The Decline of the Sea Urchin, *Tripneustes ventricosus,* Fishery of Barbados: A Survey of Fishermen and Consumers

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ABSTRACT—For over a century, Barbadians have fished the sea urchin, Tripneustes ventricosus, *for its roe which they consider a traditional delicacy. However, the abundance of these sea urchins has declined drastically in recent years resulting in the collapse of this fishery. Interviews with sea urchin fishermen and consumers document this decline and its socioeconomic impact.*

The depopulation of T. ventricosus *occurred along the south and southeast coasts of Barbados in the late 1970's and along the east coast in the early 1980's. Prior to this decline, sea urchins were intensively harvested: Average catches exceeded 1,000 sea urchins per person per day during the height of the fishing season, providing an average income of nearly $400 Bds (or US $200) per person per week. At present, sea urchins are rare to absent on traditional fishing grounds, and although their market value has increased substantially ($25-45 Bds/liter in 1985), there has been a major loss of employment and income from this fishery.*

Overfishing appears to be a major cause of the decline of T. ventricosus. *A government-imposed closed season during the peak breeding period of these sea urchins (between May and August) is not enforced and generally unheeded. Pollution may have contributed to the decline through the deterioration of natural habitats, particularly the seaweed and seagrass beds upon which these sea urchins depend for food and shelter.*

Recovery of populations of T. ventricosus *is contingent upon recruitment via planktonic larvae; however, little is known about the mechanisms of recruitment and the ecology of the early life history stages. Artificial enhancement of recruitment, by seeding natural habitats with laboratory cultured juveniles, is a potential means of rehabilitating the sea urchin fishery.*

Introduction

Sea urchins are harvested for their gonads, which are a highly prized delicacy in parts of Asia, the Mediterranean, and the Caribbean. Worldwide, the sea urchin fishery is the most important of all of the echinoderm fisheries, with reported landings of 47,560 metric tons (t) (live weight) in 1982 (Sloan, 1985). In addition, artisanal sea urchin fisheries along the coasts of many tropical countries go largely unrecorded. These fisheries make important contributions to local economies, and some may have the potential to be expanded to meet certain export markets. At present, Japan is the greatest consumer of sea urchin roe, importing it from at least 13 countries (Sloan, 1985).

In Barbados, West Indies, a local but economically important fishery for the sea urchin *Tripneustes ventricosus* has existed for more than a century. Barbadians consider the gonads of both sexes a delicacy and large numbers of these "sea eggs" have been fished each year and sold as food. Since 1879, the Barbados Government has imposed a closed season for the fishery from May to August, the peak of the breeding season (Lewis, 1958), in an effort to conserve it (Bair, 1962). However, the abundance of these sea urchins in Barbados has declined dramatically over the past decade, and the fishery has virtually collapsed.

In this study we document the recent decline of the Barbados sea urchin fishery and its socioeconomic impact by interviewing both fishermen and consumers. Since landings are not recorded and quantitative records of sea urchin abundance in Barbados do not exist, this is the only means of obtaining such information. Moreover, these interviews provide a basis for assessing the cause and consequences of the decline, and the potential for rehabilitation of the fishery.

Methods

Fishermen Interviews

We interviewed 40 sea urchin fishermen using a prepared questionnaire (copies available from the first author). The questionnaire was divided into three parts: 1) Personal information and fishing and marketing practices, 2) questions pertaining to the decline in the fishery, and 3) questions pertaining to the cause of the decline and the potential for rehabilitation. The interviewees ranged in age from 21 to 77 years ($\bar{X}$ = 43 years). The majority were veteran fishermen—37 (52 percent) had fished sea urchins for $\geq$10 years, 25 (63 pecent) had fished >20 years; only 3 (6 percent) had fished <5 years. The interviews were conducted at major fishing centers (Bridgetown, Oistins), as well as in smaller villages (Silver Sands, Long Bay, Skeete's Bay, Conset Bay) (Fig. 1). We enlisted the assistance of one fisherman, Tim Jones of Long Bay, who acted as our liaison in soliciting interviewees. Before an interview, fishermen were told only that we were researchers from Canadian

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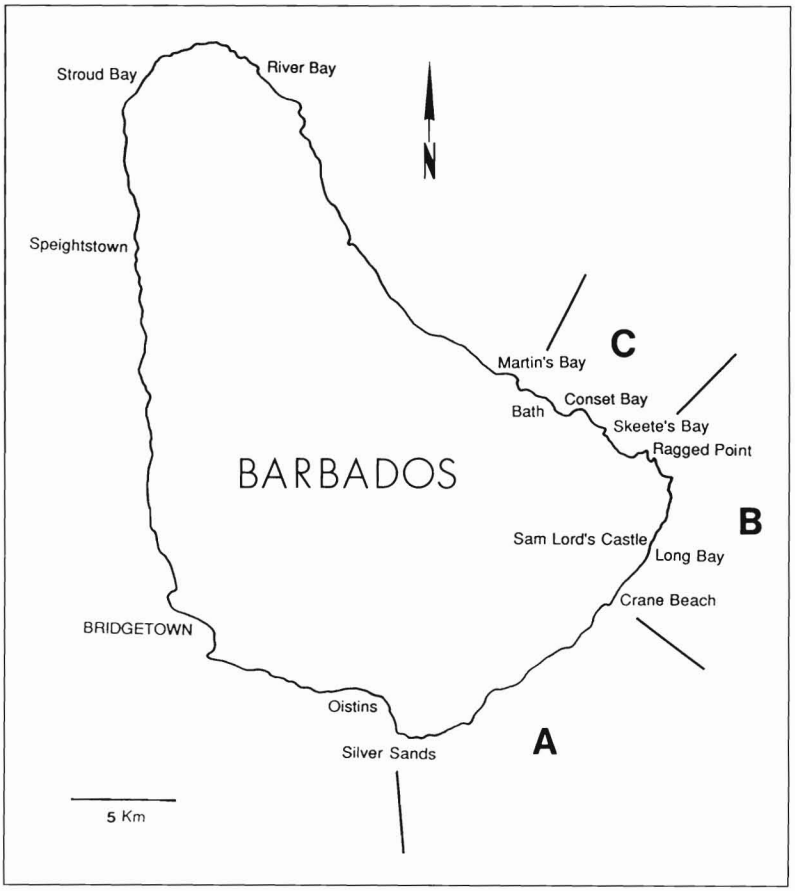
Figure 1.—Places and subareas (A, B, C) of sea urchin fishing grounds referred to in the text.



universities, unaligned with the Barbados Government, and that we wished to acquire information about the sea urchin fishery that may aid in attaining research assistance.

Consumer Interviews

Sixty Barbadian consumers were interviewed by anthropology students from Union College, N.Y., using a prepared questionnaire (copies available from the first author). The questionnaire was aimed at examining consumer preference for sea urchins and consumption habits. The respondents, representing various socioeconomic groups and occupational categories, were from the four northern parishes: St. Lucy (26), St. Peter (18), St. Andrew (9), St. James (7).

Results

Fishing Methods

Fishermen collect *Tripneustes ventricosus* by skin diving with mask, snorkel, and fins. They swim out from shore, singly or in pairs, with a floating log ("pole") from which they suspend large net bags or sacks. Sea urchins, 7-10 cm in diameter, are scraped off the rocky bottom with a small iron rod and collected in the bags which, when full, are floated back to shore on the pole. Alternatively, sea urchins may be collected in floating wooden boxes or rafts.

Fishermen may also work in teams from a boat, either a small rowboat ("Moses") or a larger (~20-foot) diesel-powered fishing boat ("day boat"). The number of fishermen per boat ranges from 2 to 6 with an average of 4 (N=20 respondents[1]). Sixty-five percent of the fishermen interviewed used both the pole-and-bag method and boats to fish for sea urchins; 25 percent used the pole-and-bag method exclusively.

In general, fishing methods have changed very little. The face mask and fins were introduced about 15-20 years ago. Although scuba is now available (and used by some spear fishermen) it is not used in the collection of sea urchins. The increasing scarcity of sea urchins has resulted in a greater dependence on boats for fishing remote populations in areas of heavy wave action. In the past many sea urchins were collected in shallow nearshore areas by wading with net bags or rafts.

[1]Where not all interviewees provided answers to a question, the number of respondents (N) is given.

Fishing Grounds

The current *Tripneustes ventricosus* fishing grounds range from Silver Sands on the south coast to Bath on the east coast (Fig. 1). This area is partitioned into three subareas for the purpose of this study: Area A, Silver Sands to Crane Beach; Area B, Crane Beach to Ragged Point; Area C, Ragged Point to Bath.

Ninety-five percent of the fishermen interviewed fished in Area B and/or Area C. Three respondents indicated that, in recent years, they had ventured as far as River Bay on the north coast to fish sea urchins. Sea urchins also were fished ex-

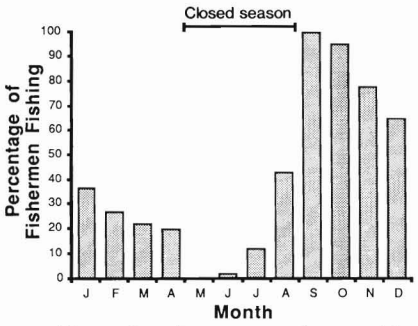


Figure 2.—Percentage of sea urchin fishermen fishing in each month when *Tripneustes ventricosus* were last abundant.

tensively at Stroud Bay on the north coast in the early 1980's.[2]

In Barbados, *T. ventricosus* occurs on patch reefs composed mainly of coral rubble, but often with scattered live corals, algae (mainly *Dictyota* spp.), or sea grass (mainly *Thalassia testudinum*). At present, sea urchins are fished at depths of 5-8 m in areas immediately within or beyond the offshore barrier reef along the southeast and east coasts of Barbados.

Fishing Season

Most of the fishing for *T. ventricosus* is concentrated in the first half of the season between September and December (Fig. 2). Sixty-five percent of fishermen interviewed admitted that they fished in the closed season, mainly in July and August. This may be a conservative estimate since some respondents may have been reluctant to admit to illegal fishing. All respondents claimed that fishing in July and August (known locally as "stealing season") is a common practice among sea urchin fishermen.

September and October represent the height of the sea urchin fishing season when virtually all of the fishermen are active. Eighty-seven percent of respondents (N=30) claimed that sea urchins were most abundant at or before the start of the season in September. Therefore the decline in the number of fishermen fishing in November and December may reflect a decrease in the abundance of sea urchins due to intensive fishing at the start of the season. A marked decrease in the number of sea urchin fishermen occurs after December, when many begin fishing for flying fish, *Cypselurus cyanopterus*.

The average (±S.D.) number of sea urchin fishing days per week reported by respondents (N=24) was 5 (±1) days. Since this did not include 14 respondents who said that they fished every day that weather permitted, this may be a conservative estimate of fishing frequency, at least at the height of the fishing season.

Marketing

Sea urchins are fished in the morning, usually during a 3- to 4-hour period. Normally, the catch is brought ashore where several helpers may assist in removing the roe. The test of the sea urchin is cracked open by hitting it with a spoon. The gut is removed and the five gonads are scooped out with the spoon and washed in sea water. The roe is then packed into intact cleaned tests through an opening in the oral region, and a leaf of the sea grape, *Coccoloba uvifera*, fashioned into a cone and filled with roe, is then placed over the oral region of the test (Fig. 3). Each "shell" as it is called, contains the roe of about 15 sea urchins[3], although the number of sea urchins needed to fill a shell may vary according to their size and reproductive condition. The unused tests are discarded in the sea or buried in large pits dug in the beach sand.

In recent years, many fishermen have elected to forego the traditional method of preparing shells, and they now package the roe in 1 or 2 liter plastic ice cream containers. One liter is equal to about 10 shells.[3]

When boats are used, the roe may be removed at sea by "crackers" who continually process the catch as it is brought aboard. The cleaned tests and guts may be discarded on the fishing grounds, although a number of fishermen that we interviewed denounced this practice, claiming that it caused the sea urchins to migrate away from the area. There may be some truth to this contention, since other species of sea urchins have been shown to be repelled by the scent of wounded conspecifics in laboratory (Tegner and Levin, 1983; Mann et al., 1984) and field (Snyder and Synder, 1970; Vadas et al., 1986) studies.

The catch is sold fresh on the beach directly to local consumers or to vendors ("hawkers") who market the roe in the streets. Twenty percent of the fishermen we interviewed sold to hawkers. Occasionally, sea urchin roe also is sold to restaurants. The current price of the roe, quoted by the fishermen, ranged from $3-6 Bds per shell (average: $4.77 Bds; N=22 respondents) or $25-45 Bds per litre container (average: $37.30 Bds; N=14).[4] The price of roe has increased markedly in recent years. Fishermen recalled that a shell generally sold for $1-2 Bds in the early 1980's.

Fishery Decline

In recent years there has been a catastrophic decline in *ventricosus* stocks in Barbados, and at present (1986) the fishery has effectively collapsed. According to fishermen, this decline occurred initially along the south (Area A) and southeast (Area B) coasts between the middle 1970's and early 1980's, and extended to the east coast (Area C) in the early 1980's (Table 1). In general, fishermen noted that the decline of sea urchins along the south and southeast coasts was gradual, occurring over 2 or more years, whereas on the east coast it occurred within 1 or 2 years.

The dramatic decrease in abundance of sea urchins is reflected by the dwindling catches in recent years. The average catch rate reported by fishermen for the period when sea urchins were last abundant (late 1970's and early 1980's) was 78.7±37.7 shells per person per day (range=30-150 shells per person per day;

[2]Stephen Willoughby, Fisheries Division, Ministry of Agriculture and Natural Resources, Barbados. Personal commun.

[3]Tim Jones, sea urchin fisherman, Long Bay, Barbados. Personal commun.

[4]In 1986, $1.00 Bds = US $0.50.

Table 1.—The estimated period of decline in abundance of *Tripneustes ventricosus* around Barbados based on interviews with fishermen.

Area	Avg. year of decline	Range	No. of respondents
A. Silver Sands	1978	1973-81	11
B. Crane Beach/ Sam Lord's Castle	1979[1]	1975-83	12
C. East Coast	1982	1981-83	14

[1]Five respondents (not included) reported that the decline occurred in the late 1970's-early 1980's.

Figure 3.—Marketing of *Tripneustes ventricosus* in Barbados. From left to right: The traditional "shell" with a sea grape leaf cone, shell with leaf removed to show test filled with roe, and an intact sea urchin. All specimens are about 6 cm in horizontal test diameter.

N=29 respondents). This is equivalent to about 8 liters (fresh roe) per person per day or 1,180 sea urchins per person per day. In contrast, all of the fishermen interviewed agreed that, at present, sea urchins are rare to absent on traditional fishing grounds. The average catch rate reported by those still fishing was 9.4±7.1 shells per person per day (range: 2-24 shells per person per day; N=9). This is equivalent to about 0.9 liters (fresh roe) per person day or 140 sea urchins per person per day.

Aside from this drastic decrease in the abundance of sea urchins, many fishermen also noted qualitative changes in the resource in recent years. Thirty-eight percent of respondents (N=34) claimed that the size of sea urchins that they fished had decreased, 34 percent (N=32) claimed that the amount of roe per sea urchin had decreased, and 49 percent (N=37) claimed that sea urchins had become less palatable, or "bitter", as the stock declined. Decreases in size, gonadal content, and palatability were attributed mainly to a reduction in the quantity and quality of algae ("moss") upon which the sea urchins feed.

Cause of the Decline

Sixty-two percent of the fishermen interviewed believed that pollution was the major cause of, or contributing factor to, the *T. ventricosus* decline in Barbados. Many felt that pollution acted to reduce algae, an important source of food and a shelter for juvenile sea urchins. Some claimed that herbicides used in the sugar cane industry killed off sea urchins in areas of freshwater runoff (e.g., Conset Bay and Bath). Others blamed oil pollution and effluents from hotels, such as chlorinated swimming pool water. A few felt that erosion of the coastline, due to the formation of sea walls and groins, had caused increased sedimentation and a reduction in algal cover.

Twenty-two percent of fishermen claimed that overfishing was the cause of the decline of sea urchin stocks. The remaining 16 percent cited various other factors including fishing with dynamite, offshore migration of the sea urchins, and disease.

Rehabilitation

When fishermen were asked what could be done to rehabilitate the sea urchin fishery, 42 percent of respondents (N=31) suggested a total ban on fishing for 1-5 years, and 29 percent called for stricter enforcement of the closed season. Twenty-three percent felt that the government should investigate means of reestablishing sea urchin stocks, including transplantation of reproductive individuals to depleted areas. Two of the respondents recounted previous transplantation efforts, initiated by sea urchin fishermen in the 1950's, in which populations were reestablished via recruitment in artificially restocked areas. Scheibling and Johnson (1985) relate a similar account.[5]

[5]Copies of reports to the Fisheries Division of Barbados are available from the senior author upon request.

Socioeconomic Impact of the Decline

The collapse of the sea urchin fishery of Barbados has resulted in a major loss of employment. Most of the fishermen interviewed claimed that they now fished less frequently or had stopped altogether. Table 2 shows a dramatic decline in the estimated number of sea urchin fishermen in three major fishing areas. Estimates of numbers of fishermen in the past (i.e., when sea urchins were last abundant) are only rough approximations. Many of the fishermen interviewed simply stated that there were "innumerable" people fishing sea urchins in the past. The Fisheries Division of Barbados has estimated that the number of people employed by the sea urchin fishery has been reduced from "over 1,000" in the early 1970's to "less than 100" at present.[6]

Sixty-three percent of the responding fishermen (N=30) claimed that sea urchins, when abundant in the past, accounted for a major portion (>50 percent) of their yearly income. The average (±S.D.) weekly income reported was $386 Bds (±164) per week (range: $100-700 Bds; N=29 respondents) during the fishing season. This closely approximates an indirect estimate of $395 Bds per week based on the estimated catch rate (79 shells per person per day and fishing frequency (5 days per week) given above, and assuming a previous market value of $1 Bds per shell (in about 1980). In contrast, 77 percent of the fishermen reported they presently (1985-86 season) had no income from this fishery, and the remaining 23 percent claimed that sea urchins accounted for only a minor portion (<25 percent) of their yearly income. The average present income reported was $21 Bds per week (range: $0-100 Bds, N=34 respondents). Therefore, despite the dramatic rise in market value of sea urchin roe over the last 5 years, there has been a serious loss of employment income from sea urchin fishing.

The collapse of the sea urchin fishery is expected to place additional pressure on other resources, most notably flying fish, as sea urchin fishermen attempt to compensate for their loss of income. The flying fish and sea urchin fisheries appear to have been complementary: 68 percent of the sea urchin fishermen interviewed also fished flying fish. Most indicated that they usually stopped sea urchin fishing around the middle of December when the flying fish season began. Twenty percent also earned income from spear fishing and shell collecting, 5 percent from farming, and 7 percent from miscellaneous jobs.

Aside from the loss of employment and income, the collapse of the sea urchin fishery represents the loss of an important food resource. Barbadians have long cherished sea urchin roe as a traditional delicacy (Nutting, 1919). It may be eaten raw, fried with seasoning, steamed, or baked in a pudding. Seventy-two percent of the consumers interviewed (N=60) rated sea urchin roe as "good" (28 percent) or "excellent" (44 percent), i.e., a "3" or "4" rating, respectively, on our 4-point scale. The average numerical rating was 3.0. Positive evaluations generally were based on taste and nutritional value, although three (male) respondents intimated that consumption of sea urchin roe enhanced sexual performance. Seventy-two percent of the consumer respondents (N=53) believed that sea urchin roe was an important component of their diet in the past. Only 15 percent of the consumers either did not like the roe or found it otherwise unacceptable (rating "1"). One-third of these consumers abstained from eating sea urchin roe for religious reasons.

When consumers were asked to compare sea urchin roe with fish, 30 percent preferred the roe over most (8 percent) or all (22 percent) fish, i.e., a rating of "4" or "5" respectively on our 5-point scale. Fifty-eight percent of consumers liked sea urchin roe as much as fish (rating "3"). The average numerical rating was 2.9.

All consumers interviewed noted that sea urchin roe had become much less available and much more expensive in recent years. In the past, the roe was eaten an average of 4 days per week (N=35 respondents). In contrast, 69 percent of consumers (N=33 respondents) in 1986 claimed that they now no longer ate sea urchin roe and 23 percent ate it only 1 day per week.

The consumers sampled in this study lived in the northern part of Barbados, an area distant from the main sea urchin fishing areas around the south and southeast coasts. Therefore, our estimates of sea urchin roe consumption may be lower than that for consumers in the southern part of the country. Although sea urchin fishermen may represent a bias in the other direction, 98 percent of those interviewed (N=40) ate the roe and considered it a delicacy. Ninety-three percent of the fishermen claimed that they ate the roe whenever they caught sea urchins. Eighty-eight percent reported that all, or nearly all, members of their family ate sea urchin roe, and 10 percent reported that most members of their family ate it.

Table 2.—Estimated numbers of sea urchin fishermen in three major fishing areas around Barbados, both before and after the decline in sea urchin abundance. Data are means, with ranges and sample sizes (number of respondents) in parentheses, based on interviews with fishermen.

Area	Number of fishermen: Pre-decline	Post-decline	% decrease
A. Silver Sands/ Oistins	150 (100-300;5)	7 (0-12;7)	95
B. Sam Lord's Castle/Long Bay	46 (30-100;4)	11 (5-25;7)	76
C. Skeete's Bay/ Conset Bay	41 (20-100;6)	3 (0-8;9)	93

Discussion

Decline in Sea Urchin Abundance

As revealed by fishermen interviews, there has been a major decline in *T. ventricosus* abundance at Barbados over the past decade. Recent surveys of traditional fishing grounds have confirmed fishermen's reports that these sea urchins are rare to absent in areas where they were once extremely plentiful (Scheibling and Johnson, 1985; Scheibling et al.,

[6]Stephen Willoughby, Fisheries Division, Barbados. Personal commun.

1985). A few localized aggregations of *T. ventricosus* still exist in some of the more remote and inaccessible areas. Densities within these aggregations range from 0.4 to 3.8 individuals/m^2, which may be indicative of natural densities of these sea urchins in the absence of intensive fishing pressure (Scheibling and Johnson, 1985). At other islands where they are not fished, average densities of *T. ventricosus* in seagrass, *Thalassia testudinum*, beds ranged from 0.6 to 1.2 individuals/m^2 (Scheibling, 1982; Keller, 1983; Tertschnig, 1985). Comparative data on the abundance of *T. ventricosus* at Barbados in the past are lacking, although fishermen frequently reported that they were so abundant "that it would be difficult to place one's hand upon the bottom without touching a sea urchin."

There is evidence of past declines in the Barbadian *T. ventricosus* fishery. In the late nineteenth century, complaints about declining numbers of sea urchins prompted the government to pass the Sea Egg Preservation Act of 1879 which prohibited fishing during what was believed to be the spawning period, April to August (Bair, 1962). This legislation was reinforced by the Fisheries Regulation Act of 1904-05, again in response to complaints of decline, with more severe penalties (fines and imprisonment) for the fishing, sale, or purchase of sea urchins during the closed season (Bair, 1962).

Fourteen of the fishermen we interviewed recalled previous declines in the abundance of *T. ventricosus* along the south or east coasts, which they placed between 20 and 40 years ago. However, they also noted that sea urchins were scarce only for 1 or 2 years, after which they returned to former levels of abundance. Brown (1942) reported that the 1941 season "was a poor one."

Between 1954 and 1957, Lewis (1958) studied a population of *T. ventricosus* near Speightstown on the west coast of Barbados. Although sea urchins were abundant and commercially exploited along parts of the west coast at that time[7], they have since all but disappeared. With the elimination of the west coast populations, sea urchin fishing was limited largely to the south and east coasts. The recent decline of sea urchin populations in these latter areas marks the culmination of a long-term trend which now extends islandwide.

Cause of the Decline

An understanding of the factors which have brought about the *T. ventricosus* decline in Barbados is of crucial importance in assessing the potential for recovery of the fishery. The spatial and temporal pattern of depopulation suggests that overfishing has been a major cause of, or contributing factor to, the demise of these sea urchins. The decline in sea urchin populations seems to have occurred initially in the most accessible areas and spread progressively to more remote areas. It is quite possible that once sea urchin populations were depleted on the sheltered west coast, fishing intensified firstly along the south coast and then along the more exposed southeast, east, and north coasts, as fishermen ventured further afield in search of exploitable stocks. The gradual decline in *T. ventricosus* along the south and southeast coasts in the late 1970's was followed by a rapid decline on the east coast in the early 1980's due to a dramatic increase in fishing pressure on the only remaining populations.

To estimate the extent of fishing pressure on *T. ventricosus* in the early 1970's we made the following assumptions based on interview data: 1) There were 500 sea urchin fishermen (this is about twice the average number given for three major centers in Table 2 and about half of the number estimated by the Fisheries Division, Barbados); 2) on average 71.5 percent of these fishermen were fishing during the first 4 months of the season (September to December, Table 1); 3) each fished an average of 5 days per week; and 4) the average catch rate was 1,180 sea urchins per person per day. This gave an estimate of 34 million sea urchins caught during the height of the season. We then assumed that this represented about 75 percent of the total annual catch (which included catches during the other 4 months of the season as well as closed season fishing) to give an estimated total catch of 45 million sea urchins per year. To estimate the areal extent of the sea urchin fishing grounds, we multiplied the length of the coastline between Silver Sands and Bath, 34 km (measured by digitizing the coastline on a map of scale 1:50,000), by 1 km, the estimated average offshore range of *T. ventricosus*. This gave an estimated area of 34 km^2. Dividing the estimated annual catch by this area gives a catch density of 1.3 individuals per m^2, which seems to be a reasonable reflection of the predecline level of abundance. Although these calculations are only crude approximations, they do indicate that sea urchin populations were subjected to intense fishing pressure in the past.

Interestingly, although only 22 percent of the fishermen that we interviewed believed that overfishing was the cause of the decline in sea urchins, 71 percent thought that strict regulatory measures, such as a total ban on fishing or rigid enforcement of the closed season, would enable the stock to recover.

Most fishermen felt that pollution has caused the decline in *T. ventricosus*, either directly or indirectly by reducing the abundance of seaweeds and sea grasses. Although pollution of coastal habitats by terrestrial effluents is a growing problem in Barbados (Lewis, 1985; Tomascik and Sander, 1985), sea urchin populations have been depleted in areas (such as the southeast and east coast) which are remote from major sources of pollution. Moreover, the existence of dense populations of these sea urchins in areas that are least accessible to fishermen also points to overfishing rather than pollution as a major factor. It seems likely, however, that a general deterioration in habitat quality, due to chemical pollution, siltation, dynamiting, and other anthropogenic changes in the environment, may have reduced the resilience of sea urchin populations to intensive fishing, thereby precipitating the catastrophic decline that occurred over the past decade.

In 1983, an outbreak of disease caused mass mortalities of another sea urchin, *Diadema antillarum*, at Barbados (Hunte et al., 1986) and throughout the

[7]J. B. Lewis, Redpath Museum, McGill University, Montreal, Que., Can. Personal Commun.

Caribbean (Lessios et al., 1984a). A few of the fishermen that we interviewed claimed to have seen *T. ventricosus* with characteristic symptoms of disease (extensive spine loss, loss of attachment to the substratum), although these observations were not coincident with the *D. antillarum* die-off. In other parts of the Caribbean, *T. ventricosus*, *T. williamsi*, and other sea urchin species apparently were unaffected by the disease which devastated *D. antillarum* (Lessios et al., 1984b). In any event, the major *T. ventricosus* decline in Barbados preceded the 1983 epizootic and cannot be attributed to it.

Recruitment and Recovery

The potential for recovery of *T. ventricosus* populations in Barbados is contingent upon recruitment via planktonic larvae. Unfortunately, information on recruitment and early life history of this species is lacking. Lewis (1958) found that recruitment was seasonal in Barbados. Metamorphosing larvae were common in the plankton between June and August, and recently settled juveniles were abundant in September. Lewis inferred a planktonic larval period of about 1 month based on the occurrence of successive larval stages in a series of plankton samples. This is consistent with our recent laboratory studies (Mladenov and Scheibling, unpubl. data) and those of Mortensen (1921), in which cultured larvae took 3-4 weeks to reach a final stage of development, although metamorphosis has not been observed in laboratory cultures.

The relatively long planktonic larval stage (probably greater than 1 month) increases the likelihood of long-distance dispersal of *T. ventricosus* by ocean currents. Barbados receives oceanic water from the Amazon River region, via the Guiana current, and from the North Equatorial Current (Borstad, 1982). Therefore, larvae recruiting in Barbados may originate from populations off the coast of South America. Alternatively, local oceanographic features, such as eddy systems (Emery, 1972), may retain even long-lived larvae from local populations in the vicinity of Barbados.

Clearly these alternatives have important implications for assessing the potential for recovery and in formulating future management strategies. If recruits originate from local breeding populations, then overfishing these populations, especially during the peak spawning period, would lead to an accelerated decline in stocks. Conversely, if recruits are derived from distant populations, fishing of local stocks should not have as great an impact, unless the presence of adults enhances larval settlement and/or postmetamorphic survival (Tegner and Dayton, 1977).

Tripneustes ventricosus juveniles may occur in habitats differing from those of adults. Off Sam Lord's Castle, we found juveniles on sand flats, whereas adults occupied rubble reefs (Scheibling and Johnson, 1985; Scheibling et al., 1985). Lewis (1958) found recently settled *T. ventricosus* juveniles under rocks and in crevices in shallow rock flats on the west coast of Barbados. Aggregations of juveniles also have been found in shallow wave-exposed areas in the Bahamas (Moore et al., 1963) and in St. Croix, U.S. Virgin Islands (Scheibling, personal observ.), and in seagrass beds in Bermuda (McPherson, 1965; Tertschnig, 1985).

Predation on juveniles may be important in limiting recruitment to adult populations of *T. ventricosus*. The cryptic behaviour of juveniles presumably is a means of avoiding visual predators such as fish. Keller (1983) found that recruitment of *T. ventricosus* in seagrass beds at Jamaica occurred only in cages which excluded fish. Barbadian fishermen report that reef fish, particularly the queen triggerfish, *Balistes vetula*, are important predators of juvenile *T. ventricosus*, and this could account for the scarcity of juveniles on reefs where adults are abundant. The rapid growth rate of juveniles may enable *T. ventricosus* to escape in size from fish predators. Lewis (1958) showed that *T. ventricosus* attained reproductive maturity at 40-60 mm test diameter and grew 60-80 mm in their first year. A better understanding of recruitment patterns and factors influencing growth and survival of the early life history stages of *T. ventricosus* is imperative for the formulation of sound management policies and assessment of the potential for recovery of the sea urchin fishery.

Rehabilitation

The occurrence of dense aggregations of *T. ventricosus* in a few remote areas around Barbados (Scheibling and Johnson, 1985) suggests that large populations of sea urchins can be reestablished in coastal habitats, at least along the less developed southeast and east coasts. For this to occur, remedial measures should be implemented to prevent any further depletion of the resource and to facilitate the recovery of populations. Such measures may include: 1) A moratorium on sea urchin fishing for at least 1 year, 2) establishment of reserves where sea urchin fishing is prohibited, and 3) strict enforcement of the closed season.

Although most of the fishermen agreed that such measures could potentially rehabilitate the sea urchin fishery, they also expressed grave doubts that they could be enforced. The general feeling was that one could not prevent a poor man, whose livelihood depended on his catch, from fishing sea urchins as long as they were available. The sporadic and apparently unsuccessful attempts of the government to impose a closed season attest to the difficulties of acceptance and enforcement of such regulatory measures.

An alternative approach would be to artificially enhance *T. ventricosus* recruitment by aquacultural techniques. Larvae and early juvenile stages could be reared in the laboratory and juveniles could be released in large numbers in selected natural habitats or protective enclosures in the field (e.g., cages or rafts). Techniques for rearing *T. ventricosus* larvae are being developed (Mladenov et al., 1985, Mladenov and Scheibling, unpubl. data), and juveniles have been grown in the laboratory and in field enclosures on a variety of algal foods (Lewis, 1958; Lilly, 1975). Moreover, fishermen claim to have successfully restocked areas by transplanting breeding adults. Therefore, in our view, artificial stock enhancement through aquaculture presents a feasible and promising means of rehabilitating the fishery in areas

where pollution and food supply are not limiting factors.

The recent collapse of the sea urchin fishery in Barbados has socioeconomic ramifications which transcend the loss of employment and hardship for the fishermen and their families. Many Barbadians consider the loss of this traditional food source as an historical and cultural tragedy. The fundamental concern, however, is the loss of a nutritious staple food.

Clearly, both basic and applied research are needed to investigate the potential for rehabilitation of this sea urchin fishery. Although the need for such research is probably more pressing now than ever, it initially was advocated by C. C. Nutting (1919) almost 70 years ago:

> There is no doubt that this sea-egg is a valuable food product, being exceedingly nutritious and quite palatable; and it is now the basis of an industry of no mean proportion and might by judicial legal and scientific encouragement be greatly enlarged, much to the advantage of our friends, the Barbadians. A laboratory for the scientific investigation of the problem of protection, based on a better knowledge of the life history of the species, could easily be established....and pay for itself many times over in a rational control and encouragement of the industry.

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