Domain (island) wide estimates of Queen conch (*Strombus gigas*) abundance for three US Caribbean Islands based on habitat-derived densities

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Background

Domain (island-wide) estimates of total queen conch abundance were calculated for Puerto Rico, and the Virgin Islands (St. Croix and St. John) based on visual census data collected by the National Oceanic and Administration Biogeography Team (NOAA BT). These estimates were calculated to determine the utility of independent fishery monitoring data in determining the fishery status of queen conch in the US Caribbean and were requested during the recent Southeast Data, Assessment, and Review (SEDAR 14) workshop held in St. Thomas during March 2007.

In 1999, scientists from NOAA's Biogeography Program (NOAA BT) initiated joint investigations with several partners to map, characterize, and monitor components of the coral reef ecosystem in the US Caribbean. Digital benthic maps of the marine waters around Puerto Rico and the US Virgin Islands were completed in 2001 and have been published on a CD-ROM and on the web at http://biogeo.nos.noaa.gov/. Since 2001, NOAA BT and its partners have used standard visual techniques to collect information on fish, queen conch and benthic composition at 3,200 randomly chosen locations. These data are available online at http://ccma.nos.noaa.gov/ecosystems/coralreef/reef_fish.html. Data on the presence, absence, and abundance of queen conch were collected at 1,571 survey locations between 2004 and 2006 and were pooled among years to derive domain-wide estimates of queen conch abundance in Puerto Rico and the Virgin Islands as requested during the SEDAR workshop.

Analytical Methods

Queen conch habitat preferences for particular habitats were first explored by analyzing the presence, absence, and abundance of sexually immature and mature queen conch in different habitats. Immature queen conch were those without a lip whereas mature or adult queen conch were those with a lip present. Geographic coordinates of point locations sampled by NOAA BT along with data on queen conch abundance were imported into ESRI ArcGIS© (Version 9.2). Attributes from the "descriptor" field of the NOAA benthic map, which had 21 classifications, were appended to the NOAA BT queen conch data set through a spatial overlay. The resulting data table was used to derive domain-wide estimates of queen conch abundance by each habitat weighted by area. Means ± standard errors (S.E.) for abundance of juvenile and adult queen conch were determined for each benthic habitat in which queen conch surveys were conducted. Data collection occurred over a three year period, and data were pooled among years to allow an adequate sample size ($n \geq 2$) to calculate means within each habitat type. The following equation was used to calculate total abundance estimates for each queen conch life stage:

$$\sum_{h=1}^{l} A_h \overline{X_h}$$

where *A* is the total area of each mapped habitat, *X bar* is the mean density (# of queen conch / m^2) in each habitat, and *l* is the total number of mapped habitats in each island. A sampling unit was a 25 m long by 4 m wide belt transect or a 100 m^2 area. Mean densities were derived from multiple surveys that occurred within each habitat type. A range of the total abundance was calculated with the equation:

$$\sum_{h=1}^{l} A_h \left(\overline{X_h} \pm S.E \right)$$

where S.E. is the standard error of the mean queen conch density in each mapped habitat in each island.

Results and Discussion

A total of 695 sexually immature and 262 mature queen conch were observed in the mapped near-shore waters of the US Caribbean between January 2004 and December 2006 (Tables 1-3). Of these conch, 38 immature, and only seven mature conch were observed among mapped benthic habitats in La Parguera, PR (Table 1). Queen conch were much more abundant in St. Croix and St. John, with a total of 729 and 190 individuals occurring in St. Croix and St. John respectively (Tables 2 and 3). Six queen conch were observed in habitats classified as unknown in La Parguera, PR and were excluded from subsequent analysis (Table 1).

In La Parguera, PR, queen conch did not vary significantly among the habitat classifications (Immature: $\chi^2 = 17.0$, df = 15, $P = 0.316$; Mature: $\chi^2 = 6.5$, df = 15, $P = 0.971$). In St. Croix, immature and adult queen conch varied significantly among the 16 habitat classifications, with higher abundance of immature conch in "patchy macro algae" and "continuous seagrass" compared with other habitats ($\chi^2 = 100.5$, df = 12, $P < 0.001$), and higher abundance of mature queen conch in continuous and patchy seagrass habitats ($\chi^2 = 69.7$ df = 12, $P < 0.001$, Figure 2). In St. John, immature conch were significantly more abundant in patch macro algae and continuous and patch seagrass habitats compared with other habitats ($\chi^2 = 65.6$, df = 17, $P < 0.001$). Mature conch were more abundant in patch macro algae, sand, and patchy seagrass habitats ($\chi^2 = 37.0$, df = 17, $P = 0.003$).

Estimates of total abundance of queen conch are given in Table 4. In Puerto Rico, the estimate ranged from 271,641 to 2,338,144 individuals with a mean of 1,304,893 queen conch. In St. Croix, total queen conch abundance ranged from 1,518,288 to 4,019,620 individuals with an estimate of 2,768,954 conch. In St. John, total queen conch abundance ranged from 65,596 to 419,743 individuals with an estimate of 242,669 conch. The large range in these estimates result from the variability in the occurrence of queen conch among different habitats (Figure 2).

It is important to note that survey sites were randomly allocated among two main benthic habitat strata (hardbottom and softbottom) rather than the 21 habitat classification scheme used in this analysis. This resulted in a few habitat classifications not being sampled because they were not selected during the sample allocation process (Tables 1-3). As such, queen conch presence or absence in those habitats cannot be ascertained, and therefore, such habitats were excluded when total queen conch abundance was being estimated. Additionally areas that were classified as unknown benthic habitats were not included when calculating domain-wide estimates, even though mutton snapper were observed in that habitat classification.

Estimates for Puerto Rico was determined from sampling that occurred in La Parguera, southwest Puerto Rico. Whether or not the variability in queen conch occurrence among benthic habitats in La Parguera is representative of the island of Puerto Rico is unknown. Similarly, in St. Croix, sampling occurred only along the northeast coast and around Buck Island, and it is unknown if the spatial distribution of queen conch in northeast St. Croix is representative of the entire island.

NOAA BT's random sampling design was optimized for monitoring reef fish populations rather than for queen conch sampling. Thus, power or variance analyses to determine the adequate sample size needed for estimating mean abundance of conch within habitats were not done. Additionally, no active searches were conducted for small or immature queen conch for example that may have been buried in the sand. Additionally, as shown in Table 3, only a very small part of each island (< 1%) was sampled. As such, it is likely that the total abundances derived here may be underestimates of the total queen conch population in the three US Caribbean Islands.

References

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Table 1 shows the area (ha) of benthic classifications calculated from the NOAA benthic map, the number of queen conch surveys, and conch abundance by life stage and benthic habitat for Puerto Rico. Sexually immature conch are those without a lip whereas, mature conch are those with a lip present. Dashes (-) indicate habitat classifications that were not sampled for conch.

Habitat descriptor	# of polygons	Area (ha)	# of surveys	# of individuals Immature	Mature	Total
Hardbottom/Reef Rubble	17	63.19	1	0	0	**0**
Macroalgae/Patchy/10-50%	84	9,228.12	6	0	0	**0**
Macroalgae/Patchy/50-90%	15	444.10	6	0	0	**0**
Mangrove	323	7,265.62	43	2	0	**2**
Mud	177	2,178.75	-	-	-	**-**
Reef/Colonized Bedrock	259	2,524.36	1	0	0	**0**
Reef/Colonized Pavement	270	17,394.17	53	1	1	**2**
Reef/Colonized Pavement with Channels	184	30,962.17	102	5	3	**8**
Reef/Linear Reef	498	7,291.08	39	0	0	**0**
Reef/Patch Reef (Aggregate	302	6,597.59	8	2	0	**2**
Reef/Patch Reef (Individual)	436	1,436.93	5	0	0	**0**
Reef/Scattered Coral-Rock	441	6,867.51	37	4	2	**6**
Reef/Spur and Groove Reef	5	45.28	-	-	-	**-**
Sand	157	2,600.48	30	7	0	**7**
Seagrass/Continuous	495	20,073.76	46	2	1	**3**
Seagrass/Patchy/10-30%	299	5,427.81	2	0	0	**0**
Seagrass/Patchy/30-50%	231	4,394.29	-	-	-	**-**
Seagrass/Patchy/50-70%	226	7,816.43	7	0	0	**0**
Seagrass/Patchy/70-90%	372	24,736.10	10	2	0	**2**
Unknown	81	334,316.81	42	6	0	**6**
Total	**4,872**	**491,664.54**	**438**	**31**	**7**	**38**

Table 2 shows the area (ha) of benthic classifications calculated from the NOAA benthic map, the number of queen conch surveys, and conch abundance by life stage and benthic habitat for St. Croix, US Virgin Islands. Sexually immature conch are those without a lip whereas, mature conch are those with a lip present. Dashes (-) indicate habitat classifications that were not sampled for conch.

Habitat descriptor	# of polygons	Area (ha)	# of surveys	# of individuals		
				Immature	Mature	Total
Hardbottom/Reef Rubble	7	15.56	4	0	0	**0**
Hardbottom/Uncolonized Bedrock	7	8.36	-	-	-	**-**
Hardbottom/Uncolonized Pavement	3	3.97	-	-	-	**-**
Macroalgae/Patchy/10-50%	10	1,268.32	-	-	-	**-**
Macroalgae/Patchy/50-90%	6	40.96	-	-	-	**-**
Mangrove	20	133.27	-	-	-	**-**
Mud	6	81.62	-	-	-	**-**
Reef/Colonized Bedrock	43	307.74	18	0	0	**0**
Reef/Colonized Pavement	211	8,173.19	190	59	37	**96**
Reef/Colonized Pavement with Channels	67	11,023.32	99	2	5	**7**
Reef/Linear Reef	160	1,195.32	24	0	1	**1**
Reef/Patch Reef (Aggregated)	62	611.05	41	1	1	**2**
Reef/Patch Reef (Individual)	18	23.43	-	-	-	**-**
Reef/Scattered Coral-Rock	151	1,973.89	63	3	11	**14**
Reef/Spur and Groove Reef	8	56.53	-	-	-	**-**
Sand	53	1,160.02	20	37	11	**48**
Seagrass/Continuous	93	1,317.39	43	250	66	**316**
Seagrass/Patchy/10-30%	66	829.09	37	37	17	**54**
Seagrass/Patchy/30-50%	59	1,243.35	16	21	26	**47**
Seagrass/Patchy/50-70%	55	1,577.80	18	28	4	**32**
Seagrass/Patchy/70-90%	65	969.72	51	92	20	**112**
Unknown	8	38,827.03	-	-	-	**-**
Total	**1,178**	**70,840.93**	**624**	**530**	**199**	**729**

Table 3 shows the area (ha) of benthic classifications calculated from the NOAA benthic map, the number of queen conch surveys, and conch abundance by life stage and benthic habitat for St. John, US Virgin Islands. Sexually immature conch are those without a lip whereas, mature conch are those with a lip present. Dashes (-) indicate habitat classifications that were not sampled for conch.

Habitat descriptor	# of polygons	Area (ha)	# of surveys	# of individuals Immature	Mature	Total
Hardbottom/Reef Rubble	13	12.94	1	0	0	**0**
Hardbottom/Uncolonized Bedrock	17	14.99	2	0	0	**0**
Macroalgae/Patchy/10-50%	9	859.47	45	8	14	**22**
Macroalgae/Patchy/50-90%	7	165.02	14	69	9	**78**
Mangrove	15	26.04	-	-	-	**-**
Midshelf Reef	2	257.23	106	0	0	**0**
Mud	1	2.05	-	-	-	**-**
Reef/Colonized Bedrock	69	285.39	20	0	0	**0**
Reef/Colonized Pavement	55	660.52	60	30	8	**38**
Reef/Colonized Pavement with Channels	29	526.18	55	0	0	**0**
Reef/Linear Reef	78	462.54	63	2	7	**9**
Reef/Patch Reef (Aggregated)	13	88.10	32	0	0	**0**
Reef/Patch Reef (Individual)	29	65.49	7	0	0	**0**
Reef/Scattered Coral-Rock	27	85.55	9	0	0	**0**
Sand	42	575.29	45	11	13	**24**
Seagrass/Continuous	42	203.16	9	8	0	**8**
Seagrass/Patchy/10-30%	20	94.09	5	1	1	**2**
Seagrass/Patchy/30-50%	20	118.51	10	2	0	**2**
Seagrass/Patchy/50-70%	23	120.02	12	1	1	**2**
Seagrass/Patchy/70-90%	19	74.67	11	2	3	**5**
Unknown	2	2.14	3	0	0	**0**
Total	**532**	**4,699.41**	**509**	**134**	**56**	**190**

Table 4 shows estimates of total queen conch abundance (number of individuals) by life stage for three US Caribbean islands.

| Island	Size of study area (ha)	% of area sampled	# of surveys	Life stage	Estimated abundance	Range of estimate		
Puerto Rico	157,348	< 0.01	394	Immature	1,100,248	236,943	-	1,963,553
				Mature	204,645	34,698	-	374,591
				Total	**1,304,893**	**271,641**	**-**	**2,338,144**
St. Croix	32,014	0.02	624	Immature	1,933,950	1,025,084	-	2,842,815
				Mature	835,005	493,204	-	1,176,805
				Total	**2,768,954**	**1,518,288**	**-**	**4,019,620**
St. John	4,697	0.11	505	Immature	169,838	39,019	-	300,656
				Mature	72,832	26,576	-	119,087
				Total	**242,669**	**65,596**	**-**	**419,743**
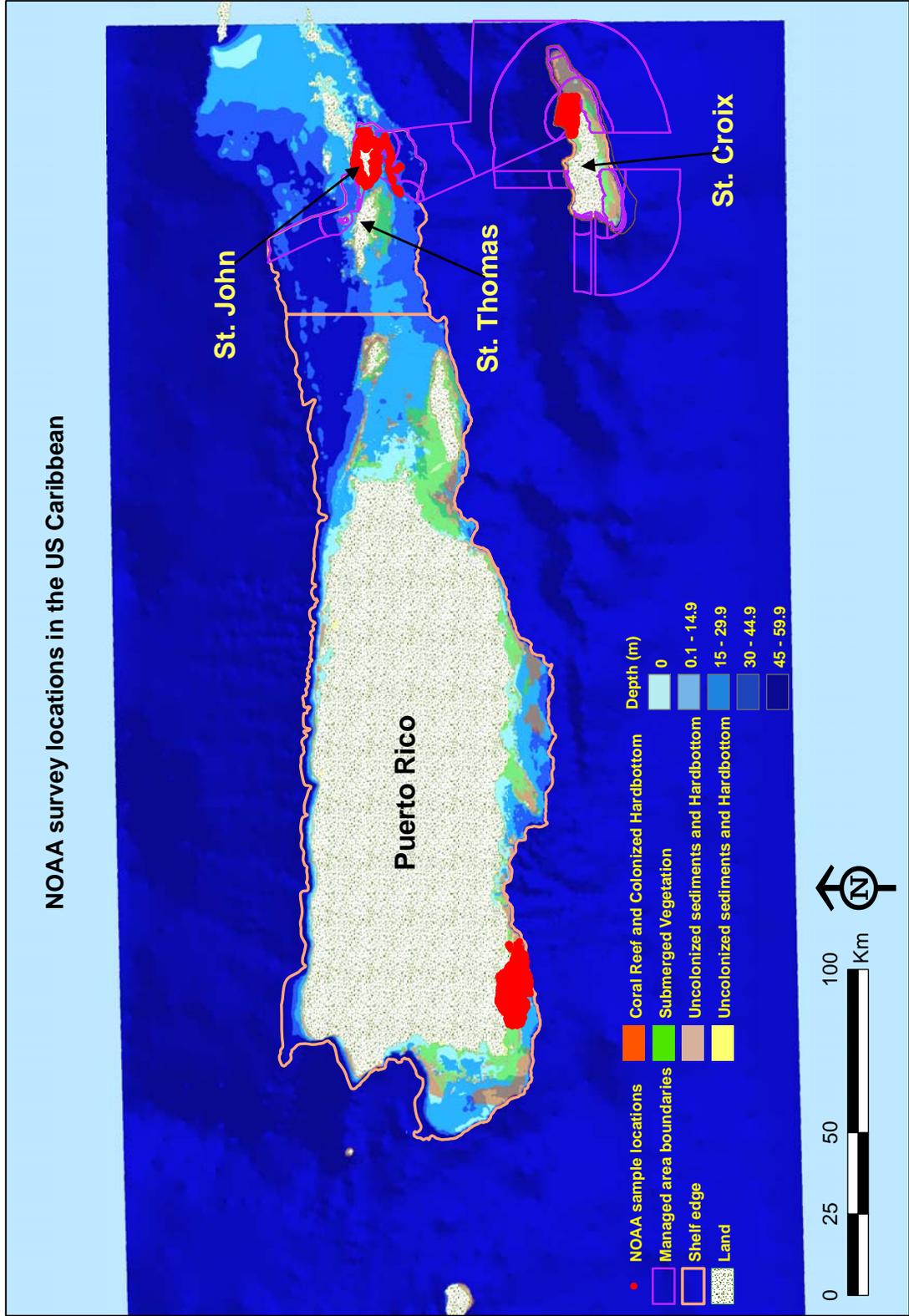
Figure 1. Map of locations where NOAA Biogeography Team conducted visual censuses for conch (*Strombus gigas*) and mutton snapper (*Lutjanus analis*) between 2001 and 2006.
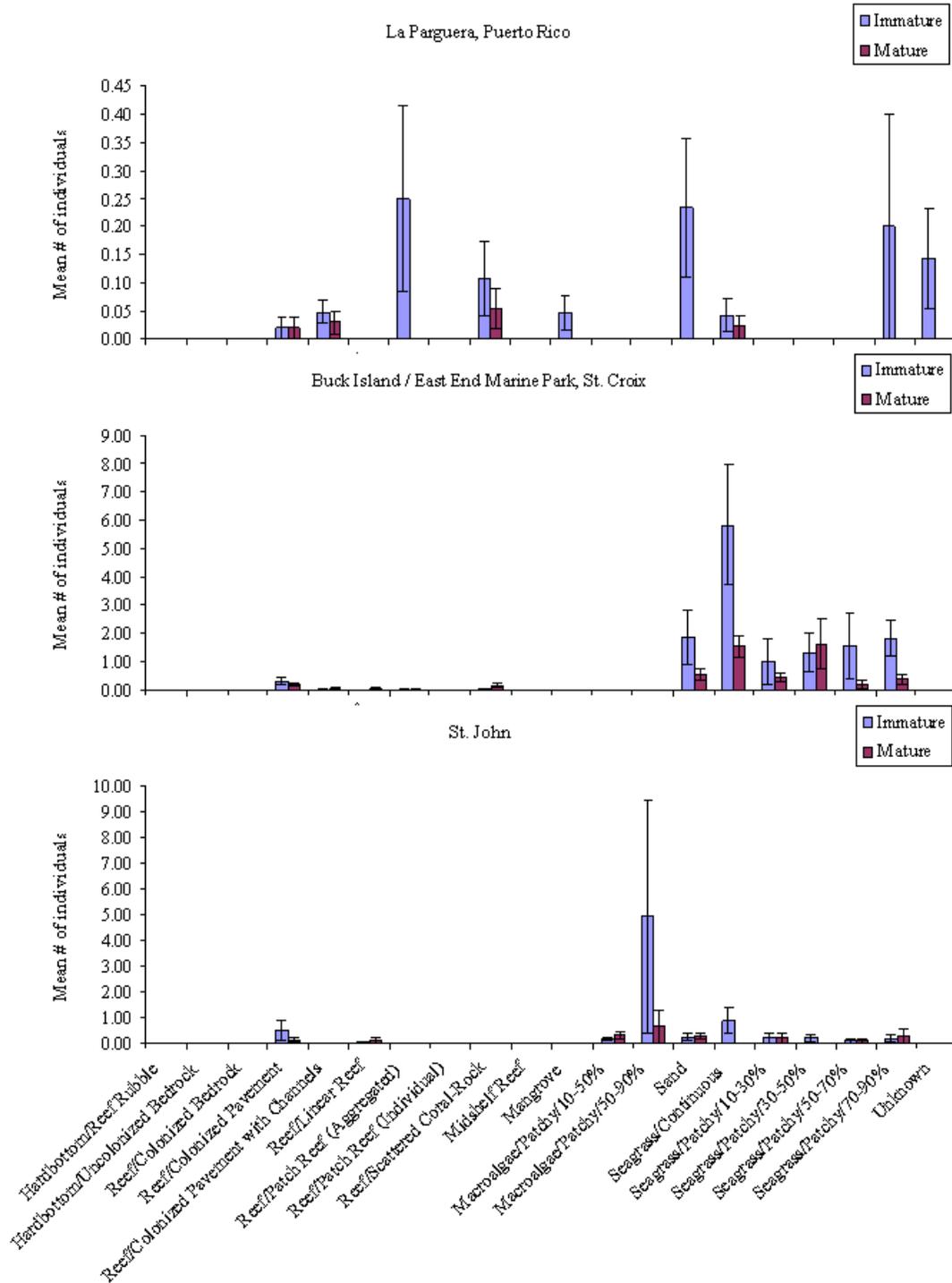
Figures 2 shows the variation in means and standard errors (S.E) for abundance of sexually
immature (juvenile) and mature (adult) queen conch among benthic habitats in three US
Caribbean islands (Puerto Rico, St. John, and St. Croix). Immature conch were those without a
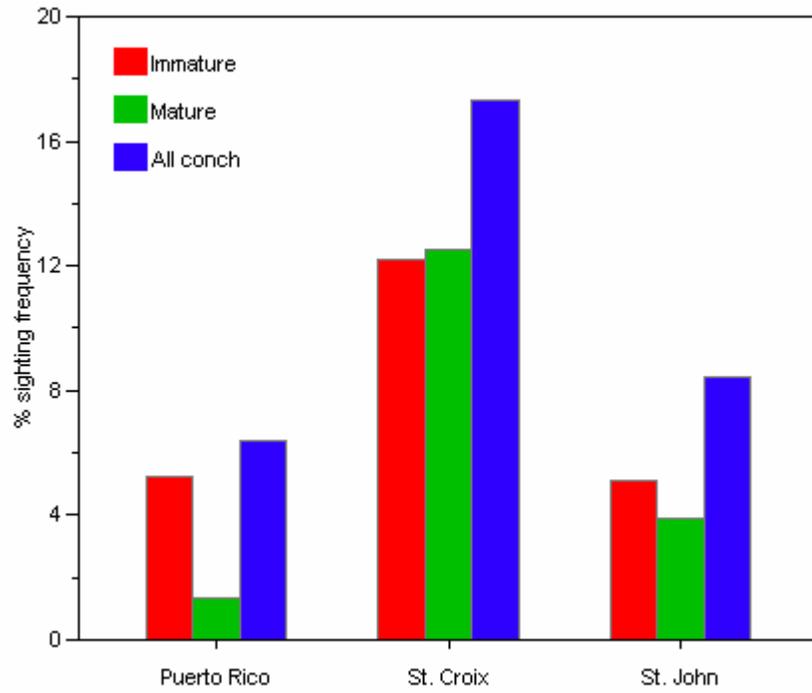lip; mature conch were those with a lip.

Figure 3 shows sighting frequency of sexually immature, mature, and all queen conch in three US Caribbean Islands. Sighting frequency was defined as the percentage of sampled sites where at least one immature or mature conch was observed.