ANNUAL PRODUCTION OF *ARTEMIA PARTHENOGENETICA* IN A SOLAR SALTWORKS

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Abstract

Production of *A. parthenogenetica* was estimated using Hynes size-frequency method in a solar saltworks. Annual production of *Artemia* was 13.98 g dw m^{-2} yr^{-1}. Mean annual standing stock biomass was 0.066 g dw m^{-2} . The population was unevenly distributed among instar and adult stages. Linear predictive models such as multiple regression and principal component analyses were evaluated for the practical aim of estimating annual *Artemia* production. The results obtained from the Hynes method were used to highlight the contribution of each instar stage to total production. Production for each size group was estimated by an empirical technique which incorporated ln instar number and total length ($\ln P_j = 1.193(\pm 0.063) \ln n_j + 0.295(\pm 0.123)L_j$). The predictive ability of the model was highly significant ($R^2 = 0.991$, $p<0.05$).

Key-words: crustacea, secondary production, growth, aquaculture

Introduction

The brine shrimp *Artemia* spp. (Crustacea, Anostraca) are found in temporary and permanent hypersaline environments (1). Beside natural saline lakes, salt ponds in which seawater evaporates to produce sodium chloride are also suited to the development of natural populations of brine shrimp (2, 3). The high salinity (80 - 180) of salt ponds often makes this filter-feeding brachiopods the top consumer in ponds lacking vertebrates in a saltern. Yet the role of brine shrimp in the trophic structure of these hypersaline ecosystems has been largely unexplored.

No studies have examined secondary production for *Artemia* in solar saltworks even though they are valuable food supply in for aquaculture species, as well as for flamingos, shelducks, gulls, eared grebes and phalaropes (4, 5, 6). The brine shrimp is a small (total length of adults 1.0-1.3 mm.), euroxybiont and eurysaline filter-feeding herbivorous crustacean that feeds on bacteria and algae in hypersaline environments. The formation of encysted, ametabolic embryos or cysts assures the survival of the species in winter and drought conditions (1).

Artemia parthenogenetica is abundant in the Izmir Çamalti Saltern, Türkiye (7). High rates of production have been reported in previous years (approx. 300 kg dry cysts and/or 500 kg wet-weight ha^{-1}) and this harvest has been used for local aquaculture of sole, red sea bream and sea bass. However, the density of the cysts and adults have decreased dramatically during recent years probably due to overharvesting and bad weather conditions. The objective of the present study is to determine annual biomass production of *A. parthenogenetica* through the use of data on natural populations and laboratory reared *Artemia*. This study is the first to measure annual production of brine shrimp for all instars with size-frequency (Hynes) method in a salt pan.

Methods

The salt pans of Izmir Çamalti saltern are located in the north-eastern part of the bay of Izmir (38° 32'N-26° 57'E). The saltern has a mean depth of 0.5 m. The salt pan in which the experiments were conducted covers an area of 0.2 ha with a mean depth of 0.6 m. Annual temperature range was 2°-32°C in January and July respectively with a mean annual temperature of 16.63±3.05. The salinity in the experimental salt pan ranged from 90-160 in January-September but 170-320 in October-November. No fish lived in the pan because of high salinity. Planktonic rotifers and cladocerans were also absent. Dissolved oxygen in the sub-surface water (0.25 m) ranged from 2.1 mg l^{-1} in March to 6.6 mg l^{-1} in January and varied between 3.1-5.4 mg l^{-1} in other months. The annual mean of dissolved oxygen was 4.27±1.14 mg l^{-1}.

The samples were collected monthly with a plexiglass nansen bottle at ten points located at 50 m intervals between the years 1990-1991. The bottle was lowered to the mud surface. Water with *A. parthenogenetica* individuals was transfered to a 1.5 liter galon with a Masterflex peristaltic pump. For determination of instar density of the brine shrimp a one liter water sample was fixed with 40 % formalin (final concentration 2-4 %) and allowed to settle for 48 hr. The superficial water was decanted with the aid of a siphon and the settled *Artemia* individuals were totally counted and total lengths were measured using a standard microscope.

Brine shrimp eggs from Çamalti Saltern were hatched in the laboratory and newly hatched first instars were reared in two ten liter plexiglass tank to determine instar development time. Instars were maintained at 23±1.0°C on a 16:8 h L/D photoperiod and fed with non-filtered natural experimental salt pan water with yeast solution (1.25 µg l^{-1} dry weight). Every two or three days 25 nauplii were collected and total lengths were measured. *Artemia* were dried at 40°C and weighed with a decimal micro balance to obtain mean individual dry weight and determine biomass. The exponential equation was used to relate the weight to length.

$$M_j = \exp^{a.Lj} \cdot b \,. \qquad \text{(eq.1)}$$

with M_j as weight in µg, L_j as lenght in mm, a and b as the constants. For time-dependent growth, lenght was calculated as sigmoid logistic growth curve

$$L_j = \frac{a}{(1+b \cdot \exp(c \cdot D_j))} \,. \qquad \text{(eq.2)}$$

where a, b and c are contants; L_j, lenght in mm; D_j, duration (8).

The size-frequency method (9, 10) was used to estimate annual production of *A. parthenogenetica* following the calculation of Menzie (11), Krueger and Martin (12) and Runck and Blinn (13).

$$P = (N_j - N_{j+1})(M_j \cdot M_{j+1})^{0.5}. \qquad \text{(eq.3)}$$

P is the annual production, Mj the mean dry weight of size class j, c the number of size classes (j = 1-8), and N_j the number of individuals that developed into size class j during the year. The fifteen instars of *A. parthenogenetica* were morphologically distinct based on total lenght and were used as eight size classes in the production calculation: instar 1 to 3, below 1000 mm.; instar 4, 1000-1500 mm.; instar 5, 1500-2000 mm.; instar 6, 2000-2500 mm., instar 7, 2500-3500 mm., instar 8, 3500-5000 mm., instar 9 to 11, 5000-7000 mm., instar 12 and up 7000< mm. (14). Because the duration of each instar was unequal, P_e/P_a correction was used, where P_e is the estimated proportion of the life cycle spent in each size class (e.g. 1/c), and P_a is the actual proportion of the life cycle spent in a particular size class (9, 11, 13). The duration of the instars were estimated from rearrangement of eq. 2, D_j was derived:

$$D_j = (1/c) \{\ln [(a-Lj)/(L_j.b)]\} \cdot \qquad \text{(eq.4)}$$

D_j were used to estimate P_a for each instar.

The annual cohort production interval (CPI) which is the time from hatching to the attainment of the largest aquatic size class was estimated from laboratory rearing data as 30 days. Nj was estimated by

$$N_j = n_j (P_e/P_a)(GP/CPI)(c) \cdot \qquad \text{(eq.5)}$$

Growth period (GP) is the number of days during the year over which production estimated and except the period between 1 January - 15 April in which *A. partenogenetica* diapouse has been occurred, GP is 260 days.

The empirical approach that was used to determine the rate of changes between total annual production and production of each instar stages was a principal component analysis with standardized data as the independent variables. Standardizations of the original dependent and independent variables were required to stabilize the variance (8, 14). For predictive purposes, yearly productivity of each instar stage was calculated from the length and instar numbers:

$$\ln P_j = a L_j + b \ln n_j \cdot \qquad \text{(eq.6)}$$

with P_j, L_j and n_j as above, a and b as constants. The total annual production was then predicted as:

$$\sum \ln P_j = \sum (a L_j + b \ln n_j) \cdot \qquad \text{(eq.7)}$$

Results

Annual production for *A. parthenogenetica* calculated by the size frequency method was 13.98 (±1.27) g dw m^{-2} yr^{-1} ($p<0.05$). Mean annual standing stock biomass of *A. parthenogenetica* was 0.066 g dw m^{-2} and was unevenly distributed among all instar and adult stages. On the basis of the area of the salt pan (2500 m^2), the total annual production by *A. parthenogenetica* was 34.95 kg dw yr^{-1}. The average density was 4552 animals m^{-2} (SE=525, n=140) during the whole sampling period. The brine shrimp was multivoltine (cohort=20.35) in the Çamalti saltern.The density of *A. parthenogenetica* was lowest (zero) between January and early April due to diapause, peaked in early May (13783 animals m^{-2}), declined through July, peaked again in September (6457 animals m^{-2}) and declined gradually through the remainder of the year. First instars (ins. 1-3) made up an average of 57.34 % of the *A. parthenogenetica* population during 1990-91. Fourth instars made up 23.09 %, fifth instars 9.05 %, sixth instars 7.09 %, seventh instars 1.90 %, eighth instars 0.44 %, nineth-eleventh instars 0.67 % and adults 0.42 % of the population. First six instars were the most commonly encountered stages and were abundantly collected on each sample dates. Adults were uncommon but were collected on all sampling periods except early May in which the first increase in the abundance of first instars began.