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BIOLOGY AND FISHERY MANAGEMENT OF THE WHITE SEA URCHIN, *TRIPNEUSTES VENTRICOSUS,* IN THE EASTERN CARIBBEAN

Cover photographs:
Left to right from top: white sea urchins on reef (courtesy of BARNUFO); pre-season population abundance survey being conducted in Barbados (courtesy of BARNUFO); consultative meeting with white sea urchin harvesters, Barbados (courtesy of Sharon Almerigi); harvester preparing white sea urchins for sale, Barbados (courtesy of Christopher Parker).

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BIOLOGY AND FISHERY MANAGEMENT OF THE WHITE SEA URCHIN, *TRIPNEUSTES VENTRICOSUS*, IN THE EASTERN CARIBBEAN

by
Maria Pena
Project Officer
CERMES, The University of the West Indies
Barbados

Hazel A. Oxenford
Professor of Marine Ecology and Fisheries
CERMES, The University of the West Indies
Barbados

Christopher Parker
Fisheries Biologist
Fisheries Division
Ministry of Agriculture
Barbados

Antoinette Johnson
Laboratory Manager
Department of Environmental Health
Cayman Islands (United Kingdom)

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PREPARATION OF THIS DOCUMENT

This publication was prepared for the Food and Agriculture Organization of the United Nations (FAO) Subregional Office for the Caribbean (FAO/SLC) as a direct output of a Special Workshop on the White Sea Urchin Fisheries in the Eastern Caribbean at the 61st Annual Gulf and Caribbean Fisheries Institute in Le Gosier, Guadeloupe, on 10–14 November 2008. In view of the importance of the collated information obtained from published and unpublished documents on the white sea urchin fisheries in the eastern Caribbean and the request by some countries to address the white sea urchin fishery from a regional perspective, it was considered that a separate document presenting this material would have a greater scientific impact and would be more accessible for information sharing than if simply incorporated into the report of the workshop.

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ABSTRACT

The white sea urchin, *Tripneustes ventricosus*, is common in shallow coastal waters of the tropical Atlantic Ocean, and is widely distributed in the Caribbean Sea. The species supports small-scale, commercially important, seasonal fisheries in several islands in the eastern Caribbean including Barbados, Martinique (France) and Saint Lucia, and minor subsistence fisheries in Grenada and Saint Vincent and the Grenadines. However, despite significant management and conservation efforts by some countries, white sea urchin population abundance has declined locally. Understanding the large fluctuations in local population size and implementing sound management practices in the white sea urchin fisheries is critical to the sustainable use of this resource in the future, and would benefit considerably from a sharing of information and management experiences. To this end, this circular has attempted to collate both published and unpublished information on the white sea urchin and its fisheries in the eastern Caribbean and perspectives on past and current management of these fisheries.

CONTENTS

ABBREVIATIONS AND ACRONYMS

BARNUFO	Barbados National Union of Fisherfolk Organisations
CANARI	Caribbean Natural Resources Institute
CERMES	Centre for Resource Management and Environmental Studies
DOF	Department of Fisheries
FAC	Barbados Fisheries Advisory Committee
FMP	fisheries management plan
IFREMER	Institut français de recherche pour l'exploitation de la mer
IRPM	Institut régional de pêche et de marine
MarGov	Marine Resource Governance in the eastern Caribbean
RAPD	Randomly Amplified Polymorphic DNA
SEFMAC	Sea Egg Fishery Management Advisory Council

EXECUTIVE SUMMARY

Stocks of the white sea urchin, commonly known as the sea egg in the eastern Caribbean, have virtually collapsed in recent years, despite serious efforts aimed at conservation and protection by some countries harvesting the resource. Some of the main fishery management measures implemented over the years include annual closed seasons; closed areas; prohibition of harvest with the assistance of scuba gear; multiyear fishing moratoria; minimum size at capture and total individual or area catch quotas.

Despite these efforts, empirical evidence indicates overall declines in white sea urchin stocks, with occasional instances of recovery not being sustained. Given these observations, FAO was requested by some eastern Caribbean countries to address the white sea urchin fishery from a regional perspective.

In response to this request, the FAO Subregional Office for the Caribbean (FAO/SLC), the Centre for Resource Management and Environmental Studies (CERMES) of the University of the West Indies (UWI) in Barbados, the Institut français de recherche pour l'exploitation de la mer (IFREMER) in Martinique (France) and the Institut régional de pêche et de marine (IRPM) in Guadeloupe (France) collaborated in hosting a Special Workshop on the White Sea Urchin Fisheries in the Eastern Caribbean at the 61st session of the Gulf and Caribbean Fisheries held in Gossier, Guadeloupe on 10-14 November 2008. The main objective of the workshop was to determine the national and/or subregional actions that could be taken for recovery of white sea urchin fisheries in the eastern Caribbean.

Prior to this workshop, the partners collaborated in collating existing information on the biology and management of the white sea urchin fisheries in the eastern Caribbean with specific responsibilities being divided as follows:

- UWI/CERMES – collation and review of published and unpublished information on the white sea urchin and its fishery in the English-speaking eastern Caribbean;
- IFREMER – collation of published and unpublished information on the white sea urchin and its fishery in Martinique and Guadeloupe;
- FAO/SLC – solicitation of national reports on the white sea urchin and its fishery from participating countries.

This synthesis incorporates published and unpublished information on the white sea urchin in the eastern Caribbean – Barbados, Carriacou (Grenada), Grenada, Martinique, Saint Lucia, and Saint Vincent and the Grenadines. The Circular consists of ten chapters. Chapters 1–6 synthesize information on the biology, ecology, population structure and aquaculture potential of the resource. Chapter 7 addresses the exploitation of the resource including the types of fishing equipment used, fishing areas and seasons. Chapter 8 examines the socio-economic importance of the white sea urchin fisheries in the eastern Caribbean. Chapter 9 focuses on the past and current management of the white sea urchin fisheries by country, and Chapter 10 identifies knowledge gaps for the sustainable management of white sea urchin fisheries and provides an overview of current research being conducted on white sea urchin fisheries in the region.

A second output of the collaboration is an annotated bibliography related to the white sea urchin and its fisheries in the eastern Caribbean. It is hoped this bibliography will be used as a reference guide for future research and will be updated regularly as literature is both produced in the future and discovered from previous studies.

Bisessar Chakalall †
Senior Fishery Officer
FAO Subregional Office for the Caribbean

1. IDENTITY: NOMENCLATURE AND TAXONOMY

Tripneustes is a pantropical genus that extends into the subtropics. The genus was traditionally believed to include three species with non-overlapping distributions: the white sea urchin, *T. ventricosus*, found on both sides of the Atlantic Ocean; the brown sea urchin, *T. depressus* (Aggasiz 1863), in the eastern Pacific Ocean only; and the collector sea urchin, *T. gratilla* (Linnaeus 1758), in the central and western Pacific Ocean as well as the Indian Ocean (Plate 1). The three species are morphologically very similar and it has been suggested they may constitute a single species (Zigler and Lessios, 2003). The nomenclature and taxonomy of the white sea urchin is given in Table 1.

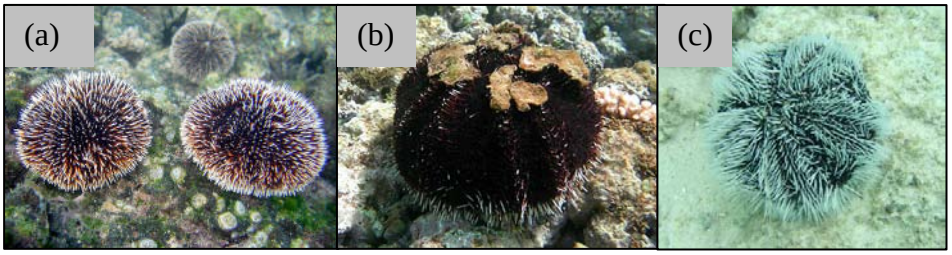


Plate 1: Species of *Tripneustes:* (a) *T. depressus*, (b) *T. gratilla*, and (c) *T. ventricosus* [(a) Wet Web Media; (b) US National Park Service; (c) authors' collection].

Table 1: Nomenclature and taxonomy of the white sea urchin

Nomenclature		**Taxonomy**
Valid name	Objective synonymy	Phylum: Echinodermata Class: Echinoidea Order: Temnopleurioda Family: Toxopneustidae Genus: *Tripneustes* Taxon: *Tripneustes ventricosus* (Lamarck 1816)
Tripneustes ventricosus (Lamarck 1816)	*Tripneustes esculentus Leske* (Lewis 1958)	

There are a number of standard common and vernacular names by which the white sea urchin is known throughout the eastern Caribbean, and these are listed in Table 2.

Table 2: Common and vernacular names of the white sea urchin used in the eastern Caribbean

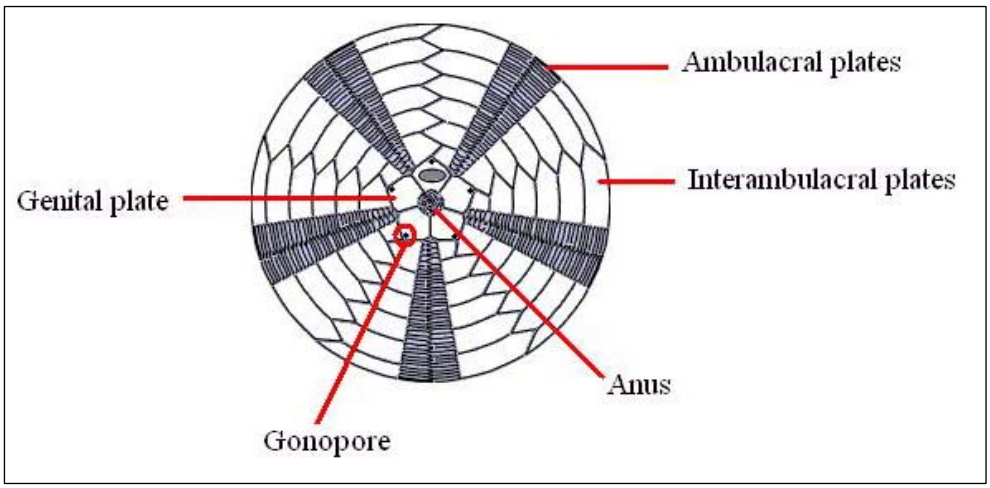
Region	**Standard common names**	**Vernacular names**
English-speaking Caribbean (Barbados, Grenada, Saint Lucia)	West Indian sea urchin White sea egg	Sea egg Chadon (Saint Lucian Creole)
French-speaking Caribbean (Guadeloupe, Martinique)	Oursin blanc	Chadron-blan

2. MORPHOLOGY

The white sea urchin is a typical, although large, member of the sea urchin (Echinoidea) group. In common with all urchins, it has a roughly spherical outer skeleton, or test, made up of fused calcareous plates arranged into two distinct groups comprising five ambulacral and five interambulacral series. These are arranged alternately in the pentaradial pattern characteristic of this taxonomic group. The plate series extend from the mouth located at the centre of the ventral side of the animal to the anus located in the centre of the dorsal side. The spines are slender white calcareous outgrowths from the test and occur over the entire test surface. The spines are used in defence against predators and may also be used in movement. However, movement is generally achieved through the action of numerous tube feet, which protrude through tiny holes in the test plates. The white sea urchin also uses these tube feet to hold on to fragments of shell, stone or other debris to cover itself

and to move food towards its mouth The spines are longer and more numerous on the interambulacral plates whereas the tube feet are more prominent on the ambulacral plates (Figure 1). This arrangement gives the urchin its characteristic dark brown to black and white banded colour pattern. However, some of the pigments from the plants consumed by the animal may become deposited in test structures, particularly the spines, which impart a brown or green hue to the test, depending on the pigment. This is mainly seen in younger animals (C. Parker, personal observation).

Figure 1: Basic body plan of a sea urchin test



Source: Parker (2005).

The mouth is a complex protrusible structure known as the Aristotle's lantern. It consists of several calcareous structures that articulate together to drag and grind food into the animal's digestive tract. Digestive waste is voided through the anus located on the dorsal (aboral) side (Plates 2 and 3).

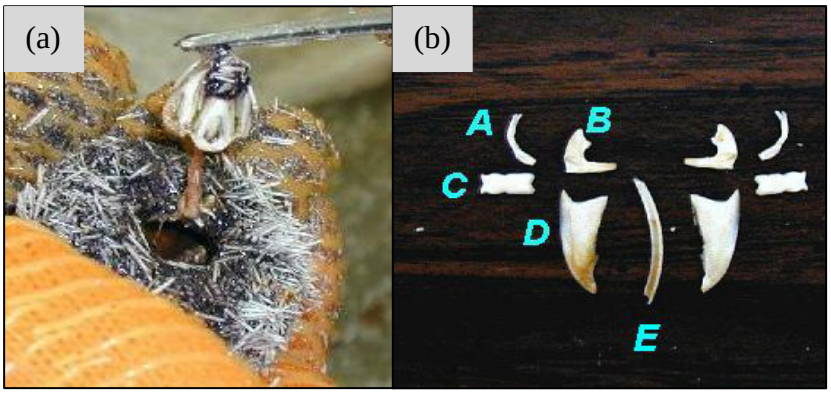


Plate 2: (a) Removing the Aristotle's lantern from a white sea urchin (with the end of the digestive tract still attached at the centre. (b) Ossicles comprising the Aristotle's lantern of a white sea urchin: A = compass (5 in total), B = epiphysis (10 in total), C = rotule (5 in total), D = demipyramid (10 in total), E = tooth (5 in total) (Parker).

The reproductive system of the white sea urchin consists of five gonads, sometimes more or less fused and suspended by mesenterial strands (Hyman, 1955) to the "roof" of both male and female urchins (Plate 3). The gonads are not only the source of eggs or sperm, which are referred to as roe, but also serve as the main nutrient storage organ (Bruce, 1988). Gonads tend to be bright orange in colour in females and light yellow in males (Lewis, 1958).

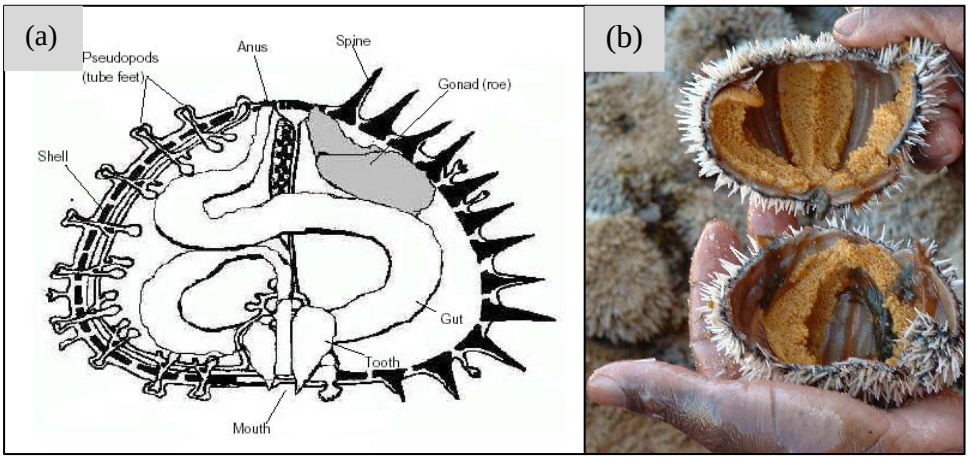


Plate 3: Morphology of the white sea urchin: (a) cross-sectional diagram of a typical sea urchin; and (b) cracked open shell of a white sea urchin containing five gonads [(a) INFOFISH International, (b) Pena].

3. DISTRIBUTION

3.1 Species range

The white sea urchin is found along the west coast of Africa from the Gulf of Guinea to Walfish Bay and along the western central Atlantic Ocean from Bermuda, to the Carolina coast of the United States of America, and the Caribbean to Brazil (Mortensen, 1921) at least as far as Rio de Janeiro (Tommasi, 1972). The western limit of its range may be the eastern side of the Yucatan Peninsula as it has been reported in Panama (Lessios, 1985) and Quintana Roo in Mexico (Caso, 1974) but nowhere within the Gulf of Mexico (Serafy, 1979). Bell (1881) provides the sole report of *T. angulosus*, which was later identified as being *T. escluentes* (later *T. ventricosus*) by Clark (1925), in Ascension Island. However the presence of the white sea urchin on this isolated South Atlantic island has not been recorded since, and as such the presence of this species at Ascension Island is questionable (Pawson, 1978) or perhaps ephemeral. The species occurs mainly in shallow waters to depths of 6–8 m (Lewis, 1958), where the penetrating light is sufficient to facilitate growth of seagrasses and algae upon which the animals feed. However, in Barbados and Saint Lucia, white sea urchins have been found at depths of 25 m (Hickey, 1982; Smith and Berkes, 1991) while Mortensen (1921) reported a maximum depth of 30 m for the species.

3.2 Habitat and distribution

White sea urchins live in a variety of shallow water habitats including rocky rubble, algal rock flats and seagrass beds. They are seldom found on living reefs and pure sand (Lewis, 1958). High abundances of white sea urchins sometimes occur in tidal pools. However, such assemblages are prone to high mortality events owing mainly to the very high water temperatures and subaerial exposure that such habitats are periodically subjected to, especially at low tide (Glynn, 1968; Hendler, 1977; Cameron, 1986). Like other relatively sessile marine organisms with planktonic early life-history stages (Chapter 4), abundance and distribution of white sea urchins are variable along spatial and temporal scales governed by habitat quality and the suite of factors, such as current flows, that affect survival and distribution at the larval stage (Parker, forthcoming).

It appears that separate nursery grounds are not necessary for successful recruitment, with juveniles being found in adult habitats and even sometimes on algae covering the adult animals. Nevertheless, certain habitat features, particularly the presence of suitable hiding places, enhance juvenile recruit survival. Juveniles are more often found under rocks and ledges and in crevices than in open areas. In seagrass beds, juveniles are often found enveloped with leaves of the adjacent plants. Similarly, juvenile white sea urchins are often found nestled among the fronds, especially of the more foliose algae. For example, the brown alga *Padina* sp. appears to constitute an especially favourable nursery

habitat for very small juvenile white sea urchins until they become too large for the plant to physically support them (Parker, forthcoming).

4. ECOLOGY AND LIFE HISTORY

4.1 Reproduction: sexuality, maturity, fertilization and spawning

Sexes are separate in the white sea urchin but it is not possible to distinguish between males and females from their external appearance unless they are running ripe. If this is the case, then sex may be determined by colour as the females' spawn is usually bright orange and the males' semen light yellow (Lewis, 1958; Plate 4). Sexual maturity is usually reached within one year of age. White sea urchins are broadcast spawners, with eggs and sperm being shed directly into the sea water column where fertilization and embryonic development occur (Hyman, 1955; Bruce, 1988). Sea urchin larvae and all developmental stages are pelagic (planktonic) up to the settlement stage or metamorphosis.

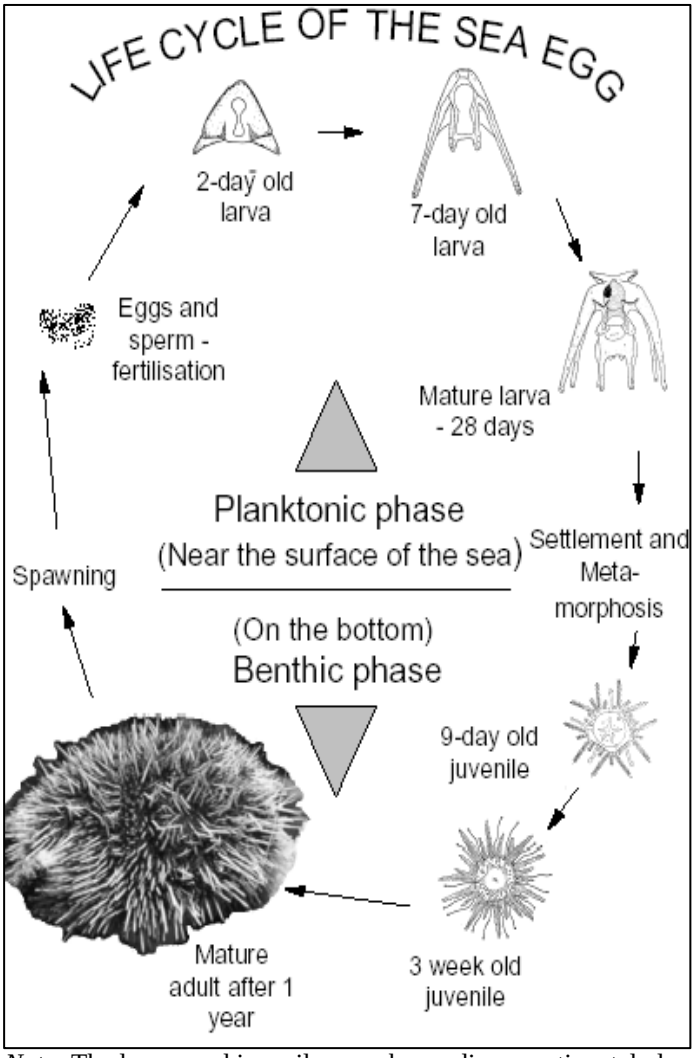
Plate 4: Partially de-spined, running-ripe white sea urchins: male (left) and female (right) (Franklin).

The length of larval development from the fertilized egg to the settlement-stage pluteus (metamorphosis), as examined for white sea urchins in Barbados, is estimated to be about one month in the wild (Lewis, 1958; Cameron 1986). This is similar to the estimate by Wolcott and Messing (2005) of 23–36 days (depending on diet) for laboratory-reared white sea urchin larvae in Florida, United States of America, to reach the juvenile stage (stage immediately after the settlement-stage pluteus). It should be noted that the term "metamorphosis" generally refers to the change in structure from larval to juvenile form, although the exact identification of the commencement and conclusion of metamorphosis has varied in the literature. The breeding season, defined as the time during which mature gametes are present in the gonads, and examined for white sea urchins in Barbados, generally lasts several months (Hickey, 1982). Analyses of seasonal variation in gonosomatic indices of white sea urchins in Barbados indicate that seasonal ripening of gonads begins early in the year from around mid-January and that the peak spawning period in Barbados is typically from April to August (Hunte, Parker and Johnson, 1993; Mahon and Parker, 1999), although it may extend beyond this. Parker (forthcoming) notes that peak spawning activity varies among sites and years, with significant spawning activity sometimes occurring as early as March and as late as September. Johnson (unpublished data) has recorded breeding in white sea urchins in Barbados up to the end of December.

Although both Lewis (1958) and Johnson (unpublished data) report seasonal spawning, the species may be capable of spawning year-round, as evidenced by the presence of mature gametes in individuals throughout the year (McPherson, 1965; Smith and Berkes, 1991; Daniel, 2003). Lewis (1958) reported that in March and April, prior to spawning, white sea urchins move from open areas in seagrass beds and hard bottom habitats, and aggregate in groups of up to a dozen under rocks and ledges. They remain in these groups throughout the spawning season, presumably as a means to enhance fertilization success, dispersing on completion of spawning. Scheibling and Mladenov (1987) also observed some clustering in June. Group spawning is stimulated by the initial spawning of one or two individuals. The eggs of the white sea urchin are about 0.08 mm in diameter and sink after release in the water column. During fertilization, active sperm become attached in a thick layer to the eggs.

Young, mobile larvae first appear in the plankton (in Barbados) at the end of May and metamorphosing larvae appear in the last week of June. Although the pluteus larvae can swim a little,

Figure 2: Life cycle of the white sea urchin



Note: The larvae and juveniles are shown disproportionately large relative to the adult.
Source: Mahon and Parker (1999).

they are at the mercy of the currents. Figure 2 outlines the life cycle of the white sea urchin, showing two phases: the planktonic, when the eggs and larvae are in the water column; and the benthic, when the young and adults live on the sea floor. Fertilization and early development of the white sea urchin are discussed in detail in Lewis (1958).

4.2 Life-history stages

4.2.1 Pre-adult: embryonic, larval and juvenile phases

The white sea urchin is a relatively short-lived sea urchin species with a maximum life span of about three years (Parker, forthcoming; Mahon and Parker, 1999; Daniel, 2003). Early development from the first cleavage to the first stage of the pluteus occurs within two days. Lewis (1958) and Hickey (1982) 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 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, 1988). There is some evidence to suggest that the presence of adult white sea urchins may also enhance successful juvenile recruitment. However, the underlying factors involved are not well understood and on-site adult presence is not construed as essential for juvenile recruitment (Parker, forthcoming). However, if adult presence does enhance recruitment success,

depletion of adult stocks may diminish recruit settlement rate, which in turn could have significant effects on white sea urchin stock abundance (Mahon, 1993).

An additional relationship between substratum and recruitment strength is also apparent. As mentioned above, certain marine flora appear to function as valuable juvenile nurseries. 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, suggesting that such marine plants may serve as better nursery habitats than hard substrates (Parker, forthcoming).

However, such plants (e.g. *Padina* and *Thalassia*) are typically located close to shore and are therefore particularly susceptible to the impact of rough seas and the effects of land-based pollutants. There is a perception in Barbados and neighbouring Caribbean islands that nearshore macroalgal and seagrass beds are decreasing in abundance. If this is the case, then there is the distinct possibility that population recovery of urchins may be constrained by limited availability of preferred nursery habitats (Hunte, Parker and Johnson, 1993; Parker, forthcoming).

Predation on juveniles may be important in limiting recruitment to adult populations of the white sea urchin. Reef fishes, particularly the queen triggerfish, *Balistes vetula*, have been noted by Barbadian fishers as being important predators of juvenile white sea urchins. The rapid growth rate of juveniles may be a strategy to evade heavy predation at small sizes (Scheibling and Mladenov, 1987).

4.2.2 Adult phase: longevity, competitors, predators, and parasites

Based on food and habitat preferences, it may be assumed that *D. antillarum* is a competitor of the white sea urchin. After the mass mortality of *D. antillarum* in the early 1980s, some research indicated that the white sea urchin increased in number, and occurred in some previously *Diadema*-dominated habitats where these species had previously been rare (Woodley, Gayle and Judd, 1999; Engman, 2000; Moses and Bonem, 2001). The grazing activity of the white sea urchin was believed to have subsequently facilitated recolonization of the habitats by *D. antillarum* after the former species grazed down the resident algae to heights that were more manageable for *D. antillarum*. Moreover, it has been posited that *D. antillarum* may actively exclude white sea urchins from reef habitats (Chow, 2005).

Several species of reef fishes, such as parrotfishes, triggerfishes and puffers, are known to prey on adult white sea urchins (Mahon and Parker, 1999). A parasite and commensal have been found living on the test and spines of the white sea urchin. The parasite, a small gastropod belonging to the family Mellanellidae, occurs on the test, and urchins infested with this small snail exhibit areas of the test bared of spines. The small commensal, *Gnathophylloides minerii* Schmitt, may be found clinging to the spines of the urchin. Lewis (1958) notes that a description of this decapod macruran is provided by both Schmitt (1933) and Lewis (1956). In addition, helmet gastropods (*Cassia* sp.) have been identified as significant predators of white sea urchins in seagrass beds (Hughes and Hughes, 1971; Tertschnig, 1989).

4.3 Nutrition and growth

The white sea urchin is a generalized grazer, feeding preferentially on turtle grass (*Thalassia testudinum*) and brown algae (e.g. *Dictyota*, *Padina* and *Sargassum* spp.), but also eating some green algae (e.g. *Ulva*, *Zonaria* and *Cladophora* spp.) (Lewis, 1958; Lilly, 1975; Mahon and Parker, 1999). When feeding on turtle grass, white sea urchins appear to prefer the distal senescent portions of the leaves. These support an epibiotic community that is believed to be more nutritious than the plant itself. The preference for leaf tips may be due to avoidance of plant sections maintaining both structural and chemical defence mechanisms (Keller, 1976, 1983; Tertschnig, 1985).

Growth varies according to environmental conditions with both somatic and gonad growth being greatly affected by diet (Lilly, 1975). Jaw–test size ratios of the white sea urchin may be sensitive to habitat conditions, including nutritional quality, and may therefore be useful for comparing the growth-supporting value of habitats in which the animals reside (Parker, forthcoming). In Barbados, very small juvenile white sea urchins are found in greatest abundance under rocks, in sheltered

crevices and among suitable flora from late August until September. Their test diameter at this time is 1–3 cm (Lewis, 1958). Test growth is then rapid from September to March, and slows in April through to July with maturation of the gonads. On completion of spawning, there is again a smaller increase in growth, with the majority of white sea urchins attaining test diameters of about 6–8 cm by the end of the first year, depending on the quality of habitat (Hickey, 1982).

4.4 Behaviour: migration and response to stimuli

Adults white sea urchins are fairly sedentary, spending their entire lives in a relatively narrow spatial range (within a 1 km radius) in nearshore habitats (Mahon, 1988, 1993). However, there may be potential for genetic mixing and recruitment interdependence among islands via the early life-history stage, during which the extent of the white sea urchin's dispersal and distribution is unknown (Chakalall, 1989).

The white sea urchin typically covers itself with *Thalassia* leaves, shells, rubble and other debris during the day and then releases all or most of this material at night (Lewis, 1958). Many species of sea urchins living in shallow water exhibit this ''covering'' or "decorating" behaviour in which they cover their aboral surface with material from the substratum. This material is actively moved onto the aboral surface by podia (tube feet) and spines, and then held in place by podia. The extent of covering may vary with sea urchin species, size and movement, and with environmental conditions such as solar radiation, temperature, surge, suspended particles and availability of cover material. The environmental factor most often associated with covering is light. In many sea urchins, covering is most pronounced during daylight hours and can be induced by artificial light. These observations are consistent with the view that the covering response to light may increase fitness by protecting sea urchins from damaging solar radiation (Fierce and Lapin, 2004; Jun, Matsura and Barger, 2005). Alternatively, covering materials may stabilize sea urchins in surge, protect them from deposits of mud and sand, conceal them from predators, or simply be collected as part of feeding (Kehas, Theoharides and Gilbert, 2005).

4.5 Diseases, pollutants and environmental sensitivity

In general, urchin health and urchin diseases are not well understood or well defined in the scientific literature, particularly in the light of the possibility of significant regional differences. However, urchin populations do experience periodic die-offs. Environmental stress is known to be a significant variable in these episodes, but the specific stressors and their mode of operation within urchin populations are unknown (Alden and Perkins, 2001). Mahon and Parker (1999) state that some fishers in Barbados believe the waterborne pathogen that killed the black sea urchin, *D. antillarum*, in 1983–84 also killed the white sea urchin. However, there is no evidence that this pathogen affected the white sea urchin.

In 2004, a number of clearly sick, dying and dead white sea urchins were observed by fishers within a localized area on the northwest coast of Barbados. Specimens of the afflicted animals presented with symptoms of significant or complete spine loss, particularly on the aboral surface of the animals, accumulation of gases in the intestines, and green coloration of the gonads (Plate 5). Histopathological examinations of samples of the animals were not conclusive enough to identify whether or which pathogens might have caused the disease. It is noteworthy that a localized mass mortality of white sea urchins, believed to have been caused by an unidentified disease, was reported to have occurred in Puerto Rico (United States of America) in early 1995 (Williams *et al.*, 1996). The symptoms of the sick animals in the Puerto Rico case were very similar to the animals in the Barbados case. However, as it is possible that the observed symptoms may be a common manifestation of illness in white sea urchins, it should not be inferred that the causes of these events in the two islands were the same. However, given the potential impacts on white sea urchin populations and even human health, it is recommended that more efforts be made in the area of sea urchin disease research (Pena, 2005).

Plate 5: Diseased urchins showing symptomatic loss of spines (Franklyn).

Gametes and embryos of white sea urchins are known to be negatively affected by elevated levels of a number of toxicants, including phosphates, nitrates, sewage effluent and stormwater runoff, and by increased temperature (Payne, 2003). Concentrations of inorganic sodium phosphate greater than 7.7 mg/litre and sodium nitrate greater than 8.2 mg/litre result in a reduction in fertilization and survival of embryos. Payne (2003) further reported that fertilization inhibition and 100 percent embryo mortality occurred at 50 percent of typical sewage effluent and stormwater runoff concentrations without adjustment of salinity to 35 parts per thousand and that if salinity was maintained at 35 parts per thousand, fertilization and embryogenic success were still significantly affected although mortality was less than 100 percent.

Payne (2003) also reported that increasing seawater temperatures above 28 °C had a negative impact on fertilization and embryogenesis in white sea urchins, and these impacts were very significant at 32 °C. Furthermore, Payne (2003) reported that the thresholds at which these developmental aberrations were observed were comparatively lower than those of two other extant sea urchin species examined, i.e. *E. lucunter* and *D. antillarum*, suggesting that the white sea urchin is more sensitive to perturbations of these environmental factors. Payne (2003) gives full details of toxicant concentrations tested and the effects concentration and lethal concentration 50 percent levels (these are the concentrations of toxicants producing a 50 percent reduction in fertilization or survival, respectively).

5. AQUACULTURE POTENTIAL

Scheibling and Mladenov (1987) suggested that artificial stock enhancement through aquaculture could be a feasible alternative approach to rehabilitation and recovery of the white sea urchin fishery in Barbados. They suggested that 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. Similar reseeding exercises using hatchery-reared animals are reported to have contributed to the rebuilding of stocks of *T. gratilla* in the Philippines (Juinio-Meñez *et al*., 2008).

In the past, Lewis (1958) had little success rearing white sea urchin larvae in the laboratory – they survived for only 7–10 days. This was attributed to poor culture conditions, specifically a poor food supply. Hickey (1982) managed to rear some of the animals to just over two weeks of age, and Johnson and Parker (unpublished) successfully reared a small number of larvae to about four weeks of age, but the animals did not survive the settlement phase. However, Mladenov, Scheibling and Brady (1985) demonstrated that the larvae of this species could possibly be reared on a large scale, but noted that the long larval phase would mean that culture conditions would have to be maintained for long periods.

Wolcott and Messing (2005) note that large-scale hatchery culturing has the potential to produce white sea urchins in sufficient numbers for remediation of degraded coral reefs overgrown by macroalgae, for restocking of overharvested nearshore habitats, and for development of an aquaculture industry for one or more Caribbean islands. Given the potential for commercial aquaculture of this resource, they investigated methods of water agitation and diets for larval culture

of white sea urchin and were successful in culturing the species from fertilization through to feeding juveniles on algal diets of *Isochrysis*, *Rhodomonas* and a *Rhodomonas/Isochrysis* combination.

Although white sea urchins are not currently commercially reared, Lawrence and Bazhin (1998) concluded that the resource would be suitable for aquaculture owing to its faster growth rate and shorter time to sexual maturity than other sea urchin species. White sea urchins appear to allocate more energy to production than to protection and maintenance. Therefore, they grow rapidly and have great roe production at an early stage making them suitable candidates for aquaculture.

Interest in white sea urchin aquaculture has been expressed in Barbados, especially with the high demand for the high-priced roe, both locally and internationally. *Tripneustes* sp. produce a quality roe that is of high value in Japan for the sushi industry (Fisheries Division, 2001, 2004, forthcoming). However, rearing for re-stocking could substantially alter the genetic variation of the wild stock.

6. POPULATION STRUCTURE

6.1 Stock structure

There has been no published research on the genome of the white sea urchin in the Caribbean. However, a number of preliminary studies have been conducted and these are summarized here. 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, Hunte and Oxenford, 2005).

Attempts to determine the population structure of the white sea urchin in the Caribbean have focused on comparisons of population parameters such as monthly abundance and size frequency data and isozyme analyses of white sea urchins among Caribbean islands, specifically Barbados, Grenada, Saint Lucia, and Saint Vincent and the Grenadines (Johnson, unpublished data), and within Barbados (Parker, forthcoming). 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, Parker and Johnson, 1993). Results of the Barbados study indicated possible differentiation, at least occasional, of white sea urchin populations between coasts.

Differentiation of white sea urchin populations between coasts has also been observed in Martinique from size frequency data obtained from four years of monitoring (2005–08), suggesting that there are possibly two stocks of sea urchins that may need to be managed independently of each other. White sea urchins in the south of the island are generally smaller than the legal diameter of 9 cm whereas those in the southeast tend be larger than 9 cm (Reynal and Bertrand, 2009). However, the observed differences may also be caused by differences in habitat quality influencing urchin growth rates.

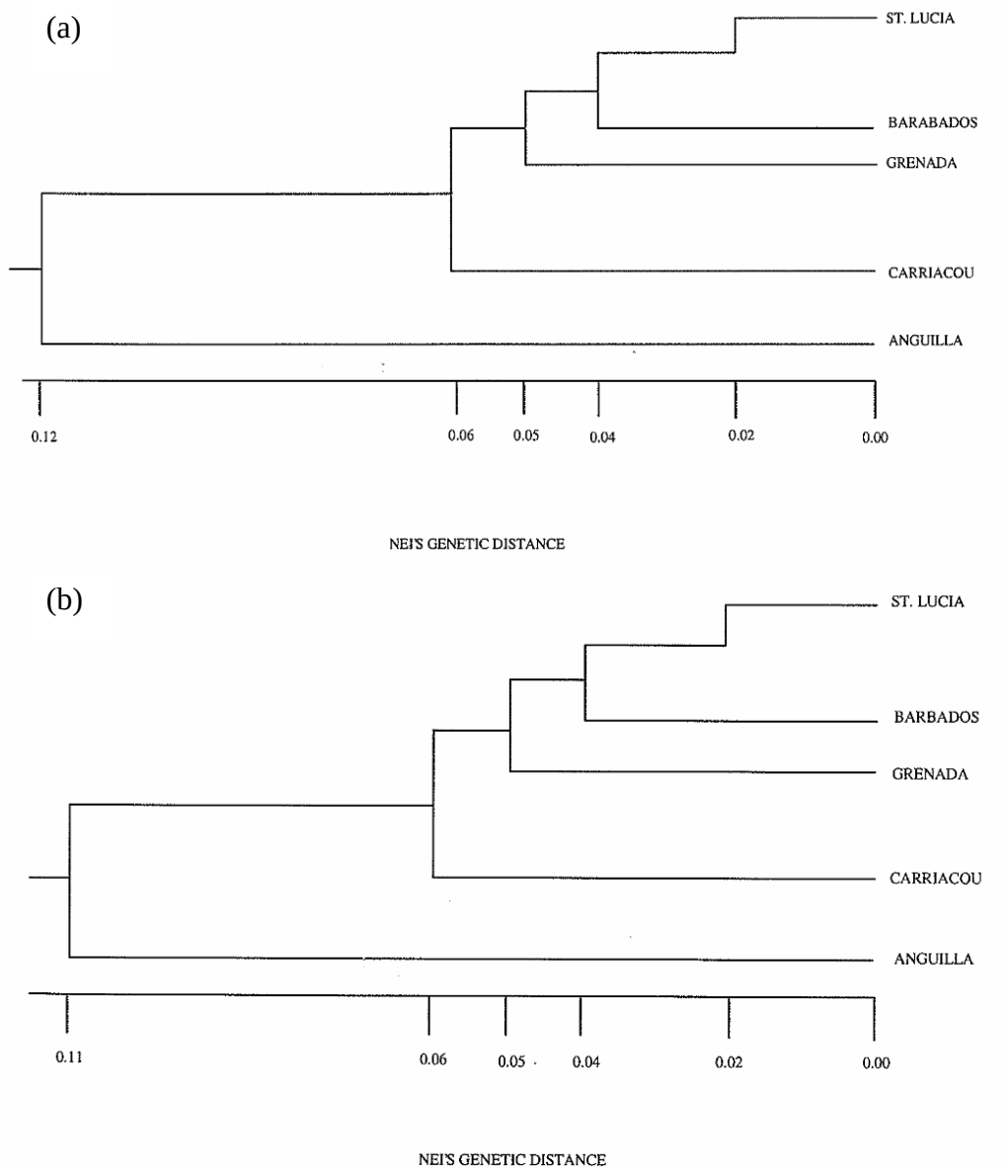
After an extensive review of the existing body of scientific literature on current patterns and larval dispersal modelling studies conducted in the eastern Caribbean, it was concluded that the rate of larval exchange among the islands, particularly in relation to recruitment to Barbados, can be considered ecologically insignificant, further supporting island-specific management approaches Parker (forthcoming).

Pena Rey (1998) investigated genetic differences among populations of urchins in the eastern Caribbean: Anguilla, Barbados, Carriacou, Grenada and Saint Lucia, using randomly amplified polymorphic DNA (RAPD) analysis. The study suggested significant genetic heterogeneity among all white sea urchin populations with restricted gene flow resulting in a subdivision of the studied populations into five distinct groups representing the five islands (Figure 3). 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.

6.2 Abundance and density

White sea urchin abundance is highly variable and prone to large interannual fluctuations (see Chapter 8), with an enormous increase in juveniles one year sometimes being followed by a number of years of low settlement (Smith and Koester, 2001). Under natural conditions, the fluctuations in abundance are largely attributable to variations in recruitment from the plankton (itself governed by

Figure 3: Nei's genetic distance dendrograms based: (a) on similarity indices of the shared presence of amplification products, and (b) on percentage match of shared presence and absence of amplification products, and generated from RAPD analysis of 182 white sea urchins; showing differentiation of populations into five distinct groups



Note: Sample sizes: Anguilla (n=43); Barbados (n=44); Carriacou (n=43); Grenada (n=37) and Saint Lucia (n=15).
Source: Pena Rey (1998).

myriad factors that affect the growth and survival of the larvae in the plankton), favourable currents to bring the larvae to suitable habitats and subsequently successful settlement and survival in the benthos (McConney, Mahon and Parker, 2003; Parker, forthcoming). The impact of variable recruitment success on population abundance is further augmented by the relatively short life span of white sea urchins (three years), as the abundance in any single year, even in an unfished population, would depend on the recruitment success of only the previous two years minus the accrued losses from natural mortality. However, with added fishing mortality, especially when it is high, most of the adults are removed each year, and, as such, annual stock yields are actually almost entirely dependent on the previous year's recruitment. Very high fishing pressure may drive the stock to a dispensated state.

Natural events also contribute to fluctuations in white sea urchin abundance. Smith and Koester (2001) note that, in Saint Lucia, white sea urchins 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, with the latter significantly reducing the numbers of white sea urchins in the Laborie and Vieux Fort areas. 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 white sea urchin stocks was most likely due to siltation from soil erosion and runoff. White sea urchin numbers increased very slowly in the following five years, but a strong recruitment in 2000 resulted in a dramatic increase in abundance in 2001. Similar increases were reported in the same year from Barbados, Martinique and Saint Vincent and the Grenadines.

7. EXPLOITATION

Sea urchin roe is highly valued in many countries for sushi and is a well-known product in the international seafood trade. There are many fisheries for the species that occur in temperate waters. However, there are only a few Caribbean countries in which fisheries for the white sea urchin are known to take place. Small-scale but commercially important white sea urchin fisheries occur in Barbados, Martinique and Saint Lucia (McConney, Mahon and Parker, 2003). Minor subsistence fisheries for the white sea urchin occur in Grenada and Saint Vincent and the Grenadines. Details of these fisheries are outlined here.

7.1 Fishing methods, vessel types and gear

Generally, in all the islands where white sea urchin fisheries exist, fishers collect both male and female white sea urchins by free diving with mask, snorkel and fins. However, methods of harvesting vary to some extent among the islands.

In Barbados, free divers traditionally harvested white sea urchins from nearshore areas, swimming 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 from netting, crocus bags or discarded sugar bags) were suspended (Plate 6). The white sea urchins 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 maypole log back to shore. Alternatively, sea urchins were collected in floating wooden crates or rafts (Hickey, 1982; Scheibling and Mladenov, 1987; Vermeer, Hunte and Oxenford, 2005; Mahon and Parker 1999; McConney, Mahon and Parker, 2003; Parker, 2009, forthcoming).

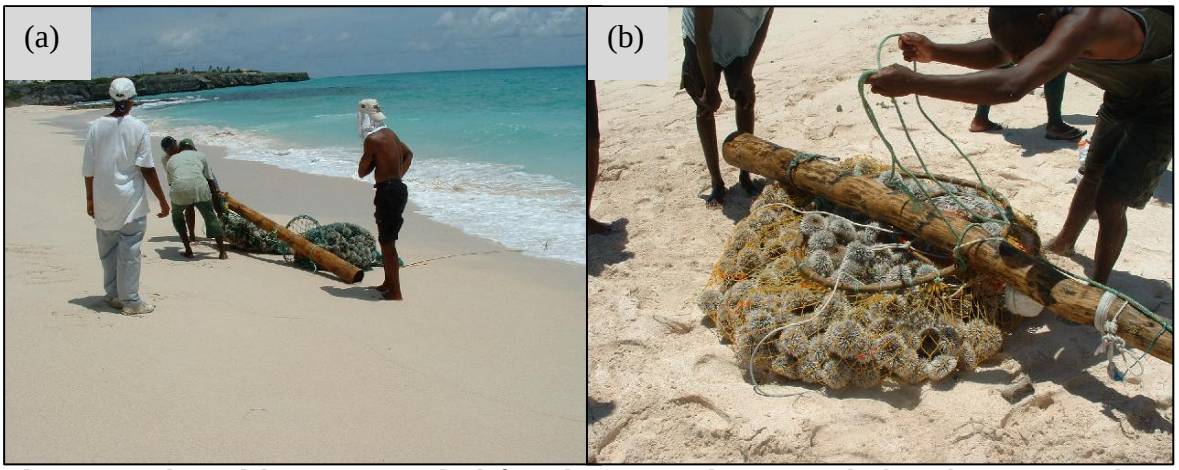


Plate 6: Traditional harvesting method for white sea urchins in Barbados, showing (a) white sea urchin divers hauling the maypole and attached bags of white sea urchins ashore, and (b) white sea urchins in a mesh bag being detached from the maypole (authors' collection).

Today, white sea urchins are often harvested by divers operating from small "moses" boats (rather than swimming from shore) and, less commonly, from other vessels such as launches (called "dayboats") and even iceboats that are used primarily in the island's pelagic fisheries. The white sea urchins are landed at numerous points along the coast, including many that are inaccessible by road (McConney, Mahon and Parker, 2003; Parker, forthcoming). A few non-traditional fishers use scuba gear ("tank men") to harvest urchins (Vermeer, Hunte and Oxenford, 2005). However, since 1998, the harvesting of white sea urchins using scuba gear has been prohibited by law and only free diving is legally allowed in the fishery (Parker, 2009).

In recent years, with the increasing scarcity of sea urchins in Barbados, there has been a greater reliance on fishing from boats, especially in the farther and less accessible areas often exposed to heavier wave action (Scheibling and Mladenov, 1987). For these areas, most fishers go out in the traditional Barbadian dayboat (7–12 m launch with inboard motor) or the iceboat (12–18 m launch with inboard motor) and some use the moses boat (3–6 m open rowboat with or without outboard motor) (see Plate 7; McConney, 2001; Smith and Berkes, 1991; Vermeer, Hunte and Oxenford, 2005).

Plate 7: Types of boats used in the harvest of white sea urchins in the eastern Caribbean: (a) small open boat ("moses" in Barbados) with outboard engine; (b) dayboat (Barbados); (c) iceboat (Barbados); (d) dugout canoe with outboard engine (Grenada and Saint Lucia); (e) wooden pirogues with outboard engines (Grenada, Martinique and Saint Lucia); and (f) small open boat with outboard engine (Saint Lucia) [(a) Franklin, (b) Parker, (c) Pena, (d) authors collection, (e) and (f) Cox].

In Saint Lucia, the fishing methods are similar to those in Barbados, *viz*. free diving, either by swimming from shore or from small open boats and pirogues (Smith and Berkes, 1991; De Beauville-Scott, 2009). Traditionally, a raft known as a dory or shaloop in Creole (transom in English) was used to float white sea urchins back to shore (Plate 8), or white sea urchins were harvested from dugout canoes. The vessel of choice used in Saint Lucia today is the pirogue (Plate 7). Smith and Koester (2001) note that diving for white sea urchins was an enjoyable activity for children, who would make rafts by putting sticks through the trunks of four or five banana plants, or by tying three or four logs of *gonmyé modi* together.

In Carriacou and Grenada, the urchins are collected from beds of *Gracilaria* spp., seagrass or reefs by diving "barewind" (free diving with mask and fins). As in Barbados, individuals sometimes swim out to collect the white sea urchins with some type of float and feed bags (Phillips, 2009; Pena Rey, 1998; Nayar *et al*., 2009). Some fishers in Carriacou and Grenada operate in groups of about two to three from wooden pirogues 2.5–6 m long powered by oars or small outboard engines (Plate 7). Typically, crews in non-motorized rowboats would often go out together, sometimes collectively hiring a boat with an engine to tow them to white sea urchin grounds. More recently, with the common use of scuba, larger boats (similar to those used to catch lobster and conch) have been used for white sea urchin harvesting.

In Saint Vincent and the Grenadines, as in the other countries, white sea urchins are harvested by free divers and by scuba divers, and in very shallow areas persons will also just pick up white sea urchins without the use of any gear (Punnett, 2009).

In Martinique, traditionally, the white sea urchin was harvested frequently by free diving (often without a mask) in groups from simple rafts (6–7 m long and 1.5 m wide) called "piketts" made of the sisal plant, or from "gommiers" (dugout canoes) powered by oars. Since 1979, the use of these rafts has declined (Daniel, 2003). Owing to the increasing demand for, and high price of, roe, sea urchin harvesting has intensified and is now demand for, and high price of, roe, sea urchin harvesting has intensified in recent times and is now associated with larger motorized boats about 7 m long with 82 hp engines (Reynal and Bertrand, 2009).

Fishers, now equipped with mask and snorkel gear, use a hook to pick the white sea urchins from the substrate. A bamboo pole with a split end similar to a fork ("croc" or "croc á chadron") may also be used as a grip to collect urchins. Once collected, the white sea urchins are placed in a basket ("panyin-chadron"), which, once full, is brought back to the boat. In some cases, the boat owners remain on board the boat during harvesting but they may also dive. Each boat generally has a team of several divers. Recently, the number of divers per boat has been limited to a maximum of three by prefectoral order No. 08-02708 of 7 August 2008.

In the past, scuba gea was used to harvest the white sea urchins. This gear was used mostly by people outside the white sea urchin fishing communities. Its use is now prohibited in the fishery.

Plate 8: Traditional harvesting method for white sea urchins using the dory in Saint Lucia (Cox).

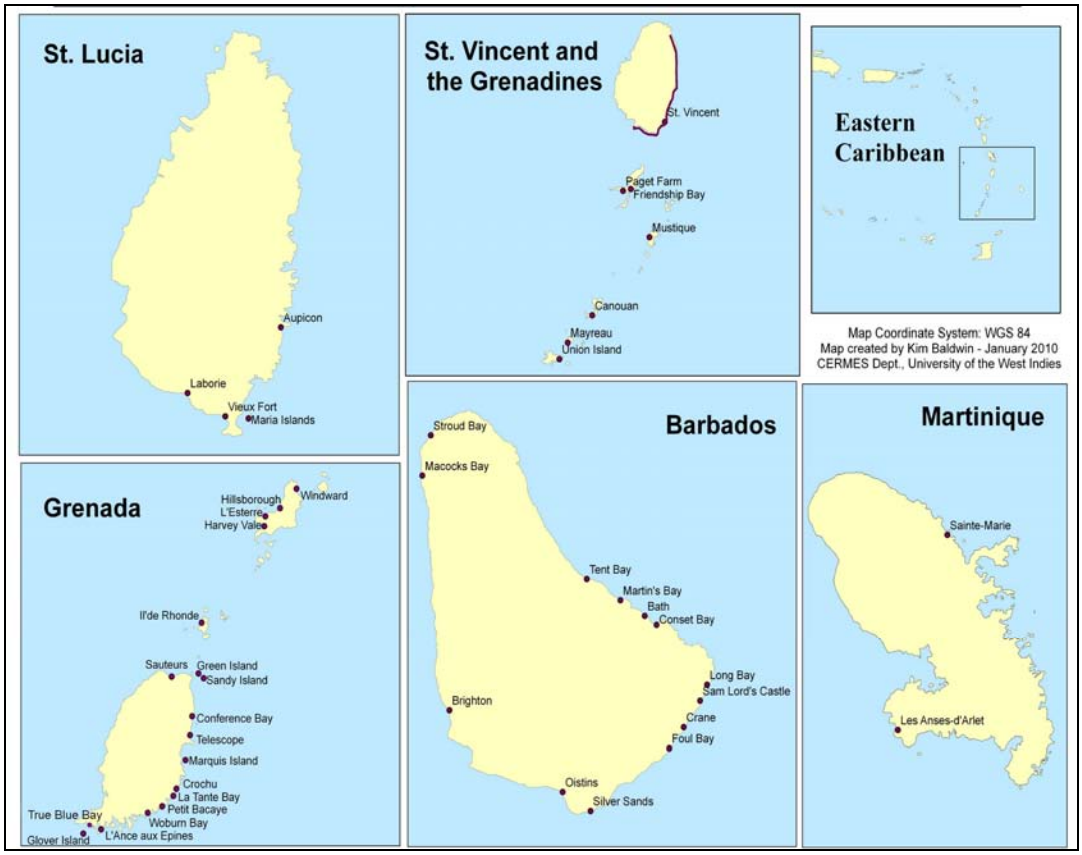
7.2 Fishing areas: national fishing locations and landing sites

White sea urchins are distributed all around Barbados but occur in greatest densities on the north, southeast and east coasts (Vermeer, Hunte and Oxenford, 2005; Parker, 2009; Figure 4). The main traditional landing sites are therefore on these coasts and include Oistins, Silver Sands, Conset Bay, Crane, Foul Bay, Long Bay, Martin's Bay, Sam Lord's Castle, 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, white sea urchins have always been rare along the west coast. This is probably because of the well-developed coral reef system along this coast (Mahon and Parker, 1999).

In Saint Lucia, white sea urchins were widely distributed in the past along all coasts. Today, white sea urchins 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; De Beauville-Scott, 2009; Figure 4). Three of the most economically important white sea urchin populations occur off Aupicon, the Maria Islands and Laborie (George and Joseph, 1994).

In Grenada, the main white sea urchin fishing areas are off the main island in the south from Point Salines within one mile (1.6 km) of the shore to L'Anse aux Epines, and in the east at Telescope. Very limited harvesting occurs along the western shelf of Grenada. Primary white sea urchin fishing grounds in Grenada include True Blue Bay, Glovers Island, Woburn Bay, Petite Bacaye, La Tante Bay, Crochu Bay, Marquis and Conference Bay. Secondary sites include Petit Trou, Requin Bay, Marene Bay, River Antoine, Sandy and Green Island, Sauteurs Bay and Isle de Rhonde (Pena Rey, 1998; Phillips, 2009; Figure 4). Before the closure of the fishery in Grenada, Carriacou was not a primary white sea urchin harvesting site – probably because the distance from Grenada made it inaccessible by rowboat. However, in recent years, with widespread ownership of motorized boats, Carriacou has been visited regularly for overnight fishing trips by many white sea urchin divers and fishers from Grenville and Soubise in Grenada (Nayar *et al.*, 2009). The main harvesting areas in the Grenadine Islands are off the east and southwest coasts of Carriacou and include Windward, Hillsborough and L'Esterre Bay/Harvey Vale Bay (Figure 4).

Figure 4: Main white sea urchin fishing areas in the eastern Caribbean



Note: Maps not drawn to same scale.

There is currently no commercial white sea urchin fishery in Saint Vincent and the Grenadines, although some export of the resource from Union Island to Martinique occurred in the late 1980s and early 1990s (Punnett, 2009). A few Vincentians do harvest the resource for subsistence. Harvesting is known to take place on the main island off the east and south coasts, and in the Grenadines off the south coast of Bequia (Paget Farm and Friendship Bay) and the west coasts of Mustique, Mayreau and Canouan (Figure 4).

In Martinique, the white sea urchin is harvested on the eastern and southern coasts of the island from Sainte-Marie to Les Anses-d'Arlet (Figure 4). In 2006, 92 landing sites were recorded over the entire harvesting area (Daniel, 2003; Reynal and Bertrand, 2009).

7.3 Fishing seasons

Variations in the date and length of white sea urchin harvesting seasons are dependent on management regulations in the respective countries. In recent decades, harvesting moratoria and/or extended closed seasons have limited the fishing season in several countries (see Chapter 9). Traditionally, however, sea urchin fisheries throughout the eastern Caribbean have tended to commence in 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 Saint Lucia, harvesting usually occurs from August to December (De Beauville-Scott, 2009). Since 1995, the white sea urchin fishery in Carriacou and Grenada has been subject to a fishing moratorium (Nayar *et al*., 2009). In Saint Vincent and the Grenadines, harvesting is irregular, often occurring when white sea urchins are abundant and when limited effort is required for searching for the resource (Punnett, 2009). In Martinique, there are two fishing seasons for the white sea urchin occurring from early October to early November and then for the first two weeks in December. This harvesting period was implemented in 2003 (Reynal and Bertrand, 2009). However, as with Barbados and Saint Lucia, although the fishers are aware of the fishing seasons, harvesting out of season persists (Daniel, 2003).

7.4 Fishing operations

7.4.1 Pre-harvest practices

In Barbados, prior to the fishing season, sea urchin fishers keep a check on fishing grounds from time to time in an attempt to determine the distribution and abundance of urchins, and they often share this information with other fishers. Because white sea urchins aggregate for spawning, gonad ripeness is synchronized within aggregations (patches). Therefore, the state of gonads for the entire patch can be predicted by subsampling a few individuals to check for ripeness of gonads (Vermeer, Hunte and Oxenford, 2005). This is done by traditional Barbadian white sea urchin fishers. The act of "testing" white sea urchins for harvesting readiness has also been traditionally practised in Carriacou, Grenada and Saint Lucia (Pena Rey, 1998; Smith and Koester, 2001; De Beauville-Scott, 2009; Phillips, 2009).

In Barbados, traditional fishers have claimed that non-traditional fishers do not "test" for ripeness before harvesting and that this has contributed to the decline of the white sea urchin population. Non-traditional fishers simply take all the urchins in a patch, regardless of their gonad state. It has been argued that this practice was encouraged by the use of scuba gear by non-traditional fishers and resulted in the harvesting of many urchins that do not contribute significantly to the quantity of gonad obtained by the harvester in the end while removing breeding stock (Hunte, Parker and Johnson, 1993).

In addition, in Barbados, since 2001, annual pre-season density, population size structure and gonosomatic index surveys at 27 index sites around the island have been conducted by groups of white sea urchin divers familiar with the sites in collaboration with the Fisheries Division (see Chapter 9). Density estimates are obtained via twenty quadrats of 1 m^2 positioned along a sampling transect. The exact area surveyed is at least 100 m wide and 200 m long. The population size structure surveys are usually conducted subsequent to the density surveys and involve measuring the maximum test diameters of a random sample of white sea urchins found in the quadrats in an area close to or along the density survey transect. This sampling process is repeated until at least 100 white sea urchins have been measured at each index site. Measurements are obtained using either beak or vernier calipers. Gonosomatic indices are calculated by weighing intact white sea urchins (body

weight) as well as the five gonads (gonad weight) from each sample. The index is calculated by finding the ratio of gonad weight to body weight. Test diameter and height measurements are also recorded. Detailed monitoring protocols for the above-mentioned surveys are provided in Parker (2005).

In Saint Lucia in the early 1990s, the Department of Fisheries distributed perspex rulers to divers to assist them in making quick measurements underwater, ensuring that urchins below the approved size limit (which is reviewed annually) were not harvested, thereby protecting the entire juvenile size class (George and Joseph, 1994). Pre-harvest population surveys by the Department of Fisheries are now used to determine the harvest period and size limit for the given season (De Beauville-Scott, 2009).

In Carriacou and Grenada, prior to harvesting, harvesters conducted their own informal surveys to determine the grounds where white sea urchins were most abundant and to test the state of the white sea urchin gonads before harvesting. As in other countries, this involved breaking a few white sea urchins from a site before collection (Pena Rey, 1998; Phillips, 2009).

In Martinique, since 2004, annual pre-season abundance surveys have been conducted by the Institut français de recherche pour l'exploitation de la mer (IFREMER). Sea urchin abundance is assessed at 28 monitoring sites across 9 white sea urchin harvesting zones identified as such by professional fishers. At each monitoring site, the density of white sea urchins is first observed to determine if it is sufficient to allow enumeration by transect. Abundance data are collected via a 35 m transect (rope) in a 50 m^2 area at each site. A diver holding a 1.43 m stick perpendicular to the transect swims along the transect counting all white sea urchins (those larger than 9 cm, less than 9 cm and dead individuals are recorded separately) under the stick. Fifty sea urchins from each site are collected and their diameter is measured using a slide caliper. The gonads of 20 white sea urchins with diameters larger than 9 cm are removed and weighed for determination of gonad indices. Additional detailed information on monitoring protocols and data time series is given in Reynal and Bertrand (2009).

7.4.2 Catch and effort trends

The white sea urchin fishery is economically valuable to the people involved because of the high unit price of the roe compared with the relatively low investment costs of fishing for the animals. As such, even relatively small catches may be quite profitable. In addition, the traditional timing of the white sea urchin fishing season coincides well with the "off season" for pelagic fishing, thus affording the fishers involved in the pelagic fishery the opportunity to fish for white sea urchins for additional income (McConney, 2001; Parker, forthcoming).

Generally, no regularly recorded landings statistics are available for white sea urchin fisheries of the eastern Caribbean, with the exception of Martinique and Saint Lucia. In Saint Lucia, the Department of Fisheries has recent catch data for 2002–04 with just over one million white sea urchins landed, an average of about 363 000 white sea urchins per year (De Beauville-Scott, 2009). For Barbados, as white sea urchins may be landed and processed at almost any beach, rarely passing through any monitored landing site, it is very difficult to collect accurate annual catch statistics (Parker, 2009). Catch and effort fluctuate with highly variable abundances, and no clear trends are obvious (McConney, 2001). A limited and sporadic set of catch statistics by weight for export are available for 1988, 1991–94 and 1997 for Carriacou and Grenada. In this period, about 28 000 kg of white sea urchins (presumably gonads) are recorded as being exported (Phillips, 2009). As currently no commercial fishery for white sea urchins occurs in Saint Vincent and the Grenadines, and harvesting is limited to a very small number of people for personal consumption on an ad hoc basis, no catch and effort data are available for these islands. However, there has been an increase in illegal export of the resource from Union Island (Punnett, 2009). In Martinique, catch and effort data are available for 1987, 1991–93, 2002–04, 2006 and 2008. During this period, the annual average catch per harvesting trip varied between 8 kg and 10 kg with maximum annual white sea urchin roe production ranging from 13 000 kg to 22 000 kg (Reynal and Bertrand, 2009).

Vermeer, Hunte and Oxenford (2005) estimated that the majority of fishers in Barbados fish daily up to five times per week during the height of the harvest season. In 1994, it was estimated that a single fisher on one trip harvested about 350 sea urchins. Based on this value, the estimated periodicity of

harvesting in the peak season (September–November) and with about 220 sea urchin fishers in the fishery in the early 1990s, it was determined that about half a million sea urchins would have been harvested per week, resulting in six million urchins being harvested in the three-month peak season alone.

Varying estimates of the number of people involved in the white sea urchin fishery have been recorded. In 1999, Mahon *et al*. (2003) estimated that about 260 people were "serious white sea urchin divers". Parker (forthcoming) estimates that there were 201 full-time and 155 part-time white sea urchin divers in 2001, while McConney and Pena (2005) estimated there were about 300 people involved in the fishery in 2004. In addition, other people crack, clean and sell white sea urchins. With harvesting also occurring out of season, the total number of white sea urchins harvested in Barbados is very high.

In Saint Lucia for 1995, only eight sea urchin fishers were licensed, and for the 2001 harvest period 13 divers were granted permits to harvest white sea urchins. Information on the numbers of urchins harvested per trip is not currently available. However, annual catches for 1995 and 2001–04 ranged between 530 kg and 8 700 kg of gonads (De Beauville-Scott, 2009).

In Carriacou and Grenada, the minimum number of active commercial sea urchin fishers in the late 1990s was estimated at 110. Although the numbers of vendors during this period are unknown, most were family members of fishers. It has been estimated that a crew, consisting of about three people, harvested 300–700 urchins on each trip, with most harvesters producing 40–60 "shells" for sale; a "shell" being a white sea urchin test filled with gonads of about 10–15 urchins. 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 500 000– 800 000 white sea urchins may have been harvested (Pena Rey, 1998; Phillips, 2009). Prior to the closure of the fishery in Grenada, four to five people were involved in the exportation of white sea urchins (Nayar *et al*., 2009).

In Martinique, the number of permits granted by the administration for white sea urchin harvesting has varied considerably from one year to the next, ranging from a high of 381 in 2004 to 162 in 2008. The total number of harvesting trips varies according to fishing sectors, with the Vauclin and Le Robert sectors having the highest number of declared trips in 2003 and 2004. In the 2003 and 2004 fishing seasons, for which detailed catch and effort data exist, a steady decline in the number of boats actively harvesting white sea urchins and the catch per unit effort were observed as the season progressed. In 2003, the number of boats decreased from 48 to 16 between the beginning of October and mid-December. An even sharper decline was recorded in 2004, when the number of boats in the fishery decreased from 119 to 17 in the same period. The daily average catch per trip decreased for the same period from 13.1 kg to 8.3 kg of white sea urchin gonad in 2003 and from 15.5 kg to 5.8 kg in 2004. Individual fishers exploit on average two zones during the annual fishing season, although some visit up to ten sectors during the season. The average number of divers per boat is two to three per trip (Reynal and Bertrand, 2009).

7.4.3 Preparation and marketing of white sea urchins

Unlike other roe products that are best at full ripeness, just prior to spawning, the quality and yield of urchin roe depend on the proportion of cells that store the nutrients needed for gamete production versus the gametes and gametocytes. That is, urchin roe produce the highest yield and best quality for consumption at the height of nutrient accumulation in the gonad tissue. This happens after spawning, when the gonads enter a phase of nutrient accumulation (repletion), increasing in both size and firmness as maximum nutrient accumulation is achieved. This is the peak condition for consumption and typically occurs between October and November each year before gametogenesis resumes. With the advancement of gametogenesis, the gonads are delicate, have a fluid texture, and exude gametes readily. In this condition, the proportions of gametes and gametocyte cells are high compared with nutritive storage cells, and the nutrient level is relatively low. In addition, there is a large amount of fluid present, and this runny state causes the product yield to be low and generally unacceptable to the consumer (Hickey, 1982; Parker, 2005, forthcoming).

Plate 9: Processing and marketing of white sea urchins for sale: (a), (b) and (c) fishers cracking shells and cleaning roe in buckets of seawater; (d) and (e) traditional way of marketing roe in Barbados using a packed half shell and grape leaf for presentation; (f) traditional way of marketing roe in Saint Lucia; (g) empty shells buried in pits on the beach; (h) and (i) modern way of marketing roe in plastic containers; and (j) and (k) the process of "baking" roe for sale [(a) Franklin, (b) Pena, (c, f, g, h, j and k) Cox, (d) Sealy, (e) Fitzpatrick, (i) authors' collection].

The method of preparation of the roe for sale is similar in all islands, although slight variations are apparent. In Carriacou, Grenada, Saint Lucia, and Saint Vincent and Grenadines, when the catch is

brought ashore by divers, the tests or shells are cracked open by hitting them with a metal spoon. The body fluid and tissue are drained away and, using the spoon, the five gonads are scooped out and placed in buckets containing fresh seawater. They are washed, and the mesenteries are removed manually before the roe is packed into cleaned hollow half tests, plastic containers or plastic bags (Plate 9). In Barbados, where urchins are captured in deeper water by fishers using boats, the same method is used to prepare and pack roe removed from urchins, the only exception being that the process occurs on the boat by helpers referred to as "crackers" (Scheibling and Mladenov, 1987; Mahon and Parker, 1999). Each half test can hold the roe of about 10–15 urchins, although the number needed to fill a shell may vary according to their size and reproductive condition (Hickey, 1982).

In Barbados, traditionally, a cone made from a leaf of the sea grape, *Coccoloba uvifera*, was filled with roe and then placed over each test also packed with roe, and marketed (Hickey 1982; Plate 9). Empty, unused tests are either thrown into the sea or buried in large pits dug into the beach sand. The former practice, if it occurs in the vicinity of the white sea urchin ground, is condemned by most fishers in Barbados, who claim that it results in the migration of sea urchins from the fishing grounds (Scheibling and Mladenov, 1987).

Marketing the roe in the "half shell" is believed to date back to at least 1803 (Parker, forthcoming). In the early 1940s, the roe was also sold in empty milk cans. Since the mid-1980s, the traditional method of preparing "shells" in Barbados has been abandoned and the fishers now pack the roe in one- or two-litre plastic ice-cream or margarine containers, with about ten "shells" (150 urchins) providing a litre of roe (Scheibling and Mladenov, 1987; Vermeer, Hunte and Oxenford, 2005). This latter method of marketing white sea urchin roe has rapidly increased in popularity and has almost completely replaced the older methods (Mahon and Parker, 1999).

White sea urchins are such a popular national delicacy that the local market easily absorbs the entire annual production and none is commercially exported (Parker, 2009). In the past, the catch was also sold to vendors ("hawkers") who transported their stock for sale, usually on trays, throughout major towns and housing areas. Some composed special jingles to advertise their goods (Parker, forthcoming). Although some people still find employment as breakers and vendors of white sea urchins, the number of, and need for, specialist vendors has decreased. Most white sea urchins are now sold by the divers directly at the beach exclusively to local consumers (Scheibling and Mladenov, 1987; Mahon and Parker, 1999) or to a combination of locals and restaurants or hotels (Vermeer, Hunte and Oxenford, 2005). They also have regular customers that leave orders by telephone. Hence, fishers have more control over their revenue from this fishery than from the major pelagic fisheries in which they tend to be price-takers subject to the market power of vendors and processors (McConney, Mahon and Parker, 2003).

Particularly during periods of fishery closure in Barbados, urchins have been imported cooked in the shell from Grenada. During the fishing moratorium of 1998–2001, frozen urchin roe (not that of white sea urchin) was also imported in bulk from California, United States of America. This was done with the permission of the Chief Fisheries Officer, as required by law, and the roe was sold to supermarkets and restaurants in Barbados (McConney, Mahon and Parker, 2003).

In Saint Lucia, the tests filled with roe and "baked" by cooking them over a fire on the beach before they are sold (Plate 9; Smith and Berkes, 1991; George and Joseph, 1994). Although vendors would occasionally take white sea urchins to Castries by bus or canoe for sale, they were mainly sold in local community areas. In the 1970s, in addition to being sold locally, white sea urchins became a significant export commodity, with a profitable business emerging based on demand for the resource in Martinique (De Beauville-Scott, 2009).

In Carriacou and Grenada, gonad preparation differed depending on whether roe was prepared for local or export markets. For the local market, the roe was placed in boiling water immediately after removal from the shells and packed into cleaned shells or plastic bags for sale by weight (Plate 9). Alternatively, the boiled roe was packed into cleaned tests and roasted in a pit in the ground covered with a sheet of galvanized metal roofing with a wood fire built on top to bake the roe in the "shells". The baked roe was then sold in the streets. Traditionally, white sea urchins were never sold at markets even when the harvest took on a more commercial nature (Pena Rey, 1998; Phillips, 2009; Nayar *et al.*, 2009).

In Carriacou and Grenada, roe for export was placed in plastic bags or buckets and is frozen. White sea urchins were exported to Barbados (during closure periods as mentioned above), Martinique and Canada (Pena Rey, 1998; Phillips, 2009). Roe for export was generally also boiled to prevent "melting" (loss of gonad form and resulting runny texture) and packaged in plastic bags or large pails. The roe was then either collected by the exporter or transported to Saint George's by the diver and sold by weight. Orders for export were packed into cold storage containers and transported by air to off-island buyers in Barbados and Martinique (Nayar *et al*., 2009).

In Saint Vincent and the Grenadines, roe for export is frozen (Punnett, 2009).

In Martinique, the sea urchin roe is generally sold raw but is eaten as "blaff" (chowder), "accras" (fritters) or omelettes. The white sea urchins can also be sold by "tête de chadron" in which the contents of 6–10 sea urchins are placed in a test (shell) and cooked for a few minutes on a wood fire. "Breaking" harvested sea urchins does not always take place at the landing sites, especially if these sites are close to white sea urchin habitats or fishing grounds. This is because fishers believe the contents and shells of the urchins dumped on or near the fishing ground could be harmful to the remaining unfished sea urchins (Reynal and Bertrand, 2009).

8. SOCIO-ECONOMIC PROFILES OF WHITE SEA URCHIN FISHERIES

Sea urchins are an important food resource for fishers and their families (Scheibling and Mladenov, 1987). The social and economic profiles of white sea urchin fisheries in the eastern Caribbean are examined in detail in the following subsections by country and territory.

8.1 Barbados

8.1.1 Social attributes

Barbadians 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, Hunte and Oxenford, 2005; Parker, forthcoming). In Barbados, the annual white sea urchin fishing season was timely for fishers engaged in other fisheries as it came when the season for flyingfish and the other large pelagic fish and dolphins, was over. Hundreds of Barbadians, including women and children became involved in some aspect of the white sea urchin fishery. In 1948, the industry was described as employing "almost every available fisherman and their families". The traditional roles for the women and children were the processing and sale of the white sea urchins on shore. People were described by their roles such as "divers", "breakers" and "vendors" (Mahon and Parker, 1999).

Estimates of the number of people seasonally involved in the fishery have ranged from almost 1 000 in the mid-1950s to 200–300 at present (McConney and Pena, 2004; Parker, 2009, forthcoming). No other fishery in Barbados so thoroughly engages people of all ages, both genders and of several other occupations as fully as the white sea urchin fishery. Recent estimates of participation have focused more on those who regularly harvest white sea urchins and, hence, may be proportionally lower than earlier, more comprehensive estimates (McConney, Mahon and Parker, 2003). Several categories of white sea urchin fishers have been identified including full-time, seasonal, casual and holiday fishers (Table 3; Mahon *et al*., 2003).

Table 3: Types of white sea urchin fishers in Barbados

Type	Activities
Seasonal divers	Fish for flyingfish and large pelagics for most of the year, and dive for white sea urchins in the off-season as an alternative source of income.
Weekend and casual divers (including opportunistic, temporarily unemployed and youth)	Dive mainly for recreation and personal consumption at weekends but may also offer white sea urchins for sale.
Full-time divers	Harvest a variety of resources by diving, including lobsters, conch, octopus and sea moss, and who turn to white sea urchins during their season.
Holiday divers	Take their vacation to coincide with the white sea urchin season as a means of supplementing their income from their main job.

McConney, Mahon and Parker (2003) state that, in the past, distinctions between categories of fishers were more defined; however, recently people in the white sea urchin fishery have been combining their roles. This reduction in the division of labour over time may also help explain the apparently declining participation.

Areas with high populations of white sea urchin fishers in Barbados are around Conset Bay on the east coast, Silver Sands on the southeast coast and Oistins on the southwest coast (McConney, Mahon and Parker, 2003). There are at least 20 recognized white sea urchin fishing "communities" or clusters of harvest groups in Barbados. Only a few of these are well defined spatially and many are far from their fishing grounds. In addition, the fishing ranges have tended to expand in recent years. Divers now live in rural coastal and inland villages, suburban housing developments and residential areas. On average, fishers harvest in groups of four, and there may be several groups operating in any white sea urchin fishing area. None of them is particularly territorial (Mahon et al., 2003).

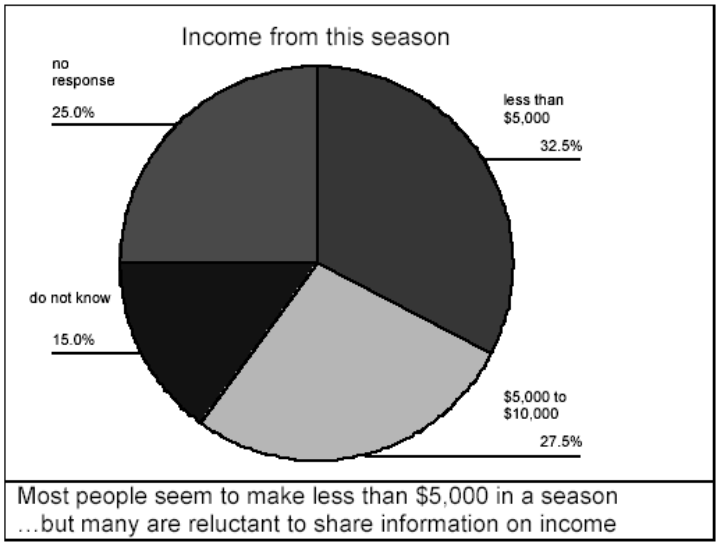
Divers, almost all of whom are male and most of whom come from fishing families, are the leading figures in this fishery, where relatives or household work teams often undertake operations collectively as a family tradition. They range in age from 25 to 81 years (average 42 years) and they have worked in the white sea urchin fishery for from 1 to 50 years (average 19 years). These divers have all achieved at least a primary-level, and some a secondary-level, school education (McConney, Mahon and Parker, 2003).

8.1.2 Economic value

Revenue from the sea urchin fishery in Barbados is an important part of some fishers' income (McConney, Mahon and Parker, 2003). While researchers differ on their estimates of mean income per fisher from the harvest (largely owing to differences in estimates of effort), there is little doubt that, when abundant, white sea urchins in Barbados are the basis of a very valuable fishery (Fisheries Division, 2003). The price of roe has varied over the years (Parker, 2002). In the early 1980s, a "shell" sold for US$0.50–1.00 (Scheibling and Mladenov, 1987). In 1991, fishers quoted the sales price of roe as US$20 per one-litre container (about US$2.00 per shell), and it was suggested, based on estimated catch rates of about six million urchins in the open season alone, that an urchin fisher could earn more than US$300 per week if fishing daily (McConney, 2001; Vermeer, Hunte and Oxenford, 2005). In 2004, white sea urchins were being sold for US$15 per one-litre container and US$30 per two-litre container (a decrease of US$5 per litre from the 1991 sales price) (McConney and Pena, 2005). Parker (forthcoming) estimated the potential monetary value of the estimated standing crop of white sea urchins around the island in 2001 alone to be as much as US$49 million.

In 2001, it was estimated that there were about 201 full-time and 155 part-time active white sea urchin divers (Parker, forthcoming). Based on information derived from interviews with fishers conducted in 2004, Mahon *et al.* (2007) estimated a value of about US$1.4 million for the local white sea urchin harvest. In 2002, a small survey of people active in the two-month season revealed that just over one-quarter of those surveyed thought that white sea urchin fishers could easily make US$2 500–5 000 during the season (Figure 5).

Figure 5: Estimates of income of regular divers in the two-month 2002 season in Barbados



Note: US$1 = about BBD2.
Source: McConney, Mahon and Parker (2003).

8.2 Saint Lucia

8.2.1 Social attributes

In spite of the importance of the white sea urchin fishery in Saint Lucia, limited information on its social characteristics exist. The beginning of the harvest was always associated with the August school holidays, when diving for white sea urchins was an activity enjoyed by children. After the school holidays, others would join in the harvest. Men, women and children all had roles to play in the production process. Women and teenagers often dived for the urchins, children would break the shells, and both men and women prepared them. Local residents harvested, cooked and sold white sea urchins to buyers from distant villages and directly to Martinican entrepreneurs who travelled between Martinique and Saint Lucia (Smith and Koester, 2001).

By 1995, only eight licensed sea urchin fishers were recorded, suggesting a major decline in white sea urchin harvesters and a struggling fishery. For the 2001 harvest period, 13 divers were granted permits to harvest white sea urchins. Information on the numbers of urchins harvested per trip is not currently available (De Beauville-Scott, 2009).

8.2.2 Economic value

The Saint Lucia white sea urchin fishery provides an important seasonal source of income for coastal communities that are adjacent to seagrass and fringing reef habitats (George and Joseph, 1994). White sea urchins became a significant export commodity in the 1970s. A profitable business emerged based on the demand for white sea urchins in Martinique (Smith and Koester, 2001). In 1991, a test filled with gonads sold for about US$2 (Smith and Berkes, 1991). In more recent years, white sea urchin collecting has become a commercial venture rather than a family-based subsistence activity. As prices were relatively high and demand exceeded supply, sea urchin collecting attracted many young and underemployed people who were looking for part-time income. White sea urchin roe production for the 1995 and 2001–2004 harvesting periods combined ranged between 530 kg and 8 700 kg, for a value of about US$ 400 000 (De Beauville-Scott, 2009).

8.3 Carriacou and Grenada

8.3.1 Social attributes

The majority of white sea urchin divers in Grenada come from communities with a strong history of fishing livelihoods. Commercial white sea urchin divers in Grenada were still small-scale fishers who

were also diving and fishing for other species at the time. Owing to the supplementary nature of the fishery, determination of the number of fishers involved has been difficult. However, in the late 1990s, it was estimated that there were about 110 commercial white sea urchin fishers in Grenada. The number of vendors is unknown but they were usually closely related to the fishers, e.g. wife, brother, son (Phillips, 2009). Owing to their ease of harvesting, white sea urchins were taken without effort by people of all ages including grandparents, children and anyone who was able to wade out from the beach to gather them. Employment as a "breaker" usually kept women, children and young men employed as the people who would crack open and scoop out the gonads when large quantities of white sea urchins were brought in and needed to be prepared (Nayar *et al*., 2009).

With increasing market demands, specialized commercial divers emerged and white sea urchins became a regular part of their weekly catch, accounting for part or most of their income. Commercial divers were typically young men between the ages of 16 and 35 years, many of whom had gained their initial experience from harvesting white sea urchins as children or teenagers; otherwise, they were already involved in fishing when they incorporated white sea urchins into their catch (Nayar *et al*., 2009).

It has been estimated that commercial harvesters would make at least six trips per week per crew (1–3 people). However, white sea urchins did not provide full-time employment for the divers. Only 4–5 people were involved in the exportation of white sea urchins (Nayar *et al*., 2009).

8.3.2 Economic value

In Carriacou and Grenada, the financial return for those involved in the fishery was relatively good, considering the low level of investment. Between the late 1980s and 1994, the cost of a packed "shell" or cost per pound (0.45 kg) was US$2–3 (Pena Rey, 1998; Nayar *et al*., 2009). White sea urchin roe was exported for a number of years with the value ranging from US$6 to US$14 per kilogram (Phillips, 2009).

8.4 Saint Vincent and the Grenadines

In Saint Vincent and the Grenadines, there is no active data collection or assessment of socio-economic information in the white sea urchin fishery. However, a fairly lucrative illegal export of white sea urchins to several islands, including Martinique, with vessels paying about US$9 per pound (0.45 kg) has been reported (Punnett, 2009).

8.5 Martinique

8.5.1 Social attributes

There is limited socio-economic information on the white sea urchin fishery in Martinique. Daniel (2003) notes that the "social unit" in the white sea urchin fishery in Martinique comprises divers who help the captain break urchins. At some sites, the social unit is larger and other people, often relatives of the crew, come to help break the white sea urchins. Based on the number of harvesting permits granted by the administration, the number of fishers involved in the fishery fluctuates annually with 162 recorded most recently in 2008 (Reynal and Bertrand, 2009).

8.5.2 Economic value

The fishery is economically very important as there is an increasing demand for the resource with roe being sold for as much as EUR70 (about US$102) per kilogram in 2008 (Reynal and Bertrand, 2009). Daniel (2003) states that although fishers indicate the fishery is lucrative, the amount of revenue generated has not been verified.

9. SEA URCHIN FISHERIES MANAGEMENT

Despite significant management and conservation efforts by some countries, white 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 white

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. Therefore, this section provides information and perspectives on past and current management of these fisheries.

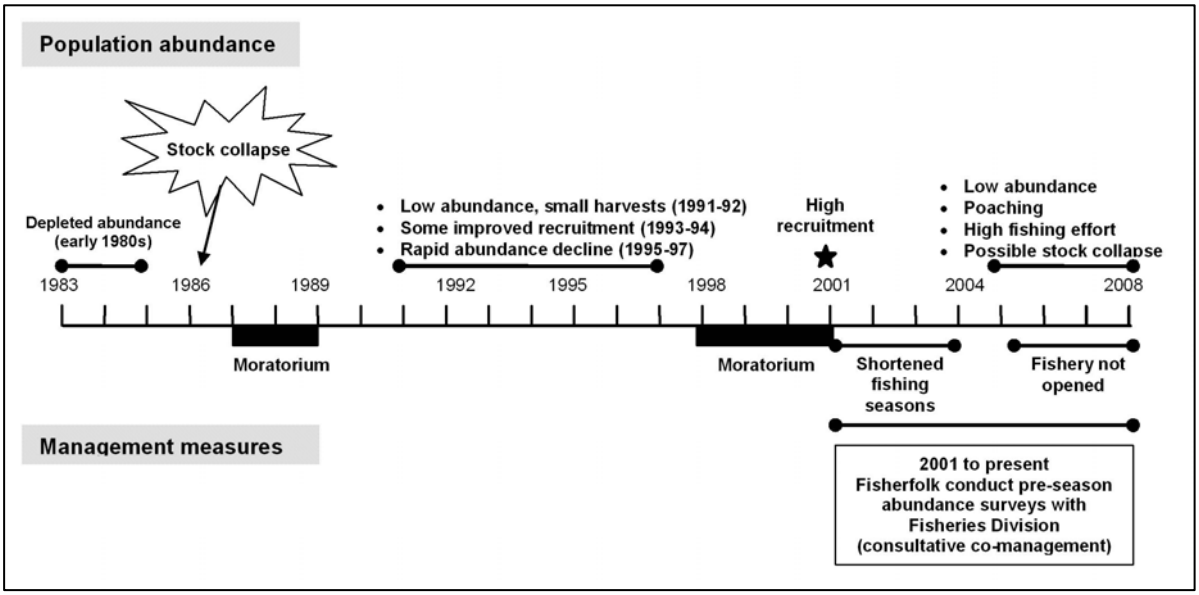
9.1 Barbados: closed seasons and moratoria

A legally designated closed season to protect the animals during their peak reproductive period has been the primary management measure applied to the white sea urchin fishery in Barbados. As early as 1879, the Government of Barbados passed the White Sea Urchin Preservation Act, which prohibited the harvest of white sea urchins between April and August, to coincide with what was thought to be the peak of the breeding season, in an attempt to conserve the resource (Scheibling and Mladenov, 1987; Parker, 2002; Vermeer, Hunte and Oxenford, 2005). The delimitation of this critical reproductive period was almost certainly based on traditional knowledge (Parker, 2009, forthcoming).

The legislation pertaining to the white sea urchin was subsequently incorporated in the consolidated Fisheries Regulation Act (1904), which was the first comprehensive set of laws applying to fisheries regulation in Barbados. Under this act, it was mandated that there would be an annual fishing closed season for the resource extending from 1 April to 31 August, unless otherwise published in the official gazette. Severe penalties (fines and imprisonment) for the fishing, sale or purchase of white sea urchins during the closed season were imposed (Bair, 1962; Scheibling and Mladenov, 1987; Parker, 2002, forthcoming). However, enforcement of this closure was never totally effective, and harvesting frequently occurred before the annual legal opening date of 1 September (Vermeer, Hunte and Oxenford, 2005). The annual closed season for white sea urchins was reportedly shortened during periods of economic hardship, such as those encompassing the two world wars (1912–1923 and 1937–1941), to ensure food supply, but lengthened whenever stocks declined (McConney, Mahon and Parker, 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 having collapsed by 1986. Overfishing was touted as the most likely cause of this reduction in abundance (Scheibling and Mladenov, 1987), and the Government of Barbados reacted by imposing a two-year moratorium on harvesting, from 1 September 1987 to 31 August 1989. The white sea urchin population was then monitored to determine the impact of this measure on the abundance (Mahon, 1993; Vermeer, Hunte and Oxenford, 2005; Parker, forthcoming). Based on a rapid increase in sea urchin abundance during the two-year fishing ban, the moratorium was lifted as planned in September 1989, with the fishery being resumed as a free-access commercial fishery. However, the closed season was revised and lengthened to cover a full eight months from 1 January to 31 August each year (Figure 6; Parker, 2002).

Figure 6: Twenty-five year summarized management history for the Barbados white sea urchin fishery



Once again, there was poor adherence to, and enforcement of, the eight-month closed season, and substantial harvesting occurred before 1 September. By 1991, the white sea urchin stock had declined to very low levels, such that harvests in both that year and the next were negligible. Surveys in 1993 and 1994 suggested some recovery of the white sea urchin populations following the two years of negligible harvesting (Vermeer, Hunte and Oxenford, 2005; Parker, forthcoming). From 1994, white sea urchin populations declined rapidly, forcing the Government of Barbados to impose another three-year ban on sea urchin fishing from 1 August 1998 to 31 July 2001. This moratorium was extended for a further two months to the end of September 2001. Assessments during the moratorium indicated low stock levels between 1998 and 2000, with significant recovery by 2001 (Figure 6).

A comanagement arrangement for the fishery involving fishers and government was recommended in the early 1990s (Vermeer, Hunte and Oxenford, 2005). One outcome of this recommendation was the implementation in 2001 of annual pre-season abundance surveys conducted collaboratively between fisherfolk and the Fisheries Division. The results of these surveys are now used, in part, to determine the length and timing of the sea urchin fishing season (Fisheries Division 2004; Parker, 2009, forthcoming).

Based on the results of the stock abundance surveys in the period 2002–04, shortened fishing seasons were imposed ranging from two weeks to two months (McConney, Mahon and Parker, 2003; McConney and Pena, 2004, 2005). In view of the results of the 2005 pre-season, island-wide survey, the fishery was not opened in 2005. Annual stock levels continued to decline in successive years and no legal fishing season has been recommended up to the time of compiling this report (Figure 6).

The Fisheries Act of 1993 mandates the minister to dictate appropriate regulations for the fishery, and facilitates the use of a wider range of possible management tools in addition to closed seasons. The Fisheries Regulations of 1998 mandate that the minister designate closed seasons for white sea urchins by notice published in the official gazette. This legislative arrangement facilitates faster adjustments to the closed seasons. In addition, the Fisheries Regulations prohibit the harvest of white sea urchins with scuba gear and state that it is "illegal to have, sell, expose for sale or purchase white sea urchins during the closed season" unless the white sea urchins were obtained with the permission of the Chief Fisheries Officer (Parker, 2009).

In addition to government-imposed management strategies, professional white sea urchin fishers have traditionally employed sensible management practices in the fishery based on their local knowledge of the biology and ecology of the resource (Table 4; Parker, 2009, forthcoming). This knowledge is important because it places the fishers in the role of conservers, rather than the usually perceived role of wanton users, and emphasizes their role in management (Mahon *et al*., 2003).

Table 4: Traditional management practices in the Barbados white sea urchin fishery

Traditional practice	**Activity**
Testing for ripeness of roes	Fishers check a few white sea urchins from a patch to determine if the white sea urchins are ripe and ready for harvesting. If not, no more white sea urchins would be taken from the patch.
"Cutting the edge"	The white sea urchins around the outer edge of a patch tend to be the ripest. Fishers would harvest these, then leave the patch for a few days until those on the inside ripened.
"Chubbing"	Fishers would not harvest extremely large individuals, leaving them scattered throughout the fishing area as breeders.
Moving white sea urchins from places of plenty to places with few	Fishers might, at the end of a diving session, take a few bags of small unripe urchins and drop them off in areas known to have been fished out.
Burying husks on the beach	Fishers would generally break white sea urchins on the beach and bury the husks so that they were not disposed of on fishing grounds. Fishers have observed that live white sea urchins leave the areas where broken white sea urchin shells are disposed of.

Sources: Mahon *et al*. 2003; McConney, Mahon and Parker, 2003.

Mahon *et al.* (2003) indicate that white sea urchin fisherfolk in Barbados are knowledgeable about the resource and its problems. They are aware of the changes that have taken place and, although they tend to be superficially in denial about the impact of fishing on the white sea urchin resource, they acknowledge that certain "bad fishing practices" have contributed to the decline.

However, although knowledgeable, there are certain examples of what McConney, Mahon and Parker (2003) term "ecological misinformation" among fisherfolk that could hinder progress with management. For example, some fishers continue to believe that the disease responsible for the depletion of the black sea urchin (*Diadema antillarum*) around 1983 is also responsible for the decline in the white sea urchin population. In addition, some fishers are insistent that many of the problems encountered by the industry are due to human impacts on the resource (through pollution, habitat destruction and fishing) and the algae food source. Other individuals believe that the sea urchins simply move away from Barbados in buoyant aggregations that are transported by currents, or down into deep water owing to pollution. This is used to explain sudden disappearances and appearances of adult urchins. There is no scientific evidence for this phenomenon, but the claim is common enough to warrant investigation (Mahon *et al*., 2003).

9.1.1 Efforts towards, and recent perspectives on, comanagement

In the early 1990s, the Fisheries Division and scientists concluded that a comanagement approach to the white sea urchin fishery might be appropriate given the nature of the fishery and the past difficulty with enforcing the closed season. A preliminary assessment of the potential for comanagement in 1993 (Vermeer, Hunte and Oxenford, 2005) was followed by a full-scale consultation with fishers in 1999 (Mahon *et al*., 1999, 2003). Based on the encouraging potential from the assessments, the first fisheries management plan (FMP) for the period 1997–2000 officially supported a comanagement approach to the white sea urchin fishery involving fishers and the Fisheries Division (Fisheries Division, 1997; McConney and Pena, 2004). Subsequent FMPs have continued to advocate comanagement of the fishery. The objective for the fishery in the 2001–03 FMP was to "rebuild populations and establish a Comanagement arrangement with fishers to maintain populations at levels which can sustain long term optimum yields for social and economic purposes" (Fisheries Division, 2001). Comanagement of the fishery, while not included in the white sea urchin management plan vision statement of the 2004–2006 FMP, is instead noted as a possible additional management measure (Fisheries Division, 2004). The summary management statement for the fishery in the draft 2009–2012 FMP notes that "it is considered vital that official Comanagement arrangements be applied for effective management of this fishery". Furthermore, comanagement is supported in the strategies for the fishery for the period 2009–2012 (Fisheries Division, forthcoming).

Mahon *et al*. (2003) state that, generally, divers in Barbados are deeply concerned about the depletion of marine resources, particularly white sea urchins. The view that it is government's job to resolve these problems is prevalent. However, there is enough of an appreciation that fisherfolk must play an important role in management to indicate that a sustained effort at promoting comanagement could be successful.

It has been suggested that there is a range of possible comanagement arrangements that could be put in place for management of the white sea urchin fishery (Figure 7). The arrangement that is currently in practice and least involves the fishers is to seek their input to a plan that is developed primarily by the Fisheries Division and implemented entirely by government agencies (consultative comanagement). The arrangement that would most involve the fishers would be to allocate them full rights to exploit the resource and, with those rights, full responsibility for management (delegated comanagement) (Mahon *et al*., 2003).

A comprehensive analysis of the white sea urchin fishery (conditions for, partners in, and steps towards comanagement) in Barbados is provided by Mahon *et al*. (2003) and McConney, Mahon and Parker (2003). At present, the regulations governing sea urchin harvest do not completely address the requirements of a formal comanagement arrangement (Parsram and McConney, 2004). However, the conditions necessary for a comanagement arrangement in which the fishers could take control of, and responsibility for, the white sea urchin resource can be brought into effect under provisions of the 1993 Fisheries Act of Barbados pertaining to licensing of fishers. This would require the

establishment of a legal entity with membership in the entity as a precondition for a permit to fish for white sea urchins. Therefore, there appears to be a legal basis for a comanagement arrangement in which the fishers have a great deal of control and responsibility for the fishery (Mahon *et al*., 2003).

Figure 7: Degrees and labels of comanagement

Government has the most control	**Consultative comanagement**	**Collaborative comanagement**	**Delegated comanagement**	*People have most control*
	Government interacts often but makes all the decisions	Government and the stakeholders work closely and share decisions	Government lets formally organised users/stakeholders make decisions	

Source: McConney, Pomeroy and Mahon, 2003.

Table 5: Recent projects aimed at developing comanagement approaches to the white sea urchin fishery

Project	**Implementation partners**	**Description**
Comanagement Demonstration Project 1998–1999	People Dynamics Associates/ Coastal Zone Management Unit (CZMU) Barbados Fisheries Division	Development of comanagement practices for exploited marine fishery resources in Barbados using the white sea urchin fishery as a test case Implementation: 1998 Funder: Inter-American Development Bank See Box 1
Pilot Project on Comanagement 2001	Barbados Fisheries Division Barbados National Union of Fisherfolk Organisations (BARNUFO)	Pilot project on fisheries comanagement with the white sea urchin fishery selected as the best candidate Implementation: 2001 Funder: Caribbean Conservation Association See Box 2
Fisheries Comanagement Annual Work Planning 2001	Barbados Fisheries Division BARNUFO	Collaborative production of annual work plans to address issues identified for each of the fisheries (including the white sea urchin fishery) in the 2001–03 Fisheries Management Plan Implementation: 2001 Funder: Caribbean Conservation Association See Box 3
Coastal Resources Comanagement project (CORECOMP) 2002–2005	Barbados Fisheries Division	Promotion of sustainable development of fisheries and other coastal resources, and to enhance food security and livelihoods of those who depend upon these resources, in the Central American and Caribbean region through improved governance Implementation: 2002 Funder: Oak Foundation See Box 4

Note: See also Parker and Pena (2006).

There have been several attempts at comanagement in Barbados. Government and resource-user stakeholders realize the need for change. Together, efforts at developing new management approaches in a limited way through discrete projects have been made (Tables 5 and 6; Boxes 1–3) but none has sought to delegate authority to the resource users to any appreciable extent (McConney, Mahon and Parker, 2003). The approaches have never been sustained long enough or over a wide enough cross-section of the fishery to be institutionalized. The attempts have been at least consultative, especially in obtaining the ecological knowledge and observations of fishers. Although the comanagement approach to management has received wide conceptual support, it has never been fully implemented in practice in Barbados due in large part to attitudes towards property rights and access, patterns of settlement and community, and attitudes towards regulation (McConney and Pena, 2004).

Table 6: Fisheries comanagement annual work planning project summary

Issue in the 2001–03 Fisheries Management Plan	**Activity category**
Poor track record of compliance with and enforcement of conservation regulations	Law enforcement: • Register all divers and create a database • Set up surveillance to monitor compliance with the regulations
Inadequate fishery information and statistics for planning and management	Education: • Prepare easy-to-read biological information on white sea urchins • Village discussions with stakeholders to exchange information • Educate public on their role in sustaining the white sea urchin fishery Resource assessment: • Set up mechanism for collection of harvest, biological, social and economic data for decision-making • Produce reports to update stakeholders on agreement and progress of harvest
Stock usually low, highly variable and extremely vulnerable to overfishing	Harvest limits: • Obtain stakeholder agreement on 2002 harvest season and make appropriate legislation • Produce reports to update stakeholders on agreement and progress of harvest
The institutional arrangements for managing this fishery have not been fully developed	Community participation: • Develop community-based reporting systems to provide feedback and communication among stakeholders

Source: McConney, Mahon and Parker (2003).

Box 1

Comanagement demonstration project summary

This project aimed to develop comanagement practices for exploited marine fishery resources in Barbados using the sea urchin fishery as a test case. The approach was to work with stakeholders, primarily the fishers, to establish a comanagement mechanism that could be operated by the fishers themselves with technical and advisory support from the Fisheries Division. The project used a participatory methodology, the technology of participation (ToP), developed by the Institute of Cultural Affairs. ToP methods used included focused conservation and participatory strategic planning. To the authors' knowledge, this methodology had not been previously applied in small-scale fisheries comanagement. Fisher involvement was developed in stages: (i) identification of groups of fishers in communities and a contact person for the group; (ii) dialogue with individuals and the small groups; (iii) discussion in larger groups to derive approaches to management; and (iv) full group participation to reach consenus regarding the most appropriate approach to management. Key persons identified in communities helped organize meetings to discuss the white sea urchin fishery. From these community meetings, individuals were selected to take part in the strategic planning. Two vision meetings with separate groups of fishers produced similar results. These groups were combined at a planning meeting where fishers examined the blocks (obstacles) to achieving the vision, developed strategies to overcome them, and drew up an action plan to implement the strategies. Fishers and government officials concluded that the methodology had successfully facilitated the input of both parties and produced a workable, consensual approach.

Source: Mahon *et al.* (2003).

Box 2

Comanagement of the white sea urchin fishery – CCA pilot project summary

Background

The fisheries authority and fishing industry were interested in instituting community-based comanagement, involving fishers in all aspects of management including: monitoring urchin size, maturity and population density; determination of when and where fishing would be allowed; and regulation of the fishery to the extent that fisher knowledge and observations could be the main inputs to management. This pilot project assisted stakeholders in pursuing their shared interest in comanagement in a manner consistent with the Barbados 2001–03 Fisheries Management Plan. The Fisheries Division and the Barbados National Union of Fisherfolk Organisations (BARNUFO) were already collaborating on surveys at sea.

Objective

The objective was for the fisheries authority and fishing industry to determine collaboratively and demonstrate the feasibility of comanagement arrangements for the Barbados white sea urchin fishery within the period of the 2001–03 Fisheries Management Plan.

Work plan

- Collaborative surveys (fisheries authority and fishing industry) from design to execution.
- Workshop on data analysis, generation and use of information as a demonstration of shared learning and to evaluate further development of these collaborative processes.
- Public education via a newspaper supplement, television promotion, fisherfolk's weekly panel discussion, brochure, poster, radio or other media, the effectiveness of which as evaluated.

Source: McConney, Mahon and Parker (2003).

Box 3

Coastal Resources Comanagement Project (CORECOMP) summary

The goal of this project was to promote sustainable development of fisheries and other coastal resources, and to enhance food security and livelihoods of those who depend upon these resources, in the Central American and Caribbean region, through improved governance. Specific objectives included: the implementation of comanagement pilot projects at selected sites; capacity building and institutional strengthening of the major partners in comanagement, including government, fishers and non-governmental organizations; and the development of strategies, processes and policies for implementation of comanagement in the region. The project aimed to demonstrate comanagement as a viable alternative management strategy under varying conditions in the Central American and Caribbean region using a "learning portfolio" approach.

One CORECOMP pilot project involved the development of an arrangement to implement sustainable comanagement of the Barbados white sea urchin fishery. The project resulted in a consensus being reached on the formation of a management council comprising representatives of government agencies and fishers that directly advise the Chief Fisheries Officer on issues pertaining to the fishery including research, regulation and enforcement. The fisher representatives nominated to serve on the proposed council include a number of fishers who have continued to show an interest in the decision-making process through participation in the annual surveys or the stakeholder meetings that were held during the course of the project, mainly to decide on the duration of the annual fishing season. The establishment of this core group of concerned and involved fishers is probably the single most important outcome of the project.

Source: McConney and Pomeroy (2006).

Numerous constraints to comanagement of the white sea urchin fishery in Barbados exist. They include: absence of community organization to facilitate comanagement by area; preference for open access and free movement between fishing grounds; open membership to the fishery encouraging opportunistic harvesters; and failure at the attempt to sustain some form of an island-wide fisherfolk divers organization (Parsram and McConney, 2004).

In addition, there is the large gap between the expressed desire of the fishing industry for comanagement reported in several studies and the actual effort made by the fisherfolk to move in this direction. Comanagement initiatives remain largely driven by government, and this suggests that the social and cultural imperative to establish management partnerships is not firmly established at the grassroots level (Parsram and McConney, 2004).

In spite of these constraints, both the Fisheries Division and the Barbados National Union of Fisherfolk Organisations (BARNUFO) – an umbrella fishing industry organization most representative of white sea urchin divers – have made attempts to involve white sea urchin fishers in management of the resource (Parker, 2003; Pena, 2005). In recent years, fisherfolk with the Fisheries Division and the BARNUFO have conducted annual stock abundance surveys just prior to the commencement of the fishing season, with the results being used, in part, to determine the length and timing of the fishing season (Fisheries Division, 2004; Parker, 2009, forthcoming). The participation of fishers in determining stock abundance has been a deliberate attempt to involve them in the decision-making process. It is expected to have several benefits, including: increasing their understanding of the process by which the duration of the fishing season is determined; lending credibility to the process; and providing some alternative employment for the divers during the closed season, thus enabling them to benefit from the management process (McConney, Mahon and Parker, 2003).

Furthermore, white sea urchin fishers have been encouraged to provide their input into ways in which the white sea urchin fishery should be managed via numerous consultative meetings at which potential management tools (e.g. the setting of annual harvest limits based on the size of the stock at the time, restrictive licensing of harvesters, closed areas, closed seasons, minimum size-at-capture limits and total and individual or area quotas of allowable catches) have been considered (Fisheries

Division, 2003). In general, licensing has not been favoured as it is thought that this approach would prevent recruitment of new fishers to the fishery. Access to the white sea urchin resources is viewed as an inherent right rather than a privilege of the State to license (McConney and Pena 2004).

In 2003, during the implementation of the Coastal Resources Comanagement Project (CORECOMP) pilot project on the white sea urchin fishery, the Fisheries Division suggested that a white sea urchin management council should be developed by 2006, comprising representatives of fishing communities and government as a means of implementing sustainable comanagement of the fishery. It was suggested that the council should be composed of no more than 15 people. The function of the council would be to obtain information on the status of the stock. The information would then be used to provide advice and recommendations directly to the Chief Fisheries Officer. As representatives of the communities, the fishers would be tasked with directly interacting with and gathering information from people at the community level to facilitate the work of the council. White sea urchin fishers have stated that this is the kind of organization that they would like to see. In July 2008, the Barbados Fisheries Advisory Committee (FAC) was awarded a grant of US$8 750 from the Marine Resource Governance in the eastern Caribbean (MarGov) project to strengthen its role in the sustainable governance of fisheries resources in Barbados. One of the governance tests in this project was the formation of the white sea urchin management council. Although still in its fledging stage, the Sea Egg Fishery Management Advisory Council (SEFMAC) was finally formed in August 2009 (Fisheries Division, 2003; McConney and Pena, 2004; McConney and Pomeroy, 2006; Parker and Pena, 2006) but steps towards its development are now under way. With the formation of the SEFMAC, comanagement of the white sea urchin fishery can now be regarded as moving towards the implementation stage (Figure 8). This vital step towards an official comanagement arrangement is critical for effective management of this fishery.

Figure 8: Phases of comanagement

Pre- implementation →	Implementation →	Post- implementation
Realise need for change	Try out new management	Maintain best arrangements
Meet and discuss change	Educate people in new ways	Resolve conflicts and enforce
Develop new management	Adjust and decide what is best	Accept as standard practice

Source: McConney, Mahon and Parker (2003).

9.1.2 Illegal harvesting and the undermining of management

Persistent high levels of year-round poaching have been blamed for the lack of sustained stock recovery. Harvesting during the closed season and, hence, illegal purchases by consumers have become customary. Some of these consumers are alleged to be individuals in positions of authority. It has been said that illegal fishers thus feel encouraged to break the law (McConney and Pena, 2005). Enforcement, compliance and the reluctance to treat contravention of the fishery regulations as a serious offence have all contributed to the white sea urchin fishery being highly uncertain and unsustainable (McConney, Mahon and Parker, 2003).

Fundamental positive changes in attitudes and behaviours in favour of sea urchin conservation and management are required to promote compliance and reduce the seemingly excessive burden of enforcement. The way in which Barbadian society views the sea urchin resource, its harvest and the harvesters must change so that illegal fishing becomes a national outrage (McConney and Pena, 2004). Therefore, more public education should be undertaken to inform people in Barbados about the consequences of illegal harvesting both for the sustainability of the resource and for them if successfully prosecuted. Information on the conservation regulations needs to reach a wide cross-section of the public, across all ages. In particular, an increased awareness among children may assist in changing the behaviour of adults (McConney and Pena, 2005).

However, to guide public education and other initiatives to promote compliance, there must also be research into the conservation ethics of resource harvesters, sellers, buyers and the general public.

Education, awareness and enforcement may be more successful if attitudes towards management of the sea urchin fishery are clearly understood. Many fishers are said to be sceptical about fishery management, and perhaps the general public shares this scepticism. If there is indeed a widespread perception that fishery management does not improve resource abundance and fishery sustainability, then these broader issues need to be tackled before the details of managing the white sea urchin fishery can be addressed. Related to this are property rights issues, as there is also the attitude that all citizens should have the right to harvest fishery resources, as reflected in the commonly heard statement that "you can't stop a man from fishing". More research into property rights and ways of acceptably eliminating open access, where necessary, are essential (McConney and Pena, 2005).

9.2 Saint Lucia: closed seasons and comanagement

In Saint Lucia, the white sea urchin has a relatively long history of sustainable harvest without legal regulation, but as in Barbados, it has suffered significant declines in the last two decades. In the past, communities such as those in Laborie and Vieux Fort harvested the resource during the two-month school summer holidays for personal consumption (Smith and Berkes, 1991). In the early 1960s, this localized 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 Saint Lucia developed (Smith and Walters, 1991).

Unacceptably high fishing levels in the late 1970s, together with the stress of successive hurricanes in 1979 and 1980, caused the fishery to collapse (Smith and Berkes, 1991). The population returned to harvestable levels by 1984, but, in response to dramatic increases in demand, harvesting increased and there was again a notable reduction in white sea urchin abundance by 1986 (Smith and Walters, 1991). Indiscriminate exploitation resulted in a second collapse in 1987, with the Department of Fisheries (DOF) officially closing the fishery in December 1987 (De Beauville-Scott, 2009). Following the depletion, the Caribbean Natural Resources Institute (CANARI) in collaboration with the DOF carried out a monitoring programme to assess abundance, growth and recruitment of the resource. The main purpose was to establish the conditions for the recovery of white sea urchin populations and the management of the fishery (George and Joseph, 1994; Smith and Koester, 2001).

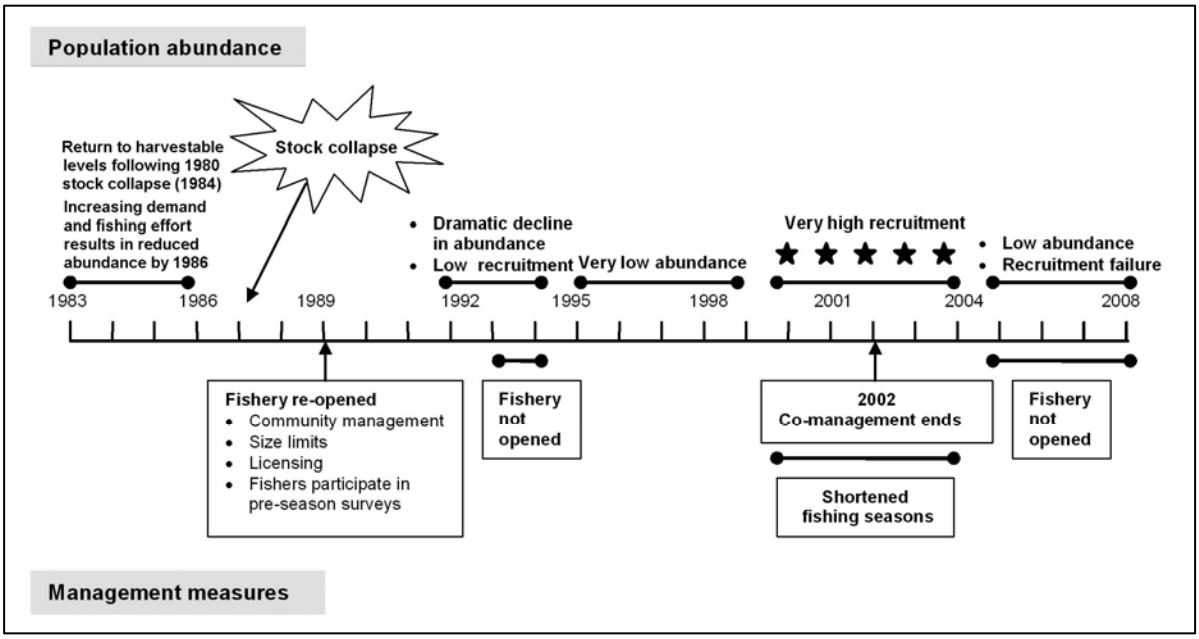
The results of the CANARI/DOF monitoring programme indicated that management of the white sea urchin fishery of Saint Lucia was possible (Smith and Walters, 1991). The nature of the resource and the fishery was considered suitable for implementing a system of community-based management. As such, the government reopened the fishery in 1989, but did not allow open access. Instead, a new participatory system of management was adopted in an attempt to avoid the overexploitation of the past. Tools implemented for controlling harvesting included size limits, limited entry by licensed urchin divers, and compulsory participation of fishers in pre-harvest surveys to determine the timing of the closure of the fishery (Smith and Koester, 2001). During this time, the structure of the legislation relating to the resource allowed for the development of participatory management. The management authority was allowed to select only individuals who had proved themselves concerned with the welfare of the resource. The legislation also allowed annual review of the permits granted so that persons had to qualify annually in order to be considered. In addition, there was scope to adjust the level of effort, number of divers and period of harvesting, to the level of the resource each year (George and Joseph, 1994).

By 1991, this initial participatory system had developed into an area-specific, community-management system with the flexibility to control, on an annual basis: the number of fishers harvesting the resource; the minimum legal size of urchin to be harvested; the length of the harvest season; and the means of disposing of urchin remains (Smith and Walters, 1991; George and Joseph, 1994).

Despite this sophisticated management arrangement and high compliance by harvesters, populations of the white sea urchin in Saint Lucia still declined dramatically after 1991, resulting in the fishery remaining closed through the 1993 and 1994 seasons due to low recruitment at all potential fishing areas (Figure 9). Overexploitation was not considered to be the cause of this recruitment failure, but other factors including natural sea conditions and pollution from raw sewage and waste from nearby laundry facilities were considered to be contributing factors (Scott and Walker, 1995). The extent to

which illegal harvesting had contributed to declines in urchin abundance was unknown (George and Joseph, 1994; De Beauville-Scott, 2009).

Figure 9: Twenty-five-year summarized management history for the Saint Lucia white sea urchin fishery



In 1995, the fishery opened for just nine days (20–28 September), and only in the southern part of the island (Scott and Walker, 1995). The fishery remained closed from 1996 to 1999 as a result of very low white sea urchin densities (Pena Rey, 1998). Short harvest periods were again allowed in 2000 and 2001 when monitoring revealed an unusually high level of recruitment. High levels of recruitment were again observed from 2002 to 2004 and the comanagement arrangement was terminated, resulting in island-wide harvesting for short periods in these years. The fishery has remained closed since 2005 as a result of continued low levels of abundance and recruitment failure, with little sign of recovery, possibly exacerbated by poaching that has occurred throughout the closed period (De Beauville-Scott, 2009).

Although comanagement of the fishery in Saint Lucia has been terminated, the sea urchin experience there 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). This approach to managing the fishery in Saint Lucia may have to be re-addressed in the future.

Prior to 1984, there was no specific legislation for the white sea urchin fishery. The 1984 Fisheries Regulations (Lobster, Turtle and Fish Protection) Section No. 10 included a “prohibition against the disturbance of sea urchins” without the written permission of the Chief Fisheries Officer. However, there was no management plan put in place at that time. The subsequent development of management strategies was largely based on increased harvesting effort particularly in Vieux Fort in 1987 owing to access to a market in Martinique. This increased effort led to a rapid decline in stocks and closure of the fishery as outlined above (Smith and Koester, 2001).

The Fisheries Regulations No. 9 of 1994 now makes provision for the white sea urchin fishery and states that, “no person shall disturb, damage, take from the fishery waters, have in his possession, purchase, expose for sale, or sell any sea urchins” without written permission of the Chief Fisheries Officer or between 30 November and 1 September or as otherwise stated by the minister. The act also makes provisions for closed areas, limited entry and moratoria, in addition to other management measures (De Beauville-Scott, 2009).

9.3 Carriacou and Grenada

The white sea urchin fishery on the main island of Grenada and the smaller Grenadine island of Carriacou was vibrant for many years as a subsistence fishery, sustaining considerable fishing pressure without management. However, the resource was eventually fished to very low levels and the Fisheries Division closed the fishery in 1994. Regulations restricting sizes, areas and seasons for urchins were issued for the first time in 1995. However, 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 comanagement arrangements (Pena Rey, 1998; Phillips, 2009).

9.4 Saint Vincent and the Grenadines

In Saint Vincent and the Grenadines, there is no formal recognition of a white sea urchin fishery. Only a minority of Vincentians enjoy the delicacy and harvest the resource for personal consumption. Harvesting is ad hoc and occurs mainly when the resource is abundant. The white sea urchin is also consumed by foreign residents and visitors who either harvest it themselves or pay fishers or snorkellers to harvest small quantities for them. There is no specific legislation pertaining to white sea urchins although fishery resources in general are subject to certain restrictions under the Marine Park Act of 1997, which allows for the designation of "no fish" zones within marine park boundaries. Furthermore, the export of any fishery product without an appropriate health certificate and permission from the relevant authorities is illegal (Punnett, 2009).

9.5 Martinique: closed seasons and moratoria

Similar to Barbados, a legally designated closed season has been the primary management measure applied to the white sea urchin fishery in Martinique. As a result of increased harvesting pressure in the late 1980s, regulation of the white sea urchin fishery was introduced in 1988 via a three-month closed season from 15 May to 15 August (Table 7). A moratorium on harvesting and sale of white sea urchins was imposed in 1989 for three years. In 1992, the fishery was reopened with the closed season extended to seven and a half months from 15 January to 1 September. In 1997, it was changed again by an "arrêté préfectoral" (by-law) declaring the fishery open for 11 months from 15 January to 15 December for a five-year period. However, after just two years, a fishing moratorium was imposed for three years from 6 August 1999. In 2002, provisional fishing was allowed only via permit on a probational basis for six hours per day from 6 a.m., except on Wednesdays and at the weekends. Fishers were had to declare their catch within 15 days after closure of the fishery. In the 2002 fishing season, white sea urchin harvesting was prohibited in reserves and polluted zones. In addition, the breaking of white sea urchins at sea was not allowed (Reynal and Bertrand, 2009).

Since 2002, harvesting start dates and the length of the harvesting period have been modified according to observed densities of the resource. The fishing season was initially fixed from 16 December to 16 January of the following year. However, in 2003, this was later adjusted to accommodate a fishing season consisting of two periods: the first from 6 October to 6 November; and the second in the first two weeks of December (1–15 December). Since 2004, decisions regarding the timing of the fishing season have been made based on annual pre-season abundance surveys. In 2004, the fishery was opened from 4 October to 5 November and from 2 to 16 December. In 2004, white sea urchin harvesting by fishers was authorized in the marine protected areas of Trinite/Sainte Marie, Sainte Anne, Cap Chevallier and Petite Anse (Reynal and Bertrand, 2009).

The white sea urchin fishery was closed in 2005 for the next three years owing to low observed densities at the time of the pre-season abundance surveys. However, in 2006, the fishery was reopened from 18 September to 20 October. In 2007, owing to the low density of white sea urchins following the passage of Hurricane Dean, the fishery remained closed. In 2008, an early opening of harvesting in mid-August was attempted in order to avoid the potential losses owing to the risk of bad weather during the hurricane period. However, owing to the low sea urchin abundance observed, fishers requested that the fishing season be closed just two days after its opening. The fishery has remained closed since 2008, when a three-year moratorium was imposed by by-law No. 08-04081 (Reynal and Bertrand, 2009).

Table 7: By-laws regulating the white sea urchin fishery in Martinique, 1988–2008

Reference of decree order	Decree dates	Management intervention
No. 88 1301	30 May 1988	Ban on fishing and sales from 15 May to 15 August 1988
No. 89 486	3 March 1989	Ban on the capture and sale of urchins
No. 92 1684	10 August 1992	Ban on fishing and sales from 15 January to 1 September
No. 97 2209	30 September 1997	Ban on fishing and sales from 15 January to 15 December, for a period of 5 years
No. 142	6 August 1999	Ban on fishing for a period of 3 years; sale of urchins in Guadeloupe remains authorized
No. 222 10	8 August 2002	Continuation of the ban on fishing; sale of urchins in Guadeloupe remains authorized.
No. 02 3731	12 December 2002	Ban on recreational fishing of the white urchin for exactly three years in order to establish conditions and zones in which fishing might be conducted by professional marine fishers.
No. 02 3788 bis	16 December 2002	Provisional fishing permitted from 16 December 2002 to 16 January 2003: • from 6.00 hours to 12.00 hours; • Mondays, Tuesdays and Fridays; • only marine fishers who routinely partake in the fishery and have permits given by to them by the DRAM; • obliged to report their catch by 31 January 2003, by fishing zone; • minimum catch size: 90 mm (without spines); • ban on fishing in the military zones and polluted areas (urban zones, ports, drainage zones); • no breaking of urchins in the sea.
No. 03 3235	02 October 2003	Identical to 2002, but with two open seasons: 6 October to 6 November and from 1 to 15 December 2003.
No. 42 451	06 September 2004	Identical to 2002, but with 2 open seasons: 4 October to 5 November and from 2 to 16 December 2004.
No. 04 3211	04 November 2004	Fishing of the white urchin for profit by professional marine fishers is authorized in the marine protected areas of Trinite/Ste. Marie, Ste. Anne, Cap Chevallier and Petite Anse.
No. 05 3582	15 November 2005	Ban on recreational fishing of the white urchin for an exact period of three years to establish conditions and zones in which fishing might be conducted by professional marine fishers.
No. 06 2976	30 August 2006	Open fishery on the conditions established in 2003, from 18 September to 20 October 2006. Fishery not open as a result of Hurricane Dean.
No. 08 2708	07 August 2008	Fishery is open under the conditions established in 2002, from 18 August to 19 September 2008, with the added following restriction: • equipment used by the skipper is limited to three persons per boat.
No. 08 2853	20 August 2008	Order to close the white urchin fishery
No. 08 4081	13 November 2008	Order to prolong the closure of the fishery and of the marketing of the white urchin

Source: Translated from Reynal and Bertrand (2009).

Fishers are required to provide the administration with a statement of catches by sector at the end of each harvesting season. In 2008, the number of divers accompanying the captain was added as a supplementary measure of regulating white sea urchin harvesting (Reynal and Bertrand, 2009).

9.6 Commonalities in white sea urchin fishery management

Although different management approaches and conservation efforts have been applied to white sea urchin fisheries in the English-speaking Caribbean, white sea urchins have shown similar trends of declining abundance, recruitment failure and stock collapse, particularly in islands with commercially important fisheries such as Barbados, Saint Lucia and Martinique (Figures 8 and 9). This might be expected if they shared the same source population. However, population genetic research using a number of different techniques has indicated the presence of island-specific and even location-specific stocks of the white sea urchin in the eastern Caribbean (Pena Rey, 1998; Parker, forthcoming). As such, these coincidental trends in population decline may, in part, be attributed to broad-scale environmental factors acting on populations already weakened by heavy fishing pressure. Further research in this area is considered critical to understanding the population dynamics and improving efforts at sustainable management of the resource.

The white sea urchin fisheries are also vulnerable to exogenous events. Such events include natural disasters (e.g. tropical storms and hurricanes) and changes in the economic and social "climate", to which small islands are particularly vulnerable and which have had negative impacts on the ability to manage white sea urchin fisheries in the eastern Caribbean (McConney, Mahon and Parker, 2003).

Numerous problems common to all countries exploiting the resource in the English-speaking Caribbean have been variously cited (e.g. McConney, Mahon and Parker, 2003; McConney and Pena, 2004, 2005; De Beauville-Scott 2009; Parker, 2009; Phillips, 2009; Punnett, 2009) and include:

- persistent illegal fishing during closed seasons and high levels of effort during open periods;
- a historical lack of, and difficulty in enforcing, regulations owing to the widely dispersed and small-scale nature of the fishery, in addition to the limited human resource capacity of management authorities and enforcement agencies;
- the reluctance to treat contraventions of fishery regulations as serious offences by some law enforcement officers and the judiciary, contributing to poor compliance;
- limited public education about white sea urchins and a lack of awareness about the importance of managing the fishery;
- insufficient information on the socio-economics of the fishery;
- limited information on the effects of environmental fluctuations on white sea urchin populations;
- inadequate timing of the fishing season owing to a limited understanding of the relationship between sea urchin gonosomatic index and readiness for harvest, resulting in wastage and lost spawning opportunity;
- poor catch and effort monitoring activities;
- limited documentation on harvest labour, marketing, distribution and trade;
- limited documentation of consumer demand and the culture of use in this fishery.

10. CURRENT AND FUTURE RESEARCH

10.1 Country-specific research needs

Further research requirements and existing information gaps in countries commercially exploiting the white sea urchin are outlined in the national reports (De Beauville-Scott, 2009; Parker, 2009; Phillips, 2009; Punnett, 2009; Reynal and Bertrand, 2009) that have been brought together under one cover in the FAO report of *The special workshop on the white sea urchin (*Tripneustes ventricosus*) fisheries in the eastern Caribbean* (forthcoming). They are summarized in Box 4.

Box 4

Research needs and existing information gaps in white sea urchin fisheries in the eastern Caribbean

Biological data:

- More detailed information on the stock–recruitment relationship of the white sea urchin is required to better predict the response of a white sea urchin stock to various levels of fishing, and to protect the stock from recruitment overfishing (removal of too many breeding adults) and eventual stock collapse.
- Identification of key white sea urchin larvae producer sites (source sites for new recruits) to protect the breeders from harvesting and the habitat from degradation.
- Size structure data, density and gonosomatic index estimation for determination of the status of white sea urchin populations in countries where this information is not regularly collected but subsistence fisheries exist. This information is crucial for informing management.
- Determination of the effects of environmental fluctuations on white sea urchin populations and their relationship, if any, to varying white sea urchin density (spatially and temporally).
- Detailed study on algal species on which white sea urchins feed. It has been claimed that white sea urchin roe have varying tastes dependent on the algal species in their diet. Some roe have a bitter taste. This will have an impact on consumer preference.
- Further diagnostic DNA analysis of populations of the white sea urchin in the eastern Caribbean should be undertaken to complement and add to that conducted by Pena Rey (1998). The elucidation of the genetic population structure of this species within the eastern Caribbean is necessary for a better understanding of the connectivity (interdependence) of the islands' white sea urchin fisheries, and will be required for rational management planning at a subregional level.

Catch and effort data:

- Improved and increased information on the number of persons involved in the fishery and catch rates for accurate determination of total fishing effort and ways of limiting fishing effort.
- Standardized method for catch and effort monitoring for regional data sharing and comparison among sites.

Governance:

- There is a need to strengthen enforcement capacities and capabilities of fishery authorities at the national level for improved compliance of white sea urchin fishery laws and regulations.

Pre- and post-harvest attributes:

- Research on harvest labour, marketing, distribution and trade should be considered, as culture of use is important but not well known. the white sea urchin fishery is one in which understanding consumer demand and the
- Extracted gonads (roe) have been reported to lose about half of their weight in a few hours. The factors influencing this loss require investigation.

10.2 Current research

In addition to the annual monitoring being conducted in Barbados, Martinique and Saint Lucia by the fishers and government authorities, research is currently being undertaken by the Centre for Resource Management and Environmental Studies (CERMES), the University of the West Indies, Barbados, and the Natural Resources Institute, University of Manitoba, Canada, on governance issues of white sea urchin fisheries in Barbados, Grenada and Saint Lucia, and may be useful in bridging some of the information gaps above. The research currently being undertaken by these institutions (Box 5) falls under the Marine Resource Governance in the eastern Caribbean (MarGov) project. The goal of this project is to understand marine resource governance related to small-scale fisheries and coastal management in the eastern Caribbean using complex adaptive system and social-ecological system concepts. The MarGov project is grant-funded by the International Development Research Centre's Rural Poverty and Environment Program Initiative launched in April 2005. Further information on the project and its outputs related to the white sea urchin fishery may be found at the CERMES Web site (www.cavehill.uwi.edu/cermes).

If the white sea urchin fisheries are to become sustainable and viable in the long term, there are a number of research needs, information gaps and management issues that should be addressed by countries currently exploiting the resource. With this in mind, it is hoped that the collaboration among the FAO Subregional Office for Latin America and the Caribbean, the CERMES, the IFREMER and the Institut régional de pêche et de marine (IRPM) in the collation of existing information on the biology and management of the white sea urchin and its fisheries in the Caribbean in this technical document, and in the formation of an ad hoc working group on white sea urchin management, can be used to begin addressing improved management of the white sea urchin.

Box 5

Current research being undertaken by the CERMES on the white sea urchin and its fisheries

Research projects include:

- Determination of the formal and informal processes and conditions for establishing and sustaining adaptive Comanagement of sea urchin fisheries in Barbados and Saint Lucia (MPhil research – CERMES, University of the West Indies, Barbados)
  - In Barbados and Saint Lucia the management of the white sea urchin (*Tripneustes ventricosus*) fishery has proved problematic for many years. Both countries place a high cultural and economic value on this fishery. This fact, in addition to the sedentary nature of these organisms and their habitat preference in the near shore, has made the white sea urchins vulnerable to overexploitation. Many management strategies, including comanagement arrangements have been attempted in the past but important attributes favouring the success of these initiatives are absent. A new approach to governance called adaptive comanagement has emerged that moves beyond the limits of comanagement with characteristics that highlight the importance of adaptation and learning. This approach to governance may be the solution to the problem of managing the sea urchin fisheries in Barbados and Saint Lucia. Therefore, this project seeks to determine the formal and informal processes and conditions for establishing and sustaining adaptive comanagement of the sea urchin fisheries in Barbados and Saint Lucia.
- 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 (MarGov project small grant, Grenada Fisheries Division)
  - The purpose of this project is to develop a draft fisheries management plan and governance arrangements for the Grenada sea urchin fishery using ecosystem-based and sustainable-livelihood approaches to fisheries management. Outputs will include: ecological, socio-economic and governance situation analyses for the sea urchin fishery; public consultations on options for managing and governing the sea urchin fishery leading to improved and shared

Box 5 (continued)

understanding of the fishery and how it can be better managed; draft fisheries management plan for the Grenada sea urchin fishery; and a report of lessons learned and recommendations.

- The sea urchin fishery in Grenada: a case study of social ecological networks (MSc research, University of Manitoba, Canada)
  - The white sea urchin (*Tripneustes ventricosus*) referred to as the "sea egg" in Grenada is most commonly found in nearshore habitats along the east and southeast coasts. The white sea urchin fishery was closed in 1995 after it collapsed following a period of increasing harvest aimed at meeting local and export demand. This research describes the fishery in Grenada prior to its closure and also examines how the fishery may operate should it be reopened. The research was conducted in Grenada in the summer of 2008 using a methodology that began by meeting with dive fishers and conducting participatory observation while accompanying them in reef fishing. This was followed by semi-structured interviews with divers, fisheries officials and marketers. Data were also obtained through a review of fisheries documents and by participation in a survey of white sea urchin fishing areas undertaken by Grenada fisheries officials and dive fishers.
- Strengthening the role of the Barbados Fisheries Advisory Committee (FAC) in sustainable governance of fisheries resources in Barbados: Examination of the FAC's ability in formation of a Sea Egg Management Council (MPhil research, CERMES, University of the West Indies, Barbados)
  - One of the case studies of this research is to determine the resilience of the Barbados Fisheries Advisory Committee (FAC) in the governance of the fishing industry in Barbados. The FAC was awarded a grant of US$8 750 in July 2008 to strengthen its role in the sustainable governance of fisheries resources in Barbados. One of the governance tests in this project is the formation of a white sea urchin management council.
- A GIS-based evaluation of index sites used in the assessment of the sea egg stock in Barbados (MSc research, CERMES, University of the West Indies, Barbados)
  - This project uses geographic information systems (GIS) to assess the current white sea urchin sampling methodology employed by the Fisheries Division in Barbados. It seeks to use the information about habitat preferences of the white sea urchin in order to determine the percentage of suitable habitat that is presently surveyed by the Fisheries Division. This information will then be used to assess the sampling methodology and make recommendations for improvement. Habitat suitability will be determined by using several secondary data sources including the Barbados Coastal Zone Management Unit habitat map, bathymetry data and published articles about sea urchins. This data will be entered into a GIS so that a spatial analysis of trends can be conducted. The outcome of this project will be a map of white sea urchin habitat and distribution that is based on the quality and quantity of data as provided by local fishers. This type of research is a good way to compare the outcome of scientific research to local knowledge and to map this information spatially so that both sets of data can be available to managers to improve the overall decision-making process.

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