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.

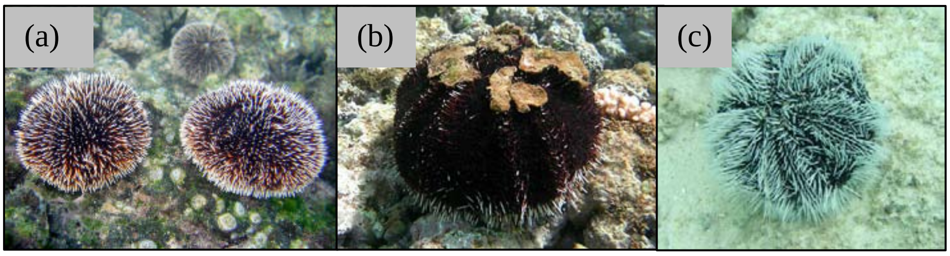


Plate 1: Species of *Tripneustes:* (a) *T. depressus*, (b) *T. gratilla*, and (c) *T. ventricosus* [(a) Wet Web Media; (b) US National Park Service; (c) authors' collection].

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.

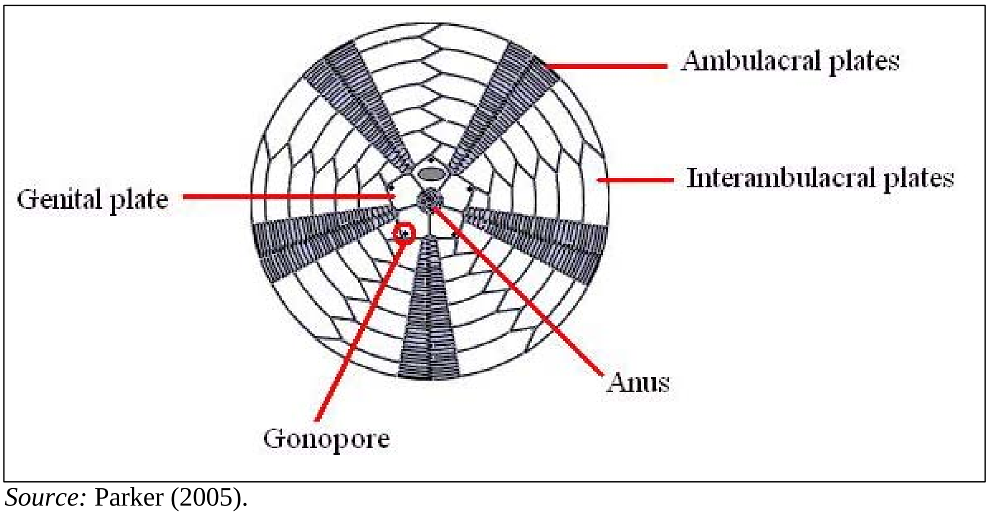
Table 2: Common and vernacular names of the white sea urchin used in the eastern Caribbean

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).

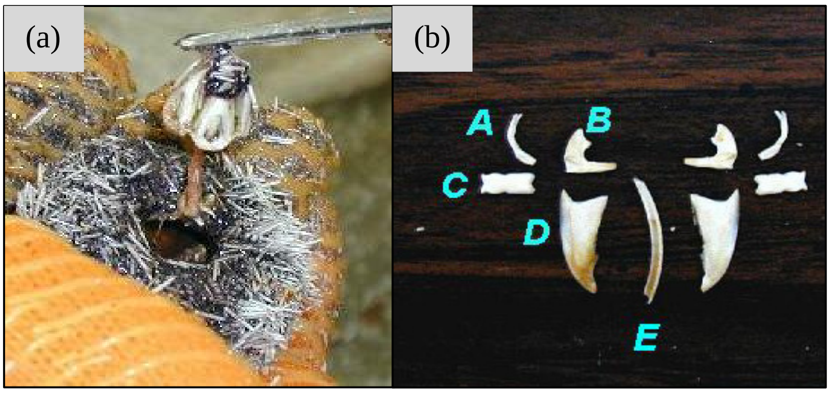


Plate 2: (a) Removing the Aristotle's lantern from a white sea urchin (with the end of the digestive tract still attached at the centre. (b) Ossicles comprising the Aristotle's lantern of a white sea urchin: A = compass (5 in total), B = epiphysis (10 in total), C = rotule (5 in total), D = demipyramid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

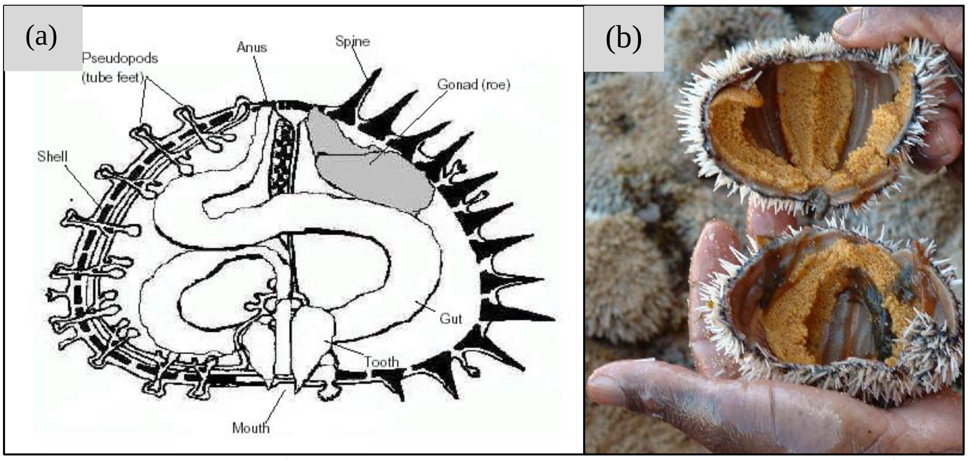


Plate 3: Morphology of the white sea urchin: (a) cross-sectional diagram of a typical sea urchin; and (b) cracked open shell of a white sea urchin containing five gonads [(a) INFOFISH International, (b) Pena].

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.

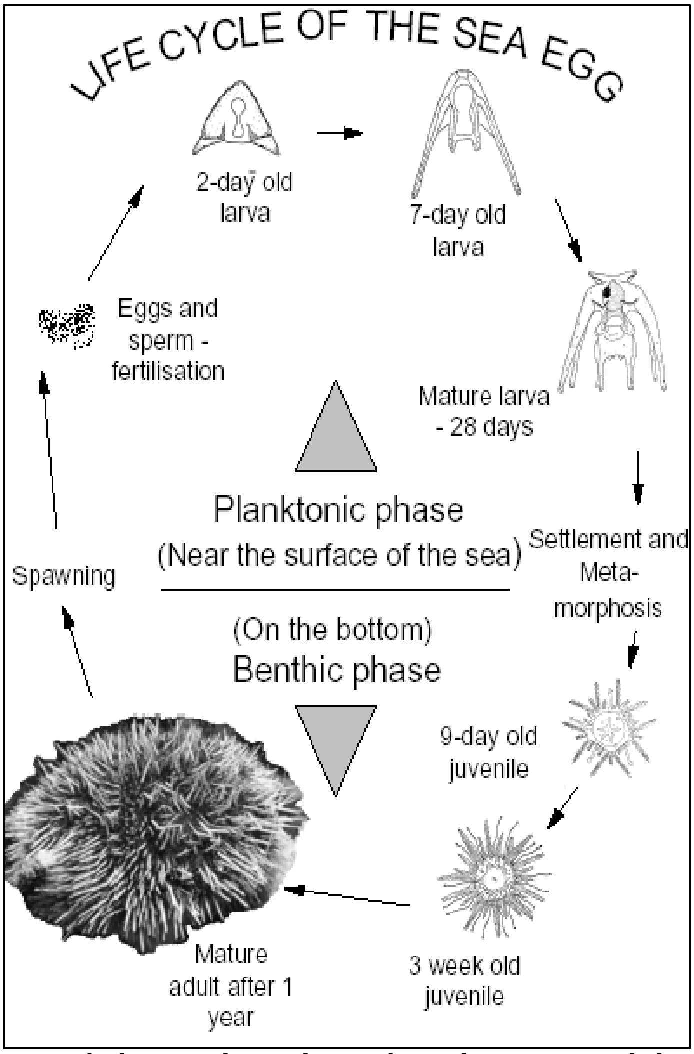
Plate 4: Partially de-spined, running-ripe white sea urchins: male (left) and female (right) (Franklin).

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.

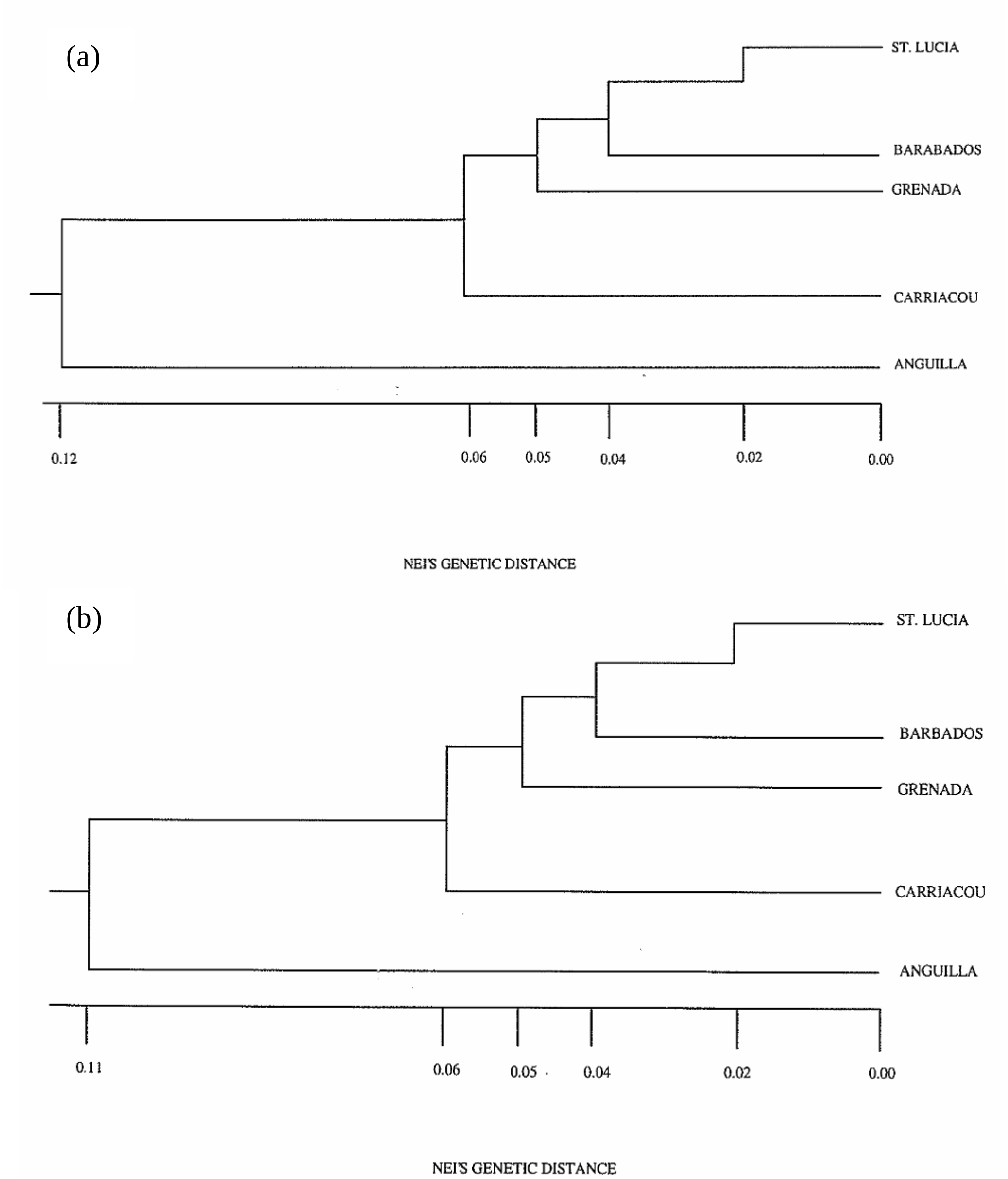
After an extensive review of the existing body of scientific literature on current patterns and larval dispersal modelling studies conducted in the eastern Caribbean, it was concluded that the rate of larval exchange among the islands, particularly in relation to recruitment to Barbados, can be considered 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).

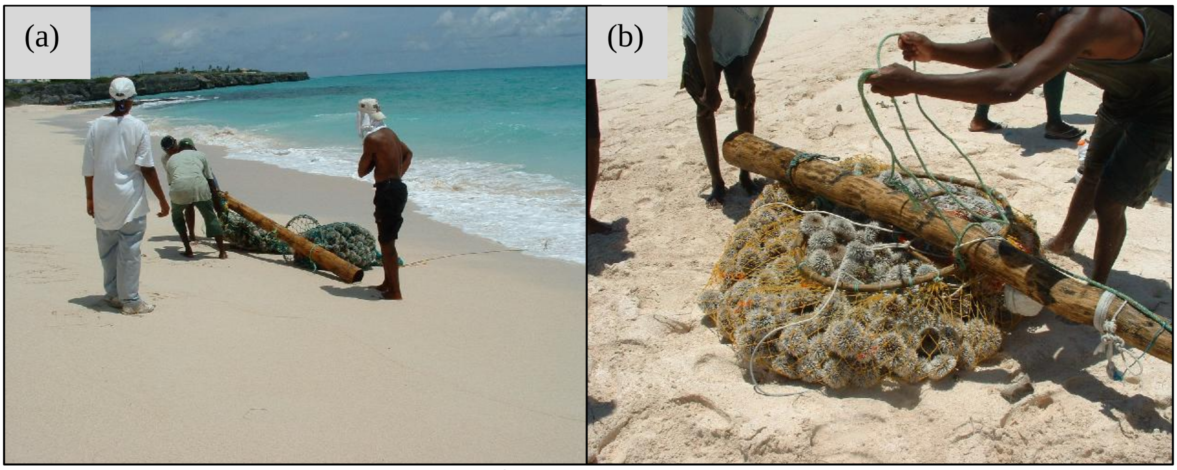


Plate 6: Traditional harvesting method for white sea urchins in Barbados, showing (a) white sea urchin divers hauling the maypole and attached bags of white sea urchins ashore, and (b) white sea urchins in a mesh bag being detached from the maypole (authors’ collection).