Marine and Freshwater Research, 2020, **71**, 1128–1148
https://doi.org/10.1071/MF19265

Supplementary material

Effect of stingray (*Hemitrygon akajei*) foraging on a ghost shrimp population (*Nihonotrypaea harmandi*) on an intertidal sandflat, western Kyushu, Japan

Akio Tamaki[A,B], *Kazuyuki Harada*[A], *Yoshinobu Sogawa*[A] *and Seiji Takeuchi*[A]

[A]Graduate School of Fisheries and Environmental Sciences, Nagasaki University,

Bunkyo-machi 1-14, Nagasaki 852-8521, Japan.

[B]Corresponding author. Email: tamaki@nagasaki-u.ac.jp

Marine and Freshwater Research, 2020, **71**, 1128–1148
https://doi.org/10.1071/MF19265

Account of the steady state of the ghost shrimp population with no stingray predation on the Tomioka sandflat

The mean densities of adult shrimp of *Nihonotrypaea harmandi* at Stations 260, 160, and 60 at the start of Period 1 in any 1 year (e.g. Year 1) can be assumed to be stable with fixed decreasing ratios (Tamaki *et al*. 1997, fig. 14), 1: k_{160}: k_{60} ($0 < k_{160}$, $k_{60} < 1$). The survival rates of adult shrimp through Period 1 are expressed as s_1 (Station X; X = 260, 160, 60). At the start of Period 2, the density of newly recruited shrimp at each station derived from all adults from the three stations is regarded as proportional to ($1 + k_{160} + k_{60}$), with the coefficient of proportion expressed as k'_X (260, 160, 60). Here, two processes are assumed to be involved: (i) self-recruitment to the Tomioka sandflat population due to a 70% dominance by the Tomioka sandflat population of the regional shrimp metapopulation (Tamaki and Harada 2005) and (ii) higher newly recruited shrimp densities in the more seaward zones of the Tomioka sandflat (Tamaki and Ingole 1993). Regarding the above item (ii), it is assumed that k'_{260}: k'_{160}: k'_{60} = a: ak_{160}: ak_{60}, where ‘a’ is a constant (Tamaki *et al*. 1997, fig. 14). Thus, the relative mean shrimp densities at Stations 260, 160, and 60 at the start of Period 2 are given as [$1 \times s_1$(Station 260) + $ak_{260}(1 + k_{160} + k_{60})$], [$k_{160} \times s_1$(Station 160) + $ak_{160}(1 + k_{160} + k_{60})$], and [$k_{60} \times s_1$(Station 60) + $ak_{60}(1 + k_{160} + k_{60})$] respectively. The survival rates of all shrimp through Period 2 and through Period 3 at each station are expressed as s_2(Station X) and s_3(Station X) respectively. Overall, the mean relative densities of adult shrimp at Stations 260, 160, and 60 at the start of Period 1 in Year 2 are given as {[$1 \times s_1$(Station 260) + $ak_{260}(1 + k_{160} + k_{60})$] $\times s_2$(Station 260) $\times s_3$(Station 260)}, {[$k_{160} \times s_1$(Station 160) + $ak_{160}(1 + k_{160} + k_{60})$] $\times s_2$(Station 160) $\times s_3$(Station 160)}, and {[$k_{60} \times s_1$(Station 60) + $ak_{60}(1 + k_{160} + k_{60})$] $\times s_2$(Station 60) $\times s_3$(Station 60)} respectively. At the steady state occurring between years, these three terms ought to be equal to 1, k_{160}, and k_{60} respectively.

References

Tamaki, A., and Ingole, B. (1993). Distribution of juvenile and adult ghost shrimps, *Callianassa japonica* Ortmann (Thalassinidea), on an intertidal sand flat: intraspecific facilitation as a possible pattern-generating factor. *Journal of Crustacean Biology* **13**, 175–183. doi:10.2307/1549132

Tamaki, A., and Harada, K. (2005). Alongshore configuration and size of local populations of the callianassid shrimp *Nihonotrypaea harmandi* (Bouvier, 1901) (Decapoda: Thalassinidea) in the Ariake-Sound estuarine system, Kyushu, Japan. *Crustacean Research* **34**, 65–86. doi:10.18353/crustacea.34.0_65

Tamaki, A., Ingole, B., Ikebe, K., Muramatsu, K., Taka, M., and Tanaka, M. (1997). Life history of the ghost shrimp, *Callianassa japonica* Ortmann (Decapoda: Thalassinidea), on an intertidal sandflat in western Kyushu, Japan. *Journal of Experimental Marine Biology and Ecology* **210**, 223–250. doi:10.1016/S0022-0981(96)02709-8