Aquaculture 496 (2018) 134–145

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

Breeding, larval development, and growth of juveniles of the edible sea urchin *Tripneustes depressus*: A new target species for aquaculture in Ecuador

Jorge I. Sonnenholzner-Varas[a,*], Noelia Touron[b], María Manuela Panchana Orrala[b]

[a] Escuela Superior Politécnica del Litoral, ESPOL, Centro Nacional de Acuicultura e Investigaciones Marinas, Facultad de Ciencias de La Vida, km. 30.5, Vía Perimetral, Guayaquil, Ecuador

[b] Escuela Superior Politécnica del Litoral, ESPOL, Centro Nacional de Acuicultura e Investigaciones Marinas, km. 30.5, Vía Perimetral, Guayaquil, Ecuador

ARTICLE INFO

Keywords:
Tripneustes depressus
Larviculture
Juveniles
Fast-growing
Sea-ranching

ABSTRACT

Sea urchin fishery has gradually expanded in different countries and territories around the world, including South America, and the sea urchin *Tripneustes depressus* is a feasible candidate for aquaculture. The aim of this study was to prepare a biotechnical protocol for rearing larvae and production of juveniles. Large *T. depressus* were collected at monthly intervals at a subtidal rocky coast off Palmar, Santa Elena, Ecuador from January 2015 to December 2017. *T. depressus* spawns when exposed to thermal shock in low illumination room. Seven spawning events were recorded between March and May and between July and August. On average, females spawned approximately $3.60 \pm 0.83 \times 10^7$ oocytes (mean diameter: 78.4 ± 2.1 μm) and males spawned approximately $5.60 \pm 1.10 \times 10^7$ spermatozoa respectively). A cohort of May 13, 2017 was followed for 250 days. Embryo and larval stages were completed within 48 h and 21 days, respectively, at 26.5 ± 0.5 °C. Larvae were fed a mixed diet of *Tysochrisis lutea*, *Chaetoceros gracilis* and *Rhodomonas* sp. at concentrations ranging from 2.5×10^3 to 2.0×10^4 cells /ml as they increased in size. Larvae were measured considering: Total Length (TL), Medium Base Line (MBL) and Base Width (BW). On day 2 after fertilization (AF): 311.7 ± 2.0 μm, 158.9 ± 1.0 and 270.7 ± 3.4 ($n = 10$), respectively. On AF_{16}: 544.7 ± 4.0 μm, 273.6 ± 6.9 and 355 ± 3.5 ($n = 10$). On AF_{21}, larval rudiment size was equal in size to that of the stomach and larvae were competent. Their body measurements, and specifically total length at that food concentration, showed no phenotypic plasticity. Thirty two days post spawning (DPS) all juveniles had open mouths and a functional gut for feeding (size: 0.40 ± 0.01 mm DT), and at DPS_{98} three size categories were differentiated. Sea urchin sizes by categories at DPS_{98} and DPS_{152} were, respectively: small (2.20 ± 0.1 mm DT and 23.9 ± 0.45 mm TD), medium (4.90 ± 0.08 mm DT and 33.3 ± 0.3 mm TD); and large (7.20 ± 0.11 mm DT and 43.8 ± 0.5 mm DT) with zero mortality. *T. depressus* reach 4 cm diameter at 188 days after metamorphosis and can reproduce after six months of life, when it reach approximately 4.2 cm diameter), although the gonads are not yet commercial in size. This protocol is an initial perfectible protocol for sea urchin aquaculturing. However, we have made recommendations for consideration that include increasing survivorship and supplying post-larvae for juvenile production.

1. Introduction

Ecuador (in the eastern tropical Pacific, ETP) is a country with a long tradition in coastal-artisanal fishery on rocky-reef ecosystems, for some marine invertebrates, such as lobsters, crabs, mollusks and sea cucumbers (Alava et al., 2015; Henchion et al., 2017).

The high demand for consuming high-quality animal protein of marine origin, consequently has made some natural populations drastically diminish by overfishing (Manabu, 2007; Hearn, 2008; Wolff et al., 2012; Castrejón and Charles, 2013; Martínez-Ortiz et al., 2015). This has triggered concerns about structural and functional changes of shore reefs through trophic cascades (Okey et al., 2004; Glynn, 2008; Sonnenholzner et al., 2011a), and decreasing the income of coastal communities. The fishermen have sought to diversify its fishing by targeting a wider range of marine benthic animals and exploring fishing grounds along the mainland of Ecuador and around the Galapagos Archipelago. But, paradoxically, aquaculture is poorly developed in Ecuador (FAO, 2016; Pullin, 2017).

A comprehensive spatio-temporal dynamics on basic biological and ecological issues (embryonic phase, larvae and juvenile) for potential

* Corresponding author at: Escuela Superior Politécnica del Litoral, Campus "Gustavo Galindo" Km. 30.5, Vía Perimetral, Casilla: 09-01-5863, Guayaquil, Ecuador.
E-mail addresses: sonnenhol@espol.edu.ec (J.I. Sonnenholzner-Varas), notouron@espol.edu.ec (N. Touron), mpanchan@espol.edu.ec (M.M.P. Orrala).

https://doi.org/10.1016/j.aquaculture.2018.07.019
Received 1 April 2018; Received in revised form 2 July 2018; Accepted 11 July 2018
0044-8486/

new marine resources for fishery and aquaculture is lacking. Due to the decline in some fisheries (*i.e*, sea cucumber, Sonnenholzner et al., 2017), interest has developed in a sustainable and alternative aquaculture production (supported with population restocking) in order to divert fishing pressure away from traditional fisheries. In this sense, sea urchin aquaculture is very pertinent.

Sea urchin fishery has gradually expanded in different countries and territories around the world (including South America, Andrew et al., 2002). At least twenty-one species of sea urchins have been heavily harvested and extensively implemented in the sea urchin trade, especially for some Asian countries (a total production of about 73,000 metric tons, Castilla-Gavilán et al., 2018). This trade represents an estimated at about 200–300 million US$ (Shimabukuro, 1991; Sun and Chiang, 2015; Castilla-Gavilán et al., 2018). > 70% of this production comes from six different areas from the Pacific region (Micael et al., 2009; FAO, 2016). Japan has long been the major lucrative market for global sea urchin production (annual domestic demand of about 50,000 metric tons whole weight) and is the major driver of global sea urchin prices. A top-quality (as fresh, dried, salted or brined sea urchin roe) can sell for over USD $60/kg (Sun and Chiang, 2015).

Roe is part of a special gastronomy part of fish markets and are prized in delicacy cuisine (in sushi or sashimi) for their sensory attributes, in terms of palatability, flavor and color (Keesing and Hall, 1998; AAFC, 2002; Devin, 2002; Muthiga, 2005; Rahman et al., 2012). They also are consumed for the high-quality protein content, polyunsaturated fatty acids; and potential use in medicine because of its rich chemical constituents and biochemical compounds, such as polysaccharides, PUFAs, β-Carotene, xanthophylls and others nutrients (Kaneniwa and Takagi, 1986; Lawrence et al., 1997; Yur'eva et al., 2003; Archana and Babu, 2016). Nonetheless, the supply of domestic sea urchins is limited and the feasibility of this industry is largely dependent on sufficient natural populations. At this juncture, this important industry is kept virtually unstable.

Because several sea urchin populations have diminished as result from ineffective fisheries policies and management (a declined pattern in catches has been noticed in several countries in the Pacific region, as Chile, China, Japan, New Zealand, and in many areas of Southern and Western Australia), interest in sea urchin aquaculture has developed rapidly and has grown steadily over the past few years (Lawrence, 2013; Lawrence and Agatsuma, 2013; Paredes et al., 2015). Sea urchin aquaculture can help alleviate the pressure for overexploitation of wild sea urchins (Barker et al., 1998; Huggett et al., 2006; Liu et al., 2010; Kayaba et al., 2012; Eddy et al., 2012; James et al., 2016).

Tripneustes is a genus of toxopneustid echinoids that recognizes three extant edible species with commercial value, *T. ventricosus* (Lamarck, 1816) from both sides of the Atlantic, *T. gratilla* (Linnaeus, 1758) in the Indo-West Pacific, and *T. depressus* (Agassiz, 1863) in the central eastern Pacific (Fig. 1a–c). A study of the phylogeography of the pantropical sea urchin *Tripneustes* by Lessios et al. (2003) revealed that based on morphology, COI, and bindin data, *T. depressus* from the eastern Pacific is in fact the same species as *T. gratilla* from the western Pacific. In the international market the gonads of *T. ventricosus* and *T. gratilla* are good vis-à-vis quality competitive in the trade with other species (Scheibling and Mladenov, 1987; Rahman et al., 2009; Pena et al., 2010). A number of studies have examined the biology, ecology, fisheries and aquaculture relevant issues of *T. gratilla* (Shimabukuro, 1991; Cyrus et al., 2013; Lawrence and Agatsuma, 2013) and *T. ventricosus* (Keesing and Hall, 1998; Andrew et al., 2002; Robinson, 2004; Wolcott and Messing, 2005), but no detailed information exists for *T. depressus* (Sonnenholzner et al., 2013).

T. depressus is a very desirable species for fishery and is a feasible candidate for aquaculture in Ecuador for its biological attributes, such as: large-size, short time to maturity, high growth rate, high reproductive effort and output, and short life span (Lawrence, 1990; Lawrence and Bazhin, 1998; Lawrence, 2013). They are part of a conspicuous assemblage of coral reef-associated communities that inhabits moderate hydrodynamic leeward rubble and open sloping rocky shores with interspersed coral-sandy rubble pockets (but never on pure sand or muddy sand) on encrusting coralline, calcareous articulated algae on rhodolith beds and on extensive and dominant soft, fleshy brown macroalgae (varieties include *Padina* and *Sargassum* species) that support their grazing activity (Sonnenholzner and Lawrence, 2002; Lawrence and Sonnenholzner, 2004; Foster et al., 2007; Irving and Witman, 2009; Uthicke et al., 2009; Sotelo-Casas et al., 2016) in shallow waters (preferentially at average 12 m depth) to 73 m depth from the Gulf of California, México to Lobos de Afuera islands, Perú, including the Galápagos and Clarion Islands (Maluf, 1988; Idrovo and Sonnenholzner, 1994) (Fig. 1a–c). In Galápagos, *T. depressus* is spread out throughout all five eco-regions with different sea temperatures ranging from 20.3–27.1 °C (Banks, 1999; Brandt and Guarderas, 2002), and bathymetrically between 3 and 40 m depth, it ranges from 17.3–28.5 °C, in the central coast off Ecuador (Datos de la Estación Oceanográfica *El Pelado* del Cenaim-Espol 2013–2017). Traditionally, this species has been locally consumed as food by fishers in Manabí (on the mainland coast of Ecuador) and Galápagos.

Since 2014, considering the importance of *T. depressus*, the Centro Nacional de Acuicultura e Investigaciones Marinas of the Escuela Superior Politécnica del Litoral of Ecuador (CENAIM–ESPOL) is promoting research studies on *T. depressus* diversify aquaculture. These studies will contribute for future management plans (as alternating new fisheries based on aquaculturing), leading to the sustainability of benthic resources in Ecuador. The aim of this study was provide

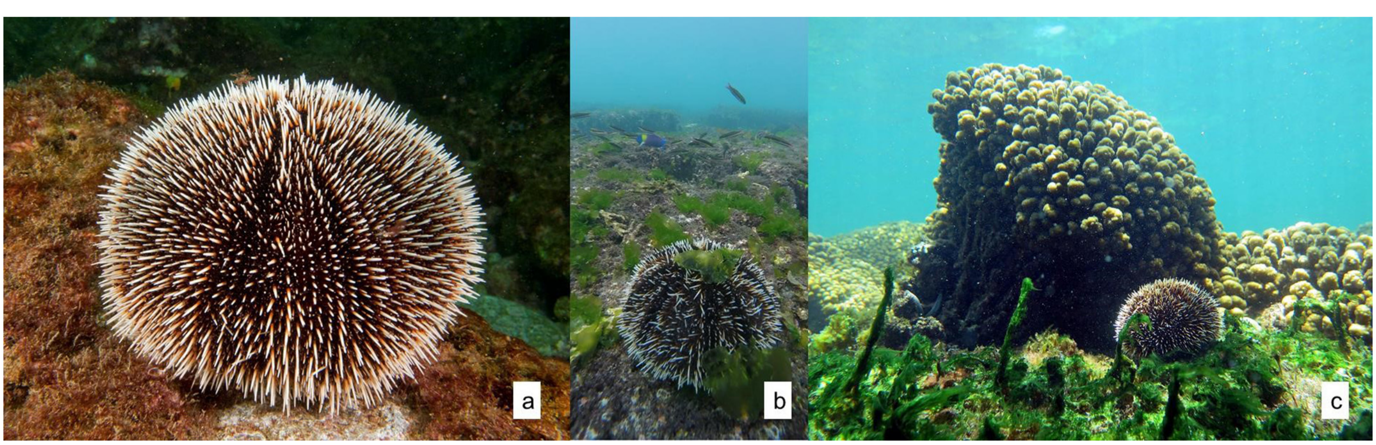

Fig. 1. View of large sea urchins *Tripneustes depressus* in open rocky and coral reef habitats; a) specimen at 12 m depth, *El Pelado* Island, Santa Elena, Ecuador; b) a covered specimen with foliose macroalgae *Ulva lactuca* at 3 m depth, Bahía Santa Elena, Guanacaste, Costa Rica; and c) specimen at 2 m depth associated with a large *Pocillopora verrucosa*, Punta Galeras, Baja California Sur, México.