Abstract— Significant differences in adult morphology, ecology, molecular phylogeny, mtDNA and loci coding for gamete recognition molecules have been combined to map the boundaries of four closely related Echinometra species occur abundantly all over the tropical Pacific. These species have recently been designated as Echinometra A, B, C and D [1–11]. Consequently, mitochondrial DNA sequence data show that the Echinometra in the central and West Pacific diverged over the past 1-3 million years [6]. Although the four Echinometra are considered to be distinct species, valid names for them have been argued. Echinometra sp. B is now recognized as Echinometra mathaei [12], while Echinometra sp. D belongs in the Echinometra oblonga species complex, which may include a cryptic species composed of at least three species [13]. The other two species, Echinometra sp. A and Echinometra sp. C have yet to be formally described and scientifically named [7, 14]. Small genetic and morphological differences among the four species coupled with their strong reproductive isolation make them a valuable group for studies of marine speciation [15].

Among these four genetically diverged species of Echinometra, two most distinct pairs, Echinometra sp. A (Ea) and E. mathaei (Em) (Fig. 1) can be distinguished from each other by differences in adult morphology and habitat preferences [9, 11]. Ea is abundant in more or less protected, constantly submerged habitat which is very calm and situated below the level of Mean Low Water Surface (MLWS), such as tidepools and shallow reef slopes or areas protected from strong wave action, whereas Em inhabits shallow burrows on reef flats behind the reef margin and with strong wave action, both above and below the level of MLWS [3, 9, 16, 17, 18]. The reproductive seasons of the two species overlap, extending from April to December with a maximum size of the gonads around September [18]. They also have significant biological, ecological, evolutionary, nutritional, pharmaceutical and cultural values [9, 11, 14].

Fig. 1 Adults of Echinometra spp.: A) Echinometra sp. A (Ea); B) E. mathaei (Em).

To explore the potentiality of producing desirable traits, interspecific hybridization between them was examined through a series of cross-fertilization and hybrid rearing experiments, following the protocols described in Rahman et al. [7, 9, 10]. Compared to conspecific crosses, fertilization rate in both heterospecific crosses were very low, even at a high sperm concentration. This strong block to fertilization indicates the presence of protein-binding system for gamete recognition. Larval survival, metamorphosis, and recovery of juveniles Em (ova) x Ea (sperm) and Ea (ova) x Em (sperm) hybrids were significantly lower than either of their conspecific controls, Ea x Ea and Em x Em. In spite of these, hybrids from crosses in both directions were developed normally through larval and juvenile stages to sexually mature adults, indicating that postzygotic isolating mechanisms were not large enough to cause developmental incompatibility or hybrid inviability. Phenotypic color patterns of the adult hybrids were maternally inherited, whereas other characters such as spine length, tubefoot and gonad spicules, pedicellaria valve length and gamete sizes were intermediate. Ova and sperm of F1 hybrids were completely fertile, minimizing the possibility that hybrid infertility is a postzygotic isolating mechanism. On the other hand, intensive field surveys failed to find individuals with such hybrid characteristics, confirming the absence of natural hybridization. These findings mirror those obtained with hybridization studies in other tropical species of West-Pacific and Atlantic sea urchins. This strongly suggests that reproductive isolation and species integrity is maintained by prezygotic isolating mechanisms in these species. Nevertheless, the growth performances (final weight, weight gain, gonad weight, gonad
index, SGR and test sizes) of 2-year-old lab-reared adult hybrids (Fig. 2) were significantly higher than the superior parent (Ea x Ea) and inferior parent (Em x Em). Gonad production showed an increase of 34%, 63% and 47% in F1 hybrid of Em x Ea and 31%, 60%, and 44% in F1 hybrid of Ea x Em over the superior (Ea x Ea), inferior (Em x Em) and mid parents, respectively. Survival was similar in Em x Em (87%) and Ea x Ea (86%), followed by Em x Ea (79%), and Ea x Em (78%). Therefore, body growth, gonad production (87%) and Ea x Ea (86%), followed by Em x Ea (79%), and Ea x Em (78%).

Hence, hybrids in both directions appear to have considerable potential for enhancing aquaculture production.

Fig. 2 Two-year-old adults of Ea, Em and their reciprocal hybrids; maternal species named first: A) Ea x Ea; B) Em x Em; C) Ea x Em; D) Em x Ea


