



# Estudi de la biologia reproductiva de la cabra de mar, *Maja brachydactyla*: aparell reproductor i qualitat de les postes en captivitat

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# Conclusions



1. La morfologia, ultraestructura i funció de l'aparell reproductor masculí de la cabra de mar són similars a la resta de braquiürs, amb les següents característiques particulars:
  - a. El testicle de *Maja brachydactyla* és de tipus tubular i està format per un únic tub seminífer recargolat.
  - b. El tub seminífer està dividit longitudinalment per unes capes d'epiteli que el compartimenten en tres zones: la germinal, que conté els espermatogonis, la de transformació, en la que té lloc l'espermatogènesi i la zona d'evacuació, que recull els espermatozoides i els transporta fins el conducte deferent.
  - c. El conducte deferent dividit en tres parts: anterior (CDA), mitjà (CDM) i posterior (CDP), en base a criteris morfològics i funcionals. El conducte deferent presenta un epiteli responsable de la producció de les secrecions involucrades en la formació de la paret de l'espermatòfor (CDA), l'emmagatzematge dels espermatòfors (CDM), i la producció de fluids seminals (CDP).
  - d. El conducte ejaculador s'encarrega de l'extrusió dels espermatòfors i fluids seminals i present adherit una massa de teixit identificada com la glàndula andrògena.
2. L'espermatogènesi de la cabra de mar és un procés semblant a aquells descrits en altres espècies de braquiürs, i l'espermiogènesi es caracteritza per:
  - a. La formació d'un complex i voluminós acrosoma, associat a l'activitat del complex de Golgi.
  - b. La formació d'un sistema de membranes (SO) a partir del reticle endoplasmàtic rugós i complex de Golgi associat a microtúbuls i a uns pocs mitocondris.
  - c. L'associació de la membrana plasmàtica i l'embolcall nuclear dóna lloc a una estructura membranosa pentalaminar en algunes regions de la superfície cel·lular.

- d. El desenvolupament d'expansions o braços radials de citoplasma que contenen cromatina.
  - e. La decondensació progressiva de la cromatina durant l'espermiogènesi.
3. La morfologia i ultraestructura de l'espermatozoide de la cabra de mar s'ajusta al model general dels braquiürs, i presenta les següents característiques:
- a. L'acrosoma ocupa la zona central de la cèl·lula i presenta una morfologia globular i una estructura complexa, amb tres capes concèntriques de diferent electrodensitat, l'opercle en posició apical i el perforatori com una columna central que conté actina.
  - b. El citoplasma forma una fina capa al voltant de l'acrosoma, i és només distingible a la base de les expansions nuclears, on forma un anell citoplasmàtic que conté el complex SO, i en la base de l'acrosoma, on presenta almenys un centríol.
  - c. El nucli presenta forma de copa amb expansions radials associades a l'anell citoplasmàtic. La cromatina està poc condensada i a voltes forma petits grups condensats propers al complex SO.
4. El gen *Mb vasa* es considera l'homòleg del gen *vasa* a la cabra de mar, en base a la seqüència deduïda d'aminoàcids, l'anàlisi filogenètic i l'expressió específica en gònades adultes. L'expressió del *Mb vasa* al llarg del desenvolupament larvari i primer estadi juvenil és baixa però detectable i s'ajusta a una corba de creixement exponencial.
5. La producció larvària i la composició bioquímica de les larves acabades de descloure es veuen afectades per la presència de mascles, tot i que la presència de dos mascles produeix una elevada mortalitat de les femelles.
- a. La presència de mascles en els tancs de les femelles deuria ser considerada per a l'optimització de la producció larvària sense comprometre la condició de les femelles. Es proposen dos models de gestió de la presència dels mascles.

- b. El model de presència puntual es basa en la individualització de tots els reproductors, tant mascles com femelles, i només es permetria el contacte per a la còpula.
  - c. En el model de presència contínua, es constituïrien uns grups de reproductors formats per un únic mascle i varies femelles en el mateix tanc.
6. La producció larvària i la composició bioquímica de les larves acabades de descloure es veuen afectades pel fotoperíode. Tanmateix, el desfament del fotoperíode no produeix un retard en la producció larvària. Així, el fotoperíode és un factor ambiental que afecta la reproducció de la cabra de mar, malgrat que la manipulació del fotoperíode és insuficient per a modificar el comportament reproductiu d'aquesta espècie.
7. Els paràmetres morfomètrics i bioquímics de les femelles reproductores, així com la producció larvària i la composició bioquímica de les larves acabades de descloure es veuen afectades per l'estoc de reproductors. Donat que aquest efecte podria tenir conseqüències al llarg del procés productiu, la domesticació de la cabra de mar seria necessària per al control de la qualitat dels reproductors i el desenvolupament d'un cultiu sostenible i profitós.





# **Bibliografia**



- Adiyodi, K.G., Anilkumar, R.G., 1988. Accessory sex glands. En: Adiyodi, K.G., Adiyodi, R.G. (Eds.), Reproductive Biology of Invertebrates. John Wiley and Sons, Kerala, pp. 261-318.
- Ahyong, S.T., O'Meally, D., 2004. Phylogeny of the Decapoda Reptantia: resolution using three molecular loci and morphology. Raffles Bulletin of Zoology. 52, 673-693.
- Alaminos, J., 2011. Efecto del confinamiento en espacios reducidos sobre el crecimiento de juveniles de centollo, *Maja brachydactyla*, y su repercusión en la madurez. Revista de Biología Marina y Oceanografía. 46, 219-230.
- Alaminos, J., Domingues, P., 2008. Effects of different natural or prepared diets on growth and survival of juvenile spider crabs, *Maja brachydactyla* (Bals, 1922). Aquaculture International. 16, 417-425.
- Andrés, M., Estévez, A., Rotllant, G., 2007. Growth, survival and biochemical composition of spider crab *Maja brachydactyla* (Bals, 1922) (Decapoda: Majidae) larvae reared under different stocking densities, prey:larva ratios and diets. Aquaculture. 273, 494-502.
- Andrés, M., Estévez, A., Anger, K., Rotllant, G., 2008. Developmental patterns of larval growth in the edible spider crab, *Maja brachydactyla* (Decapoda: Majidae). Journal of Experimental Marine Biology and Ecology. 357, 35-40.
- Andrés, M., Estévez, A., Hontoria, F., Rotllant, G., 2010a. Differential utilization of biochemical components during larval development of the spider crab *Maja brachydactyla* (Decapoda: Majidae). Marine Biology. 157, 2329-2340.
- Andrés, M., Estévez, A., Simeó, C.G., Rotllant, G., 2010b. Annual variation in the biochemical composition of newly hatched larvae of *Maja brachydactyla* in captivity. Aquaculture. 310, 99-105.
- Andrés, M., Rotllant, G., Sastre, M., Estévez, A., 2011. Replacement of live prey by formulated diets in larval rearing of spider crab *Maja brachydactyla*. Aquaculture. 313, 50-56.
- Andrés, M., Gisbert, E., Díaz, M., Moyano, F.J., Estévez, A., Rotllant, G., 2010c. Ontogenetic changes in digestive enzymatic capacities of the spider crab, *Maja brachydactyla* (Decapoda: Majidae). Journal of Experimental Marine Biology and Ecology. 389, 75-84.
- Anilkumar, G., Sudha, K., Subramonian, T., 1999. Spermatophore transfer and sperm structure in the brachyuran crab *Metopograpsus messor* (Decapoda: Grapsidae). Journal of Crustacean Biology. 19, 361-370.
- Anilkumar, G., Sudha, K., Anitha, E., Subramoniam, T., 1996. Aspects of sperm metabolism in the spermatheca of the brachyuran crab *Metopograpsus messor* (Forskäl). Journal of Crustacean Biology. 16, 310-314.

- Anònim, 2007. El centollo. Distribución y Consumo. 93, 86-89.
- Balss, H., 1922. Crustacea VII: Decapoda Brachyura (Oxyrhyncha und Brachyrhyncha) und geographische Übersicht über Crustacea Decapoda. En: Michaelsen, W. (Ed.), Beiträge zur Kenntnis der Meeresfauna Westafrikas. Friederichsen and Co., Hamburg, pp. 69-110.
- Bañón, R., 2008. La pesca con nasas en Galicia: una visión histórica. Anuario Brigantino. 31, 493-504.
- Banzai, K., Izumi, S., Ohira, T., 2012. Molecular cloning and expression analysis of cDNAs encoding insulin-like androgenic gland factor from three palaemonid species, *Macrobrachium lar*, *Palaemon paucidens* and *P. pacificus*. Japan Agricultural Research Quarterly. 46, 105-114.
- Banzai, K., Ishizaka, N., Asahina, K., Suitoh, K., Izumi, S., Ohira, T., 2011. Molecular cloning of a cDNA encoding insulin-like androgenic gland factor from the kuruma prawn *Marsupenaeus japonicus* and analysis of its expression. Fisheries Science. 77, 329-335.
- Bas, C.C., Spivak, E.D., 2000. Effect of salinity on embryos of two southwestern atlantic estuarine grapsid crab species cultured in vitro. Journal of Crustacean Biology. 20, 647-656.
- Bas, C.C., Spivak, E.D., Anger, K., 2007. Seasonal and interpopulational variability in fecundity, egg size, and elemental composition (CHN) of eggs and larvae in a grapsoid crab, *Chasmagnathus granulatus*. Helgoland Marine Research. 61, 225-237.
- Bauer, R.T., 1986. Phylogenetic trends in sperm transfer and storage complexity in decapod crustaceans. Journal of Crustacean Biology. 6, 313-325.
- Benhalima, K., Moriyasu, M., 2000. Structure and function of the posterior vas deferens of the snow crab, *Chionoecetes opilio* (Brachyura, Majidae). Invertebrate Reproduction and Development. 37, 11-23.
- Benzie, J.A.H., 1997. A review of the effect of genetics and environment on the maturation and larval quality of the giant tiger prawn *Penaeus monodon*. Aquaculture. 155, 69-85.
- Bernárdez, C., González-Gurriarán, E., García-Calvo, B., Corgos, A., Freire, J., 2003. Movements of juvenile and adult spider crab (*Maja squinado*) in the Ría da Coruña (NW Spain). En: Spedicato, M.T., Lembo, G., Marmulla, G. (Eds.), Aquatic telemetry: advances and applications: proceedings of the Fifth Conference on Fish Telemetry held in Europe. FAO/COISPA, Ustica (Italy), pp. 133-139.
- Bhavanishankar, S., Subramoniam, T., 1997. Cryopreservation of spermatozoa of the edible mud crab *Scylla serrata* (Forsk.) Journal of Experimental Zoology. 277, 326-336.

- Bradford, M.M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*. 72, 248-254.
- Brosnan, D.M., 1981. Studies on the biology, ecology and fishery of the spider crab *Maia squinado* Herbst (1768) of the west coast of Ireland, Shellfish Research Laboratory, Department of Zoology. University College, Galway, pp. 133.
- Carlisle, D.B., 1957. On the hormonal inhibition of moulting in decapod Crustacea. II: The terminal anecdyosis in crabs. *Journal of the Marine Biological Association of the UK*. 36, 291-307.
- Castilho, G.G., Ostrensky, A., Pie, M.R., Boeger, W.A., 2008. Morphology and histology of the male reproductive system of the mangrove land crab *Ucides cordatus* (L.) (Crustacea, Brachyura, Ocypodidae). *Acta Zoologica*. 89, 157-161.
- Cerezo Valverde, J., Hernández, M.D., Aguado-Giménez, F., García García, B., 2009. Oxygen consumption in spider crab (*Maja brachydactyla*): Effect of weight, temperature, sex, feeding and daily light-dark cycle. *Aquaculture*. 298, 131-138.
- Charniaux-Cotton, H., 1954. Découverte chez un crustacé amphipode (*Orchestia gammarella*) d'une glande endocrine responsable de la différenciation des caractères sexuels primaires et secondaires mâles. *Comptes Rendus de l'Académie des Sciences Paris*. 239, 780-782.
- Charniaux-Cotton, H., 1958. La glande androgène de quelques Crustacés Décapodes et particulièrement de *Lysmata seticaudata*, espèce à hermaphrodisme protérandrique fonctionnel. *Comptes Rendus de l'Académie des Sciences Paris*. 246, 2814-2817.
- Charniaux-Cotton, H., Zerbib, C., Meusy, J.J., 1966. Monographie de la glande androgène des crustacés supérieurs. *Crustaceana*. 10, 113-136.
- Cheng, Y., Wu, X., Yang, X., Hines, A.H., 2008. Current trends in hatchery techniques and stock enhancement for Chinese mitten crab, *Eriocheir japonica sinensis*. *Reviews in Fisheries Science*. 16, 377-384.
- Cheung, T.S., 1968. Trans-molt retention of sperm in the female stone crab, *Menippe mercenaria* (Say). *Crustaceana*. 15, 117-120.
- Chiba, A., Honma, Y., 1972. Studies on the maturity of the gonad in some marine invertebrates- IV: seasonal changes in the testes of the lined shored crab. *Bulletin of the Japanese Society of Scientific Fisheries*. 38, 317-329.

- Chung, J.S., Manor, R., Sagi, A., 2011. Cloning of an insulin-like androgenic gland factor (IAG) from the blue crab, *Callinectes sapidus*: Implications for eyestalk regulation of IAG expression. *General and Comparative Endocrinology*. 173, 4-10.
- Corgos, A., Verísimo, P., Freire, J., 2006. Timing and seasonality of the terminal molt and mating migration in the spider crab, *Maja brachydactyla*: evidence of alternative mating strategies. *Journal of Shellfish Research*. 25, 577-587.
- Costlow Jr, J.D., Bookhout, C.G., 1960. A method for developing brachyuran eggs in vitro. *Limnology and Oceanography*. 5, 212-215.
- Cronin, L.E., 1947. Anatomy and histology of the male reproductive system of *Callinectes sapidus*. *Journal of Morphology*. 81, 209-240.
- Cuartas, E.I., Petriella, A.M., 2010. Structure of the male reproductive tract of *Uca uruguayensis* (Decapoda, Ocypodidae). *Iheringia. Serie Zoologia*. 100, 59-66.
- Darnell, M.Z., Rittschof, D., Darnell, K.M., McDowell, R.E., 2009. Lifetime reproductive potential of female blue crabs *Callinectes sapidus* in North Carolina, USA. *Marine Ecology Progress Series*. 394, 153-163.
- De Kergariou, G., 1971. L'araignee de mer, *Maia squinado* L., sur le littoral de Bretagne. *Bulletin de l'Institut des Pêches Maritimes*. 205, 11-19.
- De Kergariou, G., 1975. Contribution - l'étude de la reproduction de l' araignée de mer, (*Maja squinado* H.). *Conseil International pour l'Exploration de la Mer. Comité des crustacés, coquillages et benthos*, pp. 8 pp.
- De Kergariou, G., 1984. L'araignée de mer, *Maia squinado* H., Biologie et exploitation. *La Pêche Maritime*. 1279, 575-583.
- Diesel, R., 1991. Sperm competition and the evolution of mating behaviour in Brachyura, with special reference to spider crabs (Decapoda, Majidae). En: Bauer, R.T., Martin, J.W. (Eds.), *Crustacean Sexual Biology*. Columbia University Press, New York, pp. 145-163.
- Djunaidah, I.S., Wille, M., Kontara, E.K., Sorgeloos, P., 2003. Reproductive performance and offspring quality in mud crab (*Scylla paramamosain*) broodstock fed different diets. *Aquaculture International*. 11, 3-15.
- Domingues, P., Alaminos, J., 2008. Efectos de la densidad de cultivo y de elementos de refugio en el crecimiento y supervivencia de juveniles de centollo, *Maja brachydactyla* (Balss, 1922). *Revista de Biología Marina y Oceanografía*. 43, 121-127.
- Domingues, P., Alaminos, J., García-Garrido, S., Hachero-Cruzado, I., Rosas, C., 2012. Growth and survival of juvenile spider crabs, *Maja brachydactyla* (Balss, 1922), fed with fresh or frozen mussels. *Aquaculture Research*. 43, 167-177.

- Du, N., Xue, L., Lai, W., 1988. Studies on the sperm of Chinese mitten-handed crab, *Eriocheir sinensis* (Crustacea, Decapoda). 2. Spermatogenesis. *Oceanologia et Limnologia Sinica*. 19, 71-75.
- Dubois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A., Smith, F., 1956. Colorimetric method for determination of sugars and related substances. *Analytical Chemistry*. 28, 350-356.
- Edwards, E., 1979. Preliminary results of an investigation on a new fishery for spider crabs (*Maia squinado*) along the south coast of England. ICES, Shellfish Committee. C.M. 1979/K, 9.
- El-Sherief, S.S., 1991. Fine structure of the sperm and spermatophores of *Portunus pelagicus* (L.) (Decapoda, Brachyura). *Crustaceana*. 61, 271-279.
- Erkan, M., Tunali, Y., Balkis, H., Oliveria, E., 2009. Morphology of testis and vas deferens in the xanthoid crab, *Eriphia verrucosa* (Forskål, 1775)(Decapoda: Brachyura). *Journal of Crustacean Biology*. 29, 458-465.
- Estampador, E.P., 1949. *Scylla* (Crustacea: Portunidae) II. Comparative studies on spermatogenesis and oogenesis. *The Philippine Journal of Science*. 78, 95-109.
- Fahy, E., 2001. The Maharees spider crab *Maja squinado* fishery in 2000. *Irish Fisheries Investigations (New Series)*. 9, 1-14.
- Fahy, E., Carroll, J., 2009. Vulnerability of male spider crab *Maja brachydactyla* (Brachyura: Majidae) to a pot fishery in south-west Ireland. *Journal of the Marine Biological Association of the United Kingdom*. 89, 1353-1366.
- FAO, 2006. Cultured Aquatic Species Information Programme. *Eriocheir sinensis*. Programa d'informació d'espècies acuàtiques. Text de Weimin, M. En: Departament de Pesca i Aqüicultura de la FAO [en línia]. Roma. Actualitzat el 7 d'Abril de 2006. [Citat el dia 26 de juny de 2012]. [http://www.fao.org/fishery/culturedspecies/Eriocheir\\_sinensis/es](http://www.fao.org/fishery/culturedspecies/Eriocheir_sinensis/es).
- FAO, 2010a. El estado mundial de la pesca y la acuicultura, FAO. FAO, Rome, pp. 219.
- FAO, 2010b. Cultured Aquatic Species Information Programme. *Scylla serrata*. Programa d'informació d'espècies aquàtiques. Text per Quinitio, E.T. - SEAFDEC. En: Departament de Pesca i Aqüicultura de la FAO [en línia]. Roma. Actualitzat en 2010. [Citat el 26 de juny de 2012]. [http://www.fao.org/fishery/culturedspecies/Scylla\\_serrata/en](http://www.fao.org/fishery/culturedspecies/Scylla_serrata/en).
- Fasten, N., 1915. The male reproductive organs of some common crabs of Puget Sound. *Puget Sound Marine Station Publications*. 1, 35-41.
- Fasten, N., 1917. Male reproductive organs of decapoda, with special reference to Puget Sound forms. *Puget Sound Marine Station Publications*. 1, 285-307.

- Fasten, N., 1918. Spermatogenesis of the pacific coast edible crab, *Cancer magister* Dana. The Biological Bulletin. 34, 277-307.
- Fasten, N., 1924. Comparative stages in the spermatogenesis of various *Cancer* crabs. Journal of Morphology. 39, 47-61.
- Felgenhauer, B.E., Abele, L.G., 1991. Morphological diversity of decapoda spermatozoa. En: Bauer, R.T., Martin, J.W. (Eds.), Crustacean Sexual Biology. Columbia University Press, New York, pp. 322-339.
- Figueiredo, J., Narciso, L., 2008. Egg volume, energy content and fatty acid profile of *Maja brachydactyla* (Crustacea: Brachyura: Majidae) during embryogenesis. Journal of the Marine Biological Association of the UK. 88, 1401-1405.
- Figueiredo, J., Penha-Lopes, G., Anto, J., Narciso, L., Lin, J., 2008. Fecundity, brood loss and egg development through embryogenesis of *Armases cinereum* (Decapoda: Grapsidae). Marine Biology. 154, 287-294.
- Folch, J., Lees, M., Sloane Stanley, G.H., 1957. A simple method for the isolation and purification of total lipides from animal tissues. Journal of Biological Chemistry. 226, 497-509.
- Fransen, C., Türkay, M., 2012. *Maja brachydactyla* Balss, 1922. World Register of Marine Species. <http://www.marinespecies.org/aphia.php?p=taxdetails&id=107347> el 2012-02-28.
- Freire, J., 2001. Análisis de la pesquerías en Galicia, pp. 1-22.
- Freire, J., Carabel, S., Verísimo, P., Bernárdez, C., Fernández, L., 2009. Patterns of juvenile habitat use by the spider crab *Maja brachydactyla* as revealed by stable isotope analyses. Scientia Marina. 73, 39-49.
- Freire, J., Bernárdez, C., Corgos, A., Fernández, L., González- Gurriarán, E., Sampedro, M.P., Verísimo, P., 2002. Management strategies for sustainable invertebrate fisheries in coastal ecosystems of Galicia (NW Spain). Aquatic Ecology. 36, 41-50.
- García-Flórez, L., Fernández-Rueda, P., 2000. Reproductive biology of spider crab females (*Maja brachydactyla*) off the coast of Asturias (north-west Spain). Journal of the Marine Biological Association of the United Kingdom. 80, 1071-1076.
- García-Flórez, L., Fernández-Rueda, P., 2003. Parámetros biológicos del centollo, *Maja brachydactyla* (BRACHYURA: MAJIDAE), procedente de capturas comerciales en la zona central de Asturias (España) y su aplicación a la gestión pesquera. Naturalia Cantabrigae. 2, 45-52.
- García, T.M., Silva, J.R.F., 2006. Testis and vas deferens morphology of the red-clawed mangrove tree crab (*Goniopsis cruentata*) (Latreille, 1803). Brazilian Archives of Biology and Technology. 49, 339-345.



- George, M.J., 1963. The anatomy of the crab *Neptunus sanguinolentus* Herbst. Part IV: reproductive system and embryological studies. Journal of Madras University. B33, 289-304.
- González- Gurriarán, E., Freire, J., 1994. Movement patterns and habitat utilization in the spider crab *Maja squinado* (Herbst) (Decapoda, Majidae) measured by ultrasonic telemetry. Journal of Experimental Marine Biology and Ecology. 184, 269-291.
- González- Gurriarán, E., Freire, J., Bernárdez, C., 2002. Migratory patterns of female spider crabs *Maja squinado* detected using electronic tags and telemetry. Journal of Crustacean Biology. 22, 91-97.
- González-Gurriarán, E., Fernández, L., Freire, J., Muiño, R., 1998. Mating and role of seminal receptacles in the reproductive biology of the spider crab *Maja squinado* (Decapoda: Majidae). Journal of Experimental Marine Biology and Ecology. 220, 269-285.
- González-Gurriarán, E., Fernández, L., Freire, J., Muiño, R., Parapar, J., 1993. Reproduction of the spider crab *Maja squinado* (Brachyura: Majidae) in the Southern Galician coast (NW Spain). ICES, Shellfish Committee. K:19, 15.
- González-Gurriarán, E., Freire, J., Parapar, J., Sampedro, M.P., Urcera, M., 1995. Growth at moult and moulting seasonality of the spider crab, *Maja squinado* (Herbst) (Decapoda: Majidae) in experimental conditions: implications for juvenile life history. Journal of Experimental Marine Biology and Ecology. 189, 183-203.
- Goy, J.W., Morgan, S.G., Costlow Jr, J.D., 1985. Studies on the reproductive biology of the mud crab, *Rhithropanopeus harrisi* (Gould): induction of spawning during the non-breeding season (Decapoda, Brachyura). Crustaceana, 83-87.
- Guerao, G., Rotllant, G., 2009a. Post-larval development and sexual dimorphism of the spider crab *Maja brachydactyla* (Brachyura: Majidae). Scientia Marina. 73, 797-808.
- Guerao, G., Rotllant, G., 2009b. Survival and growth of post-settlement juveniles of the spider crab *Maja brachydactyla* (Brachyura: Majoidea) reared under individual culture system. Aquaculture. 289, 181-184.
- Guerao, G., Rotllant, G., Anger, K., 2010. Characterization of larval moulting cycles in *Maja brachydactyla* (Brachyura, Majidae) reared in the laboratory. Aquaculture. 302, 106-111.
- Guerao, G., Andree, K.B., Rotllant, G., 2011a. Direct evidence of parasitism by *Copidognathus stevcici* (Acari, Halacaridae) in crabs *Maja squinado* and *M. brachydactyla* (Brachyura, Majidae) in the laboratory. Aquaculture. 316, 136-138.

- Guerao, G., Andree, K.B., Frogliá, C., Simeó, C.G., Rotllant, G., 2011b. Identification of European species of *Maja* (Decapoda: Brachyura: Majidae): RFLP analyses of COI mtDNA and morphological considerations. *Scientia Marina*. 75, 129-134.
- Guerao, G., Pastor, E., Martín, J., Andrés, M., Estevez, A., Grau, A., Duran, J., Rotllant, G., 2008. The larval development of *Maja squinado* and *M. brachydactyla* (Decapoda, Brachyura, Majidae) described from plankton collected and laboratory-reared material. *Journal of Natural History*. 42, 2257-2276.
- Gupta, R.S., Chatterjee, N.B., 1976. Anatomical observations of the internal male reproductive organs of *Scylla serrata* (Forskál). *Indian Journal of Physiology and allied Sciences*. 30, 34-42.
- Haddon, M., Wear, R.G., 1993. Seasonal incidence of egg-bearing in the New Zealand paddle crab *Ovalipes catharus* (Crustacea: Brachyura), and its production of multiple egg batches. *New Zealand Journal of Marine and Freshwater Research*. 27, 287-293.
- Hamasaki, K., 2002. Effects of temperature on the survival, spawning and egg incubation period of overwintering mud crab broodstock, *Scylla paramamosain* (Brachyura: Portunidae). *Suisan Zoshoku*. 50, 301-308.
- Hamasaki, K., Imai, H., Akiyama, N., Fukunaga, K., 2004. Ovarian development and induced oviposition of the overwintering swimming crab *Portunus trituberculatus* (Brachyura: Portunidae) reared in the laboratory. *Fisheries Science*. 70, 988-995.
- Hartnoll, R.G., 1965. The biology of spider crabs: A comparison of British and Jamaican species. *Crustaceana*. 9, 1-16.
- Hasegawa, Y., Haino-Fukushima, K., Katakura, Y., 1987. Isolation and properties of androgenic gland hormone from the terrestrial isopod, *Armadillidium vulgare*. *General and Comparative Endocrinology*. 67, 101-110.
- Hines, A.H., 1982. Allometric constraints and variables of reproductive effort in brachyuran crabs. *Marine Biology*. 69, 309-320.
- Hines, A.H., 1991. Fecundity and reproductive output in nine species of *Cancer* crabs (Crustacea, Brachyura, Cancridae). *Canadian Journal of Fisheries and Aquatic Sciences*. 48, 267-275.
- Hinsch, G.W., 1968. Reproductive behavior in the spider crab, *Libinia emarginata* (L.). *The Biological Bulletin*. 135, 273-278.
- Hinsch, G.W., Walker, M.H., 1974. The vas deferens of the spider crab, *Libinia emarginata*. *Journal of Morphology*. 143, 1-20.
- Hoestlandt, H., 1948. Recherches sur la biologie de l'*Eriocheir sinensis* en France. *Annales de l'Institut Océanographique*. 24, 1-116.

- Huang, W.S., Wang, K.J., Yang, M., Cai, J.J., Li, S.J., Wang, G.Z., 2006. Purification and part characterization of a novel antibacterial protein Scygonadin, isolated from the seminal plasma of mud crab, *Scylla serrata* (Forskäl, 1775). *Journal of Experimental Marine Biology and Ecology*. 339, 37-42.
- Iglesias, J., Sánchez, F.J., Moxica, C., Fuentes, L., Otero, J.J., Pérez, J.L., 2002. Datos preliminares sobre el cultivo de larvas y juveniles de centolla *Maja squinado* Herbst, 1788 en el Centro Oceanográfico de Vigo del Instituto Español de Oceanografía. *Boletín del Instituto Español de Oceanografía*. 18, 25- 30.
- Jamieson, B.G.M., Tudge, C.C., 2000. Progress in male gamete ultrastructure and phylogeny. En: Adiyodi, K.G., Adiyodi, R.G. (Eds.), *Reproductive Biology of Invertebrates*. John Wiley and Sons, Kerala, pp. 1-95.
- Jayasankar, V., Subramoniam, T., 1999. Antibacterial activity of seminal plasma of the mud crab *Scylla serrata* (Forskäl). *Journal of Experimental Marine Biology and Ecology*. 236, 253-259.
- Jeyalectumie, C., Subramoniam, T., 1987. Biochemical composition of seminal secretions with special reference to LDH activity in the reproductive tissues of the field crab, *Paratelphusa hydrodromous* (Herbst). *Experimental biology*. 46, 231-236.
- Jeyalectumie, C., Subramoniam, T., 1989. Cryopreservation of spermatophores and seminal plasma of the edible crab *Scylla serrata*. *The Biological Bulletin*. 177, 247-253.
- Jivoff, P., 1997. The relative roles of predation and sperm competition on the duration of the post-copulatory association between the sexes in the blue crab, *Callinectes sapidus*. *Behavioral Ecology and Sociobiology*. 40, 175-185.
- Kang, X., Li, G., Mu, S., Guo, M., Ge, S., 2009. Acrosome reaction of Chinese mitten-handed crab *Eriocheir sinensis* (Crustacea: Decapoda) spermatozoa: promoted by long-term cryopreservation. *Aquaculture*. 295, 195-199.
- Kendall, M.S., Wolcott, D.L., Wolcott, T.G., Hines, A.H., 2001. Reproductive potential of individual male blue crabs, *Callinectes sapidus*, in a fished population: depletion and recovery of sperm number and seminal fluid. *Canadian Journal of Fisheries and Aquatic Sciences*. 58, 1168-1177.
- Kim, D.H., Kim, S.K., Choi, J.H., Kim, B.R., Seo, H.C., Jang, I.K., 2010. The effects of manipulating water temperature, photoperiod, and eyestalk ablation on gonad maturation of the swimming crab, *Portunus trituberculatus*. *Crustaceana*. 83, 129-141.

- Kon, T., Honma, Y., 1970. Studies on the maturity of the gonad in some marine invertebrates- IV: seasonal changes in the testes of the Tanner crab. Bulletin of the Japanese Society of Scientific Fisheries. 36, 1028-1031.
- Krol, R.M., Hawkins, W.E., Overstreet, R.M., 1992. Reproductive components. En: Harrison, F.W., Humes, A.G. (Eds.), Microscopic Anatomy of Invertebrates. Wiley-Liss, Inc., New York, pp. 295-343.
- Kurtz, K., Ausió, J., Chiva, M., 2009. Preliminary study of sperm chromatin characteristics of the brachyuran crab *Maja brachydactyla*. Histones and nucleosome-like structures in decapod crustacean sperm nuclei previously described without SNBPs. Tissue & Cell. 41, 334-344.
- Lang, R., 1973. Die Ontogenese von *Maja squinado* (Crustacea malacostraca, Decapoda, Brachyura), unter besonderer Berücksichtigung der embryonalen Ernährung und der Entwicklung des Darmtraktes. Zoologische Jahrbücher Anatomie Bd. 90, 389-449.
- Langreth, S.G., 1969. Spermiogenesis in *Cancer* crabs. Journal of Cell Biology. 43, 575-603.
- Le Foll, D., 1993. Biologie et exploitation de l'araignée de mer *Maja squinado* Herbst en Manche Ouest. Université de Bretagne Occidentale. IFREMER, pp. 524.
- Lee, T.-H., Yamazaki, F., 1989. Cytological observations on fertilization in the Chinese fresh-water crab, *Eriocheir sinensis*, by artificial insemination (in vitro) and incubation. Aquaculture. 76, 347-360.
- Lee, T.H., 2009. Relationship between hatching rate and the outer egg membranes of the in vitro artificially fertilized eggs of the Japanese mitten crab *Eriocheir japonica*. Aquaculture. 298, 168-171.
- Lee, T.H., 2011. A method for reducing the thickness of the outer egg membrane of the Japanese mitten crab *Eriocheir japonica* to improve the normal zoeal larvae hatching rate of in vitro artificial fertilized eggs. Aquaculture. 318, 176-179.
- Li, S., Li, F., Sun, Z., Xiang, J., 2012. Two spliced variants of insulin-like androgenic gland hormone gene in the Chinese shrimp, *Fenneropenaeus chinensis*. General and Comparative Endocrinology. <http://dx.doi.org/10.1016/j.ygcen.2012.04.010>.
- Li, T.W., 1995. On spermatogenesis and sperm ultrastructure of blue crab *Portunus trituberculatus* (Crustacea, Decapoda). Acta Zoologica Sinica. 41, 41-47.
- MacDiarmid, A.B., Butler IV, M.J., 1999. Sperm economy and limitation in spiny lobsters. Behavioral Ecology and Sociobiology. 46, 14-24.
- Magallón-Gayón, E., Briones-Fourzán, P., Lozano-Álvarez, E., 2011. Does size always matter? Mate choice and sperm allocation in *Panulirus*

- guttatus*, a highly sedentary, habitat-specialist spiny lobster. Behaviour. 148, 1329-1354.
- Manor, R., Weil, S., Oren, S., Glazer, L., Aflalo, E.D., Ventura, T., Chalifa-Caspi, V., Lapidot, M., Sagi, A., 2007. Insulin and gender: an insulin-like gene expressed exclusively in the androgenic gland of the male crayfish. General and Comparative Endocrinology. 150, 326-336.
- Mareddy, V.R., Rosen, O., Thaggard, H.B., Manor, R., Kuballa, A.V., Aflalo, E.D., Sagi, A., Paterson, B., Elizur, A., 2011. Isolation and characterization of the complete cDNA sequence encoding a putative insulin-like peptide from the androgenic gland of *Penaeus monodon*. Aquaculture. 318, 364-370.
- Marques, A., Teixeira, B., Barrento, S., Anacleto, P., Carvalho, M.L., Nunes, M.L., 2010. Chemical composition of Atlantic spider crab *Maja brachydactyla*: Human health implications. Journal of Food Composition and Analysis. 23, 230-237.
- Martin, G., Sorokine, O., Moniatte, M., Bulet, P., Hetru, C., Van Dorselaer, A., 1999. The structure of a glycosylated protein hormone responsible for sex determination in the isopod, *Armadillidium vulgare*. European journal of biochemistry / FEBS. 262, 727-736.
- Martin, J., 1983. Période d'éclosion des larves d'araignée de mer *Maja squinado* Herbst en Manche et température de l'eau au printemps. CIEM Conseil International pour l'Exploration de la Mer, Comité des mollusques et crustacés., pp. 10.
- Matsuda, H., Takenouchi, T., Yamakawa, T., 2002. Effects of photoperiod and temperature on ovarian development and spawning of the Japanese spiny lobster *Panulirus japonicus*. Aquaculture. 205, 385-398.
- McConaughy, J.R., McNally, K., Goy, J.W., Costlow, J.D., 1980. Winter induced mating in the stone crab, *Menippe mercenaria*. Proceedings of the World Mariculture Society. 11, 544-547.
- Medina, A., Rodríguez, A., 1992. Spermiogenesis and sperm structure in the crab *Uca tangeri* (Crustacea, Brachyura), with special reference to the acrosome differentiation. Zoomorphology. 111, 161-165.
- Meusy, J.-J., 1972. La gamétogenèse et la fraction protéique de l'hémolymphe spécifique du sexe femelle chez quelques Crustacés supérieurs: étude descriptive et rôle des glandes androgènes. Université Paris VI, Paris, pp. 165.
- Minagawa, M., Chiu, J.-R., Kudo, M., Takashima, F., 1994. Male reproductive biology of the red frog crab, *Ranina ranina*, off Hachijojima, Izu Islands, Japan. Marine Biology. 118, 393-401.

- Morgan, S.G., Goy, J.W., Costlow Jr, J.D., 1983. Multiple ovipositions from single matings in the mud crab *Rhithropanopeus harrisi*. *Journal of Crustacean Biology*. 3, 542-547.
- Moriyasu, M., Benhalima, K., 1998. Snow crabs, *Chionoecetes opilio* (O. Fabricius, 1788) (Crustacea: Majidae) have two types of spermatophore: hypotheses on the mechanism of fertilization and population reproductive dynamics in the southern Gulf of St. Lawrence, Canada. *Journal of Natural History*. 32, 1651-1665.
- Moriyasu, M., Benhalima, K., Duggan, D., Lawton, P., Robichaud, D., 2002. Reproductive biology of the male Jonah crab, *Cancer borealis* Stimpson, 1859 (Decapoda, Cancridae) on the Scotian shelf, Northwestern Atlantic. *Crustaceana*. 75, 891-913.
- Mouchet, S., 1931. Spermatophores des Crustacés Décapodes Anomures et Brachyours et castration parasitaire chez quelques Pagures. *Annales Station Océanographique de Salammbô*. VI, 1-203.
- Nagao, J., Munehara, H., 2003. Annual cycle of testicular maturation in the helmet crab *Telmessus cheiragonus*. *Fisheries Science*. 69, 1200-1208.
- Nagao, J., Munehara, H., 2007. Characteristics of broods fertilized with fresh or stored sperm in the helmet crab *Telmessus cheiragonus*. *Journal of Crustacean Biology*. 27, 565-569.
- Neumann, V., 1996. Comparative gonopod morphology of the European spider crabs of the genus *Maja* Lamarck 1801. *Senckenbergiana biologica*. 75, 143-157.
- Neumann, V., 1998. A review of the *Maja squinado* (Crustacea: Decapoda: Brachyura) species-complex with a key to the eastern Atlantic and Mediterranean species of genus. *Journal of Natural History*. 32, 1667-1684.
- Nicolau, C.F., Nascimento, A.A., Machado-Santos, C., Sales, A., Oshiro, L.M.Y., 2012. Gonads of males and females of the mangrove tree crab *Aratus pisonii* (Grapsidae: Brachyura: Decapoda): a histological and histochemical view. *Acta Zoologica*. DOI: 10.1111/j.1463-6395.2011.00516.x.
- Palma, J., Correia, M., Andrade, J.P., 2008. Usefulness of flat bottom tanks on the settlement of spider crab (*Maja squinado*, Herbst) larvae. *Aquaculture Research*. 39, 1005-1008.
- Paterson, B.D., 2009. Advances in the culture of crabs. En: Burnell, G., Allan, G. (Eds.), *New technologies in aquaculture: improving production efficiency, quality and environmental management*. Woodhead Publishing, pp. 845-865.
- Paul, A.J., 1984. Mating frequency and viability of stored sperm in the tanner crab *Chionoecetes bairdi* (Decapoda, Majidae). *Journal of Crustacean Biology*. 4, 375-381.

- Penha-Lopes, G., Rhyne, A.L., Figueiredo, J., Lin, J., Narciso, L., 2006. Can larvae produced from stored sperm in the ornamental crab *Mithraculus forceps* (A. Milne Edwards, 1875)(Decapoda: Brachyura: Majidae) be used in aquaculture? *Aquaculture*. 257, 282-286.
- Phoungpetchara, I., Hanna, P.J., Sobhon, P., 2008. Identification of an insulin-like factor from *Cherax destructor* androgenic gland mRNA. <http://www.ncbi.nlm.nih.gov/nuccore/EU718788.1>.
- Pochon-Masson, J., 1962. Le chondriofusome des gamètes males du Crustacé Décapode *Carcinus maenas*. *Comptes Rendus de l'Académie des Sciences Paris*. 254, 4076-4078.
- Quinitio, E., de la Cruz, J., Eguia, M., Parado-Esteva, F., Pates, G., Lavilla-Pitogo, C., 2011. Domestication of the mud crab *Scylla serrata*. *Aquaculture International*. 19, 237-250.
- Racotta, I.S., Palacios, E., Ibarra, A.M., 2003. Shrimp larval quality in relation to broodstock condition. *Aquaculture*. 227, 107-130.
- Reger, J.F., 1970. Studies on the fine structure of spermatids and spermatozoa of the crab, *Pinnixia* sp. *Journal of Morphology*. 132, 89-100.
- Rodhouse, D.M., 1984. Experimental fishing for the spider crab, *Maia squinado*: sea and laboratory trials. *Journal of the Marine Biological Association of the UK*. 64, 251-259.
- Rondeau, A., Sainte-Marie, B., 2001. Variable mate-guarding time and sperm allocation by male snow crabs (*Chionoecetes opilio*) in response to sexual competition, and their impact on the mating success of females. *The Biological Bulletin*. 201, 204-217.
- Rosen, O., Manor, R., Weil, S., Gafni, O., Linial, A., Aflalo, E.D., Ventura, T., Sagi, A., 2010. A sexual shift induced by silencing of a single insulin-like gene in crayfish: ovarian upregulation and testicular degeneration. *PLoS one*. 5, e15281.
- Rotllant, G., González-Gurriarán, E., Fernández, L., Benhalima, K., Ribes, E., 2007. Ovarian maturation of the multi-spawning spider crab *Maja brachydactyla* (Decapoda: Majidae) with special reference to yolk formation. *Marine Biology*. 152, 383-394.
- Rotllant, G., Moyano, F., Andrés, M., Estévez, A., Díaz, M., Gisbert, E., 2010. Effect of delayed first feeding on larval performance of the spider crab *Maja brachydactyla* assessed by digestive enzyme activities and biometric parameters. *Marine Biology*. 157, 2215-2227.
- Rubolini, D., Galeotti, P., Pupin, F., Sacchi, R., Nardi, P.A., Fasola, M., 2007. Repeated matings and sperm depletion in the freshwater crayfish *Austropotamobius italicus*. *Freshwater Biology*. 52, 1898-1906.

- Ryan, E.P., 1967. Structure and function of the reproductive system of the crab *Portunus sanguinolentus* (Hersbt) (Brachyura: Portunidae) I. The male system. Proceedings of the Symposium on Crustacea. Marine Biological Association of India. 2, 506-521.
- Sachlikidis, N.G., Jones, C.M., Seymour, J.E., 2005. Reproductive cues in *Panulirus ornatus*. New Zealand Journal of Marine and Freshwater Research. 39, 305-310.
- Sagi, A., Aflalo, E.D., 2005. The androgenic gland and monosex culture of freshwater prawn *Macrobrachium rosenbergii* (De Man): a biotechnological perspective. Aquaculture Research. 36, 231-237.
- Sainte-Marie, B., 1993. Reproductive cycle and fecundity of primiparous and multiparous female snow crab, *Chionoecetes opilio*, in the northwest Gulf of Saint Lawrence. Canadian Journal of Fisheries and Aquatic Sciences. 50, 2147-2156.
- Sainte-Marie, G., Sainte-Marie, B., Sévigny, J.-M., 2000. Ejaculate-store patterns and the site of fertilization in female snow crabs (*Chionoectes opilio*; Brachyura, Majidae). Canadian Journal of Zoology. 78, 1902-1917.
- Sal Moyano, M.P., Gavio, M.A., Cuartas, E.I., 2010. Morphology and function of the reproductive tract of the spider crab *Libinia spinosa* (Crustacea, Brachyura, Majoidea): pattern of sperm storage. Helgoland Marine Research. 64, 213-221.
- Sampedro, M.P., González-Gurriarán, E., Freire, J., Muiño, R., 1999. Morphometry and sexual maturity in the spider crab *Maja squinado* (Decapoda: Majidae) in Galicia, Spain. Journal of Crustacean Biology. 19, 578- 592.
- Santos, C.M., Lima, G.V., Nascimento, A.A., Sales, A., Oshiro, L.M.Y., 2009. Histological and histochemical analysis of the gonadal development of males and females of *Armases rubripes* (Rathbun 1897)(Crustacea, Brachyura, Sesarmidae). Brazilian Journal of Biology. 69, 161-169.
- Sapelkin, A.A., Fedoseev, V.Y., 1981. Structure of male reproductive system of Tanner crabs. Soviet Journal of Marine Biology. 7, 37-43.
- Sarker, M.M., Islam, M.S., Uehara, T., 2009. Artificial insemination and early embryonic development of the mangrove crab *Perisesarma bidens* (De Haan)(Crustacea: Brachyura). Zoological Studies. 48, 607-618.
- Sastry, A.N., 1987. Ecological aspects of reproduction. En: Vernberg, F.J., Vernberg, W.B. (Eds.), The Biology of Crustacea. Environmental Adaptations. Academic Press, New York, pp. 179-269.
- Sato, T., Goshima, S., 2007a. Sperm allocation in response to a temporal gradient in female reproductive quality in the stone crab, *Hapalogaster dentata*. Animal Behaviour. 74, 903-910.



- Sato, T., Goshima, S., 2007b. Female choice in response to risk of sperm limitation by the stone crab, *Hapalogaster dentata*. *Animal Behaviour*. 73, 331-338.
- Sato, T., Yoseda, K., 2010. Influence of size- and sex-biased harvesting on reproduction of the coconut crab *Birgus latro*. *Marine Ecology Progress Series*. 402, 171-178.
- Sato, T., Ashidate, M., Wada, S., Goshima, S., 2005. Effects of male mating frequency and male size on ejaculate size and reproductive success of female spiny king crab *Paralithodes brevipes*. *Marine Ecology Progress Series*. 296, 251-262.
- Sato, T., Ashidate, M., Jinbo, T., Goshima, S., 2006. Variation of sperm allocation with male size and recovery rate of sperm numbers in spiny king crab *Paralithodes brevipes*. *Marine Ecology Progress Series*. 312, 189-199.
- Scalici, M., Scuderi, S., Gibertini, G., 2010. Gonad structure in the river crab, *Potamon fluviatile* (Herbst, 1785)(Decapoda, Brachyura). *Crustaceana*. 83, 61-72.
- Schöne, H., 1968. Agonistic and sexual display in aquatic and semi-terrestrial Brachyuran crabs. *American Zoologist*. 8, 641-654.
- Sherkane, U.D., Patil, M.U., Pande, G.S., 2010. Gross anatomy of male reproductive system and histology of testis and vas deferens in freshwater crab *Barytelphusa cunicularis* (Wetwood 1836) (Decapoda: Crustacea). *The Bioscan*. 5, 599-603.
- Shinozaki-Mendes, R.A., Silva, J.R.F., Hazin, F.H.V., 2012. Development of male reproductive system of the blue land crab *Cardisoma guanhumi* Latreille, 1828 (Decapoda: Gecarcinidae). *Acta Zoologica*. DOI: 10.1111/j.1463-6395.2011.00513.x.
- Simeó, C.G., Ribes, E., Rotllant, G., 2009. Internal anatomy and ultrastructure of the male reproductive system of the spider crab *Maja brachydactyla* (Decapoda: Brachyura). *Tissue & Cell*. 41, 345-361.
- Simeó, C.G., Kurtz, K., Chiva, M., Ribes, E., Rotllant, G., 2010a. Spermatogenesis of the spider crab, *Maja brachydactyla* (Decapoda: Brachyura). *Journal of Morphology*. 271, 394-406.
- Simeó, C.G., Kurtz, K., Rotllant, G., Chiva, M., Ribes, E., 2010b. Sperm ultrastructure of the spider crab *Maja brachydactyla* (Decapoda: Brachyura). *Journal of Morphology*. 271, 407-417.
- Smith, E.G., Ritar, A.J., Carter, C.G., Dunstan, G.A., Brown, M.R., 2003. Morphological and biochemical characteristics of phyllosoma after photothermal manipulation of reproduction in broodstock of the spiny lobster, *Jasus edwardsii*. *Aquaculture*. 220, 299-311.

- Sotelo, G., Morán, P., Posada, D., 2008. Genetic identification of the north-eastern Atlantic spiny spider crab as *Maja brachydactyla* Balss, 1922. *Journal of Crustacean Biology*. 28, 76-81.
- Sroyraya, M., Chotwiwatthanakun, C., Stewart, M.J., Soonklang, N., Kornthong, N., Phoungpetchara, I., Hanna, P.J., Sobhon, P., 2010. Bilateral eyestalk ablation of the blue swimmer crab, *Portunus pelagicus*, produces hypertrophy of the androgenic gland and an increase of cells producing insulin-like androgenic gland hormone. *Tissue & Cell*. 42, 293-300.
- Stevcic, Z., 1971. Laboratory observations on the aggregations of the spiny spider crab (*Maja squinado* herbst). *Animal Behaviour*. 19, 18-25.
- Stewart, M.J., Stewart, P., Soonklang, N., Linthong, V., Hanna, P.J., Duan, W., Sobhon, P., 2010. Spermatogenesis in the blue swimming crab, *Portunus pelagicus*, and evidence for histones in mature sperm nuclei. *Tissue & Cell*. 42, 137-150.
- Subramoniam, T., 1991. Spermatophores and sperm transfer in marine crustaceans. *Advances in Marine Biology*. 29, 129-214.
- Subramonian, T., 1991. Chemical composition of spermatophores in decapod crustaceans. En: Bauer, R.T., Martin, J.W. (Eds.), *Crustacean Sexual Biology*. Columbia University Press, New York, pp. 308-319.
- Sudha Devi, A.R., Adiyodi, R.G., 1995. The coral-shaped accessory gland of the ghost crab, *Ocypode ceratophthalmus*. *Journal of Animal Morphology and Physiology*. 42, 69-73.
- Suganthi, A.S., Anilkumar, G., 1999. Molt related fluctuation in ecdysteroid titre and spermatogenesis in the crab, *Metopograpsus messor* (Brachyura: Decapoda). *Zoological Studies*. 38, 314-321.
- Sulkin, S.D., Branscomb, E.S., Miller, R.E., 1976. Induced winter spawning and culture of larvae of the blue crab, *Callinectes sapidus* Rathbun. *Aquaculture*. 8, 103-113.
- Sun, X., He, Y., Hou, L., Yang, W.X., 2010. Myosin Va participates in acrosomal formation and nuclear morphogenesis during spermatogenesis of Chinese mitten crab *Eriocheir sinensis*. *PLoS one*. 5, e12738.
- Tsang, L.M., Ma, K.Y., Ah Yong, S.T., Chan, T.Y., Chu, K.H., 2008. Phylogeny of Decapoda using two nuclear protein-coding genes: Origin and evolution of the Reptantia. *Molecular Phylogenetics and Evolution*. 48, 359-368.
- Tudge, C., 2009. Spermatozoal morphology and its bearing on decapod phylogeny. En: Martin, J.W., Crandall, K.A., Felder, D.L. (Eds.), *Crustacean Issues 18: Decapod Crustacean Phylogenetics*. CRC Press, Taylor & Francis Group, Boca Raton, Florida, pp. 101-119.

- Tudge, C.C., Justine, J.L., 1994. The cytoskeletal proteins actin and tubulin in the spermatozoa of 4 decapod crabs (Crustacea, Decapoda). *Acta Zoologica*. 75, 277-285.
- Urcera, M., Arnaiz, R., Rua, N., Coó, A., 1993. Cultivo de la centolla *Maja squinado*: Influencia de la dieta en el desarrollo larvario. *Actas IV Congreso Nacional Acuicultura*, 269-274.
- Ventura, T., Sagi, A., 2012. The insulin-like androgenic gland hormone in crustaceans: from a single gene silencing to a wide array of sexual manipulation-based biotechnologies. *Biotechnology Advances*. doi:10.1016/j.biotechadv.2012.04.008.
- Ventura, T., Rosen, O., Sagi, A., 2011. From the discovery of the crustacean androgenic gland to the insulin-like hormone in six decades. *General and Comparative Endocrinology*. 173, 381-388.
- Ventura, T., Manor, R., Aflalo, E.D., Weil, S., Rosen, O., Sagi, A., 2012. Timing sexual differentiation: full functional sex reversal achieved through silencing of a single insulin-like gene in the prawn, *Macrobrachium rosenbergii*. *Biology of Reproduction*. 86, 90, 91-96.
- Ventura, T., Manor, R., Aflalo, E.D., Weil, S., Raviv, S., Glazer, L., Sagi, A., 2009. Temporal silencing of an androgenic gland-specific insulin-like gene affecting phenotypical gender differences and spermatogenesis. *Endocrinology*. 150, 1278-1286.
- Verísimo, P., Bernárdez, C., González-Gurriarán, E., Freire, J., Muiño, R., Fernández, L., 2011. Changes between consecutive broods in the fecundity of the spider crab, *Maja brachydactyla*. *ICES Journal of Marine Science*. 68, 472-478.
- Wang, L., Du, N.-S., Lai, W., 1999. Studies on spermiogenesis of a freshwater crab *Sinopotamon yangtsekiense* (Crustacea Decapoda). *Acta Hydrobiologica Sinica*. 23, 29-33.
- Wang, Y.L., Zhang, Z.P., Li, S.J., 1997. Ultrastructure of spermatogenesis in the crab *Scylla serrata*. *Acta Zoologica Sinica*. 43, 249-254.
- Wear, R.G., 1974. Incubation in British decapod Crustacea, and the effects of temperature on the rate and success of embryonic development. *Journal of the Marine Biological Association of the United Kingdom*. 54, 745-762.
- Williams, P.D., Day, T., Cameron, E., 2005. The evolution of sperm-allocation strategies and the degree of sperm competition. *Evolution*. 59, 492-499.
- Wolcott, D.L., Hopkins, C.W.B., Wolcott, T.G., 2005. Early events in seminal fluid and sperm storage in the female blue crab *Callinectes sapidus* Rathbun: Effects of male mating history, male size, and season. *Journal of Experimental Marine Biology and Ecology*. 319, 43-55.

- Wu, X., Cheng, Y., Zeng, C., Wang, C., Cui, Z., 2010a. Reproductive performance and offspring quality of the first and the second brood of female swimming crab, *Portunus trituberculatus*. *Aquaculture*. 303, 94-100.
- Wu, X., Cheng, Y., Zeng, C., Wang, C., Yang, X., 2010b. Reproductive performance and offspring quality of wild-caught and pond-reared swimming crab *Portunus trituberculatus* broodstock. *Aquaculture*. 301, 78-84.
- Wu, X., Cheng, Y., Sui, L., Yang, X., Nan, T., Wang, J., 2007. Biochemical composition of pond-reared and lake-stocked Chinese mitten crab *Eriocheir sinensis* (H. Milne-Edwards) broodstock. *Aquaculture Research*. 38, 1459-1467.
- Yamaguchi, T., 1998. Longevity of sperm of the fiddler crab *Uca lactea* (De Haan, 1835)(Decapoda, Brachyura, Ocypodidae). *Crustaceana*. 71, 712-713.
- Yu, K., Hou, L., Zhu, J.-Q., Ying, X.-P., Yang, W.-X., 2009. KIFC1 participates in acrosomal biogenesis, with discussion of its importance for the perforatorium in the Chinese mitten crab *Eriocheir sinensis*. *Cell and Tissue Research*. 337, 113-123.
- Zara, F.J., Toyama, M.H., Caetano, F.H., López-Greco, L.S., 2012. Spermatogenesis, spermatophore, and seminal fluid production in the adult blue crab *Callinectes danae* (Portunidae). *Journal of Crustacean Biology*. 32, 249-262.
- Zeng, C., 2007. Induced out of season spawning of the mud crab, *Scylla paramamosain* (Estampador) and effects of temperature on embryo development. *Aquaculture Research*. 38, 1478-1485.
- Zmora, O., Findiesen, A., Stubblefield, J., Frenkel, V., Zohar, Y., 2005. Large-scale juvenile production of the blue crab *Callinectes sapidus*. *Aquaculture*. 244, 129-139.

