temporal scales. Indeed, the two stations (51 and 56) sample in both May and December showed marked reductions in density in the latter survey. As fishing was not occurring, the differences must arise from the combination of spatial and temporal variability, again reinforcing the idea that repeated samples can be treated randomly.

Similarly, there was no correlation among stations in the 20-30 m stratum comparing 1994 to 2002 (Figure 5). Comparing size/age distributions (Figure 6), the large abundance of stone conch originally seen in this stratum has been greatly reduced. This follows the trends observed in the 10-20 m stratum (Tewfik and Appeldoorn 1998, and this study) indicating substantial fishing has occurred in the areas sampled. However, in the deeper stratum, the biomass of stoned conch has largely been replaced by increased biomass among the other size/age classes, including juveniles. Exploitable biomass is, thus, little changed in this stratum. It is clear from the size/age class structure that the new biomass (replacing the stone conch) has recruited only recently, e.g., the substantial increase in large juveniles represents 3-yr-old conch. Given the temporal dynamics of the fishery on Pedro Bank, this suggests that the exploitable stock in this stratum first underwent an initial steep decline (during years of high fishing effort) followed by recovery during years of low fishing effort. This mimics trends observed in the 10-20 m stratum (see also below). Unknown is whether the proportion of total fishing effort applied to the deep stratum has been constant over the eight years between surveys and whether all of this stratum is being fished. Anecdotal information suggests that the 2002 survey represented areas primarily fished in the 20-30 m stratum, but the areas further to the east and especially west were not as heavily fished.

While the overall apparent increase in the density of larger, exploitable conch since 1997 (10-20 m stratum) is encouraging, its exact significance is difficult to fully understand due to confounding processes (variable recruitment versus variable exploitation), because it is not certain where on the bank harvesting is taking place, because there is missing CPUE data, and because the 20-30 m stratum, harboring the largest reserve of exploitable conch was not surveyed in 1997 and much of the western part of this stratum has not been sampled at all. Figure 7 depicts the dynamics of the fishery and stock over the past decade. Both CPUE and the estimates of exploitable stock density in the 10-20 m stratum show an early decline in stock abundance during a period of high fishing rate. Ideally, CPUE can act as an indicator of stock abundance. The remarkably good correlation evident between CPUE and exploitable stock over the three surveys indicates that CPUE potentially can be used as such an indicator. However, CPUE can be affected by other factors, particularly in this case the spatial distribution of fishing effort over the entire bank, which is unknown. In the figure, CPUE is seen to be leveling off by the 1996-97 fishing season despite the very high level of exploitation that occurred in the previous year. This could only be explained if there was extremely high juvenile recruitment in 1995 (not seen in the 1994 survey) or, conversely, if fishing effort expanded into deeper, previously unexploited areas. In the latter case, CPUE would no longer be proportional to stock size. Roughly, however, stock dynamics in the exploited areas of the 20-30 m zone are thought to parallel those of the 10-20 m stratum, so CPUE may still reflect stock size, although perhaps with added variability.

In more recent years the interpretation is limited by the lack of CPUE data that would otherwise fill in during years lacking survey information. The increase in abundance observed at the end of this period can be seen as a result of two processes. The first is the growth of the very large juvenile recruitment seen in 1997 into the exploitable stock.

This process is depicted in Figure 8. Tewfik and Appeldoorn (1998) calculated that such recruitment might result in an annual increase to the exploited stock of over 1,000 mt. The other notable process was the large reduction in fishing pressure that occurred during this time. In response to the large drop in the exploitable stock evident in the 1997 survey, quotas were decreased significantly, but additionally these quotas were not met and there was no fishing at all in 2000. Thus, this reduction in fishing allowed for greater survival of both existing adults and recruiting individuals.

Table 5 presents a calculation of the impact of fishing effort reduction. Since the 1997 survey, the average catch has been 916 mt. Over the past three years only, the catch has averaged only 587 mt, half the allowable catch under the proposed quotas and less than 25% of the catch rates earlier in the decade. In Table 5 the catch (weight) ***not*** taken is converted into an equivalent number of individuals and then to density based on the area of the 10-20 m stratum. This is compared with the gain in exploitable stock density within the same stratum observed over the period between the last two surveys. The unharvested conch stock is greater than the observed increase, indicating that if the conch fishery had remained open and the full quota met, the entire gain observed would have been taken and that a further decrease in the exploitable stock would have been found in the most recent survey. This further indicates that the very high recruitment seen in the 1997 survey would not have been sufficient to offset this decline. Indeed, without that high recruitment the expected decline under full fishing pressure would have been much greater.

The calculations in Table 5 cannot be used to set a quota for maximum sustainable yield, but they can be used to set limits on the harvest under the current conditions under which the fishery is operating. On the one hand, since the last survey the average harvest rate of approximately 900 mt was sufficient to result in an apparent increase in stock size. On the other hand, the quotas set over the same period (mean approximately 1200 mt) would have resulted in a loss. This would suggest that a quota of 900 mt might be appropriate depending on the long term rates of recruitment (i.e., are the high levels of juveniles observed in 1997 sufficiently frequent events). A more cautious approach would build a buffer into the quota by lowering it further, perhaps to 800 mt.

Two factors impact this calculation. First, there are substantial unknowns relative to the fishing (degree and variability in effort and location) in the 20-30 m stratum. On the one hand, from 1994 to 2002 there is little difference in exploitable stock. If this stock had stayed constant in all years over this period, there would be no impact on the calculations above (i.e., all variability could be ascribed to conch in the 10-20 m stratum). However, the more likely scenario was that the exploitable stock in the deep stratum was increasing in a manner somewhat parallel to that of the 10-20 m stratum. Lacking are estimates of how much of an increase occurred since 1997 and (equally important) over what area (%) of the deep stratum such an increase should be applied (i.e., the % of the stratum actually fished). The larger the increase and the larger the proportion of the stratum fished, the larger would be the productivity of the population above that indicated in the calculations of Table 5, and hence the higher the quota could be.

The second significant unknown in the Pedro Bank fishery is the degree of poaching that might be occurring. The above calculations should already account for poaching, as the observed increase in stock abundance between 1997 and 2002 occurred at whatever the level of poaching was. Thus, if poaching were eliminated, the quota could be increase by an equal amount, if this was known.

Recommendations

Data Collection

Catch per unit effort (kg/diver•hour) is a potentially important indicator of stock abundance that can be easy and cost effective to obtain with no additional requirements for data collection as these data are already routinely collected by ships' captains. CPUE could be used to track the performance of the fishery in years where no survey data exist and provide a more timely feedback on the response of the stock to exploitation. Equally important, a time series of CPUE, especially when standardized to estimates of stock abundance) will eventually provide confident estimates of maximum sustainable yield and harvest levels. Strong efforts should be made to obtain CPUE data both in the future and also for past years from log books. While estimates of CPUE can be obtained from a sampling of the available data (as opposed to complete reporting), samples should be both random and sufficiently large to be representative of fishing by different boats and across all areas of the bank. The location of fishing associated with this CPUE is important to record.

At present, the spatial distribution of the catch on Pedro Bank is unknown. Interpretation of stock variability and resulting allowable catch is strongly dependent upon the assumption of over what area fishing is occurring. Thus it is imperative to have data on the location of fishing effort. As above, sampling need not be comprehensive as long as it is representative of the distribution of true effort over space. While GPS technology can provide precise location of the mother vessel (this is sufficient relative to the distance traveled by the individual dive boats), data need not be collected with such precision if this is considered proprietary information by the captains. It would be sufficient to use a coarse grid system to divide the bank into squares, with recording of only the coordinates of the square being fished.

Placing observers on vessels would be useful to provide this information in the future, but more comprehensive data, and (most critically) past data, ought to be available from vessel log books.

Annual Harvest Level

Based on arguments presented in the Discussion, a quota of 800-900 mt is recommended. Future sampling surveys are recommended to check stock response under this quota. Regardless of the response of the population, an increase in the quota is not recommended until the data requirements of the fishery (as specified above) are being met on a routine basis, as this is the only way in which the dynamics of the stock and the fishery can be fully understood and correctly interpreted.

Poaching

Obviously, poaching can be stopped only with greater enforcement, and recommendations here are beyond the scope of stock assessment. However, two recommendations can be made with respect to data collection and stock assessment. What is first needed is an indication of the amount of effort, primarily number of boats and time on the bank. If it is more difficult to intercept illegal boats than to observe them (by other fishing vessels or aerial over-flights) efforts should be made to collect as much sighting data as possible. Secondly, it is recommended that the log books of any vessels caught poaching be confiscated to obtain the detailed data on magnitude and location of the catch.

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Table 1. Definition of size/age categories for queen conch.

Category	Description
Small juvenile	< 150 mm shell length
Medium juvenile	151-200 mm shell length
Large juvenile	> 200 mm shell length, but without flared shell lip
Subadult	Flared lip starting to grow, but not fully developed (lip < 4 mm thick)
Adult	Flared lip is fully formed, with minimal to moderate shell erosion
Stoned conch	Shell characterized by heavy to serious erosion and heavy fouling (coral, sponges, bryazoans, algae, etc.). Shell lip thick and worn.

List of Figures

Figure 1. Pedro Bank showing the location of sampling sites.

Figure 2. Relationship between the density (N/ha) of all conch and the density of medium juveniles in the 10-20 m stratum on Pedro Bank.

Figure 3. Relationship between the density (N/ha) of all conch and the density of the exploitable stock in the 10-20 m stratum on Pedro Bank.

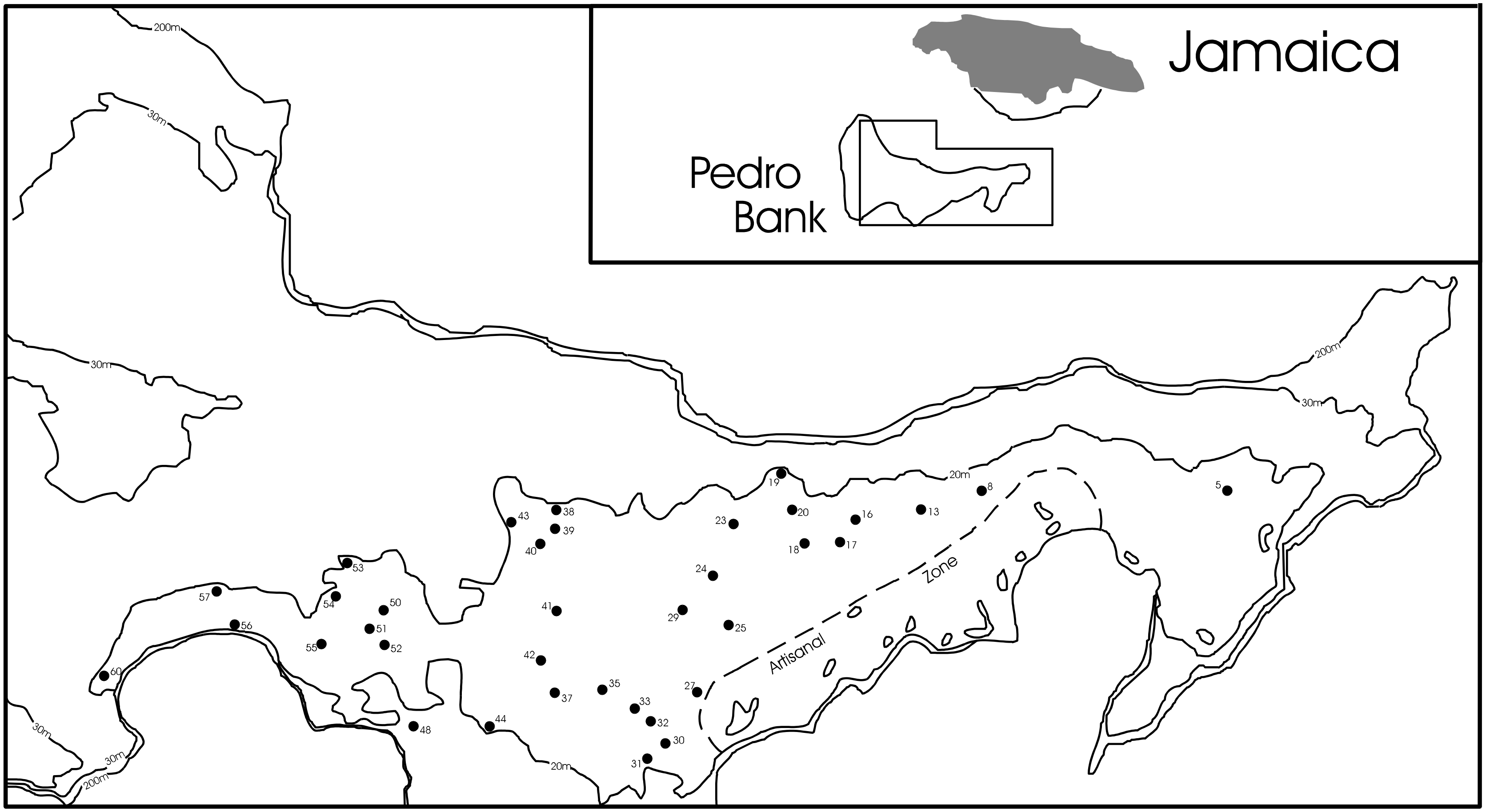
Figure 4. Density (N/ha) of conch by age-class in the 10-20 m stratum on Pedro Bank for 2001 (this study) as compared to densities in 1994 and 1997 as reported by Tewfik and Appeldoorn (1998).

Figure 5. Comparison of estimates of conch density (Number/ha) in the 20-30 m stratum between 1994 (from Appeldoorn 1995) and 2002 (this study) for seven stations sampled in both years.

Figure 6. Density (N/ha) of conch by age-class in the 20-30 m stratum on Pedro Bank for 2002 (this study) as compared to densities in 1994 as reported by Appeldoorn (1995).

Figure 7. Recent trends in the Pedro Bank conch fishery. Large solid circles are estimated exploitable stock density (N/ha) in the 10-20 m stratum. Thin horizontal bars above and below represent 95% confidence limits. Catch per unit effort (x's) (CPUE = kg/diver•hour) is scaled to stock density such that the line goes through the 1994 estimate of stock density. Thick horizontal bars represent the annual quota (mt/10), while the solid line represents reported annul exports (mt/10), which is equal to catch.

Figure 8. Shift in conch abundance (N/ha) across age classes over time. Density data are from Figure 4. Lines show the growth and recruitment of small age classes into the exploited stock. Sm, Me, L = small, medium and large juveniles, respectively. SA, N, S = Subadult, Normal Adult and Stoned, respectively.



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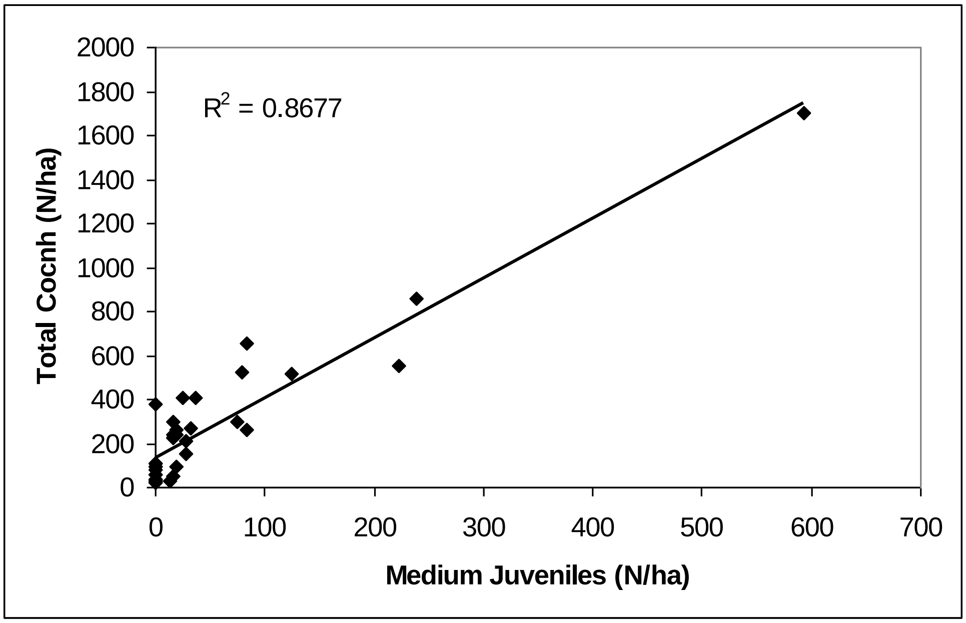

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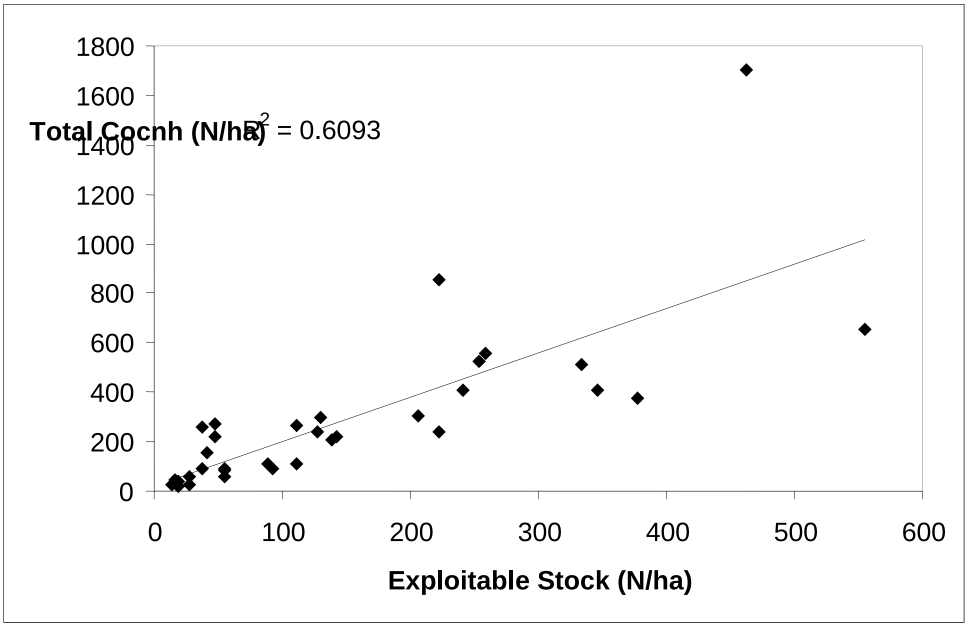

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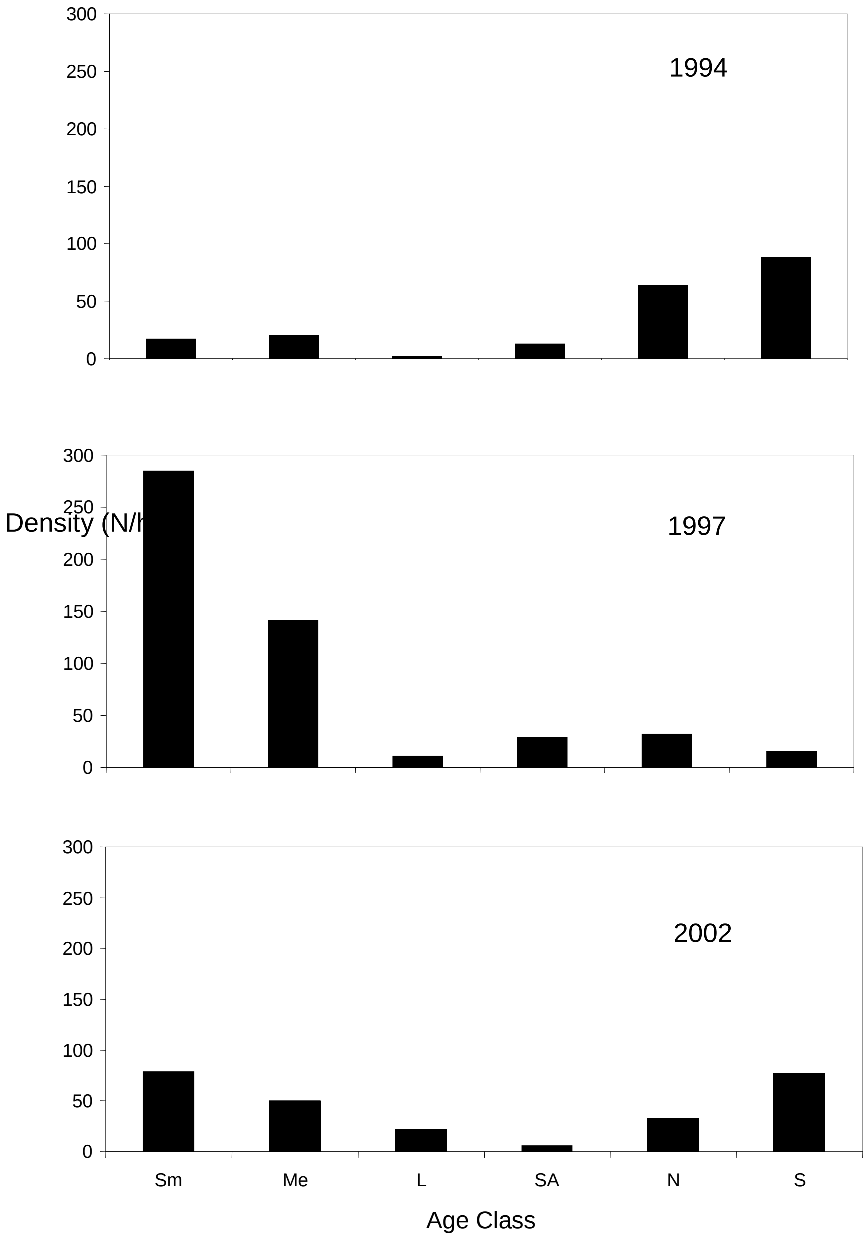

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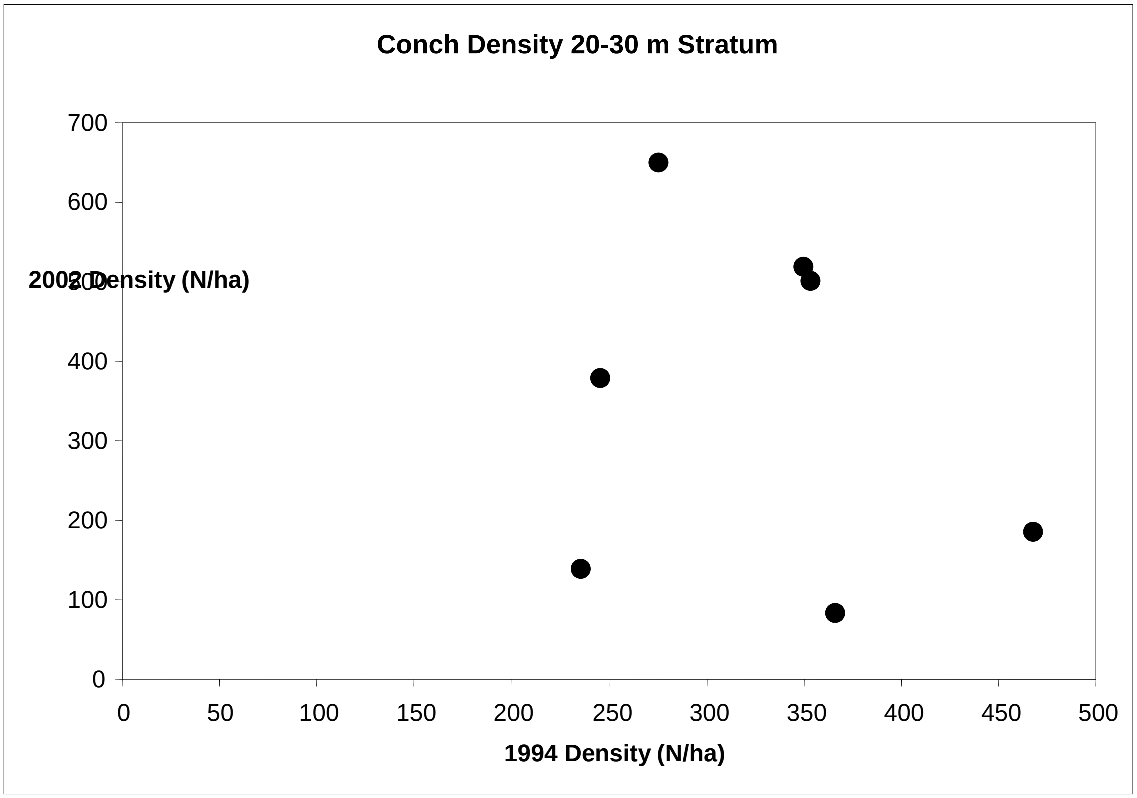

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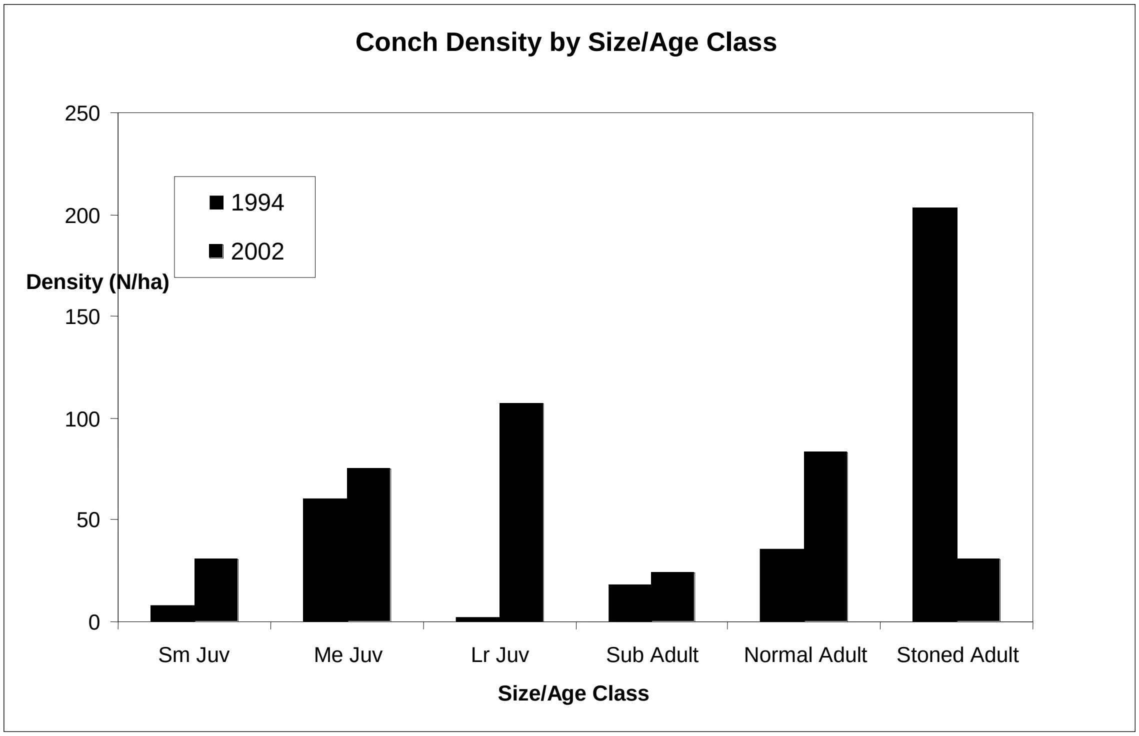

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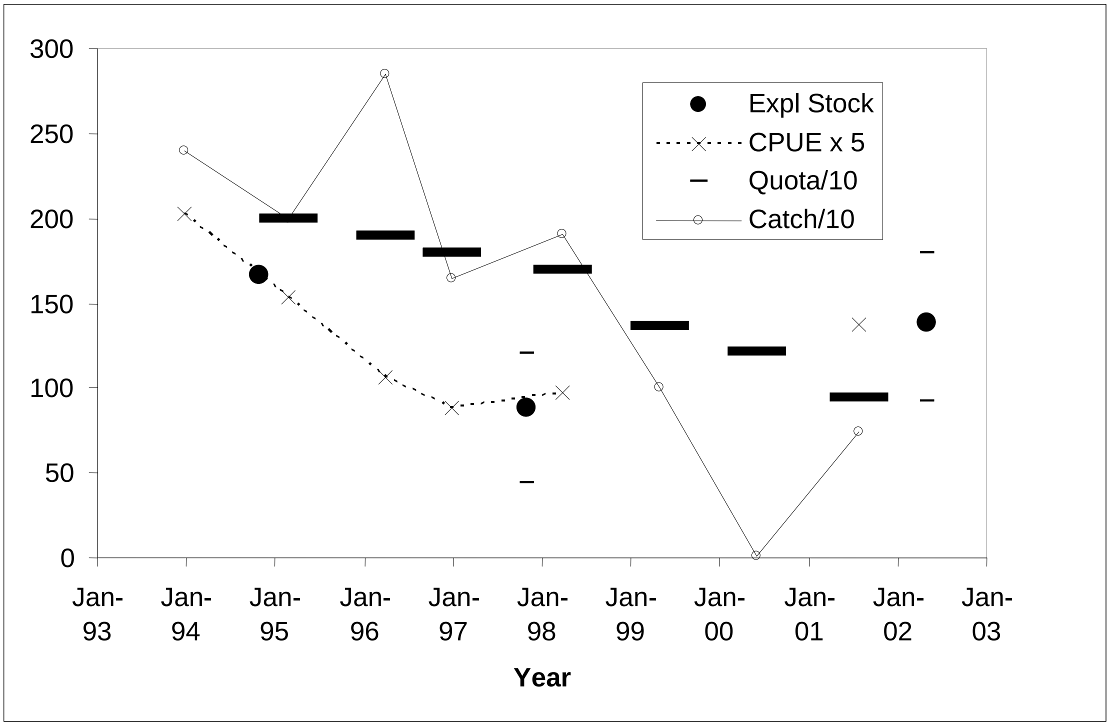

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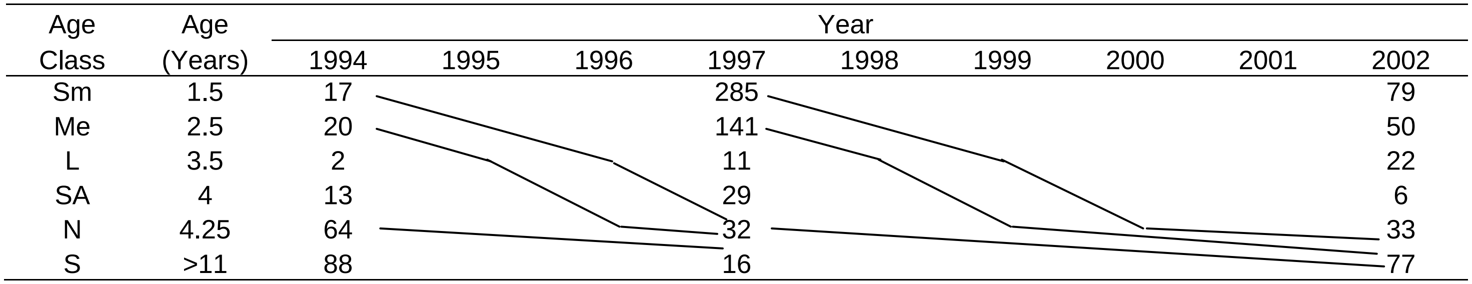

Age Class	Age (Years)	Year								
		1994	1995	1996	1997	1998	1999	2000	2001	2002
Sm	1.5	17			285					79
Me	2.5	20			141					50
L	3.5	2			11					22
SA	4	13			29					6
N	4.25	64			32					33
S	>11	88			16					77

Figure 8. Shift in conch abundance (N/ha) across age classes over time. Density data are from Figure 4. Lines show the growth and recruitment of small age classes into the exploited stock. Sm, Me, L = small, medium and large juveniles, respectively. SA, N, S = Subadult, Normal Adult and Stoned, respectively.