Abundance and potential yield of spiny lobster (Panulirus argus) on the Little and Great Bahama Banks

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ABUNDANCE AND POTENTIAL YIELD OF SPINY LOBSTER (*PANULIRUS ARGUS*) ON THE LITTLE AND GREAT BAHAMA BANKS

Gregory B. Smith and Michiel van Nierop

ABSTRACT

Spiny lobsters (*Panulirus argus*) were surveyed at 227 stations on the Little Bahama Bank and Great Bahama Bank (northern one-half only) during June 1983–June 1984 using a random stratified sampling program incorporating visual (i.e., SCUBA) assessment techniques. This resources survey was part of a larger UNDP/FAO Fisheries Development Project (BHA/82/002) in the Bahamas. Mean density of spiny lobsters was 420 kg/km^2 and 287 kg/km^2 for Little Bahama Bank and Great Bahama Bank respectively. Based upon the yield equation MSY = 0.5(Y + MB), potential yield estimates ranged from 155 kg/km^2 for Great Bahama Bank to 257 kg/km^2 for Little Bahama Bank.

Present standing stock and potential yield estimates for spiny lobster are far higher than earlier predictions for the Bahamas and, in fact, compare favorably with those for other shelf areas within the tropical Western Atlantic region. Such findings largely refute earlier forecasts that fishery yields in the Bahamas would be relatively low due to reduced primary productivity in waters overlying the banks. Reported landings (1982) of spiny lobster on Little Bahama Bank are roughly 30% of the estimated annual potential yield; landings on Great Bahama Bank constitute only about 10% of the estimated potential yield. The highest densities of spiny lobsters were at rocky (rather than reef) stations along the north-central and eastern edges of Little Bahama Bank and northwestern portion of Great Bahama Bank.

The Government of the Bahamas, assisted by the United Nations Development Program (UNDP) and Food and Agriculture Organization (FAO) of the United Nations, inaugurated a Fishery Development Project (BHA/82/002) in December 1982. A major component of this Project was a Fishery Resources Survey initiated in March 1983 and completed during August 1984 (Smith and van Nierop, 1984).

The paramount objectives of the Resources Survey were to provide rough estimates of the abundance and potential annual yield for queen conch (*Strombus gigas*), spiny lobster (*Panulirus argus*), groupers (Serranidae), snappers (Lutjanidae), grunts (Haemulidae) and other fishery resources within the 18.3-m (60-feet) isobath on the Little and Great Bahama Banks. The data for spiny lobster constitute the basis of the present report.

Background Information.—Fisheries in the Bahamas are being developed at a rapid rate. Between 1975 and 1982, total fishery landings in the Bahamas increased from 4 million pounds to over 10 million pounds (Bahamas Fisheries Department data, Nassau). Presently, however, the fishery is almost exclusively restricted to spiny lobster, queen conch and, to a far lesser extent, a few species of groupers, snappers, grunts and jacks.

The usual method of estimating potential yield is through analysis of catch per unit effort data. Unfortunately, such data are generally lacking for Bahamian fisheries. Accordingly, most estimates of standing stock and/or potential yield have been based upon data from similar or related fisheries in the tropical Western Atlantic region (Gulland, 1971; Klima, 1976a; 1976b). A notable exception was a UNDP/FAO survey of deep-water fishery resources in the Bahamas (Gonzalez-Alberdi, 1975; Thompson, 1978).

Unfortunately, yield estimates based upon data from other areas are apt to be

Table 1. Description of biotopes (strata) delineated during UNDP/FAO Fishery Resources Survey BHA/82/002

Biotope	Description
Reef	This category includes a variety of reef morphologies (e.g., barrier, fringing and patch). Since these reef types represent a continuum in which each grades almost imperceptibly into the next, further discrimination would be difficult. Nevertheless, these reefs, although of varying relief, typically include the massive corals of the genera *Acropora, Montastrea, Diploria* and *Meandrina*. Although soft corals do occur, the reefs are largely dominated by the stony (scleractinian) corals, especially of the head-forming variety.
Rock	Variously colonized by small, solitary corals, soft corals, sponges, assorted benthic invertebrates and macroalgae, especially *Sargassum*. The rocky substrate may be locally covered with a veneer of sediment (giving the false impression of sandy bottom) and occasional patches of the seagrass *Thalassia*. In certain areas, the rock may be elevated relative to surrounding bottoms (commonly referred to as banks or bars). However, the lack of large boulder or plate-forming stony corals, the predominance of soft corals (sponges in certain locales) and low relief most noticeably identify this biotope. Dead, eroded coral reefs were classified as rocky bottom.
Vegetated	Bottoms covered with turtlegrass (*Thalassia*) on sediments of varying texture and thickness. Other seagrasses locally abundant may include shoal grass (*Haludole*) and manatee grass (*Syringodium*). Green macroalgae (especially *Caulerpa, Halimeda* and *Penecillus*) may also be of local importance. Soft corals and an occasional stony coral may occur spottily throughout the area, especially where small rocky patches interrupt the sediment.
Unvegetated	Mostly barren sediments varying in texture and thickness, ranging from calcareous rubble (near reef tracts) to calcareous muds (e.g., off the west coast of Andros Island) and sands. Rather unstable, shifting bottoms which inhibit the growth of epibiota.

highly biased since they fail to consider the individual, and often unique, characteristics of the Bahama Banks. Accordingly, the UNDP/FAO Fishery Resources Survey was specifically designed to improve earlier estimates by providing first-hand information on Bahamian fishery stocks. To this end, a random stratified sampling design which considered differences in the fishery productivities of major biotopes on the Bahama Banks was implemented.

Survey Design

Since potential yields of Bahamian fisheries could not be ascertained through catch per unit effort analysis, a fisheries survey was designed to provide biomass estimates from which rough approximations of potential yield could be extrapolated. Direct census of fishery resources by SCUBA divers swimming underwater transects was selected as the most feasible and expedient means by which to enact the Resources Survey. Census procedures generally followed methods prescribed by Brock (1954).

Table 2. Areas and relative importance of biotopes delineated on Little Bahama Bank (LBB) and the northern one-half of Great Bahama Bank (GBB) during UNDP/FAO Fishery Resources Survey BHA/82/002

Stratum	Area (km²)		Percent of shelf	
	LBB	GBB	LBB	GBB
Reef	324	983	2.2	2.1
Rock	3,256	5,804	21.7	12.4
Vegetated	8,821	28,450	58.7	60.6
Unvegetated	2,629	11,693	17.5	24.9
Total	15,030	46,931	100.1	100.0

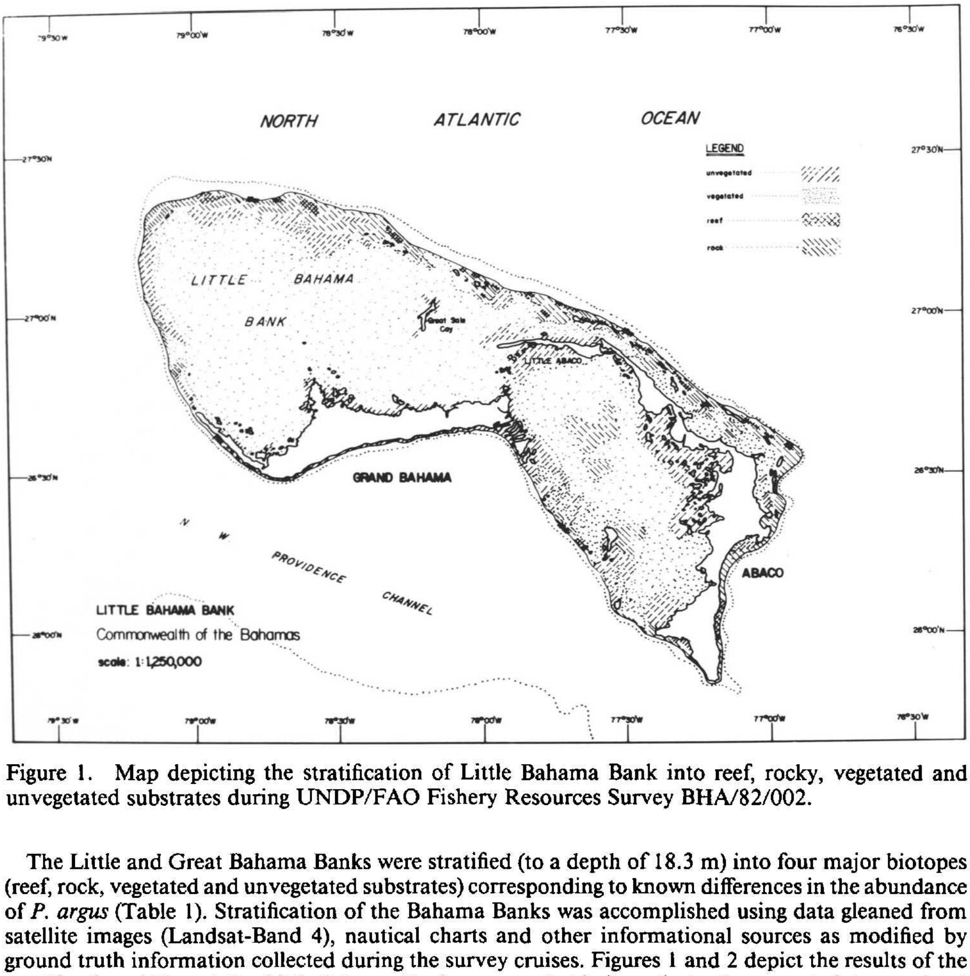

Figure 1. Map depicting the stratification of Little Bahama Bank into reef, rocky, vegetated and unvegetated substrates during UNDP/FAO Fishery Resources Survey BHA/82/002.

The Little and Great Bahama Banks were stratified (to a depth of 18.3 m) into four major biotopes (reef, rock, vegetated and unvegetated substrates) corresponding to known differences in the abundance of *P. argus* (Table 1). Stratification of the Bahama Banks was accomplished using data gleaned from satellite images (Landsat-Band 4), nautical charts and other informational sources as modified by ground truth information collected during the survey cruises. Figures 1 and 2 depict the results of the stratification. Although the Little Bahama Bank was sampled in its entirety, time constraints permitted sampling only the northern one-half (above 23°40'N latitude) of Great Bahama Bank. Absolute and relative areas of each stratum were determined by planimetry for both Little and Great Bahama Bank (Table 2).

A total of 67 stations was assigned to Little Bahama Bank; 160 stations were allocated to the northern one-half of Great Bahama Bank. For each bank, station density within a particular stratum was made roughly proportional to the product of its area and relative resource density (as determined from preliminary visual censuses) according to the methodology prescribed by Saville (1977). According to this convention, 39, 15, 10 and 3 stations were allocated to rocky, vegetated, reef and unvegetated strata, respectively, on Little Bahama Bank. Rocky, vegetated, reef and unvegetated strata in the surveyed portion of Great Bahama Bank received 69, 46, 36 and 9 stations respectively. Locations of all fishery stations appear in Figures 3 and 4.

It was impossible to discern seasonal changes in spiny lobster abundance during our study. Accordingly, computation of stratum means (numbers and biomass) is based upon the assumption that lobster abundance remained quasi-stable throughout the sampling period. Stratum means therefore represent simple (i.e., non-weighted) averages of the station data.

Population estimates for each stratum were combined to yield a stratified mean (i.e., weighted for relative areas of each stratum) according to Saville's (1977) formula:

$$\bar{x}_{st} = \sum \bar{x}_n \cdot \text{area (N)/total area.}$$

The stratified mean variance was derived from the relationship:

$$\text{var } \bar{x}_{st} = \sum \text{var } \bar{x}_n[\text{area (N)/total area}]^2.$$

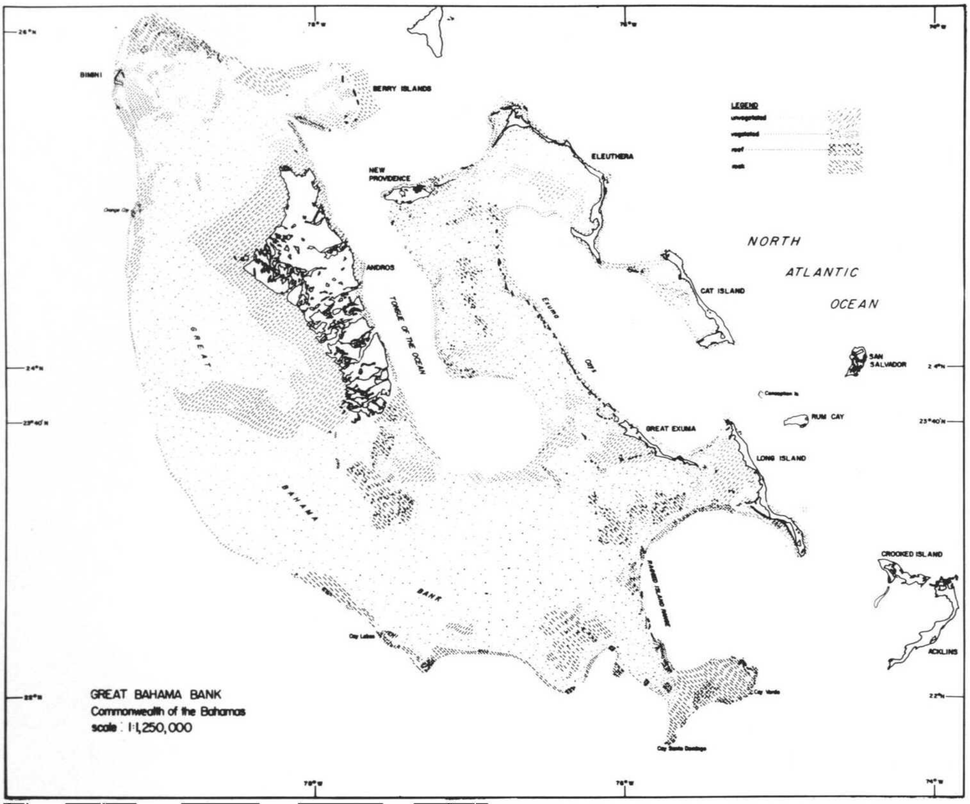

Figure 2. Map depicting the stratification of Great Bahama Bank into reef, rocky, vegetated and unvegetated substrates during UNDP/FAO Fishery Resources Survey BHA/82/002.

Minimum estimates of stock size for both Little and Great Bahama Bank were derived from areal expansion of the stratified mean number and biomass per station.

Station Randomization.—The Little and Great Bahama Banks were divided into grids (10′ latitude × 10′ longitude). Each grid was then mapped according to the strata contained within. The predetermined number of stations for each stratum was then randomly allocated to grids containing that stratum. Within grids, station locations were randomized over 1.0 microsecond loran-C coordinates. If, upon arriving at a preselected station, the appropriate bottom type was not encountered, a randomly selected compass course was steered until such bottom was detected.

Visual Assessment Methodology.—Visual assessment by SCUBA divers was determined to be the best method by which to survey fishery resources of the Bahama Banks. The method seems particularly appropriate for the clear waters and irregular hard bottom areas which characterize the banks. The advantages of visual transect methods for sampling reef faunas have been presented and discussed by Bardach (1959).

Spiny lobsters were counted and placed into estimated length intervals (10 cm TL) by SCUBA divers swimming along two 150-m-long (10-m-wide) transect lines laid along the seafloor at each station. Divers swam in tandem: one diver recorded resources in an imaginary 5-m-wide land alongside one side of the transect; the other diver performed similarly on the opposite side. Divers typically conducted their census 1.0–1.5 m above bottom but meticulously searched under reef ledges and other obstructions which would conceal lobsters. All data were recorded in situ on plastic slates upon which the length intervals had previously been inscribed. In this way, divers only had to make a single pencil stroke for each individual sighted.

Underwater Length Estimation.—Preparatory to the actual survey, divers were trained to rapidly and accurately estimate the size of spiny lobsters in situ. Using a population of artificial lobsters (i.e.,

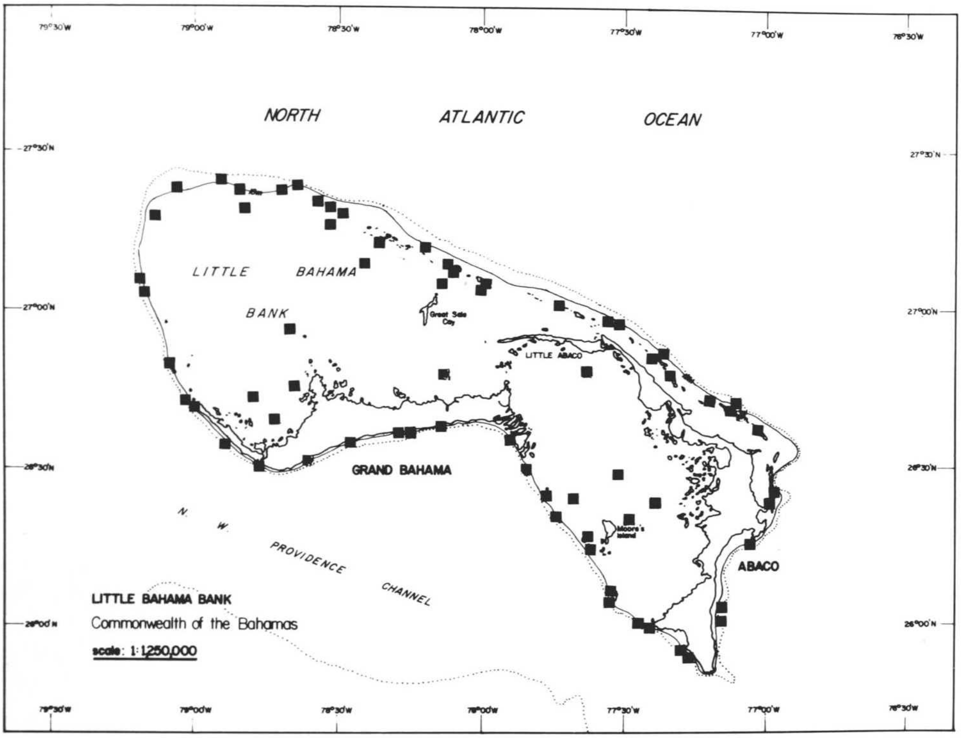

Figure 3. Location of UNDP/FAO Fishery Resources Survey stations on Little Bahama Bank.

plastic silhouettes), divers repeated a series of length estimation exercises underwater until their estimated length frequency distributions were no longer significantly different ($P = 0.95$) from the actual distributions when treated with the Kolmogorov-Smirnov test (Siegel, 1956).

To generate estimates of biomass, median lengths for each size interval were converted to weight using published length-weight relationships (Munro, 1983). Biomass estimates were then computed for each station to permit calculation of the stratified mean.

Potential Yield Estimates.—Maximum sustainable yield estimates were derived from the relationship $MSY = 0.5(Y + MB)$ where Y equals the annual yield, M equals the instantaneous natural mortality rate, and B is the biomass estimate (see Cadima, in Troadec, 1977). Instantaneous natural mortality (M) was estimated to be 1.03 after Munro's (1974) data on Jamaican stocks. Obviously, such a method provides only a rough estimate of potential yield which will make comparison with estimates from other areas more qualitative than quantitative. However, it is hoped that these estimates will provide the impetus for more refined potential yield estimates in the future.

Visual Census Efficiency.—Various field exercises were conducted to test the efficacy of the visual census technique. Briefly, spiny lobsters were visually censused over various substrates, then routed from their lairs with irritants (Nox-Fish rotenone or household bleach) to determine what proportion of each population had been sampled. As expected, census efficiency varied according to bottom type (65% for reef; 90% for rocky bottom and 100% for vegetated substrates).

Since census efficiency was 90–100% for all but the reef substrate and because the stratified mean would be little affected by the poorly represented reef stratum, abundance data were not adjusted to compensate for sampling bias. Accordingly, abundance estimates referred to in this paper are conservative and afford a "margin of safety" if data are to be used as a basis for fishery development and management. Also, data are more directly comparable to other studies which failed to consider this source of sampling bias.

Cruise Schedules.—A total of 20 cruises was conducted during the Fishery Resources Survey (Table 3). Nearly all cruises were effected aboard the R/V GUANAHANI, a 20-m diesel-powered Thompson Trawler belonging to the Bahamas Department of Fisheries.

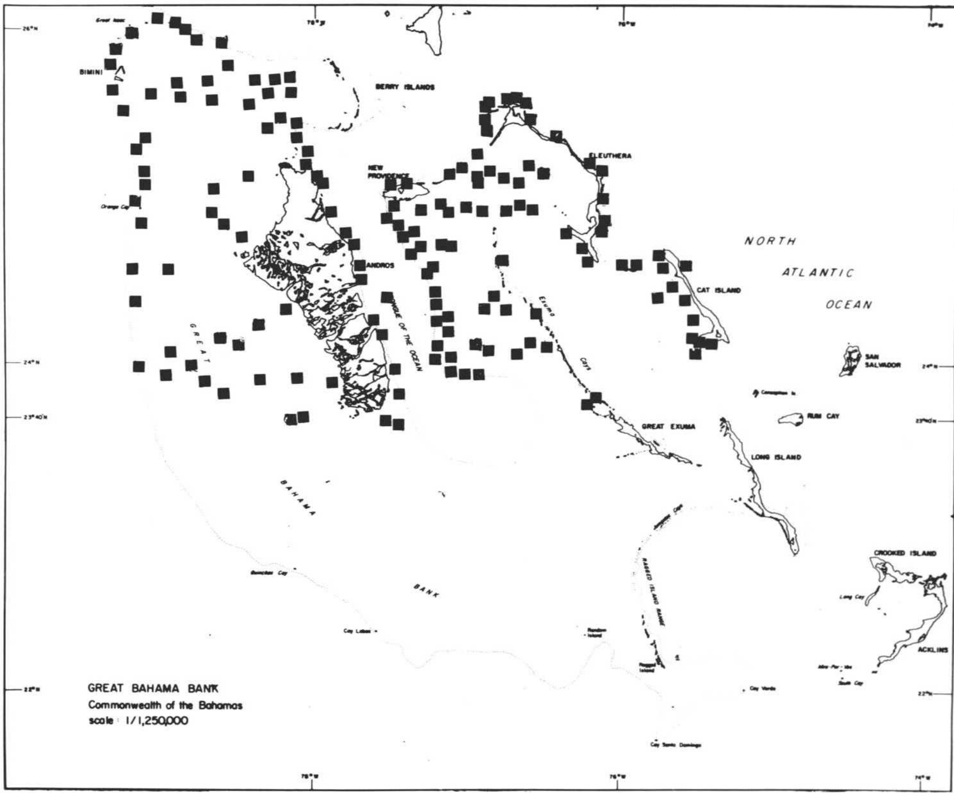

Figure 4. Location of UNDP/FAO Fishery Resources Survey stations on Great Bahama Bank.

Table 3. Inventory of UNDP/FAO Fishery Resource Survey cruises to Little Bahama Bank (LBB) and Great Bahama Bank (GBB).

Cruise No.	Duration	Area
83-001	6 June 1983	GBB
83-002	7 June 1983	GBB
83-003	9 June 1983	GBB
83-004	13 June 1983	GBB
83-005	14–16 June 1983	GBB
83-006	22 June–2 July 1983	LBB
83-007	13–22 July 1983	LBB
83-008	9–19 August 1983	LBB
83-009	30 August–6 September 1983	GBB
83-010	13–19 September 1983	GBB
83-011	18–19 November 1983	GBB
84-001	2–5 March 1984	GBB
84-002	14–15 March 1984	GBB
84-003	22–25 March 1984	GBB
84-004	6–11 April 1984	GBB
84-005	17–23 April 1984	GBB
84-006	1–8 May 1984	GBB
84-007	14–21 May 1984	GBB
84-008	4–9 June 1984	GBB
84-009	14–20 June 1984	GBB

Table 4. Stratum means and stratified means for numbers and biomass of spiny lobster (*Panulirus argus*) on Little Bahama Bank (LBB) and Great Bahama Bank (GBB) (Standard error of the mean within parentheses)

Stratum	Stratum mean*		Stratified mean*	
	Numbers	Biomass (kg)	Numbers	Biomass (kg)
Reef				
LBB	1.1 (0.5)	1.5	1.5 (0.7)	1.3
GBB	2.5 (0.9)	2.5	1.5 (0.9)	0.9
Rock				
LBB	3.0 (1.5)	4.2		
GBB	2.8 (1.1)	2.5		
Vegetated				
LBB	1.5 (1.0)	0.5		
GBB	1.8 (1.4)	0.8		
Unvegetated				
LBB	0.0 (0.0)	0.0		
GBB	0.0 (0.0)	0.0		

* Per station (=3,000 m^2).

Results

Table 4 presents the stratum means (numbers and biomass) and stratified means for spiny lobsters on Little Bahama and Great Bahama Banks. Based upon areal expansion of these stratified means, the mean density of spiny lobsters was 420 kg/km^2 for Little Bahama Bank and 287 kg/km^2 for Great Bahama Bank.

Based upon the biomass estimates above, 1982 reported landing data (Bahamas Fisheries Department data, Nassau), and a mortality estimate of 1.03 (Munro, 1974), the potential yield [from MSY = 0.5(Y + MB)] is 257 kg/km^2 for Little Bahama Bank and 155 kg/km^2 for Great Bahama Bank.

Fishing mortality (F) for spiny lobster on Little Bahama Bank is 0.19 (from Y/B) based upon 1982 landing data. Total instantaneous mortality (Z) can then be calculated at 1.24(F + M), a value consistent with Waugh's (1980) estimate of Z = 1.28 for spiny lobster stocks of West End, Grand Bahama Island. This correspondence gives credence to our potential yield estimates.

Spiny lobsters were most common (per unit area) over reef and rocky bottoms on both banks (Table 4). As indicated by the low mean weight, spiny lobsters distributed over vegetated bottoms consisted mainly of juveniles and preadults.

Station densities for spiny lobsters were greatest along the north-central and eastern edges of Little Bahama Bank and northwestern portion of Great Bahama Bank (Figs. 5 and 6).

Discussion

Standing stock and potential yield estimates for the Bahama Banks compare favorably with other spiny lobster fisheries throughout the tropical Western Atlantic region (Table 5). In fact, it appears that the Bahamian fishery may be second only to that of south Florida in terms of potential yield per unit area.

Earlier estimates of the potential yield of spiny lobster in the Bahamas ranged from an equivalent of 11.8 kg/km^2 to 60.0 kg/km^2 (Smith, unpubl.; Fisheries Development Limited, 1981). Obviously, these estimates greatly underestimated potential yield for at least Little Bahama Bank where recent (1982) reported yields exceeded 80.0 kg/km^2 (Bahamas Fisheries Department data, Nassau).

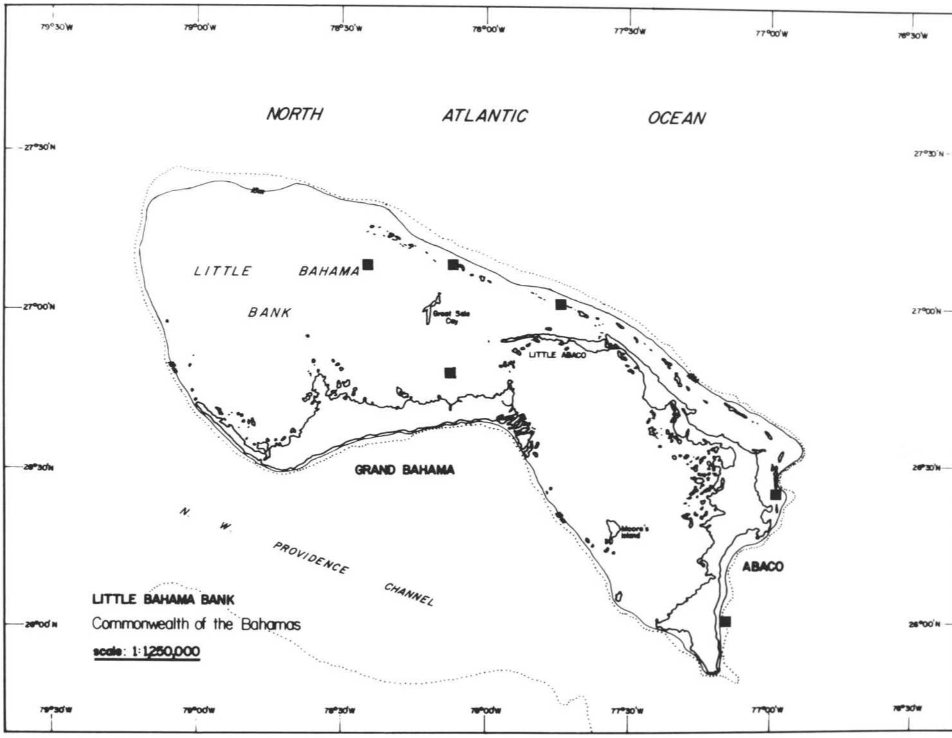

Figure 5. Stations with the highest densities (>6 individuals) of spiny lobsters on Little Bahama Bank during UNDP/FAO Fishery Resources Survey BHA/82/002.

Present estimates suggesting high potential yields for Bahamian lobster stocks appear totally conceivable in the context of the south Florida fishery where reported landings alone are in excess of 371 kg/km^2 (Centaur Associates, 1982).

Bahamian lobster stocks are presently underexploited. Reported landings (1982) on Little Bahama and Great Bahama Bank represent only about 32% and 9%, respectively, of conservatively estimated potential yields. The potential yield approximations are regarded conservative since (1) not all lobsters caught are included in the reported landings and (2) resource survey divers underestimated lobsters at rocky and, especially, reef stations.

If one refers to Beverton and Holt's (1966) tables of yield functions assuming $M = 1.03$ (from Munro, 1983), $K = 0.21$ (from Munro, 1983), $c = 0.46$ (minimum legal size/asymptotic length), and $F = 0.19$ for Little Bahama Bank and 0.05 for Great Bahama Bank (from Y/B and data in Table 5), present yields on Little and Great Bahama Bank could be increased nearly 400% and 1,000%, respectively, when moving to Ymax. These estimates complement those based upon the yield equation $MSY = 0.5(Y + MB)$.

One explanation for the high abundance of spiny lobsters on the Bahama Banks might be the high proportion of vegetated substrate (Table 2) which serves as important nursery areas for juvenile and preadult populations. This habitat accounts for roughly 60% and 70%, respectively, of the total number of spiny lobster on the Little Bahama Bank and Great Bahama Bank (from data in Tables 2 and 4) and as such represents an important source of recruitment to the fishery. Similarly, Munro (1974) has established that shallow-water rocky bottoms and

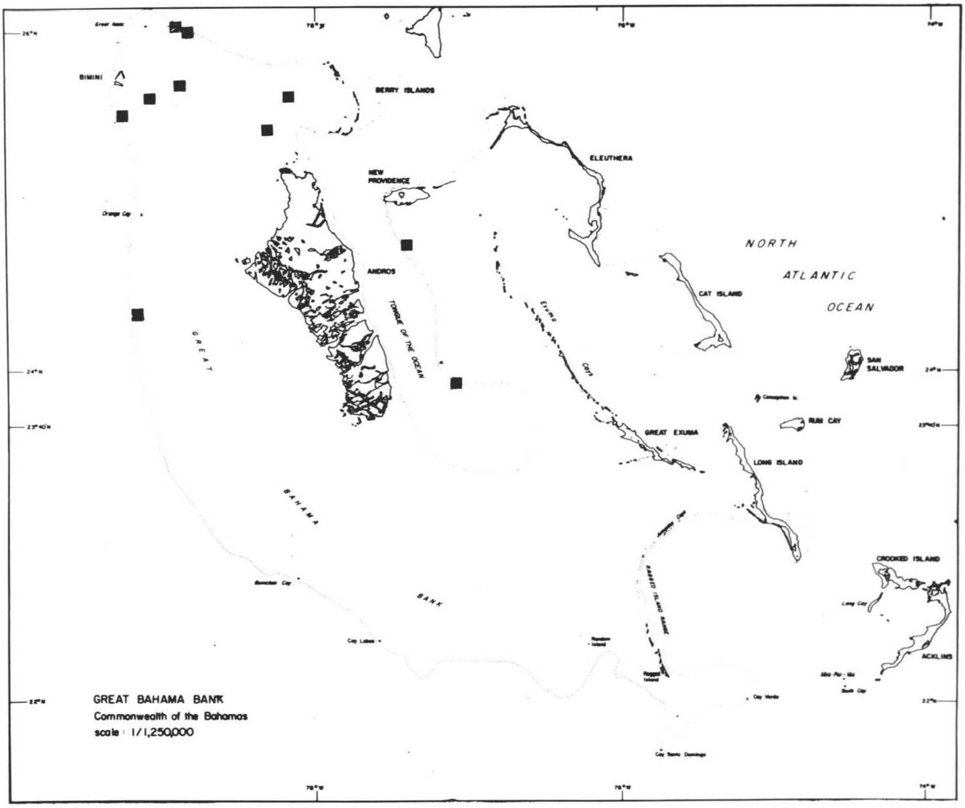

Figure 6. Stations with the highest densities (>6 individuals) of spiny lobsters on Great Bahama Bank during UNDP/FAO Fishery Resources Survey BHA/82/002.

Table 5. Comparative data for spiny lobster (*Panulirus argus*) fisheries in the tropical Western Atlantic region

Area	Density (kg/km²)	Potential yield (kg/km²)	Actual yield (kg/km²)	Reference*
Little Bahama	420	257	81 (1982)	1
Great Bahama	287	155	14 (1982)	1
South Florida	—	890	371†	2
Dry Tortugas	583	—	—	3
Barbuda Lagoon	83–158	—	—	4
Honduras/ Nicarauga	—	25–39	—	5
Belize	—	—	28–38	6
Puerto Rico	—	—	99 (1976)	6
Cuba	252	—	—	7
Turks/Caicos	—	36	—	8
Jamaica	—	—	86 (1968)	9
Los Roques	—	—	88	10

* 1 = present study; 2 = Fishery Management Plan, 1982; 3 = Davis, 1977 in Fisheries Development Limited, 1981; 4 = Peacock (cited by Munro, 1974); 5 = Yesaki and Guidicelli, 1971; 6 = Western Atlantic Fishery Commission, 1978; 7 = Buesa Mas, 1965; 8 = Simon, 1983; 9 = Munro, 1974; 10 = Cabo de Barany et al., 1972.

† Actual yield may be twice this figure if estimated unreported landings are considered.

turtlegrass (*Thalassia*) beds are important habitats for juvenile spiny lobsters. The south Florida shelf is also characterized by vast *Thalassia* meadows (Tabb and Manning, 1961; Turney and Perkins, 1972) and concomitant high yields of spiny lobster.

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