7. Background of Research

Most of marine crustacean decapods (e.g. crabs, shrimps and lobsters) release dispersive larvae that act as the primary connectivity agents among populations. Planktonic larval stages are critical time points in the life cycles of crustaceans since mortality is normally higher than in later benthic life, and because surviving larvae must also recruit to replenish adult populations. Therefore, it is not surprising that planktonic larvae have developed unique morphologies and a suite of swimming behaviors that provide a measure of control over their dispersal patterns, and foraging abilities. It is a key factor to understand population dynamics, and then, constitutes a useful tool for the management of commercial species, the design of marine protected areas, and the spread of invasive species.

Recent studies have highlighted that planktonic larvae are not passive drifters, since the vertical swimming controls their transport by exploiting variations in the strength and direction of advective currents with depth. In addition, swimming behaviors affect larval survival, because other environmental characteristics, such as temperature and abundances of predators and food, are also vertically structured. Hence, swimming behavior has important consequences for adult population dynamics, (e.g. maintenance crustacean stocks and fishing grounds) although, to date, insufficient quantitative information exists on larval swimming (especially at scales smaller than centimeters, cm) to understand and predict swimming movements in most marine crustacean species. It is well known that invertebrate larvae aggregate along thermoclines and haloclines or in food patches, and avoid water masses with predator cues. However, these studies do not provide a strong basis for predicting larval distribution in the field, because they do not quantify the underlying behaviors that lead to the observed aggregations. Therefore, additional quantitative descriptions of larval swimming behaviors and of how swimming movements change in response to the environmental variability will enable us to better parameterize such distribution patterns and how environmental alterations can affect larval performance and survival is of paramount importance.

8. Research methodology

Research methodologies are described in detail in the initial project proposal and in the scientific publications.

9. Results/impacts

The project was focused on the the brush-clawed shore crab *Hemigrapsus takanoi* Asakura and Watanabe, 2005, that was used as model species. *H. takanoi* is a common species of inner bays and estuaries of East Asia, occurring in oyster beds and under boulders and rocks in the intertidal/subtidal zones. The native geographical range in East Asia includes the coast of Far East Russia, the Korean Peninsula and Japan. Moreover, *H. takanoi* is an invader of European Atlantic coast. Since this crab was reported for the first time in 1994 in France, it has expanded its range rapidly in the Bay of Biscay from northern Spain to southern Brittany, and northward in English Channel and southern North Sea coast from the Cotentin peninsula to the Dutch Delta, the whole Wadden Sea, as well as the western Baltic Sea.

Larval studies are useful to understand the population dynamics, and the complex patterns of connectivity. In fact, it has been particularly useful for the detection of non-native species in planktonic monitoring programs conducted in the Mediterranean Sea. However, to date, these studies are not possible for *H. takanoi*, because its larval development is still completely unknow. We filled this gap, providing a full description and illustration of the larval morphology of *H. takanoi* from specimens obtained in the laboratory from its type locality, Tokyo Bay, Japan. We showed that its larval development follows the pattern of the family Varunidae, that involves five zoeae and one megalopa (Figure 1).

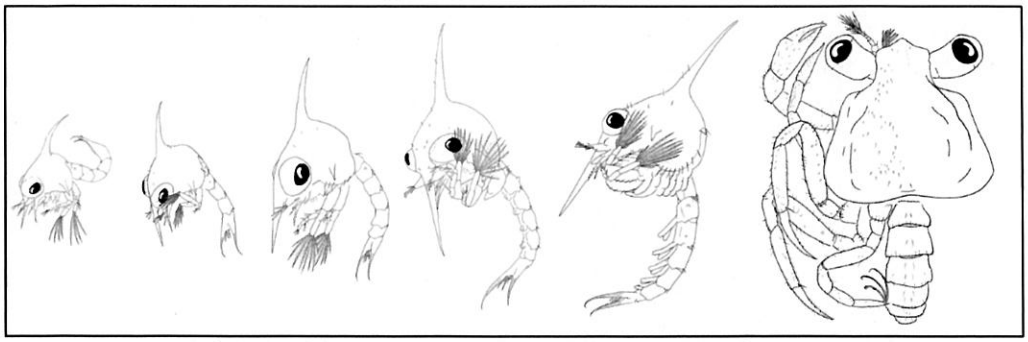

Figure 1. morphological description of the larval development of *Hemigrapsus takanoi.*

Moreover, we made a summary of the key characters for the identification of the larval stages for the family Varunidae in European Atlantic waters to facilitate their detection and track their expansion.

On the other hand, adult crabs tolerate wide range of salinities, inhabiting brackish and seawater intertidal areas, ability that has facilitated its invasive expansion outside the native distribution. *H. takanoi* produce planktonic larvae that are exported from the spawning habitat and are physically transported in the water column where they undergo the zoeal development. During this period, the larvae are exposed to a changing environment (e.g. salinity, temperature, food), but its effect on the swimming behavior is completely unknown. Using experiments in the laboratory with video recording and 2D particle tracking technique, we analyzed the speed and direction of swimming trajectories performed by the first zoeal stage of *H. takanoi* in presence and absence of phytoplankton as food (Tetraselmis spp.) under different salinity conditions (5, 10, 15, 20, 25,30, 35). We observed that larvae showed a complex swimming behavior performing displacement not faster than 10 mm s^{-1}. In general, larvae swam faster at higher salinities, and under food conditions. Differences in speed were also found in the swimming direction, being the upward trajectories faster than the downward ones. Under food conditions larvae showed more frequent vertical trajectories (~90°) related with an "up-down" feeding strategy, whereas under "no food" conditions the larvae swam at more diverse angles likely searching for external cues. This pattern was especially evident at high salinities and disappear at salinities lower than 20. Suboptimal conditions of salinity can impact in the swimming performance and feeding efficiency of decapod larvae in complex changing ecosystems like estuaries. These results provide novel information that can be used to understand better the dispersal capacity of this invasive crab.

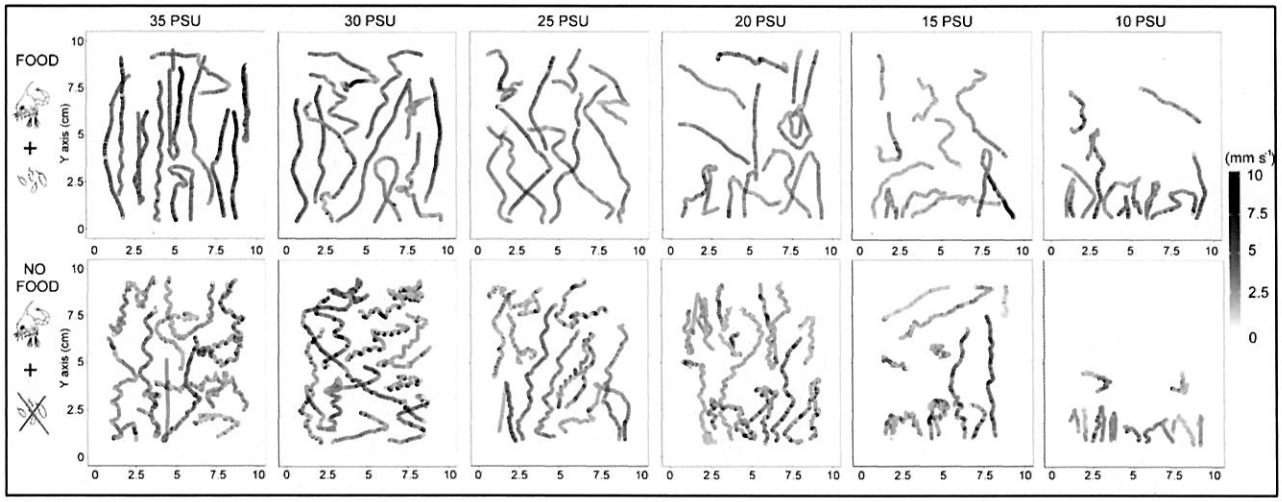

Figure 2. Swimming trajectories performed by the firs larval stage of *Hemigrapsus takanoi* under different levels of salinity and presence/absence of food.

Publications directly related with this research topic:

1. J.M. Landeira, J.A. Cuesta, Y. Tanaka. Larval development of the brush-clawed shore crab *Hemigrapsus takanoi* Asakura & Watanabe, 2005 (Decapoda, Brachyura, Varunidae). Journal of the Marine Biological Association of the UK (submitted).

2. J.M. Landeira, B. Liu, T. Omura, T. Akiba, Y. Tanaka. Salinity and food availability modify the swimming patterns of the early larval stages of *Hemigrapsus takanoi* (Decapoda: Brachyura: Varunidae). Journal of Experimental Marine Biology and Ecology (in preparation).

10. Research Presentations during the period of the fellowship (Name of the conference, title, place, date)

1. The Crustacean Society Mid-year meeting. First record of tanner crab, *Chionoecetes bairdi*, larvae in the Chukchi Sea: a future northward expansion in the Arctic?19-22 June 2017. Barcelona, Spain.

2. International symposium "Fisheries Science for the Future Generations". Potential northward expansion of tanner crab, *Chionoecetes bairdi*, in the Arctic: evidence from planktonic larvae. Tokyo, Japan. 22 September 2017.

3. Plankton Society of Japan. Crustacea Decapoda (larval stages). Hachioji, Japan. 9 Sepetember 2018

4. The Carcinological Society of Japan 56th Annual Meeting. Salinity and food availability modify the swimming patterns of the early larval stages of *Hemigrapsus takanoi* (Decapoda: Brachyura: Varunidae). Shizuoka, Japan. 20 October 2018.

11. A list of paper published during or after the period of the fellowship

Author(s)	Title	Name of Journal	Vol	Page	Date	Note
Landeira, J.M., Matsuno, K., Yamaguchi, A., et al.	Abundance, development stage and size of decapod larvae through the Bering and Chukchi Seas during summer	Polar Biology	81	299-315	2017	
Landeira, J.M., Brochier, T., Mason, E., et al.	Transport pathways of decapod larvae under intense mesoscale activity in the Canary-African coastal transition zone: implications for population connectivity.	Scientia Marina			2017	Digital
Landeira, J.M., González, J.A.	First record of *Pelagopenaeus balboae* and Sergia wolffi (Decapoda, Dendrobranchiata) from the Canary Islands, with an annotated checklist of the Dendrobranchiata in the area	Crustaceana	91	379-387	2018	
Landeira, J.M., Matsuno, K., Tanaka, Y., Yamaguchi, A.	First record of the larvae of tanner crab *Chionoecetes bairdi* in the Chukchi Sea: A future northward expansion in the Arctic?	Polar Science	16	86-89	2018	
Landeira, J.M., Tamura, H.	Morphology of the first zoea of *Chaceon affinis* (A. Milne-Edwards & Bouvier 1894) and occurrence of *Chaceon* spp. larvae (Decapoda: Brachyura: Gerynonidae) in the Canary Islands waters, Northeastern Atlantic.	Zootaxa	4413	579-585	2018	
Landeira, J.M., Lozano-Soldevilla, F.	Seasonality of planktonic crustacean decapod larvae in the subtropical waters of Gran Canaria island, NE Atlantic.	Scientia Marina	82	119-134	2018	
Liu, B. Akiba, T. **Landeira, J.M.,** Tanaka, Y.	Individual-level variability in the behavioral responses of female *Oithona davisae* (Copepoda: Cyclopoida) to hydromechanical stimuli.	Le Mer	56	21-35	2018	
Author(s)	Title	Name of Journal	Vol	Page	Date	Note

Landeira, J.M., Cuesta, J. A., Tanaka, Y.	Larval development of the brush-clawed shore crab *Hemigrapsus takanoi* Asakura & Watanabe, 2005 (Decapoda, Brachyura, Varunidae)	Journal of the Marine Biological Association of UK				Under review
Genis-Armero, R., **Landeira, J.M.,** Capaccioni-Azzati, R., Palero, F.	Island colonization and long-distance dispersal in *Scyllarus subarctus* (Crustacea: Scyllaridae)	Journal of the Marine Biological Association of UK				Under review
Jiang, G-C., **Landeira, J.M.,** Shih, T-W., Chan, T-Y.	First zoeal stage of *Plesionika crosnieri* Chan & Yu, 1991, *P. ortmanni* Doflein, 1902, and *P. semilaevis* Bate, 1888, with remarks on the early larvae of Plesionika Bate, 1888 (Crustacea, Decapoda)	Zootaxa				Under review
Landeira, J.M., Liu, B., Omura, T. Akiba, T., Tanaka, Y.	Salinity and food availability modify the swimming patterns of the early larval stages of *Hemigrapsus takanoi* (Decapoda: Brachyura: Varunidae).	In preparation				

Note: This form must be submitted along with your Host's Form 8 within one month of the end of your fellowship tenure.