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Growth and Production of *Aulichthys japonicus* in an Eelgrass (*Zostera marina*) Bed of Dongdae Bay, Korea

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동대만 잘피밭에 서식하는 실비늘치(*Aulichthys japonicus*)의 성장과 생산량

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Abstract : *The growth and production of Aulichthys japonicus (6.70～15.32 cm TL) were investigated in an eelgrass bed of Dongdae Bay, Korea throughout 2006. A total 888 A. japonicus were collected with a small beam trawl. Growth in fish total length was expressed by the von Bertalanffy's growth equation as:* $L_t=24.8257(1-e^{-0.5583(t+0.4816)})$. *The densities, biomass, daily, annual production, and P/B ratio were 0.01±0.009/m*$^{-2}$, *0.17±0.16g/m*^{2}, *0.00006±0.00006g AFDW/m*^{2}*/day, 0.02g AFDW/m*^{2}*/yr, and 0.12, respectively. Monthly variation in production of A. japonicus was large; the peak occurred at July, September and November 2006 (0.000182, 0.000127 and 0.000123 g AFDW/m*^{2}*/day), where as the lowest value was 0.000003g AFDW/m*^{2}*/day at April and May 2006. Monthly change in production of A. japonicus was positive correlated with number of individuals, biomass and growth rate.*

Key Words : *Aulichthys japonicus, Growth, Production, AFDW, Eelgrass bed*

요 약 : 실비늘치(6.70～15.32 cm TL)의 성장과 생산량에 대한 연구는 동대만 잘피밭에서 2006년도에 실시하였다. 실비늘치 시료는 소형 빔트롤에 의해서 총 888개체가 채집되었다. Bertalanffy 성장식을 이용하여 구한 전장의 성장식은 $L_t=24.8257(1-e^{-0.5583(t+0.4816)})$이었다. 실비늘치의 밀도, 생체량, 일일생산량, 연간생산량, 그리고 P/B ratio는 각각 0.01±0.009/m^2, 0.17±0.16g/m^2, 0.00006±0.00006g AFDW/m^2/day, 0.02g AFDW/m^2/yr, 그리고 0.12이었다. 실비늘치 생산량의 월변화는 컸으며, 7월(0.000182g AFDW/m^2/day), 9월(0.000127g AFDW/m^2/day) 그리고 11월(0.000123g AFDW/m^2/day)에 높았으며, 4월과 5월(0.000003g AFDW/m^2/day)에 가장 낮았다. 실비늘치의 생산량의 월변화는 개체수와 생체량, 그리고 성장률과 양의 상관관계를 보였다.

핵심용어 : 실비늘치, 성장, 생산량, AFDW, 잘피밭

1. Introduction

Extensive data indicate that seagrass meadows provide a high quality habitat for fishes (Bell and Westoby, 1986; Thayer and Chester 1989; Sogard, 1989) when compared to unvegetated habitats (Weinstein, 1983; Ferrell and Bell, 1991). The ecological importance of eelgrass as food source, nursery habitat and substrate stabilizers in estuaries and coastal areas throughout the world is well established (Klumpp et al., 1989; Edgar and Shaw, 1995a, b; Connolly et al., 1999; Hemminga and Duarte, 2000; Nagelkerken et al., 2002). *Aulichthys japonicus* (family Aulorhynchidae) has been known as one of common fish species in an eelgrass bed and along the rocky shore around Korean peninsula (Kim, 1970; Kim et al., 2005). Recent studies of *A. japonicus* have extensively described its morphology of larval and young stages (Kim, 1970), urogenital papilla (Sasaki, 1977),

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growth, reproduction and feeding habits (Go et al., 1997), reproductive behavior (Akagawa et al., 2004), and egg concealment in ascidians (Akagawa et. al., 2008) in Korea and world wide.

Shallow waters with rich eelgrass beds are located in Dongdae Bay where haven ever been influenced by human impacts until now provide a habitat for variety of invertebrates and small fish, particularly which in turn are the potential food of large fishes. In this perspective, understanding the potential of eelgrass bed of fish production and the influence of numerous biotic variables affecting individual growth and population mortality for accurate estimation of fish production (Cusson and Bourget, 2005; Dolberth et al., 2005). Despite of higher abundances of *A. japonicus*, several studies have been confined to describing the feeding habits, growth and spawning (Go et al., 1997). The domestic studies on fish production were reported production of *Acanthogobius flavimanus* and *Pholis nebulosa* collected in an eelgrass bed of Dongdae Bay(Kwak et al., 2009; on submitted).

The objective of this study was to estimate growth and production of *A. japonicus*, one of dominant fish species, inhabiting an eelgrass bed of Dongdae Bay, Korea. It is a fundamental part of a wider study aimed at understanding the functional characteristics on fish assemblages in an eelgrass bed, and estimation of fish production may be useful as a tool to support protection measures and ensure fish resources sustainability or for the study of the overall eelgrass bed ecological integrity.

2. Materials and methods

2.1 Study site and sampling procedures

The eelgrass, *Zostera marina* is widespread in shallow areas, forming subtidal bends with a width approximately 3,000 m along the shoreline of Dongdae Bay, Korea (Fig. 1). A total of 888 *A. japonicus* were collected with a small beam trawl (1.9 cm mesh wing and body, 0.6 cm mesh liner, sampling area of 180 m^2) in an eelgrass bed. All fish samples were preserved immediately in 10 % formalin after capture, and their total length and body weight were measured to the nearest millimetre and 0.01 g in the laboratory. Water temperature at the study site ranged from 5.7 to 26.4 ℃, and salinity ranged from 28.5 to 34.8 ‰ in the study area.

2.2 Growth

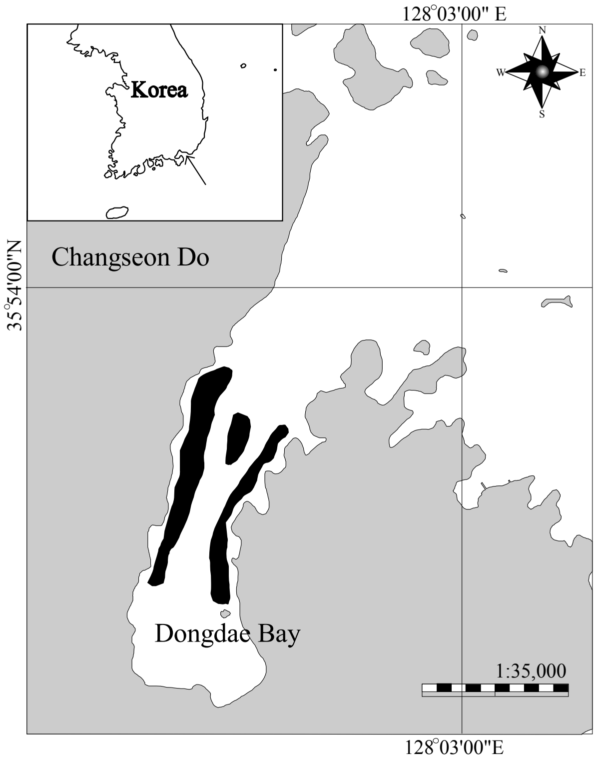

Fig. 1. Location of study area (the black area: eelgrass bed).

Growth was deduced by tracking recognisable cohorts along size-frequency distributions (1-mm TL classes) from successive sampling sessions. All fish born during the same reproductive period were assigned to the same cohort (Fernandez-Delgado and Rossomano, 1997). Length-age was modelled using three key parameters of von Bertalanffy growth model (Bertalanffy, 1938) described as $L_t = L_\infty [1 - e^{-k(t-t_0)}]$, where L_t is the length-at-age t, L_∞ is the maximum theoretical length, K is the body growth coefficient synonym to the rate at which L_∞ is attained and t_0 is the age of zero length fish.

2.3 Production

Production of *A. japonicus* was calculated using information on mean daily length increments input to the Bertalanffy growth model according to the cohort analysis method of this study. Production was estimated using a newly-derived general equation $P = aB^{\alpha}T^{\beta}$(a,α,β: coefficients) that relates daily fish production P (g AFDW/day) to ash-free dry weight, biomass (g), and water temperature T (℃). Also annual fish production P (g AFDW/year) was estimated with multiply daily fish production by 365. These values were based on monthly data. Water temperatures were measured at each sampling occasion, and these were ranged 5.7～26.4 ℃. To measure ash-free dry weight of each specimen, individuals were dried for 2-3 weeks at 80 ℃ and weighted to the nearest 0.0001 g. Individuals were then burned to ash at 500 ℃ for a minimum of 4 h. The weight of the remaining ash was measured and subtracted from the dry weight measurement to get the ash-free dry weight of each individual. Where multiple specimens of the same length were used to determine a mean ash-free dry weight, only one resulting data point was used in the regression analysis. Regression analysis of natural log-transformed data were used to determine the equations describing the relationship between total length and body weight, and ash-free dry weight for each species or species group (Gould, 1965; Burton, 1998). A one-way ANOVA with orthogonal design was used to analyse variations in density, biomass, and production across months. The relationships between production and the number of individuals, biomass, growth rate, condition factor, and water temperature were analysed using Pearson's correlation coefficient.

3. Results

3.1 Population structure

The *A. japonicus* were collected throughout the year except June 2006 with higher were in September (234 ind.) and November (221 ind.) 2006 (Fig. 2). For size-frequency distribution, *A. japonicus* has been ranged from 6.70cm TL to 15.32 cm TL (n = 888), and one mode appeared at 11.25～15.21 cm TL from January 2006. These cohorts occurred at 11.04～15.20 cm TL from February 2006 to May 2006, however, new cohort ranged from 7.80 cm TL to 8.25 cm TL was in July 2006, and occurrence of this cohort continued in the remaining study periods.

3.2 Growth

The totally one cohort (to 1 year cohort) have been observed during study periods with tracking recognizable cohorts along size-frequency distributions (0.1 cm TL classes) from successive sampling occasions. The total length was increased significantly with body weight (Fig. 3). For example, body weight was plotted against length over the range 6.70-15.32 cm for total length and 0.40-6.28 g for weight, and this was calculated as $W = 0.001\ TL^{3.1752}$ (r^2=0.9618, $p<0.001$). The variation in total length demonstrated also remarkable differences with time (or day) (TL = 2.4869 Ln(d)-0.5313, r^2=0.90, $p<0.001$, Fig. 4). Thus the average growth rate of *A. japonicus* was estimated 7.97 cm TL at 0.2 year, 14.13 cm TL at 1 year with cohort analysis. These growth-data-fitted von Bertalanffy' model (1938) well predicted the

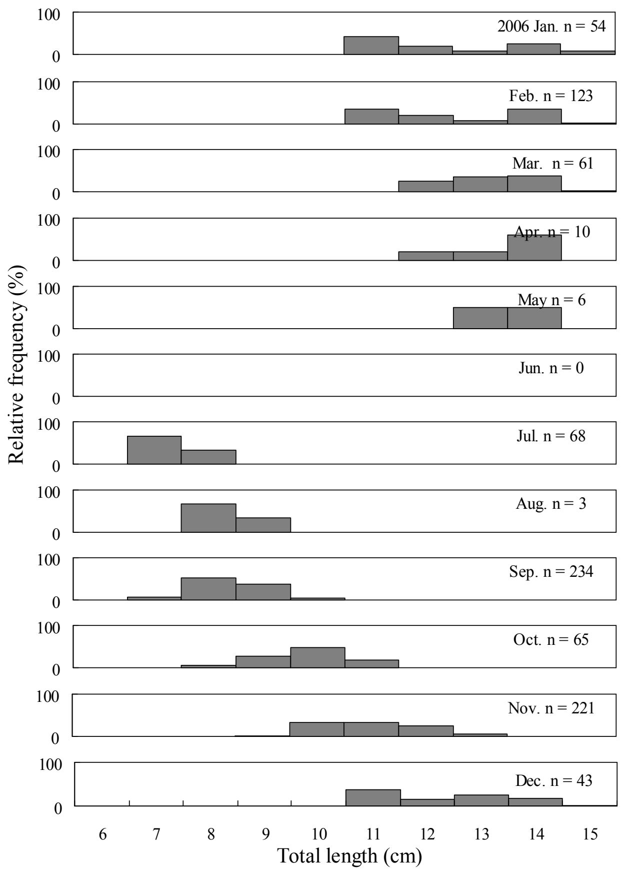

Fig. 2. Monthly variation in size-frequency distribution of *A. japonicus* in an eelgrass bed of Dongdae Bay.

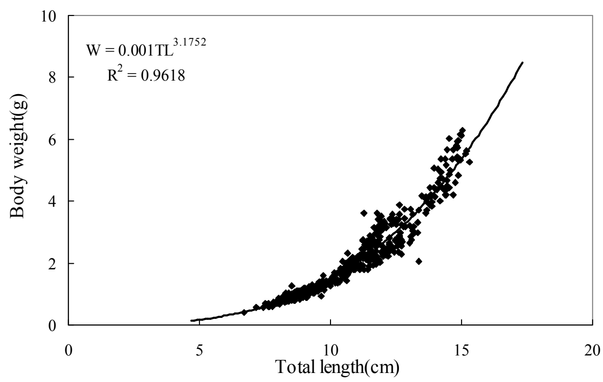

Fig. 3. Relationships between total length and body weight of *A. japonicus* in an eelgrass bed of Dongdae Bay.

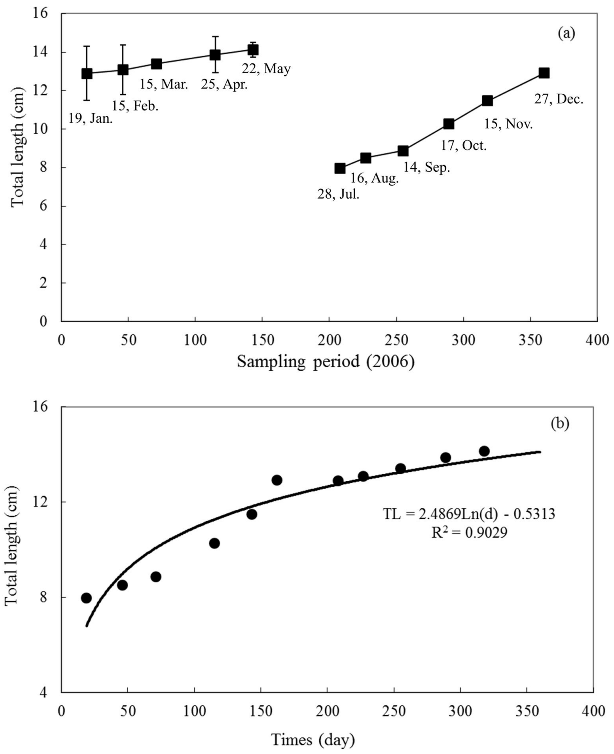

Fig. 4. Temporal variation in total length(a) and growth curve(b) of *A. japonicus* with cohort analysis in an eelgrass bed of Dongdae Bay (The square and bar represented mean value and standard deviation of each cohort).

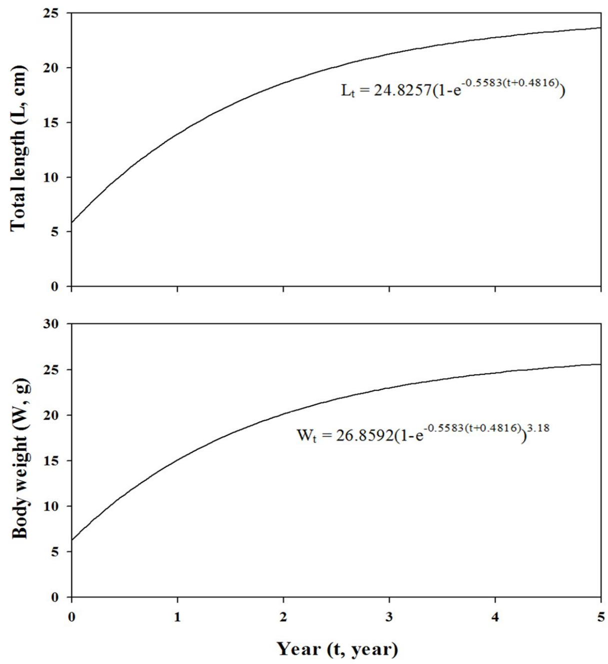

Fig. 5. Theoretical von Bertalanffy growth curve in length(a), weight(b) of *A. japonicus* in an eelgrass bed of Dongdae Bay.

results for *A. japonicus*, and model parameters were estimated as follows: L_{max}=24.8257 cm TL; t_0=0.4816 year; k=0.5583 (Fig. 5).

3.3 Production estimation

The relationships between total length and body weight, and ash free dry weight (AFDW) was estimated as $AFDW=0.0002TL^{3.2106}$ and $AFDW=0.2134BW^{1.0185}$ (Fig. 6). For daily growth rate, $AFDW/day=0.0021B^{0.9996}$ (R^2=0.906) was based on the value of AFDW on monthly. The production of *A. japonicus* thus was estimated as $P = 0.0112B^{-1.1418}T^{0.0019}$. The density (/$m^2$) differed substantially between different months with higher values were in February 2006 (0.028/m^2) and November 2006 (0.026/m^2) (ANOVA, Fig. 7-a). Significant difference was observed between months for biomass (g/m^2) (ANOVA, Fig. 7-b). The biomass was higher in February and November 2006 (0.43 and 0.44 g/m^2). The daily production (g AFDW/m^2/day) was found to differ significantly between months with peak values were at July, September, and November 2006 (0.00018, 0.00013 and 0.00012 g AFDW/m^2/day) (ANOVA, Fig.

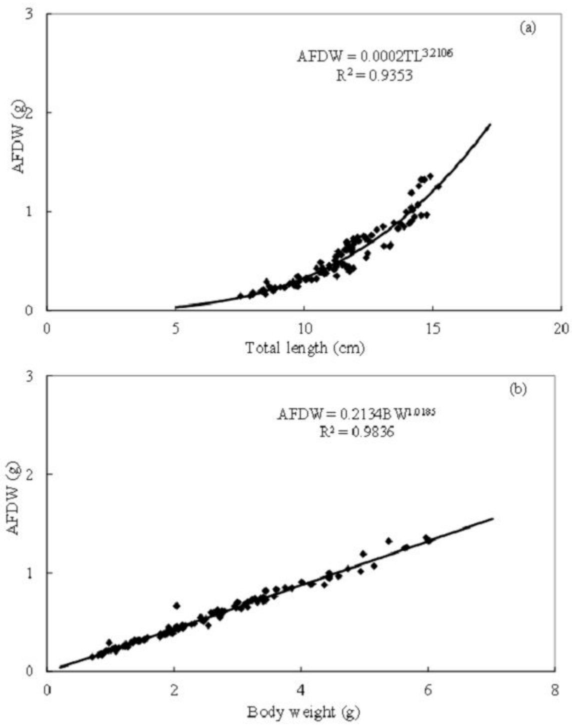

Fig. 6. Relationships between ash-free dry weight and total length(a), and body weight(b) of *A. japonicus* in an eelgrass bed of Dongdae Bay.

7-c). On the other hand, the average density, biomass, daily and annual production, and P/B were 0.0095±0.0094/m^2, 0.174±0.158 g/m^2, 0.000055±0.000063 g AFDW/m^2/day, 0.02 g AFDW/m^2/year, and 0.12 at study sites during study periods.

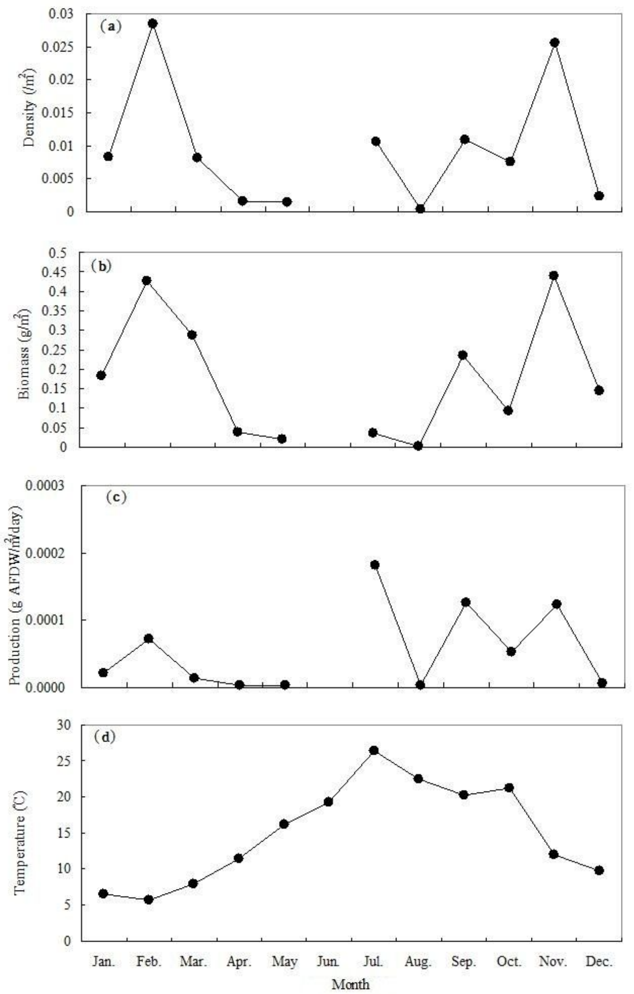

Fig. 7. Monthly variations in density(a), biomass(b), production(c), and temperature(d) of *A. japonicus* with relating to temperature in an eelgrass bed of Dongdae Bay.

4. Discussion

The present study is the first to provide quantification of the density, growth, and production of *A. japonicus* in an eelgrass bed. Fish populations are often dynamic due to variation of recruitment and migration, which creates difficulties when trying to estimate their production in an eelgrass bed. The accurate estimation of fish production has been provided in this study with both a short time interval relative to the dynamics of the fish and a large population size (Hemminga and Duarte, 2000; Nagelkerken et al., 2002). Hence *A. japonicus* was one of the most abundant species in our study site, comprising of more than 2.3 % of biomass of the whole fish community (Kim, 2010), and production was estimated daily with growth and temperature over a year. Furthermore, this method was calculated for many kinds of fish production worldwide (Edgar and Shaw, 1995a; Edgar and Shaw, 1995b).

The one cohort of *A. japonicus* have been inhabited as one lifetime spawning species with the other modes were also not found although more than 15 cm TL were not collected during study period. For back calculation in growth of *A. japonicus*, $L_{1.0}$=13.97 cm TL, $L_{2.0}$=18.61 cm TL, $L_{3.0}$=21.27 cm TL for total length, and $W_{1.0}$=4.33 g, $W_{2.0}$=10.77 g, $W_{3.0}$=16.45 g for weight have been occurred to 1 year with cohort analysis. The *A. japonicus* population was dominated over the study periods with monthly variations. Smaller individuals (about 7 cm TL) occurred from June to September 2006 for the first time, and then the numbers of this cohort varied with month in the remaining periods. This pattern has been paralleled with similar size groups appeared from July to December over a year in the eelgrass beds around Cheju Island (Go et al., 1997). These results were due to the monthly variation of spawning parameters and recruitment periods. For example, the smaller individuals of *A. japonicus* would be recruited in July 2006 from most of individuals were spawned from February to May 2006 when was based on the GSI values of female and male and condition factor (Fig. 8). Such conclusions were in agreements with other studies that most of individuals of *A. japonicus* have been spawned when temperatures begin to warm up, e.g. from February to May in the same year, with gonad development (Go et al., 1997). Thus most of individuals (more than 6 cm TL) of *A. japonicus* in an eelgrass bed of Dongdae Bay have been moved after these had spawned from February to May nearby at study area.

Monthly variations of production appear to be considerable for *A. japonicus* utilizing at our study sites with higher production was at July, September, and November 2006. The correlations analysis between production and some factors (e.g. number of individuals, biomass, growth rate, condition factor, and water temperature) revealed that number of individuals, biomass, and growth rate were significant positive, while condition factor were negative correlation for production ($p<0.01$). These patterns were similar to those of other species e.g. *A. flavimanus*, *Sebastes*

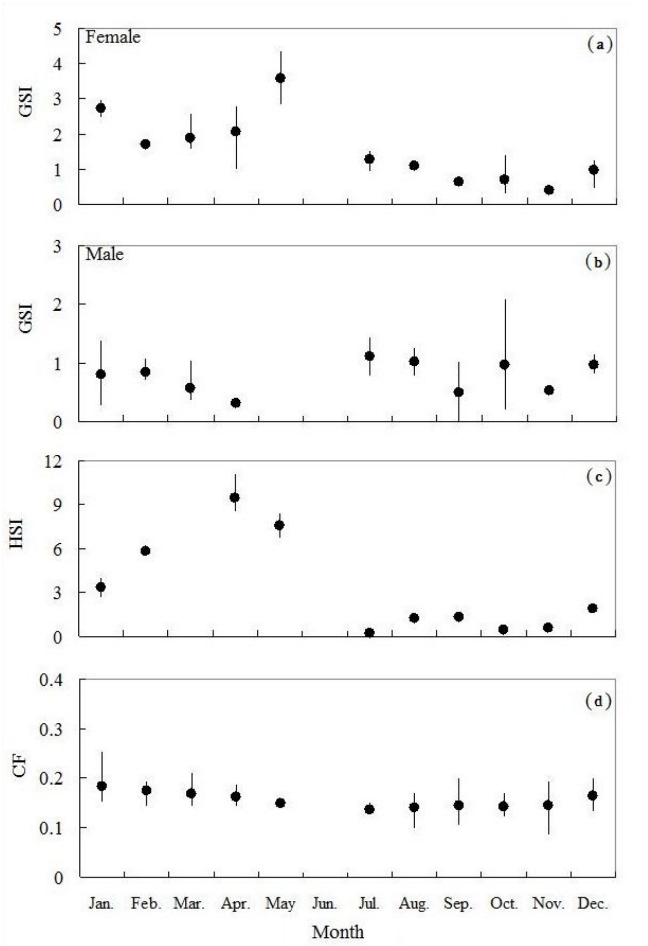

Fig. 8. Monthly variations gonadosomatic index(a, b), hepatosomatic index(c) and condition factor(d) of *A. japonicus* in an eelgrass bed of Dongdae Bay (Circle and bar represent the mean and range.)

inermis, *Pholis nebulosa*, *Psedoblennius cottoides*, and *Synganthus schlegeli* which were significantly influenced by condition factor in the study area (Kwak et al., 2009; Kim, 2010). The specific growth rate and production of fish species has been highly correlated with condition factor, or the ratio of liver weight to total weight, and then has to be used in interpretations as indicators of growth rates (Cui and Wotton, 1998; Diana, 2004).

The daily and annual production of *A. japonicus* were lower values (0.00006 g AFDW/m^2/day and 0.02g AFDW/m^2/yr) than that of *A. flavimanus* was 0.001 g AFDW /m^2/day and 0.351g AFDW/m^2/yr at unvegetated area nearby at our study sites although *A. flavimanus* was similar value in an eelgrass bed of Dongdae Bay (Kwak et al., 2009). On the other hand, this value was also lower than those of other fishes (e.g. *Pholis nebulosa*, *Pseudoblennius cottoides*, and *Sebastes inermis*) in the study area (Kwak et al., 2009; Kim, 2010), and other species *Aldrichetta forsteri* (41.61 g AFDW/m^2/yr), *Engraulis mordax* (9.31 g AFDW/m^2/yr), and *Gobius cobitis* (2.86 g AFDW/m^2/yr) in coastal areas (Gibson, 1970; Chubb et al., 1981; Parrish et al., 1985) worldwide. For productivity, *A. japonicus*, P/B (0.12) was lower than those of other fish species such as *A. flavimanus*, *S. inermis*, *P. nebulosa*, and *P. cottoides* in an eelgrass bed of Dongdae Bay (Kwak et al., 2009; Kim, 2010). Thus the production of *A. japonicus* was lower value despite of higher abundances of them were in the study area Probably these results have been due to different spawning strategy (e.g. the recruitment periods and total length of recruits etc.) and growth patterns from higher production of fish species were at study sites. For example, *A. japonicus* have been spawned in the gill of ascidians on the rocky area in the coastal waters, and then most of individuals have not collected in the eelgrass beds (Go et al., 1997). This result indicated that eelgrass beds have been not the nursery grounds but feeding grounds for *A. japonicus*. Furthermore, the lower production of *A. japonicus* has even been continued in the following year 2007.

This conclusion should, however, be treated with caution, as it assumes that the production of *A. japonicas* that we observed is comparable lower with published estimates for temperate and subtropical seagrass fish communities elsewhere, despite difference in the study area and the number of fish species present there. Therefore, the reproductive strategy and recruitment have the potential to hold production of *A. japonicas* although eelgrass beds contain good environmental conditions for fish such as a variety prey organisms and microhabitats.

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