Synthesis of the Biology, Fisheries and Management of the White Sea Urchin, *Tripneustes ventricosus,* in the Caribbean

MARIA PENA[1], CHRISTOPHER PARKER[2], HAZEL A. OXENFORD[1], and ANTOINETTE JOHNSON[3]
[1]*CERMES, UWI Cave Hill Campus, St. Michael, Barbados*
[2]*Fisheries Division, Princess Alice Highway, Bridgetown, Barbados*
[3]*Department of Environmental Health, Cayman Islands Government, Box 1820, Grand Cayman KY1-1109, Cayman Islands*

ABSTRACT

The white sea urchin, *Tripneustes ventricosus*, is common in shallow coastal waters of the tropical Atlantic, and is widely distributed in the Caribbean. This species is short-lived with a maximum life span of 2 - 3 years. It reaches sexual maturity in one year at around 6 - 7cm test diameter. *T. ventricosus* supports small scale commercially important seasonal fisheries in several islands in the eastern Caribbean including St. Lucia, Barbados, Grenada and to some extent, St. Vincent and the Grenadines and harvesting typically begins in September to October. Methods of harvesting may vary among the islands but generally fishers collect both male and female urchins by free-diving. Despite significant management and conservation efforts by some countries, sea urchin population abundance has declined locally. Management approaches range from command-and-control regulation by governments to community-level responsibility. Management tools include closed seasons and even complete closures, minimum size and limited licensing. Understanding the large fluctuations in local population size and implementing sound management practices in the sea urchin fisheries is critical to the sustainable use of this resource in the future, and would benefit enormously from a sharing of information and management experiences. To this end we have attempted to synthesise past and current research and information on this species. Past research has focused mainly on the ecology, life history, fishery characteristics and management of the species, whilst limited information also exists on genetic population structure. Current research is focused on governance and investigation of social-ecological networks within the sea urchin fishery.

KEY WORDS: White sea urchin, *Tripneutes ventricosus*, Caribbean, research synthesis

Síntesis de la Biología, Pesca y Manejo del Erizo de Mar Blanco, *Tripneustes ventricosus,* en el Caribe

El erizo de mar, *Tripneustes ventricosus*, es común encontrarlo en aguas costeras poco profundas en el Atlántico tropical, y se encuentra ampliamente distribuida dentro del Caribe. Esta especie vive pocos años con un máximo de 2 - 3 años. Llega a madurez sexual en un año alrededor de 6 - 7 cm. diámetro de testa. *T. ventricosus* soporta la pesca temporal a pequeña escala de importancia comercial en varias islas dentro del Caribe Oriental incluyendo Sta. Lucia, Barbados y Grenada y hasta cierto punto San Vicente y las Granadinas, y su recolección inicia típicamente de Septiembre a Octubre. Los métodos de recolección pueden variar entre las islas pero generalmente los pescadores recolectan erizos tanto machos como hembras a través del buceo libre. A pesar de existir esfuerzos significantes de manejo y conservación en algunos países, la población de erizos de mar ha declinado localmente. Los enfoques de manejo van de regulación de orden-y-control de los gobiernos hasta el nivel de responsabilidad comunal. Las herramientas de manejo incluyen veda y hasta cierre total, talla mínima y limite de licencias. Comprender la gran fluctuación en el tamaño de la población local e implementando prácticas de manejo sólidas en la pesquería de erizos de mar es crítico para el uso sostenible de este recurso en el futuro, y se beneficiara enormemente al compartir información y experiencias de manejo. A este fin hemos intentado sintetizar investigaciones pasadas y actuales e información sobre esta especie. Investigaciones pasadas se han enfocado principalmente en la ecología, historia de vida, característica de la pesca y manejo de de la especie, en tanto existe limitada información sobre la estructura genética de la población. Investigaciones actuales se enfocan en gobernabilidad e investigación de redes socio-ecológicas dentro de la pesquería de erizo de mar.

PALABRAS CLAVES: Erizo de mar blanco, *Tripneutes ventricosus*, Caribe, síntesis de investigación

Synthèse de la Biologie, Pêche et Gestion des Gamis Blancs, *Tripneustes ventricosus,* aux Caraïbes

Les gamins blancs, *Tripneustes ventricosus*, sont communs dans les eaux peu profondes de l'Atlantique tropicale et sont largement distribués dans les Antilles. L'espèce a une durée de vie courte de 2 à 3 années. L'âge de la maturité sexuelle est atteinte à la première année quand le gamin mesure 6 - 7cm de diamètre. La récolte de *T. Ventricosus* soutient plusieurs communautés côtières en petite pêches saisonnières qui se déroullent typiquement de Septembre à Octobre dans les îles des petites Antilles de la St. Lucie, la Barbade et Grenade et dans une certaine mesure, St. Vincent et les Grenadines. Les méthodes de récolte peuvent varier parmi les îles mais de manière générale cela s'effectue en apnée. Malgré des efforts poussés pour la gestion et conservation de l'espèce dans certains pays, l'abondance des populations de gamins est en baisse au niveau locale. Les approches de gestion varient de contrôles governmentales implementés par la volonté des dirigeants jusqu'aux modes de gestion où les responsabilités se trouvent au niveau communautaire. Les outils de gestions incluent la fermeture des saison de pêche, l'interdiction de pêche, le contrôle de tailles de specimens récoltés et ainsi que limiter le nombre de permis de pêche. Une meilleure compréhension des grandes fluctuations des tailles de population locale de *T. Ventricosus* ainsi que l'implementation de bonnes pratiques de gestion sont des aspects critiques pour assurer une exploitation de cette resource qui est soutenable dans le future, et, de cette manière il y a

d'énormes bénéfices qui suivent des échanges d'informations et d'expériences de gestion. A ce propos, nous avons tenté de de synthétiser des recherches passées et courrantes ainsi que des reseignments sur l'espèce. Les recherches passées se concentraient surtout sur l'écologie, les traits d'histoire de vie, les caractéristiques de la pêche et la gestion de l'espèce ainsi que quelques informations limitées sur leur structure génétique. Les recherches courrantes se concentrent davantage sur la governance et l'investigation des réseaux socio-écologique à l'enceinte des petites pêches des gamins blancs.

MOTS CLÉS: Gamins blancs, *Tripneutes ventricosus*, Caraïbes, recherche synthèse

INTRODUCTION

The white sea urchin, *Tripneustes ventricosus*, also known as the sea egg or chadon, supports small scale but commercially important fisheries in a few Caribbean countries, notably, Barbados and St. Lucia, and to a lesser extent, Grenada and Carriacou, and St. Vincent and the Grenadines. Particularly in Barbados and St. Lucia, the resource is important culturally and economically and there is a high demand for this delicacy. Given this, as well as its sedentary nature, blunt spines and preference for nearshore, easily accessible habitats, the white sea urchin is vulnerable to overexploitation and a common characteristic of fisheries for the species is localised depletion. Presently, *T. ventricosus* is overexploited in Barbados and St. Lucia, moderately exploited in Grenada and Carriacou, and lightly exploited in St. Vincent and the Grenadines. Despite significant management and conservation efforts by some countries, local sea urchin population abundances have declined. In an attempt to determine country-specific needs and improve management of this resource in the region, the Food and Agriculture Organisation Subregional Office for the Caribbean (FAO/SLAC); the Centre for Resource Management and Environmental Studies (CERMES) at the University of the West Indies, Cave Hill Campus, Barbados; Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Martinique; and L'Institut Régional de pêche et de Marine (IRPM), Guadeloupe, are collaborating to collate existing information on the biology and management of the white sea urchin and its fisheries in the Caribbean. This paper is an output of a CERMES review of past and current research, and information, on this species in the English-speaking Caribbean. A more detailed version of this synthesis incorporating information on the sea egg and its fisheries in Martinique and Guadeloupe will be published later as FAO/CERMES/IFREMER/IRPM outputs.

DISTRIBUTION

T. ventricosus is found along the west coast of Africa and in the south Atlantic (Lewis 1958, McPherson 1965, Hickey 1982). It is also widely distributed throughout the Caribbean, ranging from Bermuda, the Carolina coast (Lewis 1958) and Florida (McPherson 1965, Hickey 1982) in the north and west, to the east coast of Mexico, Central America, and Brazil (Lewis 1958, McPherson 1965, Hickey 1982).

MORPHOLOGY

T. ventricosus is one of the largest representatives of the regular Echinoidea. The roughly spherical outer skeleton, or test, is comprised of fused calcareous plates. The plates are arranged into two distinct groups or series, known as the ambulacral and the inter-ambulacral series. The five ambulacral and five inter-ambulacral series are arranged alternately in the characteristic penta-radial pattern of the group running from the mouth located at the center of the animal's ventral or oral side to the anus located in the center of the dorsal or aboral side. The spines are white slender calcareous outgrowths from the test and occur over the entire surface of the test. The spines are used in defence against predators but may also be used in movement. However, the animals mainly move through the action of numerous tube feet which protrude through tiny holes in the test plates particularly the ambulacral plates (hence the name). The spines are longer and more numerous and prominent along the interambulacral series whereas the tube feet are more prominent along the ambulacral series. This arrangement gives the urchin its characteristic dark brown and white banded appearance.

The mouth is a complex protusible structure known as the Artistotle's lanterncomposed of several calcareous structures that articulate together to drag food while grinding it into the animal's digestive tract. Digestive waste is voided through the anus located on the dorsal, or aboral, side.

ECOLOGY AND LIFE HISTORY

Reproduction: Sexuality, Maturity, Fertilisation and Spawning

Sexes are separate in the white sea urchin, and sexual maturity is usually reached within one year of age. Sea eggs are broadcast spawners with eggs and sperm shed directly into the sea water where fertilisation and development ensue immediately in the water column (Hyman 1955, Bruce 1988).

The length of larval development from the fertilised egg to settlement-stage pluteus is estimated to be about one month in the wild (Lewis 1958, Cameron, 1986). Laboratory reared *T. ventricosus* larvae reportedly reached metamorphosis in 23 - 36 days, depending on their algal diets (Wolcott and Messing 2005). Although the pluteus larvae can swim a bit, they are mainly at the mercy of the currents during development (Lewis 1958).

The breeding season or reproductive period may be defined as the time during which mature gametes are present in the gonads. Most sea urchins have a definite breeding period, which extends over the period of a few to

several months (Hickey 1982). Analyses of seasonal variation in gonosomatic indices in Barbados indicate that seasonal ripening of gonads begins early in the year from around mid-January. Varying ranges for spawning period in Barbados exist but typically are between April to August (Lewis 1958, Hunte *et al.* 1993, Mahon and Parker 1999). However, breeding may often extend beyond this. Parker (In prep.) notes that peak spawning activity may vary between sites and between years with significant spawning activity sometimes occurring as early as March and as late as September. Johnson (Upubl. data) states that breeding may occur up to the end of December.

Although both Lewis (1958) and Johnson (Unpubl. data) reported seasonal spawning, the species may be capable of spawning throughout the year, as evidenced by the presence of mature gametes in individuals throughout the year (McPherson 1965). This is further confirmed by the year round operations of harvesters both in the absence and presence of restrictions on harvesting. Despite a lower return per unit effort outside the peak reproductive periods, at least some of the urchins would contain mature gonads at any given time (Smith and Berkes 1991).

During March and April, prior to spawning, white sea urchins move from seagrass beds and the surfaces of rocks, and aggregate in groups of up to a dozen, under rocks and ledges. They remain in these groups throughout the spawning season, dispersing on completion of spawning. The tendency of ripening sea urchins to gather in groups facilitates the successful fertilisation of eggs. The stimulation to spawning of large groups at one time is provided by the initial spawning of one or two sea urchins (Lewis 1958).

Life History Stages: Pre-adult and Adult Phases

T. ventricosus is a relatively short-lived sea urchin species with a maximum life span of 2 - 3 years (Parker, In prep.., Mahon and Parker 1999). Early development from the first cleavage to early stage pluteus occurs within two days. Lewis (1958) and Hickey (1983) provide details on early embryonic and larval development.

Sea urchin recruitment has been found to be highly variable both temporally and spatially. Research on Caribbean sea urchin species that are not exploited (specifically *Diadema antillarum*) indicates that juveniles settling from the plankton may use the presence of conspecific adults as a cue for an appropriate settlement site and hence that recruitment strength is greatest in habitats where adult density is highest (Hunte and Younglao 1987, Mahon 1993). There may be some evidence to suggest that the presence of adult sea eggs enhances juvenile recruitment, but this has not been confirmed. In Barbados and St. Lucia where fisheries for this species have existed for years, management efforts have been directed at protecting a portion of the adult breeding stock in order to enhance the following year's recruitment success via harvest season timing and minimum size limits.

An additional relationship between the effects of substratum and recruitment strength is also apparent. For example, it has been shown that significantly more recruits are found in the macroalga *Padina* sp. and the seagrass, *Thalassia* sp. than on areas of coral rubble covered by short algal turf, even though the latter substrate was considerably more common (Parker In prep.).

Nutrition and Growth

T. ventricosus is a generalized grazer preferentially feeding on seagrass species such as *Thalassia testudinum* (turtle grass) ;brown algae such as *Dictyota*, *Padina* and Sargassum spp; but also will eat some green algae such as *Ulva*, *Zonaria* and *Cladophora* spp (Lewis 1958, Lilly 1975 and Mahon and Parker 1999). When feeding on turte grass, sea eggs appear to prefer the distal senescent portions of the leaves that support an epibiotic community that are believed to be more nutritious than the plant itself (Lilly 1975, Keller 1983a,1983b, Tertschnig 1985).

Growth varies according to environmental conditions. Both somatic and gonad growth is greatly affected by diet (Lilly 1975, Parker, In prep.). Most growth takes place in the first year of development. Gonads ripen seasonally (Hickey 1983, Johnson, Unpubl. data). Juvenile urchins first appear under rocks and in sheltered crevices and amongst suitable flora in August and then increase in abundance during the early part of September. Their test diameter at this time is between 1 to 3cm (Lewis 1958). Growth is rapid from September to March of the following year, slowing down in April through to July. The period from April to July and through part of August corresponds with the period of growth and maturation of the gonads (Lewis 1958). On completion of spawning, there is again an increase in growth rate, at which time the urchins have attained a test diameter of 6 to 8cm.

POPULATION STRUCTURE

Stock Structure

There has been no published research on the genome of *T. ventricosus* in the Caribbean. The elucidation of the population structure of this species within the eastern Caribbean is necessary since it is a commercially important resource that is being managed in the absence of information on population structure. The fact that abundance can decrease markedly in some countries while remaining high in others is circumstantial evidence that island populations of sea urchins are functionally or genetically discrete (Pena Rey 1998, Vermeer *et al.* 1994).

Attempts to determine the population structure of the white sea urchin in the Caribbean has focused on comparisons of population parameters such as monthly abundance and size frequency data (Hunte *et al.* 1993) and isozyme analyses among Caribbean islands, specifically Barbados, St. Lucia, Grenada and St. Vincent, and the Grenadines (Johnson Unpubl. data), and within Barbados (Parker, In

prep.). Results of these population studies revealed the separation of populations of the white sea urchin into isolated units, indicating that separate island stocks may exist (Hunte *et al.* 1993). Results of the Barbados study indicated possible differentiation between coasts (Parker, In prep.). However, owing to the limitations of the use of traditional stock discrimination techniques and isozyme analyses for the determination of population structure, the need for further research was warranted.

Pena Rey (1998) investigated genetic differences among populations of urchins from Anguilla, St. Lucia, Barbados, Carriacou and Grenada using randomly amplified polymorphic DNA (RAPD) analysis. The study suggested significant genetic heterogeneity between all populations, restricted gene flow between *T. ventricosus* populations in the eastern Caribbean, and subdivision of the studied populations into five unit stocks. Based on these results, it may be justifiable for stock assessment and management of this resource to be implemented at the national rather than regional level in the eastern Caribbean (Pena Rey 1998). In order to confirm these results, further diagnostic DNA analysis of populations of the white sea urchin in the eastern Caribbean should be undertaken.

Abundance and Density

Sea egg abundance is highly variable and prone to appreciable inter-annual fluctuations (Parker In prep., Parker 2008). It is assumed that sea eggs, like other organisms with planktonic early life-history stages, exhibit highly variable recruitment due to variability in currents and other conditions in the ocean that affect survival and transportation back to suitable adult habitat at settlement time (McConney *et al*. 2003, Parker In prep.). An enormous increase in juveniles one year may be followed by a number of years of low settlement (Smith and Koester 2001). Another factor contributing to the variability in abundance and landings from year to year is the short lifespan of sea eggs. The maximum age attained may be three years, but the majority of mature individuals are ages one and two. Therefore, stock abundance depends on recruitment in the previous two years. When fishing pressure is very high, and most adults are removed each year by the fishery, the yields are almost entirely dependent on the incoming recruits that are determined largely by the prevailing environmental conditions. High fishing pressure may also reduce the adult stock to low levels that result in increased recruitment variability (McConney *et al*. 2003, Parker In prep.).

Natural events also contribute to fluctuations in sea egg abundance. Smith and Koester (2001) note that in St. Lucia, sea eggs were abundant in Laborie Bay and the adjacent smaller bays for many years prior to the time of Hurricane David in 1979 and Hurricane Allen in 1980. Recovery was slow, but numbers had increased noticeably by 1986. A second decline in abundance occurred in late 1994, coinciding with the passage of Tropical Storm Debbie in September of that year. The storm brought very heavy rains, and its impact on the sea egg stocks was most likely due to siltation from erosion and run-off (Smith and Koester 2001).

FISHERY EXPLOITATION

Fishing Seasons

Sea urchin fisheries throughout the eastern Caribbean tend to commence around August or September of each year (George and Joseph 1994). In Barbados, most of the harvesting of the white sea urchin is concentrated between September and December (Scheibling and Mladenov 1987). In St. Lucia harvesting usually occurs from August to December (De Beauville-Scott 2008). In Grenada and Carriacou, fishing was an activity occurring year round until 1981 when a closed season was declared and enforced (Pena Rey 1998). Harvesting in Grenada now occurs from August to November, and from October to November in Carriacou (Fisheries Division 2008a). In St. Vincent and the Grenadines, harvesting is irregular often occurring when sea eggs are abundant and when limited effort is required for searching for sea eggs (Fisheries Division 2008b). Variations in the date and length of sea egg harvesting seasons are dependent on management regulations in the respective countries.

Fishing Areas: National Fishing Locations and Landing Sites

Sea eggs are distributed all around Barbados, but occur in greatest densities on the north, southeast, and east coasts (Vermeer *et al.* 1994, Parker In prep., Mahon and Parker 1999). The main landing sites are therefore on these coasts and include Oistin's, Silver Sands, Conset, Crane, Foul Bay, Long Bay, Martin's Bay, Sam Lord's, Skeete's Bay, Tent Bay and Bath. Stroud Bay on the northwest coast is also used. With a few exceptions, such as Maycocks Bay and Brighton, sea eggs have always been rare along the west coast. This is probably due to the presence of the well developed coral reef system along this coast (Parker In prep., Mahon and Parker 1999).

In the past in St. Lucia, sea urchins were widely distributed along coasts. Today, sea eggs are found primarily in nearshore waters on the south and east coasts of the island, with lower numbers found along the west coast (Smith and Walters 1991, Anonymous 1996, De Beauville-Scott 2008). Three of the most economically important sea egg populations occur off Aupicon, the Maria Islands and Laborie (George and Joseph 1994).

In Grenada, the main sea urchin fishing areas are in the south from Point Saline within one mile of the shore to Lance aux Epines, and in the east at Telescope and towards the Grenadines. Major harvesting areas in Carriacou are on the west and southeast coasts. Very limited sea egg harvesting occurs along the western shelf of Grenada (Pena Rey 1998, Fisheries Division 2008a).

There is no commercial sea egg fishery in St. Vincent and the Grenadines since only a minority of Vincentians harvest the resource for local consumption. Harvesting is known to take place on the east and south coasts of St. Vincent, the south coast of Bequia (Paget Farm and Friendship Bay) and the west coasts of Mustique, Mayreau and to some extent, Canouan. It is assumed that more significant harvesting occurs in and around Union Island where there is a greater demand for the delicacy by foreign residents and tourists (Fisheries Division 2008b).

Fishing Methods, Vessel type, and Gear

Generally, in all islands fishermen collect both male and female sea eggs from the reefs by skin diving with mask, snorkel, and fins. However, methods of harvesting vary to some extent among the islands. In Barbados, traditionally the majority of divers working the sea egg beds closer to shore would swim out from the shore, singly or in pairs, carrying a floating maypole (Agave flower stalk, *Agave barbadiensis*) from which large net bags or sacks (made of netting, crocus bags, or discarded sugar bags) were suspended. The sea eggs were "picked" from the sea floor by hand, or forced out of crevices with pieces of iron referred to as "rakes" and placed in the bags, which when full were floated on the log back to shore Alternatively, sea urchins were collected in floating wooden crates or rafts (Hickey 1982, Scheibling and Mladenov 1987; Vermeer *et al.* 1994; Parker In prep., Mahon and Parker 1999, McConney *et al*. 2003, Parker 2008). Today, sea eggs are now often harvested by divers operating from small boats and less commonly, from launches (called day boats) used primarily for other types of fishing. They are landed at numerous points along the shore, many of which are not easily accessible by road. (Parker In prep., McConney *et al*. 2003). A few non-traditional fishermen used SCUBA gear ("tank men") to harvest urchins (Vermeer *et al.* 1994). However, since 1998, the harvesting of sea eggs with SCUBA has been prohibited by law, and only free diving is allowed (Parker 2008).

In St. Lucia, the fishing methods are similar to those in Barbados, *viz*. free-diving, either by swimming from shore or from dugout canoes (Smith and Berkes 1991, De Beauville-Scott 2008). In Grenada and Carriacou, the urchins are collected on beds of *Gracilaria spp.*, seagrass beds or reefs by diving. As in Barbados, sometimes individuals swim out to collect the sea eggs with some type of float and feed bags (Pena Rey 1998, Fisheries Division 2008a). Some fishermen in Grenada and Carriacou operate from wooden pirogues (2.5 - 6m long) with oars or small outboard engines. Recently with the onset of SCUBA, larger boats (similar to those used to catch lobster and conch) are used for sea egg harvesting (Pena Rey 1998, Fisheries Division 2008a). In St. Vincent and the Grenadines, sea eggs are just picked up off the substrate by snorkelers and SCUBA divers (Fisheries Division 2008d).

Fishing Operations and Socio-economic Importance

Catch and effort trends — Generally, no regularly recorded landings statistics are available for sea egg fisheries, with the exception of St. Lucia. There, the Department of Fisheries has recent catch data for the 2002 - 2004 period with just over one million sea eggs landed, an average of approximately 363,000 sea eggs per year (De Beauville-Scott 2008). For Barbados, since sea eggs may be landed and processed at nearly any beach, rarely passing through any monitored landing site, it is very difficult to collect accurate annual catch statistics (Parker 2008). Catch and effort fluctuate with highly variable abundances and no clear trends are obvious (McConney 2001). A limited set of catch statistics by weight for export are available for 1988, 1991 - 1994 and 1997 for Grenada and Carriacou. For this time-period, approximately 28,000 kg of sea eggs are recorded as being exported (Fisheries Division 2008a).

Vermeer *et al*. (1994) estimated that the majority of fishermen from Barbados fish daily up to five times per week during the height of the urchin harvesting season. In 1994, it was estimated that approximately 350 sea urchins were harvested by a single fisherman on one trip. Based on this value, the estimated periodicity of harvesting in the peak season (September - November) and with approximately 220 sea urchin fishermen in the fishery in the early 1990s, it was determined that approximately half a million sea urchins would be harvested per week, resulting in six million urchins being harvested in the three month peak season alone. In 1999 Mahon *et al*. estimated that around 260 persons were "serious sea egg divers" and Parker (In prep.) estimated that they were 201 full time and 155 part-time sea egg divers in 2001, while McConney and Pena (2005) estimated approximately 300 persons involved in the fishery in 2004. All of these estimates indicate increased fishing effort. In addition, other people crack, clean and sell sea eggs (McConney and Pena 2005). With harvesting also occurring out of season, it is obvious that the total number of sea eggs harvested in Barbados is high. However in recent years with the decline in abundance of sea urchins island-wide numbers harvested has probably significantly declined compared to the numbers in the first three years of this century.

In St. Lucia for 1995, only eight licensed sea urchin fishermen were recorded, evidence of a struggling fishery. For the 2001 harvest period 13 divers were granted permits to harvest sea eggs (De Beauville-Scott 2008). Information on the numbers of urchins harvested per trip is not currently available. However annual catches for the period 1995, and 2001-2004 ranged between 530 – 8,700 kg (De Beauville-Scott 2008).

In Grenada and Carriacou, the minimum number of active commercial sea urchin fishermen in the late 1990s was estimated at 110. The numbers of vendors during this period is unknown, however most are family members of fishers. It has been estimated that a crew, consisting of

about three persons, harvests 300 - 700 urchins on each trip, with most harvesters producing 40 - 60 "shells" for sale. For the wholesale market,catches are considerably larger. In both cases, a minimum of six trips per week are made by each crew, with the result that in a good year, at least 500 - 800 thousand sea eggs may be harvested (Pena Rey 1998, Fisheries Division 2008a).

Since no commercial fishery for sea eggs occurs in St. Vincent and the Grenadines with harvesting limited to a small number of persons for personal consumption on an irregular basis, no catch and effort data for the fishery exists. However, it has been noted that there has been an increase in illegal export of the resource from Union Island (Fisheries Division 2008b).

Socio-economic Importance

Sea urchins are an important food resource to fishermen and their families (Scheibling and Mladenov 1987). In particular, Barbadians and St. Lucians have long treasured sea urchin roe as a traditional delicacy and therefore it may be considered an important part of their culture (Scheibling and Mladenov 1987, Vermeer *et al.*, 1994).

Most sea urchin fishermen in Barbados are full-time fishermen who focus their efforts on the offshore pelagic fishery between December and June and switch to the sea urchin fishery during the pelagic off-season (July-November). In addition, the beginning of the season also coincided with the last weeks of the school summer holidays. Hundreds of Barbadians, including women and children became involved in some aspect of the sea egg fishery. The traditional roles for the women and children were the processing and sale of the sea eggs on shore. Persons were described by the tasks to which they were assigned such as "divers", "breakers" and "vendors" (Parker In prep., Mahon and Parker 1999).

Estimates of the numbers of people seasonally involved in the sea egg fishery have ranged from nearly 1000 in the mid-1950s to between 200 - 300 at present (Mahon *et al*. 2003, McConney *et al*. 2003, McConney and Pena 2004, Parker 2008, Parker, In prep.). No other fishery in Barbados so thoroughly engages people of all ages, both sexes, and of several other occupations as fully and intensely as the sea egg fishery. Recent estimates of participation have focused more on those who regularly harvest sea eggs and hence may be proportionally lower than earlier, more comprehensive, estimates (McConney *et al*. 2003). Several categories of sea egg fishers including full-time, seasonal, casual and holiday fishers have been identified (Mahon *et al*. 2003).

Revenue from the sea urchin fishery in Barbados is an important part of some fishermen's income (McConney *et al*. 2003). While researchers differ on their estimates of mean income per fisher from the sea egg harvest (largely due to differences in estimates of effort), there is little doubt that, when abundant, Barbadian sea eggs are the basis of a very valuable fishery (Fisheries Division 2003). The price of roe has increased markedly in recent years. In the early 1980s a "shell" sold for US $0.50 - 1.00 (Scheibling and Mladenov 1987). In 1991, fishermen quoted the sales price of roe as US$20 per litre container, and it was estimated based on estimated catch rates of approximately six million urchins in the open season alone, that an urchin fishermen could earn more than US$300 per week if fishing was daily (Vermeer *et al.* 1994, McConney 2001). In 2004, sea eggs were being sold for US$15 for per one litre container and US$30 per two litre container (McConney and Pena 2005). In 2001 it was estimated that there were around 201 full-time and 155 part-time active sea egg divers (Parker In prep., McConney *et al*. 2003), and based on information derived from interviews of fishers conducted in 2004, Mahon et al. (2007) estimated a value of around US $1.4 million for the local sea egg harvest.

The St. Lucia sea egg fishery provides an important seasonal source of income for coastal communities, which are adjacent to seagrass and fringing reef habitats (George and Joseph 1994). Sea eggs became significant as an export commodity in the 1970s. A profitable business emerged based on the demand for sea eggs in Martinique (Smith and Koester 2001). In 1991, a test filled with gonads sold for approximately US$2 (Smith and Berkes, 1991). In more recent years, sea egg collecting has become a commercial venture rather than a family-based subsistence activity. As prices were relatively high and demand exceeded supply, sea urchin collecting attracted many young and underemployed people who were looking for part-time income, and considering that three to four sea urchins sold for US$5 -7 in 1991, the potential incomes were attractive (Smith and Berkes 1991). The St. Lucia Fisheries Division estimated the total value of the sea egg harvest for the 1995 and 2001 - 2004 harvesting periods combined to be approximately US$400,000 (De Beauville-Scott 2008).

In Grenada and Carriacou, the financial return from those involved in the fishery is reasonable, considering the low level of investment. In 1990, the cost of a packed "shell" varied between US$1.00 - 2.00. The wholesale price of roe was approximately US$9.00/kg. It has been estimated that a day's share, including boat share would be at least US$15-75/week, on the basis of three harvesters carrying 40 "shells" to market each day for five days a week (Pena Rey 1998). Sea egg roe was exported for a number of years with the value ranging from US$6.00 - 14.00/kg.

In St. Vincent and the Grenadines, there is no active data collection and assessment of socio-economic information on the white sea egg. However, a fairly lucrative illegal export of sea eggs to several islands, including Martinique, with vessels paying approximately US$20/kg has been reported (Fisheries Division 2008b).

HISTORICAL AND CURRENT MANAGEMENT

Despite significant management and conservation efforts by some countries, sea urchin population abundance has declined locally. Management approaches range from command-and-control regulation by governments to community-level responsibility. In general, management tools include closed seasons and even complete closures, minimum size, and limited licensing. In St. Vincent and the Grenadines, no management has been enforced due to the irregularity and subsistence nature of the fishery there. The following sections provide an overview of the management approaches implemented by Barbados, St. Lucia, Grenada and Carriacou, and St. Vincent, and the Grenadines.

Barbados Sea Egg Fishery

From 1879 to the present, a closed season to protect the peak reproductive period has been the primary management measure applied to the sea egg fishery in Barbados. The results of annual stock assessments are used to determine the respective timing and length of the seasons. Additionally, multi-year harvest moratoria have been imposed (1987 - 1989, 1998 - 2001, and 2005 to the present) to conserve stocks during years of low abundance (Parker In prep., Parker 2008).

From as early as the late 1870s complaints by fishermen of a decline in the abundance and distribution of urchins prompted the Barbados Government to pass the Sea Egg Preservation Act (1879), which prohibited the harvest of urchins between May to August during the peak of the breeding season, in an attempt to conserve the resource (Scheibling and Mladenov 1987, Vermeer *et al.* 1994, Parker,, 2002, 2008, In prep.). The delimitation of this period was almost certainly based on traditional knowledge (Parker 2008, Parker In prep.). The sea egg legislation was incorporated into the consolidated Fisheries Regulation Act (1904) which wasthe first comprehensive set of laws, applying to fisheries regulation in Barbados. With regard to sea urchins, it was mandated that there would be an annual fishing closed season between 1April to 31 August unless otherwise published in the Official Gazette. Severe penalties (fines and imprisonment) for the fishing, sale or purchase of sea urchins during the closed season were imposed (Bair 1962, Scheibling and Mladenov 1987, Vermeer *et al.* 1994, Parker 2002, In prep.). Enforcement of this closure had never been effective and harvesting frequently occurred before the annual legal start date of 1 September (Vermeer *et al.* 1994). The annual closed season was shortened in war years to ensure food supply but lengthened whenever stocks declined (Parker 2002, In prep., McConney *et al*. 2003).

In the mid 1970s and early 1980s, there was a major decline in the white sea urchin population in Barbados, with the fishery deemed as collapsed by 1986. Overfishing was touted as the most likely cause of the reduction in abundance (Scheibling and Mladenov 1987). Due to the decline in abundance, the Barbados Government imposed a two-year moratorium, from September 1987 to August 1989, on sea urchin harvesting and the population was monitored to determine the impact of this measure (Mahon 1993, Vermeer *et al.* 1994, Parker In prep.). The moratorium was lifted as planned in September 1989, with the fishery being reopened as a free access commercial fishery, however, the closed season was revised to January to August each year (Mahon 1993, Vermeer *et al.* 1994).

Again, there was little co-operation with, or enforcement of, the January to August closed season and substantial harvesting still occurred before 1 September. By 1991, the sea egg stock had declined so much that harvests in both that year and the next were negligible. Surveys in 1993 and 1994 again suggested fairly rapid recovery of the white sea urchin sub-populations following the two years of negligible harvesting (Parker In prep., Vermeer *et al.* 1994). The fishery continued to struggle and owing, once more, to the rapid decline of the fishery, the government of Barbados imposed a three-year ban on sea urchin fishing from 1998 to 2001. The lengths of harvest seasons during the period 2001 to 2004 have been considerably shorter than previous seasons, ranging from a maximum of two months in 2001 and 2002 to two weeks in 2004. Based on annual stock abundance surveys in recent years, no legal fishing season has been recommended since 2004 (McConney *et al.* 2003, McConney and Pena 2004, McConney and Pena 2005, Parker 2008). Reportedly persistent high levels of year-round poaching have been blamed for the collapse of the stock and have contributed to the lack of sustainable gains in recent seasons. Enforcement, compliance and the reluctance to treat contravention of the fishery regulations as a serious offence have all contributed to the sea egg fishery being highly uncertain and perhaps also unsustainable (McConney *et al*. 2003).

A comprehensive analysis of the sea egg fishery, conditions for, partners in, and steps towards co-management in Barbados is provided by Mahon *et al*. 2003 and McConney *et al*. 2003. During the early 1990s, the Fisheries Division and other organisations that have been involved in the management of the sea urchin fishery in Barbados concluded that a co-management approach to the fishery would have the greatest likelihood of success given the nature of the fishery and the past difficulty of enforcing the closed season. Therefore, the potential for co-management of sea eggs in Barbados was assessed by consultation with fishers (Mahon *et al*. 1999 and 2003). Vermeer *et al*. (1994) undertook the first assessment for the potential of sea urchin co-management in Barbados but specifically in the form of community-based management such as introduced in St. Lucia. The essence of this co-management approach encompassed adjusting the duration and timing of the traditional closed season in response to an assessed abundance of the population in the coming harvest season (Hunte 1989, Vermeer *et al.* 1994). It was proposed that urchin abundance would be assessed

between March and May by the urchin fishermen in several fishing areas. The fishermen would then collaborate with the Fisheries Division and assist in determining the most appropriate start date and duration of the coming harvesting season (Vermeer *et al.* 1994). This collaborative approach to management, which was being tried in St. Lucia, achieved wide conceptual support but it was not fully implemented in practice in Barbados. However, from 2001, fisherfolk in collaboration with the Fisheries Division have conducted annual stock abundance surveys just prior to the commencement of the fishing season and the results have been, and are currently used in part, to determine the length and timing of the fishing season (Fisheries Division 2004, Parker, In prep. 2008). The use of fishers in determining stock abundance was a deliberate attempt to involve them in the assessment and management process (McConney *et al*. 2003).

Based on the encouraging potential from the assessment by Vermeer *et al.* 1994, the 1997 - 2000 Fisheries Management Plan (FMP) supported a co-management approach to the sea egg fishery involving fishers and the Fisheries Division (McConney and Pena 2004). This support was again reiterated in the 2001 - 2003 FMP in which the objective for the fishery was to, "Rebuild populations and establish a co-management arrangement with fishers to maintain populations at levels which can sustain long term optimum yields for social and economic purposes" (Fisheries Division 2001).

However, Barbados has proven to be quite different in terms of attitudes towards property rights and access, patterns of settlement and community, and attitudes towards regulation. Sea eggs are widely abundant around the island, there is no small-scale community ownership therefore the whole island must be considered as the "management community" (McConney and Pena 2004). Efforts to introduce aspects of co-management that are not quite as community-based, but are still participatory have been made in recent years by several governmental and non-governmental agencies but none of them have sought to delegate authority to the resource users to any appreciable extent (McConney *et al*. 2003). All of the attempts have been at least consultative, especially in obtaining the ecological knowledge and observations of fishers. At present, there is no co-management of the sea egg fishery because none of these initiatives has been sustained (Parsram and McConney 2004).

St. Lucia Sea Egg Fishery

In St. Lucia the sea egg has apparently been harvested sustainably until recent years. In the past, the fishery was open access with the exception of Laborie, where, for at least six decades, only the local community was permitted to fish (Smith and Koester 2001, Smith and Walters 1991). From 1990 to 2001 during the open seasons, a co-management approach with limited entry to the fishery was implemented. From 2002, the fishery was once again declared open access (De Beauville-Scott 2008).

Throughout the 1950s and 1960s, communities harvested sea urchins from August to December for local consumption (De Beauville-Scott 2008). In the early 1960s this localised harvesting and use of the white sea urchin began to change, when a modest trade in cooked sea urchin between some harvesters in Vieux Fort and visitors from other areas of St. Lucia developed (Smith and Walters 1991).

Unacceptably high fishing levels were reached in the late 1970s, and the additional stress of successive hurricanes in 1979 and 1980 caused the fishery to collapse (Smith and Berkes 1991, George and Joseph 1994). The population returned to harvestable levels by 1984, but in response to dramatic increases in demand and supply, there was again a notable reduction in abundance by 1986 (Smith and Berkes 1991, Smith and Walters 1991, George and Joseph 1994). Indiscriminate exploitation resulted in the collapse of the fishery in 1987. The Division of Fisheries (DOF) therefore closed the sea urchin fishery in December of 1987 (Smith and Berkes 1991, Smith and Walters 1991, George and Joseph 1994, De Beauville-Scott 2008). Following the depletion of the white sea urchin sub-populations, the Caribbean Natural Resources Institute (CANARI) in collaboration with the DOF carried out a monitoring programme to assess sea egg abundance, growth and recruitment. The main purpose was to establish the conditions for the recovery of sea urchin sub-populations and the management of the fishery (George and Joseph 1994, Smith and Koester 2001, Smith and Walters 1991).

The results of the CANARI/DOF monitoring programme indicated that management of the white sea urchin fishery of St. Lucia was possible (Smith and Walters 1991), the nature of the resource apparently lending itself towards facilitating a system of community-based management (George and Joseph 1994). In 1989, the government reopened the fishery but did not allow open access. Instead a new participatory system of sea urchin management was adopted in an attempt to avoid the overexploitation of the past with certain conditions for controlling harvesting which included size limits, licensing of divers, participation of fishers in carrying out pre-harvest surveys, and determining timing of the closure of the fishery (George and Joseph 1994, Smith and Koester 2001, Smith and Walters 1991).

By 1991, this had developed into an area-specific community management system which on a yearly basis controlled the number of fishermen harvesting the urchins, the extent of ownership of each harvest zone; the urchin size limit for each year's fishery, the maximum harvest period/season, and the means of disposing of urchin remains (Smith and Walters 1991, George and Joseph, 1994).

Despite these precautions, sub-populations of the white sea urchin in St. Lucia declined dramatically after

1991, resulting in harvesting being prohibited during 1993 and 1994 (George and Joseph 1994, De Beauville-Scott 2008)., The decline in sea urchin abundance was attributed to natural sea conditions, pollution from raw sewerage, and waste from nearby laundry facilities, rather than to overfishing (Scott and Walker 1995), but the extent to which illegal harvesting had contributed to the decline was unknown.

In 1995, harvesting was again allowed for nine days only, in the southern part of the island (Scott and Walker 1995, De Beauville-Scott 2008). Surveys in 1996 revealed either declines in urchin abundance or scarce sub-population densities. The fishery was not opened in 1996 and remained closed (Pena Rey 1998). Harvest seasons were allowed for the period 2000 - 2004 when monitoring activities revealed high levels of recruitment (De Beauville-Scott 2008).

It should be noted that in 2002, the co-management arrangement came to an end when the DOF was forced to take a decision to return to an open access fishery based on a number of reasons including increased abundance of the resource coincident with a general decline in the economy and increased numbers of persons wishing to harvest sea eggs, high levels of illegal harvesting due to high demand, and inadequate enforcement capacity (De Beauville-Scott 2008). In 2005, sea egg densities declined significantly and ranged from low to extremely low. ,Additionally, there seemed to be little or no recruitment due to the absence of juveniles during monitoring surveys. The fishery has been closed since 2005 with little signs of recovery. It is likely that poaching which occurred throughout the closed periods has significantly hampered the recovery of this fishery (De Beauville-Scott 2008).

It is important to note that these sea urchin sub-populations in St. Lucia declined in abundance, although they have been under area-specific community management since 1991, and mechanisms to deter illegal harvesting and encourage involvement of licensed harvesters in surveillance of their harvest stock had been devised (George 1994). Some sea egg harvesters suggested that the resource may not have been easy for a community to manage in recent years of the co-management approach as in the past, due in part, to the increased need for cash income (Smith and Koester 2001).

Prior to 1994 there was no specific legislation for the sea egg fishery. The 1984 Fisheries Act Section No. 10 provided a general clause for management and development of all fisheries. The subsequent development of management strategies was largely based on increased harvesting effort particularly in Vieux Fort in 1987, due to access to a market in Martinique (Smith and Koester 2001). The Fisheries Regulations No. 9 of 1994 now makes provision for the sea egg fishery. The Fisheries Act also makes provisions for closed areas, limited entry, and moratoria, in addition to other management measures (De Beauville-Scott 2008).

The current structure of the legislation relating to this resource allows for the development of participatory management. It permits the management authority to select only individuals who have proven themselves concerned with the welfare of the resource. It also allows annual review of the permits granted so that persons have to qualify annually in order to be considered. In addition there is scope to adjust the level of effort, number of divers and period of harvesting, to the level of the resource each year (George 1994).

The sea urchin experience in St. Lucia demonstrates that a user group can become actively involved in the central aspects of resource management and play an important role in ensuring its sustainable exploitation (George and Joseph 1994).

Grenada and Carriacou Sea Egg Fishery

There has been no historical management aimed at the sustainable use of the white sea urchin in Grenada and Carriacou due largely to its subsistence nature. The fishery in these islands was vibrant for many years, sustaining considerable fishing pressure. However, the resource was eventually fished to very low levels and the Fisheries Division closed the sea urchin fishery in 1994. Regulations restricting sizes, areas, and seasons for urchins were promulgated for the first time in 1995. The fishery has remained closed to the present. Future management options for the resource include gear restrictions, size limits, effort reduction, closed seasons, closed areas and co-management arrangements (Pena Rey 1998, Fisheries Division 2008a).

St. Vincent and the Grenadines Sea Egg Fishery

There is currently no management plan for the white sea urchin in St. Vincent and the Grenadines. It is not illegal to harvest sea eggs, but the resource is subject to certain restrictions under the Marine Park Act of 1997 which allows for the designation of “no fish” zones within marine park boundaries, where the taking of any marine fauna or flora is prohibited. The export of sea eggs without the appropriate health certificates and permission from relevant authorities is illegal.

RESEARCH NEEDS

There are a number of research needs and existing information gaps which need to be identified and filled by countries in the Caribbean currently exploiting the white sea urchin if management of its fisheris are to be sustainable and viable in the long-term. T he information required is similar for all countries and includes (De Beauville-Scott 2008, Fisheries Division 2008a, Fisheries Division 2008b Parker, 2008):

i) Detailed information on number of persons involved in the fisheries,
ii) Catch rate and density estimation for determination of total fishing effort,

iii) Examination of the stock-recruitment relationship and recruitment patterns,
iv) Identification of larvae producer ("source sites") sites,
v) Adoption of a standard method for catch and effort monitoring across the region,
vi) Determination of the effects of environmental fluctuations on sea egg populations,
vii) Strengthening enforcement capacities and capabilities of fishery authorities at the regional level,
viii) Population size structure determination,
ix) Estimation of gonosomatic indices,
x) Information on sea egg diet,
xi) More information on the socio-economic aspects of the fisheries

Current research being undertaken by the CERMES, University of the West Indies, Barbados, and the Natural Resources Institute, University of Manitoba, Canada, is concentrated on governance issues of the sea urchin fisheries in Barbados, St. Lucia, and Grenada and may be useful in providing some of the required information above. The research currently being undertaken by these institutions falls under the Marine Resource Governance in the eastern Caribbean (MarGov) project and includes:

Current research being undertaken by CERMES, University of the West Indies, Barbados; the Natural Resources Institute, University of Manitoba, Canada; and relevant fishery authorities in the Caribbean, is concentrated on social-ecological and governance issues of the sea urchin fisheries in Barbados, St. Lucia, and Grenada and may be useful in providing insight into sea egg fishery management issues. The research currently being undertaken by these institutions falls under the Marine Resource Governance in the eastern Caribbean (MarGov) project and includes:

i) Determination of the formal and informal processes and conditions for establishing and sustaining adaptive co-management of sea urchin fisheries in Barbados and St. Lucia (Cox In prep.),
ii) Development of a draft fisheries management plan and governance arrangements for the Grenada sea urchin fishery, using ecosystem-based and sustainable livelihood approaches to fisheries management (Fisheries Division In prep.),
iii) Examination of social-ecological networks in the Grenada sea urchin fishery (Nayar In prep.)
iv) Strengthening the role of the Barbados Fisheries Advisory Committee (FAC) in sustainable governance of fisheries resources in Barbados, one component of which will examine the FACs ability in formation of a Sea Egg Management Council (Grant In prep.)
v) A GIS based evaluation of index sites used in the assessment of the sea egg stock in Barbados (Welch In prep.)

LITERATURE CITED

Bruce, C.A. 1988. Sea urchins. *INFOFISH International* **3**: 32-34.

Cameron, R.A. 1986. Reproduction, larval occurrence and recruitment in Caribbean sea urchins. *Bulletin of Marine Science* **39**:332-346.

De Beauville-Scott, S. 2008. St. Lucia National Sea Egg Country Report. January 2008. Department of Fisheries. 12 pp.

Fisheries Division. 2001. Barbados fisheries management plan 2001-2003: Schemes for the management of fisheries in the waters of Barbados. Ministry of Agriculture and Rural Development. 72 pp.

Fisheries Division. 2003. Summary report of the sea egg fishery management focus group meeting held at the Fisheries Division, 4 November 2003. 6 pp.

Fisheries Division. 2004. Barbados fisheries management plan 2004-2006: Schemes for the management of fisheries in the waters of Barbados. Ministry of Agriculture and Rural Development. 68 pp.

Fisheries Division. 2008a. Grenada National Sea Egg Country Report. May 2008.Fisheries Biology Unit, Ministry of Agriculture, Lands, Forestry, Fisheries and Energy. 6 pp.

Fisheries Division. 2008b. St. Vincent and the Grenadines National Sea Egg Country Report. Biology/Research Unit, Fisheries Division, Ministry of Agriculture, Forestry and Fisheries, St. Vincent and the Grenadines. 2 pp.

George, S. and W. Joseph. 1994. A new participatory approach towards sea urchin management in St. Lucia, West Indies. *Proceedings of Gulf and Caribbean Fisheries Institute* **46**:197-203.

Hunte, W., C. Parker, and A. Johnson. 1993. Rehabilitation and management of sea urchin populations in Barbados and the eastern Caribbean. Interim Technical Report prepared on behalf of Bellairs Research Institute and the University of the West Indies, for the International Development Research Centre, Ottawa, Canada. 12pp.

Johnson, A. Unpublished thesis.

Kehas, A.J., K.A. Theoharides, and J.J. Gilbert. 2005. Effect of sunlight intensity and albinism on the covering response of the Caribbean sea urchin *Tripneustes ventricosus*. *Marine Biology* **146**:1111-1117.

Keller, B.D. 1983a. Food quality, growth and size frequencies if two tropical sea urchins. *American Zoology* **23**:1016

Keller, B.D. 1983b. Coexistence of sea urchins in seagrass meadows: An experimental analysis of competition and predation. *Ecology* **64**:1581-1598.

Lewis, J. 1958. The biology of the tropical sea urchin *Tripneustes esculentus* Leske in Barbados, British West Indies. *Canadian Journal of Zoology* **36**:607-621.

Lilly, G.R. 1975. The Influence of Diet on the Growth and Bioenergetics of the Tropical Sea Urchin *Tripneustes ventricosus* (Lamarck). Ph.D. Thesis. University of British Columbia, Canada. 216 pp.

Mahon, R. 1993. Marine fishery resources of the Lesser Antilles. Pages 5-79 in: FAO Fisheries Technical Paper No. 326. FAO, Rome, Italy. 235 pp.

Mahon, R. and Parker, C. 1999. Barbados sea eggs, past, present, future. Fisheries Division, Ministry of Agriculture and Rural Development, Barbados. Fisheries Management Plan, Public Information Document No.1. 15pp.

Mahon, R., S. Almerigi, P. McConney, C. Parker, and L. Brewster. 2003. Participatory methodology used for sea urchin co-management in Barbados. *Ocean & Coastal Management* **46**:1-25.

McConney, P. 2001. Multi-objective management of inshore fisheries in Barbados: a biodiversity perspective. Paper presented at World Fisheries Trust, IDRC, UNEP Conference. Blue Millennium: Managing Global Fisheries for Biodiversity, Victoria, Canada, 25 – 27 June 2001.

McConney, P., R. Mahon, and C. Parker. 2003. Barbados case study: The sea egg fishery. Caribbean Coastal Co-management Guidelines Project. Caribbean Conservation Association, Barbados. 74 pp.

McConney, P. and M. Pena. 2004. Events and institutional arrangements in the management of the 2003 Barbados sea egg season (15 September – 15 October). Coastal Resources Co- management Project (CORECOMP). Centre for Resource Management and Environmental Studies, University of the West Indies Cave Hill Campus, Barbados. 36 pp.

McConney, P. and M. Pena. 2005. Summary of events in the 2004 Barbados sea egg fishing season (15-30 September 2004). Centre for Resource Management and Environmental Studies. The University of the West Indies, Cave Hill Campus, Barbados. 17 pp.

Parker, C. [In prep]. *UWI doctoral dissertation on the sea urchin fishery*. Department of Biology. Faculty of Pure and Applied Sciences, Cave Hill, Barbados.

Parker C. 2008. Barbados National Sea Egg Country Report. 4 pp.

Parsram, K. and P. McConney. 2004. Barbados case study: The sea egg fishery. Caribbean Conservation Association, Barbados. 13 p

Pena Rey, M. 1998. The application of randomly amplified polymorphic DNA (RAPD) markers to stock discrimination of the white sea urchin, *Tripneustes ventricosus*, in the eastern Caribbean. MSc Thesis. The University of the West Indies, Cave Hill Campus, Barbados. 125pp.

Scheibling, R.E. and P.V. Mladenov. 1987. The decline of the sea urchin, *Tripneustes ventricosus*, fishery of Barbados: A survey of fishermen and consumers. *Marine Fisheries Review* **49**(3):62-69.

Smith, A.H. and F. Berkes. 1991. Solutions to the "Tragedy of the Commons": sea urchin management in St. Lucia, West Indies. *Environmental Conservation* **18**(2):131-136.

Smith, A.H. and S. Koester. 2001. A description of the sea urchin fishery in Laborie, St. Lucia. CANARI LWI Project Document no. 4. CANARI Technical Report no. 294:8 pp.

Smith, A.H. and R. Walters. 1991. Co-management of the white sea urchin resource in St. Lucia.

Tertschnig, W.P. 1985. Sea urchins in seagrass communities: Resource management as functional perspective of adaptive strategies. Pages 361-368 in: B.F. Keegan and B.D.S. O'Connor (Eds.) *Proceedings Fifth International Echinoderm Conference, Ireland.*

Vermeer, L.A., W. Hunte, and H.A. Oxenford. 1994. An assessment of the potential for community-level management of the sea urchin fishery in Barbados. *Proceedings of the Gulf and Caribbean Fisheries Institute* **47**:79-103.

Wolcott, R. and C.G. Messing. 2005. A comparison of diets and agitation methods for larval culture of the edible sea urchin, *Tripneustes ventricosus*. *Bulletin of Marine Science* **77**(2):177-190.