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Role of temperature and salinity on survival and growth of crustacean larvae*

Hubert J. CECCALDI** and Hiroki YAGI***

Abstract: Growth and survival of marine animals depends on their physiology. Temperature plays an important role on general metabolism, and salinity on osmotic pressure variations, free amino acid content and proteic metabolism. Generally, researches developed on biology of larvae are studying the effect of only one external factor on some biological characters, as growth, respiration, food consumption, etc. In order to develop a better knowledge of the survival rate of crustacean larvae of the species *Palaemon serratus*, several studies have been done in different combinations of salinities and temperatures, leading to a design of tridimensional abacus. These abacus are a characteristic of the species, and they may be used to predict the survival rate of the larvae in their natural environment. The optimal survival is varying at different steps of the larval growth, leading to a beginning of explanation of the migratory processes and behavior. Digestive capacities are also affected by temperature and salinities as well as oxygen consumption, and intracellular free amino acids. Excretion of ammonia and other nitrogen containing molecules are also affected by such variations of external factors of environment. The results of these studies will be very helpful to understand the equilibrium between species in the marine populations in natural ecosystems.

1. Introduction

The study of processes governing recruitment are almost always taking in consideration the number of juveniles entering in a fishery or the number of larvae constituting the phase of prerecruitment. But very seldom the studies take care of the qualitative factors who play a role in the recruitment processes. These qualitative factors play nevertheless an important effect in the survival of larvae, and we have to evaluate them as precisely as possible to understand in detail how the survival rate is affected by these factors.

Two main factors play a role in the survival of larvae:

– the quality of the eggs spawned, especially for the composition of their reserves, and their genetic characters,

– the resistance of larvae hatched, to the external factors as temperature, salinity, oxygen, dissolved organic matter, quality and quantity of food, etc. (CECCALDI, 1982).

It is not possible to understand all the effects of each of these factors, taken separately, and much more difficult to study the simultaneous variations of all of the edaphic factors. Nevertheless, it is possible to study two of these factors, taken in combination, all other factors remained fixed. (COSTLOW, 1967; REGNAULT and COSTLOW, 1970; ZEIN-ELDIN and ALDRICH, 1965).

The survival of larvae and postlarvae depends on the conditions of environment and on trophic factors (CAMPILLO, 1975; FORSTER, 1970). If one take a sample of 100 larvae hatched on the same time, coming from the same female mother, they are growing approximately at the same growth rate. A few of them show a slower growth rate, a few other ones a higher growth rate, even if they are fed the same way. We have developed specific experiments to increase our knowledge in that field.

2. Experiments

Survival and Growth

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**Ecole Pratique des Hautes Etudes.
Maison Franco-Japonaise,
3, Kanda Surugadai 2chome, Chiyoda-ku,
Tokyo, 101 Japan
***Hokkaido Central Fisheries Experimental Station,
238 Hamanaka-cho, Yoichi-machi, Hokkaido,
046 Japan

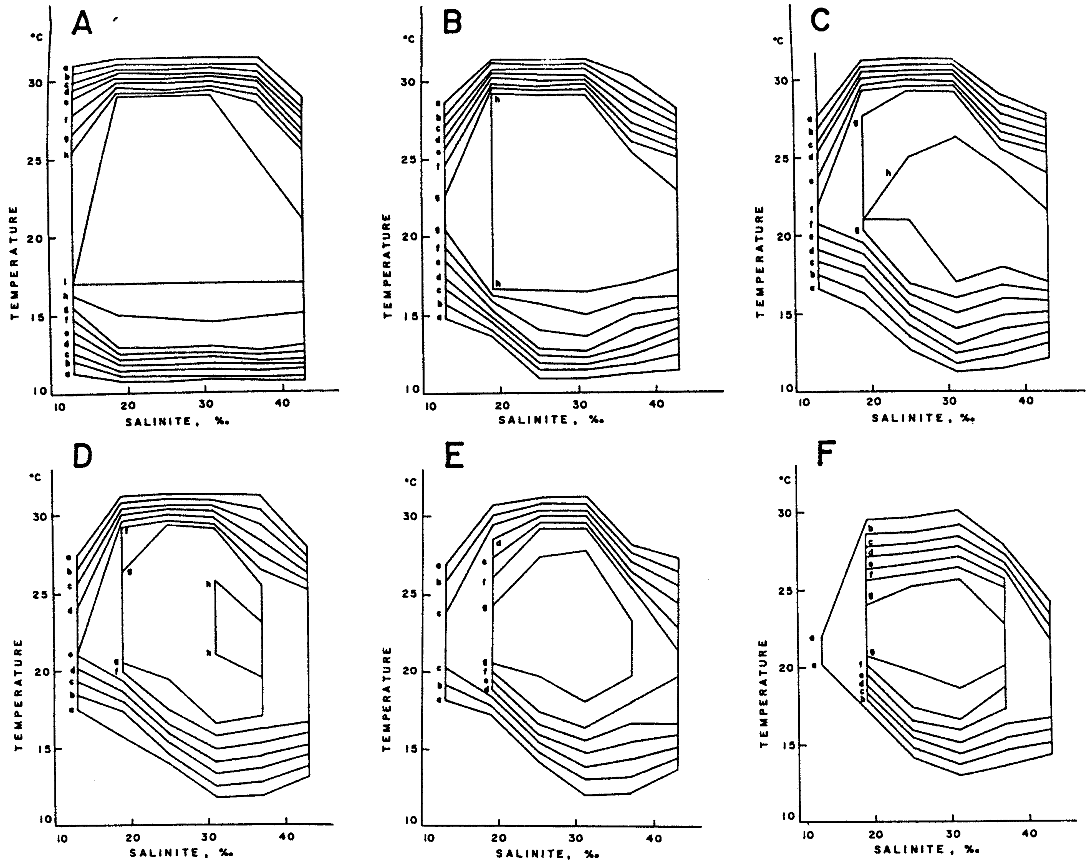

Fig. 1. Estimates of survival patterns between larval stages of *Palaemon serratus* as a function of different temperature-salinity concentrations. a, 20%; b, 30%; c, 40%; d, 50%; e, 60%; f, 70%; g, 80%; h, 90%; i, 100%. A, from ZI to ZII; B, from ZI to ZIII; C, from ZI to ZIV; D, from ZI to ZV; E, from ZI to ZVI; F, from ZI to PL (Post larve).

In order to study the variability of the survival and the growth rate, we have studied samples of 50 larvae of *Palaemon serratus* just hatched (Yagi and Ceccaldi, 1985; Yagi *et al.*, 1990).

The rate of survival and the duration of the intermolt were established for each of the six zoea stages and also the rate of metamorphosis and total duration in thirty different temperature and salinity combinations. Postlarvae were obtained in 24 combinations. The rate of survival for each larval stage was influenced significantly by salinity as well as by temperature. The values of the combinations allowing 50% survival decrease during larval development. Mortality is particularly high for thresholds of low temperature – low salinity and high temperature – high salinity. It is remarkable to note that survival is better in conditions of high salinity and low temperature or low salinity and high temperature (Fig. 1).

Temperatures allowing 50% survival range between 11.7 and 30.5 ℃, up to the third molt, from 14.1 to 30.3 ℃, up to the fourth molt, from 14.7 to 30.0 ℃, up to the fifth molt, and from 15.1 to 27.8 ℃, up to metamorphosis. In the same way, salinity ranges from 13‰ to 43‰ from the first stage and from 19‰ to 43‰ beyond this stage. Rate of survival decreases by half between the first larvae and the postlarvae.

The first postlarva appeared on the fifteenth day in combinations of 25 ℃–19‰ and 21 ℃–25‰. Q_{10} values, according to Van't Hoff"s formula for speed of growth during

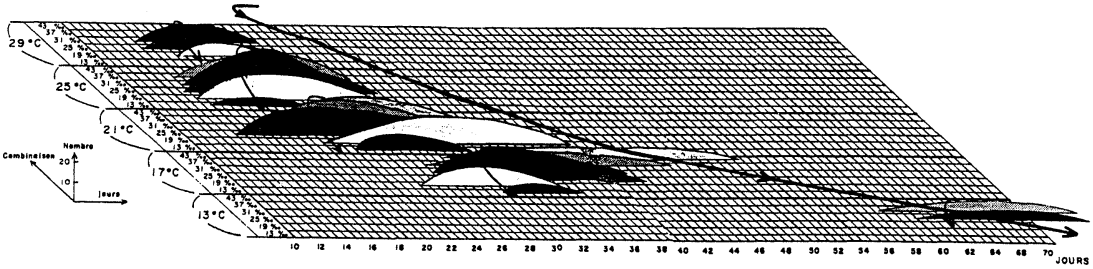

Fig. 2. Perspective model to show the combined temperature–salinity effects on the number of daily incidences of metamorphased postlarve of *Palamon serratus*.

their larval development up to metamorphos is, vary from 1.78 minimum for a salinity of 19‰ to 2.52 maximum for a salinity of 43‰.

Three-dimensional perspective model were also drawn to improve knowledge of the combined influence of temperature and salinity on larval development and the number of appearances of postlarvae during metamorphosis (Fig 2).

Oxygen consumption

The oxygen consumption of the six successive zoeal stages of *Palaemon serratus* reared in 30 different combinations of temperature and salinity was measured. Oxygen consumption per individual, R, increased with the age (or the dry weight, W) of the larvae according to a power function $R=a \cdot Wb$ but no significant relationship was found between the specific respiration, R′ (respiration rate per dry weight unit), and the dry weight of successive larval stages. Nevertheless, highest rates were always observed in the Zoea IV, for all temperature and salinity conditions. These maxima were probably related to a large nutritional changes occurring at this period of development.

Temperature affected according to a linear funtion $R'=a'+b' \cdot T \cdot Q_{10}$ values varied between 1.50 and 2.58 according to the larval stage and the salinity, except for the Zoea I at the lowest salinity where a very high value of 5.89 was recorded. The respiration rate decreased at the lowest and highest salinity values. The salinity effect on metabolic rates is described by a quadratic equation $R'=a''+b''S+cS2$. The combined effect of temperature and salinity on the respiration of the six successive larval stages is tllustrated using tridimentional models. respiration rates were recorded at salinities between 25 ‰ and 31‰ and at the highest temperature (29℃), as shown by YAGI *et al.* (1990) (Fig 3).

Free amino acid

From our another studies, we have shown that free amino acid composition is varying very much at different steps of the larval growth in the shrimp *Penaeus japonicus* (MARANGOS *et al.*, 1990). Free amino-acid content increases from 83 to 687 micromoles/g dry weight from egg to post larval stage (20 days old: P20). There is a sharp increase between zoea and mysis stages, and another one between one day post-larvae (P1) and P20. After the mysis stage, free essential and non-essential amino-acid evolve in a different way: the non-essential free amino-acid content, mainly glycine, increases cont inuously whereas essential free amino-acids content decreases (about 40%) from the mysis stage to metamorphosis in post-larvae (P1).

Free amino acids content evolution during larval development exhibits the same trend as the variation of the digestive enzyme activity. These experiments show that the osmoregulatory processes of crustacean larvae are varying at different steps of the larval growth.

But we have to point out that the amino-acid content depends also on salinity and on temperature. These results show the complexity of the regulatory processes, as they occur in nature, if we are considering only temperature and salinity.

Essential amino-acid in that species show a diminution at mysis and following stages. It

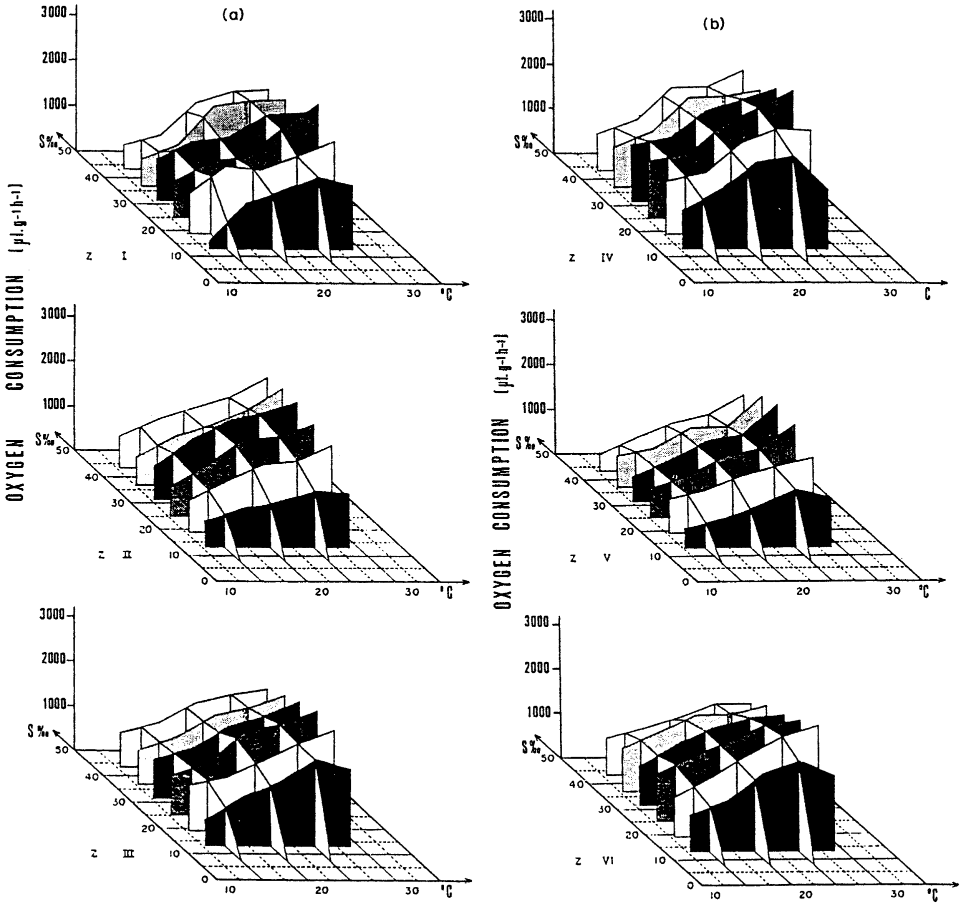

Fig. 3. Three-dimentional models of the influence of combinations of temperature and salinity on the consumption of oxygen per unit of dry weight of the larvae of *Palaemon serratus*: (a) stages ZI–ZIII; (b) stages ZIV–ZVI.

seems also that the potential of protein synthesis, which is in connection with essential free amino-acids, is in opposition with the capacity of osmotic regulation of these larvae.

There is a link between the age of the larvae, the food they are consumed, and their capacity to survive; this could be explained as zoea and mysis are living in desalted water of estuaries, as other *Penaeids*, and post-larvae are settled in the bottom located at a higher distance than the first larvae.

Detailed analysis of such amino acid show large variations of each one; the integration of all of them conduct to the osmoregulatory capacity of the larvae.

The evolution of amino-acid content on the passage of zoea stage to mysis stage, then to following stages, should have some straight relation to the competition of the food eaten, and the capability of the larvae to adapt these physiology to that composition.

The quality of food plays also a prominent role in crustaceans. For instance, in *Penaeus vannamei*, for biochemical analyses, nine individuals per treatment were used for the determination of the hepatosomatic ratio, proteins, proteases, amylases and trypsin. The results show that a high level of soya bean of fish meals in the diet strongly depresses growth without any apparent effect on the digestive enzymes or the hepatopancreas parameters. No effect of soya bean meal type or geographical origin on the fish meal was detected. The results suggest that the incorporation of both soya bean and fish meals in the diet should be restricted to low concentrations and only with the aim of diversifying the protein sources (GALGANI *et al*, 1988). These results concerns adults but the same situation exist in larvae, who are rather selective for their food, at different steps of their growth.

3. Discussion

It appears, from the results obtained, that it is necessary to draw specific abacus, for each species, and for each larval stage.

Resistance of first stages: The younger stages are less sensitive to large variations of temperature, and salinities than the older ones.

This could be interpretated as an advantage for the species; when the eggs are layed and when the first larvae are hatched, they are transported passively by currents. As the adults are living on shallow water, the eggs and larvae may enter in estuaries or desalted waters,without great damages.

The aged larvae adcquire regulatory processes in the same time than their swimming capacities.

Seasonal variations of survivors: Of interest also are the observation of tridimensional models showing the survival rates at various combinations of an optimal zone of survival. But if the external temperature and salinity are changing, some mortality appears in the group who was able to survive in the optimal combination of external factors.

The original sample of the larvae was not genetically homogenous, and a selective mechanism appears when the external condition are fixed for a long time. If several successive winters are very cold, an evolution process begins, as the most resistant larvae to cold survive better to the other larvae. They will grow, giving adults who are better survivors in cold conditions than the "usual" or "ordinary" adults.

Year after year, there is a genetic play, favorising one part of the population or another one depending of the meteorological conditions and of the hydroclimat.

Daily incidences of metamorphosed postlarvae: For high temperatures, between 25 and 29℃, the apparition of metamorphosed post-larvae occurs 15 days after hatching and the last one several days after. The whole sample metamorphoses in a short period of time, but the molts are not simultaneous. They appears at different days from the first incidence of metamorphosed post-larvae.

For the combinations, temperature 17℃, salinity 31‰, that period of time is very long, reaching almost one month. That characteristic represent an evident advantage for the species because the dissemination of the post-larvae will be much longer that for high temperatures and high salinities conditions.

Metamorphosis and salinity

One more surprising fact appeared in the study of that results: the optimal survival is better in rather desalted water, (salinity 31, 25 and even 19‰) than in sea water (salinity 37‰). It seems that, for sea water species, the salinity of sea water is too high, at least for the species we have studied; this could be of great help in aquaculture for instance, if one wish to obtain a population of larvae metamorphosing in the same time for aquaculture, to have a large range of sizes of post-larvae.

4. Conclusion

The role of temperature and salinity on survival and growth of crustacean larvae is more more complex than expected.

Survival rate depends on both factors taken simultaneously as it occurs in nature. But the results obtained in aquaculture tanks may give us interesting results in a rather short period of times. They have to be completed by physiological and biochemical works, then by genetical and molecular biology studies. These three ways of reseach remains open.

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