International Journal of Fisheries and Aquatic Research
ISSN: 2456-7248; Impact Factor: RJIF 5.44
Received: 23-04-2020; Accepted: 24-05-2020; Published: 11-06-2020
www.fishjournals.com
Volume 5; Issue 2; January 2020; Page No. 38-45

The effect of temperature on reproductive cycles, growth and survival of two estuarine mysid species

Neetha Nandanie Punchihewa
Department of Zoology, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka

Abstract

The effects of seasonal temperature on intra-marsupial development, growth and survival of two mysid species, *Tenagomysis novaezealandiae* and *T. chiltoni*, in the Auckland region are reported using laboratory studies. Replicated experiments at multiple temperature treatments were selected with reference to the average temperatures in the field along with the ambient temperatures around Auckland over the course of four seasons: winter, 13 ± 1°C, spring and autumn, 18 ± 1°C and summer, 23 ± 1°C. Higher temperatures accelerated the incubation period and growth whereas it decreased the survival of mysids. *Tenagomysis chiltoni* exhibited a longer incubation period than *T. novaezealandiae* at all temperatures. The warmer temperature accelerated the growth rate of immature individuals than that of mature individuals. Further temperature enhanced the faster maturation. In addition to this, shorter generation time was also observed at higher temperatures. Both species showed multivoltine life cycles and produced up to five generations within their life time. Life span varied according to the seasonal cohort, shortest in summer and longest in winter. Their maximum life span was eight months for *T. chiltoni*, and seven months for *T. novaezealandiae*, that were born during autumn and winter. To have an enhanced growth and survival, temperature is the most contributing factor to be considered.

Keywords: generation time, multivoltine, intra-marsupial development, post-marsupial development, temperature

1. Introduction

Water temperature is the abiotic determinant purported to have the greatest effect on productivity of wild mysid populations [1, 2] and it is responsible for variations in the incubation period of mysids [3, 4, 5, 6]. Hence, the time taken for intra-marsupial development (incubation period) from stage I– III larvae and the release of young, is closely related to environmental temperature [7, 6]. In New Zealand the environmental temperature widely varies during the seasons. Therefore, when considering the eco-biology of New Zealand mysids, it is important to study their biological processes such as reproductive cycles, growth and survival in relation with the temperature variations.

The average daily growth rate of immature and mature *Acanthomysis robusta* increased with elevated temperature and hence shortened the inter-moult period [8]. Growth rate and maturity of *Neomysis intermedia* are strongly affected by temperature [1].

Several studies showed that incubation period decreased with the increasing temperature. This is evidenced from two studies on *Acanthomysis mitsukurii* [4] and *A. robusta* [8] that were reared in the laboratory. Similarly, *A. mixta australis* and *T. tasmaniae*, showed that incubation period was shorter at the summer temperature than at the winter temperature [3]. Further, high temperature shortened the development time of *N. integer* [6].

The laboratory culturing experiments revealed that mysid survival rates were lower at higher temperatures than at lower temperatures [4, 6, 9]. The highest survival of *N. integer* larvae were found to be at the lowest temperatures (<14°C) compared to higher temperatures, 15–21°C [6] and *Mysis relicta* survival was high (93%) up to 17°C and decreased with an increase in temperature over 18°C [6]. Similarly, survival rates of *A. mitsukurii*, was lower at 23°C than at 20°C [4].

A study conducted in southern New Zealand estuaries, found that salinity could influence osmoregulation and survival of *T. chiltoni* and *T. novaezealandiae* when interacting with temperature [10]. However, there haven't been any known studies carried out on effect of temperature on survival and the intra-marsupial or post-marsupial development of mysid taxa in New Zealand. Understanding this scarcity of knowledge, on the above aspects the present study has been focussed mainly on the reproductive cycles, life histories, growth and survival of mysid species in Auckland region.

2. Method

To investigate the effect of seasonal temperature on incubation period, growth and survival, three different temperature treatments were selected with reference to the average temperatures in the field as well as the ambient temperatures around Auckland over the course of four seasons: winter, 13 ± 1°C; spring and autumn; 18 ± 1°C and summer, 23 ± 1°C. For all the experiments the common procedures were used as follows.

Mysids were collected, from Kakamatua stream using a dip net of 500 µm. Three replicate glass beakers (*T. chiltoni*, 2000 ml beakers; *T. novaezealandiae*, 1000 ml beakers) were used with water from the sampling site and a continuous aeration [11]. The experimental beakers for 13 ± 1°C, 18 ± 1°C and 23 ± 1°C were kept in separate light-controlled incubators under 12 hours of light and 12 hours of dark. Mysids were transferred at one-hour intervals in graded steps of first 15°C then 18°C followed by 21°C and 23°C as a safeguard against thermal shock. Temperature, pH, dissolved oxygen and salinity, were monitored in each replicate beaker using WTW 3400i Multi-Parameter Water Quality Field Meter. Ammonia levels were monitored using an Ammonia Test Kit. Mysids were fed with newly hatched Artemia. Approximately one third of the water was renewed daily and, the water in each beaker was completely renewed every fourth day. Faeces and possible moults were removed daily.

2.1. Effect of temperature on intra-marsupial development

To investigate the effect of seasonal temperature on the incubation period of *T. chiltoni* and *T. novaezealandiae*, experiments were undertaken in November 2007. Gravid females collected from the sampling site were examined under the light microscope to determine the status of larvae within the brood. Three replicate glass beakers, each containing six mature females consist of gravid females & post-spawned females and four males were held at each temperature treatment for six weeks. To observe the intra marsupial development from the initial egg stage, males were also kept in the beaker to allow for reproduction to get fresh eggs. Mysid stocking density and suitable sources of food were decided based on the preliminary investigations.

To distinguish the individual female mysids over the experimental period of six weeks, mysids with different lengths were selected for each replicate beaker. Brooded females were examined under the light microscope daily to observe the stage of larval development within the marsupium and to determine the number of days larvae spent in each developmental stage. Dead mysids were removed and replaced with new ones of known size from the original collection.

2.2. Effect of temperature on growth

To investigate the effect of temperature on the growth rate of both mysid species from the juvenile stage up to maturation, experiments were carried out in October 2008. Based on preliminary survey, non-lethal stocking density of juvenile mysids was decided as 15 juveniles per beaker (culture).

Brooding females collected from the wild were kept in aerated plastic buckets at 18 ± 1°C. After thorough observation, females that had broods in final phase of larval development in stage III larvae were selected. They were kept in 2000 ml glass culture beakers maintained at 18 ± 1°C. Culture beakers were filled with 1700 ml water collected within one week from the sampling site. Juveniles released within 24 hours were selected at random for each replicate. In both species, lengths of free-swimming juveniles were measured. Three replicate glass beakers, each containing 15 newly hatched (< 24hour old) juvenile mysids were held at each temperature treatment for six weeks. The total body length of each juvenile was measured every four days by transferring them into a Sedgwick rafter cell and observed under the light microscope fitted with an eye piece micro meter.

2.3. Effect of temperature on survival

The experiments were undertaken in November 2008. Adult mysids were collected from the wild and were held in aerated plastic buckets at 18 ± 1°C. Adult mysids (*T. chiltoni*: 10–14 mm; *T. novaezealandiae:* 6–8 mm) were selected at random from this stock. For each replicate beaker, 10 (6 ♀, 4 ♂) mysids were held at each temperature treatment for a period of four weeks. Survival rates were recorded in each beaker, every day over the course of 31 days; any dead individuals were removed.

3. Results

3.1 Effect of temperature on intra-marsupial development

For both *Tenagomysis* species, incubation period and the duration of each larval development varies with different temperature treatments (Table 1, Figs. 1a & b). The one-way ANOVA indicated development period of *T. chiltoni* is significantly longer than that of *T. novaezealandiae* at each temperature. The longest incubation period was recorded at 13°C (*T. chiltoni*, 24 days; *T. novaezealandiae*, 21 days). At the highest temperature (23°C), both species showed the shortest incubation period (*T. chiltoni*, 10–11 days; *T. novaezealandiae*, 7–8 days). Intermediate values, recorded at 18°C (*T. chiltoni*, 19–20 days; *T. novaezealandiae*, 12–13 days) (Table 1). In each temperature, development time of stage I in both species was shorter than those of stages II and III (Table 1, Figs. 1a & b). Each species identify a significant difference in mean incubation period with temperature. Higher temperatures accelerated the intra marsupial development. At 13°C, the average incubation time was nearly double at 23°C in *T. chiltoni* and approximately it was taken three times in *T. novaezealandiae* (Table 1).

Table 1: Variation of mean incubation time and mean development time of stage I–III of *T. chiltoni* and *T. novaezealandiae* at different temperatures.

Species	Temperature	Stage I	Stage II	Stage III	IMD time
		Mean time (day) ±SE			
T. chiltoni	13°C	6.07±0.07	8.79±0.11	9.07±0.07	23.93±0.13
	18°C	4.77±0.12	6.07±0.07	6.20±0.10	17.04±0.16
	23°C	3.10±0.10	3.80±0.13	3.90±0.10	10.80±0.20
	F value=1012.90	df = 2	S		
T. novaezealandiae	13°C	5.92±0.08	7.23±0.12	7.85±0.10	21.00±0.16
	18°C	3.94±0.06	4.40±0.12	4.59±0.12	12.94±0.06
	23°C	2.11±0.11	2.67±0.17	2.89±0.11	7.63±0.18
	F value=1409.30	df =-2	S		

s = significant at $P \leq 0.05$, SE-standard error, df=degrees of freedom

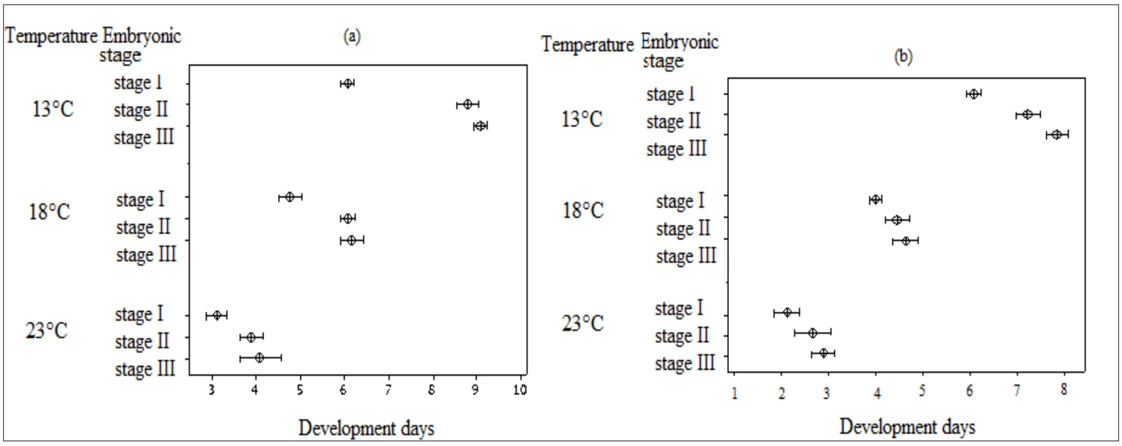

Fig 1: Mean development period of each embryonic stage (I–III), at different temperatures. (a) *T. chiltoni* (b) *T. novaezealandiae.* (Bar indicates 95% confidence intervals).

3.2 Effect of temperature on post-marsupial development (growth)

The length of juveniles release from the marsupium and their growth up to maturity at different temperatures are given in Table 2. The growth curves plotted for both species clearly showed distinctly different growth patterns (Figs. 2a–d). It was apparent that the juveniles released from the marsupium take lesser time to reach sexual maturity at higher temperatures than that of lower temperatures (Fig. 2, Table 2). Increasing temperature shortened the time to reach sexual maturity. At each temperature, both species grew almost linearly up to a certain length before the sexual maturation (Figs. 2a–d). The differences in growth rate at all temperatures were significant at post marsupial development (Table 3) ($P \leq 0.05$), with the warmest temperature treatment resulting in the fastest growth rate (Figs 2a–d). The growth rate of both species at each temperature increased during the early stages, and then decreased steadily at larger sizes before maturation (Figs. 2a–d). In later stages there is no significant difference in growth rate at each temperature.

Table 2: Length of maturity and the time taken for maturation at different temperatures, *T. chiltoni* and *T. novaezealandiae*.

	Temperature (°C)	*T. chiltoni*	*T. novaezealandiae*
Length of juveniles (mm) release from the marsupium		2–2.14	1.60–1.70
Length of maturity (mm)		9–10	5–6
Time taken to reach maturity at different temperatures (days)	13±1	73–93	57–65
	18±1	61–73	45–53
	23±1	49–57	25–33

Table 3: Significance/non significance in variation of growth of *T. chiltoni* and *T. novaezealandiae* at temperatures of 13, 18 and 23°C.

Species	Factor	df	F value	Significance
T. chiltoni	Days	14	141.58	S
	Temperature	2	55.67	S
T. novaezealandiae	Days	14	489.71	S
	Temperature	2	611.98	S

s = significant at $P \leq 0.05$, df=degree of freedom

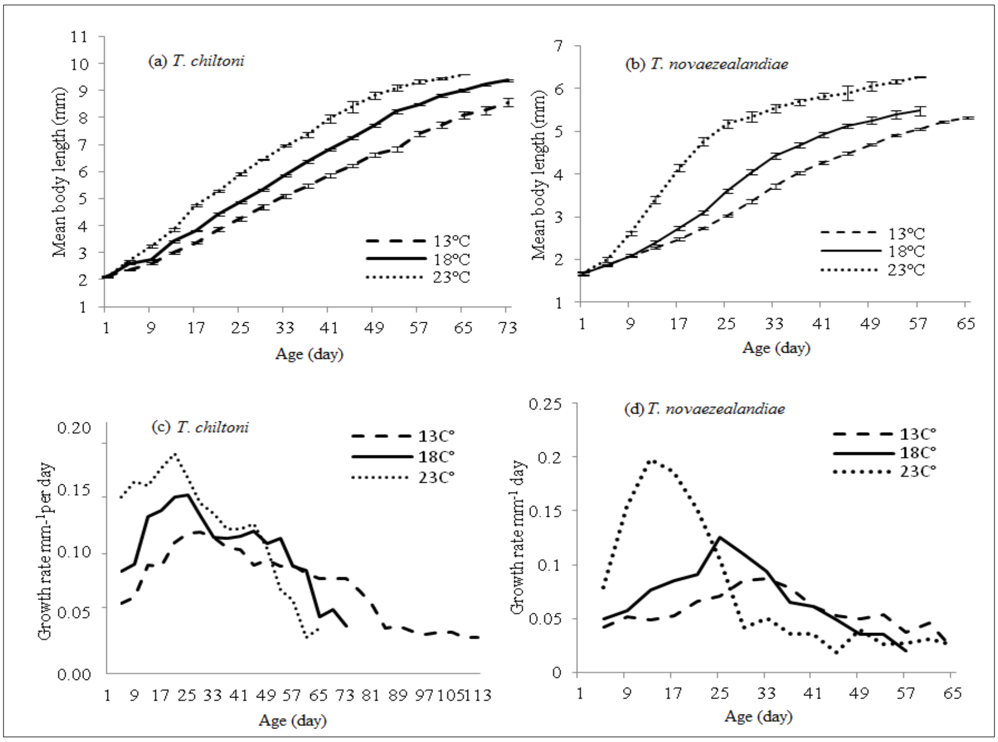

Fig 2: Growth of mysids reared in the laboratory at different temperature. (a & c) *T. chiltoni*, (b & d) *T. novaezealandiae*.

3.3 Effect of temperature on survival of adult mysids

Temperature has a significant effect on the survival of both adult *Tenagomysis* sp. According to the Kaplan-Meier non-parametric survival test, the lowest survival of adult *T. chiltoni* and *T. novaezealandiae* was at 23±1°C. The recorded maximum survival was at 13±1°C, *T. chiltoni* (76%) and *T. novaezealandiae* (80%). Moderate survival for both species was recorded at 18 ± 1°C (Fig. 3). Wilcoxon test and Log-Rank test confirmed ($P \leq 0.05$) that median survival for *T. chiltoni* and *T. novaezealandiae* were significantly different at the three different temperatures (Table 4).

Table 4: Significance/non significance in variation of survival of *T. chiltoni* and *T. novaezealandiae* at 13, 18 and 23°C.

Species	Method	Chi-square	df	Significance
T. chiltoni	Log-Rank	24.08	2	s
	Wilcoxon	22.55	2	s
T. novaezealandiae	Log-Rank	20.75	2	s
	Wilcoxon	19.68	2	s

s = significant at $P \leq 0.05$, df = Degree of freedom

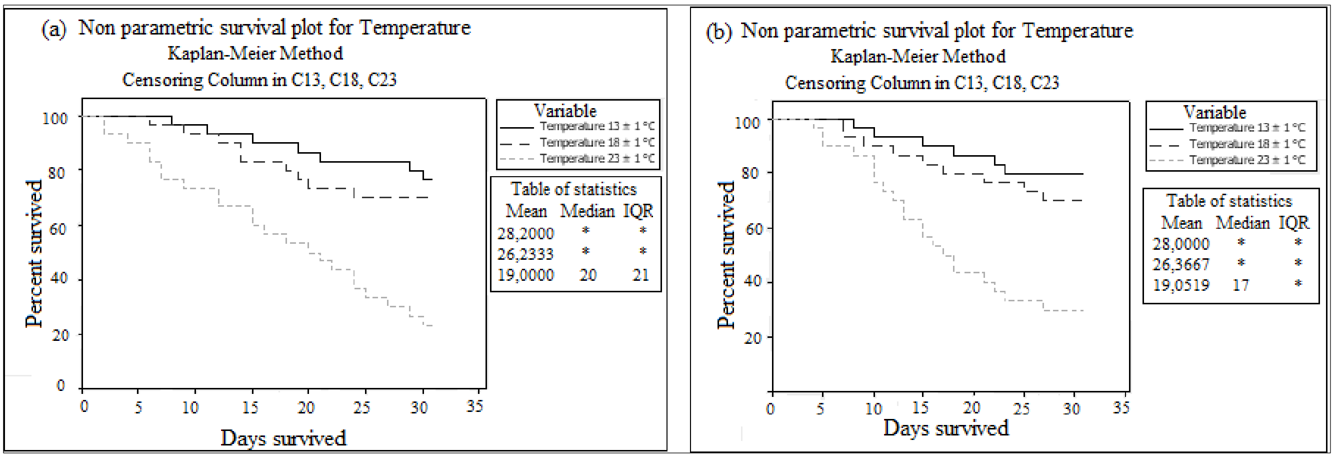

Fig 3: Survival plot of adult mysids at different temperatures, (a) *T. chiltoni* (10–14 mm) (b) *T. novaezealandiae* (6–8 mm)

3.4 Life histories and generations of mysids

Each larval stages and the post larval stages of *T. chiltoni* were larger than *T. novaezealandiae*. At all temperatures, *T. chiltoni* had a significantly longer incubation period than *T. novaezealandiae*. Both intra-marsupial and post-marsupial development period until maturation is introduce here as the generation time.

Table 5: Summary of calculated generation time of mysids at different temperatures.

Species	Temperature (°C)	Intra-marsupial development time (≈ day)	Post-marsupial development time (≈ day)	Generation Time (≈ month)
T. chiltoni	13±1*w	24	73–93	3.50–4.00
	18±1*sp	16–17	61–73	2.75–3.25
	23±1*su	10–11	49–57	2.00–2.50
T. novaezealandiae	13±1*w	21–22	57–65	2.75–3.00
	18 ±1*sp	12–13	45–53	2.00–2.25
	23±1*su	8	25–33	1.25–1.50

w≈ Winter temperature, *sp ≈ Spring and Autumn temperature, *su ≈ Summer temperature

At each temperature the generation time was longer in *T. chiltoni* than *T. novaezealandiae*. Based on the findings of incubation time and growth in both species reared in the laboratory conditions, the approximate generation time at each temperature is calculated and given in Table 5.

3.5 Generations and cohorts

During the culture experiments both *T. chiltoni* and *T. novaezealandiae* produced five broods. The lengths of brooding females ranged between 11–17.8 mm and 5.9–10.1 mm for *T. chiltoni* (Table 6) and *T. novaezealandiae* (Table 8) respectively.

Table 6: Monthly collected adult female *T. chiltoni*, with their potential production of generations and the condition of their marsupium.

	Adult Length (mm)				
Time	**Generation 1**	**Generation 2**	**Generation 3**	**Generation 4**	**Generation 5**
June	11.2-11.9(M) 12.0-12.7(L)	12.2-13.1(M) 13.3 -13.9(L)	13.5-14.6(M) 13.6-15.0(L)	14.8-15.7(M) 15.0-16.3(L)	16.2-17.2(M) 16.6(L)
July	10.8-12.2(M)	12.1-13.0(M) 13.3-13.6(L)	13.5-14.0(L) 14.6-15.0(L)	15.2-15.7(M) 15.2-16.6(L)	16.6-17.3(L)
August	10.5-11.9 (M)	12.1-13.1(M)	13.2-13.9(M) 13.6-15.0(L)	15.6 -16.1(M) 15.2-16.7(L)	16.8-17.1(M) 16.5-17.9(L)
September	10.4-11.8(M) 12.6 (L)	12.0-12.9(M) 13.2-13.5(L)	13.4-14.8(M) 13.9-15.4(L)	15.0-16.4(M) 15.16-16.7(L)	16.5-17.8(M) 17.4-18.4(L)
October	10.4-11.9(M)	12.4-12.5(M) 12.6-13.8(L)	13.2-13.6(M) 13.5-15.3(L)	14.7-15.8(M) 15.0-16.2(L)	17.4(M) 17.2-18.5(L)

November	10.4-11.6(M) 11.9-12.9(L)	12.6-13.1(M) 12.6-13.9(L)	13.2-14.1(M) 13.2-15.4(L)	14.4-15.4(M) 14.4-16.6(L)	16.0-17.2(M) 17.0(L)
December	10.2-11.9(M) 10.7-12.4 (L)	12.1-12.9(M) 12.6-13.2(L)	13.4-13.6(M) 13.4-14.5(L)	14.1-15.5(M) 15.5-16.6(L)	
January	10.3-11.7(M) 12.2-13.0(L)	12.2-12.9(M) 12.9-13.3(L)	14.2(L)		
February	10.6-11.6(M) 10.1-10.9(L)	12.1-12.8(M) 12.1-13.3(L)	14.0-14.5(L)		
March	10.6-11.5(M)	13..4-13.8(L)			
April	10.5-11.0(M) 11.3(L)	12.2-12.5(M) 12.5(L)	13.5-14.4(M)		
May	11.0-11.8(M)	12.1-12.5(M) 13.3(L)	13.5-14.4(M) 14-14.7(L)	15.3-15.4(L)	

. (*M – marsupium without larvae, L – Stage I- III larvae present).

Based on the length classes of brooding females, growth rates and generation time of both species, the adult females can be grouped into generations (Table 6, 8). According to both laboratory and field data it is obvious that both species produced five successive broods within their life span. The fifth generation of *T. chiltoni* and *T. novaezealandiae* was detected at the lengths of 16–18 mm (Table 6) and 9–10 mm (Table 8) respectively.

In New Zealand four seasons are: summer, December to February; autumn, March to May; winter, June to August; and spring, September to November. The juveniles released in these seasons produced different seasonal cohorts. Seasonal cohorts for *T. chiltoni* (Table 6, 7) and *T. novaezealandiae* were identified based on the findings of growth rates, generation time, number of generations and number of length classes (Table 8, 9).

T. chiltoni: The juveniles released in early summer (December), mature during January. Their first generation released in early February (Table 7). In summer temperatures (23±1 °C) recorded generation time for *T. chiltoni* was 2.00–2.50 months. Based on this period, successive generations are presented in Table 7. Due to the shorter incubation period (10**–**11 days**)** in summer temperatures (Table 5), they are capable of producing the 2nd generation at the end of February. Accordingly further 3rd, 4th, and 5th generations appeared in March, April and May or up to June respectively. The juveniles born during early January and February also behaved in the same manner (Table 7).

Autumn cohorts produced their first generations during May–August and the successive generations up to September, November and December respectively. This prediction also based on the calculated autumn generation time and incubation period (18±1°C, 2.75–3.25 months) (Table 5). Similarly, winter cohorts produced their successive generations up to summer; the spring cohorts up to autumn (Table 7). Predicted life span of the seasonal cohorts were also calculated and given in Table 7. Accordingly, the shortest life span calculated for summer cohorts (6–7 months) and the longest life span for winter and autumn cohorts (7–8 months). The largest individuals of *T. chiltoni* were recorded during winter, spring and early summer (Table 6).

Table 7: Prediction of seasonal cohorts of *T. chiltoni* and their successive generations.

Initial juvenile Development	**Maturation and successive generations**						**Approximate Life span**
	Maturation	**1st**	**2nd**	**3rd**	**4th**	**5th**	
Summer cohorts							
December	Jan	Feb	Feb	Mar	Apr	May	6 months
January	Feb	Mar	Mar	Apr	May	June	6 months
February	Mar	Apr	May	June	July	Aug	7 months
Autumn cohorts							
March	May	May	June	July	Aug	Sep	7 months
April	June	July	Aug	Sep	Oct	Nov	8 months
May	Aug	Sep	Oct	Nov	Dec	Dec	8 months
Winter cohorts							
June	Sep	Oct	Nov	Dec	Dec	Jan	8 months
July	Oct	Nov	Dec	Dec	Jan	Jan	7 months
August	Nov	Dec	Dec	Jan	Jan	Feb	7 months
Spring cohorts							
September	Nov	Dec	Jan	Jan	Feb	Mar	7 months
October	Dec	Jan	Jan	Feb	Mar	Apr	7 months
November	Jan	Feb	Feb	Mar	Apr	May	7 months

T. novaezealandiae: The juveniles released in early summer mature during January and released their 1st generation during early January (Table 9). In summer temperatures recorded generation time for *T. novaezealandiae* was 1.25–1.50 months. Based on this, successive generations were presented in Table 9. Due to the shorter incubation period (8 days) in summer temperatures (Table 5), they are capable of producing the 2nd generation in early February and 3rd in late February. Accordingly, further 4th and 5th generations can be appeared during March. The juveniles born during early January and February also behaved in the same manner (Table 9).

Autumn cohorts produced their first generations during May–August and the successive generations up to October, November and December respectively. Winter cohorts produced their generations up to summer and spring cohorts produced generations up to summer and autumn (Table 9). Predicted life span of each cohort is given in Table 9.

Accordingly, the shortest life span calculated for summer cohorts (4–5 months) and the longest life span for winter and autumn cohorts (5–6 months). The largest individuals of *T. novaezealandiae* were recorded during winter and spring (Table 8).

Table 8: Monthly collected adult female *T. novaezealandiae*, with their potential production of generations and the condition of their marsupium (with/without larvae).

			Adult Length (mm)		
Time	**Generation 1**	**Generation 2**	**Generation 3**	**Generation 4**	**Generation 5**
June		6.9(M) 6.6-7.1(L)	7.0-7.1(M) 7.2-7.6(L)	8.0-8.6(L)	9.4(M)
July		6.8-6.9(L)	7.4-7.8(M) 7.4-7.6(L)	8.4-9.0 (L)	9.2(L)
August		6.0-6.9(M) 6.9-7.1(L)	7.2-8.00(M) 7.4-8.0(L)	8.2-8.4(M) 8.2-8.9 (L)	9.0(M)
September	5.6(M)	6.6-6.9(M) 6.6-7.1(L)	7.1-8.00(M) 7.2-7.9(L)	8.2-8.6(M) 8.2-9.0 (L)	9.2-9.9(M) 9.2-10.1(L)
October	5.7-6.0 (M)	6.2-6.9(M) 6.7-6.8(L)	7.3-7.8(M) 7.3-7.9(L)	8.2-8.6(M) 8.7-8.9 (L)	9.0-10.3(M) 9.8-10.1(L)
November	5.9(L)	6.3-6.9(M) 6.2-6.9(L)	7.9-8.0(M) 7.4-8.3(L)	8.1-8.8(M) 8.4-9.0(L)	9.0-9.3(M)
December	5.3-5.9(M) 6.0-6.1(L)	6.1-6.9(M) 6.3-6.9(L)	7.1-7.7(M) 7.4-7.8(L)	8.6-8.9(M) 8.6-8.8(L)	
January	5.8-5.9(M) 6.0-6.3(L)	6.1-6.9(M) 6.2-7.1(L)	7.1-8.00(M) 7.4-7.8(L)		
February	5.0-5.8(M) 6.0-6.6 (L)	6.2-7.0(L) -	7.4-7.5(L) -		
March	6.0(M) 6.0-6.4(L)	6.4-6.6(M) 6.5-6.7(L)			
April		6.2-6.9(M) 6.5-7.0(L)	7.4(M) 7.8-8.0(L)		
May	5.8-6.0(M)	6.6-7.0(M) 6.8-7.1(L)	7.2-7.8(M) 7.2-8.0(L)	8.3(M) 8.3-9.3(L)	

(*M – marsupium without larvae; L – Stage I-Stage III larvae present).

All five generations of *T. chiltoni* existed together in the same period during June, September, October, November and December. Four generations existed together in July and August (Fig. 4). Similarly, in *T. novaezealandiae* five generations existed together during April, June to October. Four generations existed together in February, March and November (Fig. 5).

Table 9: Prediction of seasonal cohorts *T. novaezealandiae* and their successive generations.

Initial juvenile development	**Maturation and successive generations**						**Approximate Life span**
Summer cohorts	Maturation	1st	2nd	3rd	4th	5th	
December	Jan	Jan	Feb	Feb	Mar	Mar	4 months
January	Feb	Feb	March	March	Apr	April	4 months
February	March	March	April	April	May	June	5 months
Autumn cohorts							
March	April	April	May	June	July	Aug	6 months
April	May	June	July	Aug	Sep	Oct	7 months
May	July	July	Aug	Sep	Oct	Nov	7 months
Winter cohorts							
June	Aug	Aug	Sep	Oct	Nov	Dec	7 months
July	Sep	Sep	Oct	Nov	Dec	Jan	7 months
August	Oct	Oct	Nov	Dec	Jan	Jan	6 months
Spring cohorts							
September	Nov	Nov	Dec	Dec	Jan	Feb	6 months
October	Dec	Dec	Jan	Jan	Feb	Feb	5 months
November	Jan	Jan	Feb	Feb	Mar	Mar	5 months

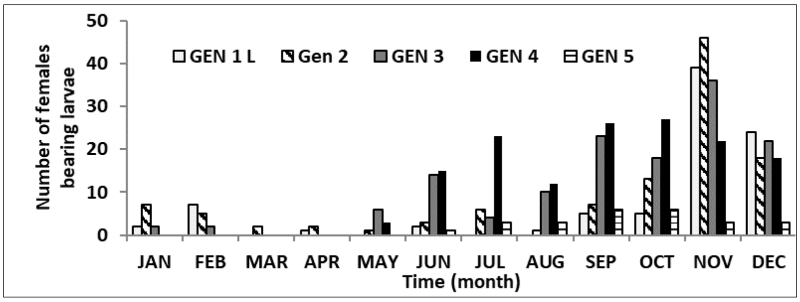

Fig 4: Summary of *T. chiltoni* generations.

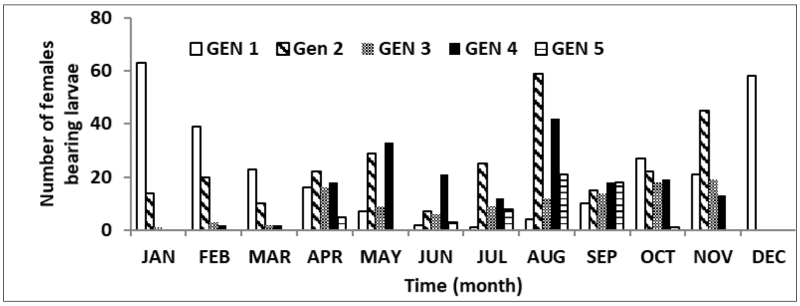

Fig 5: Summary of *T. novaezealandiae* generations.

4. Discussion

Present study revealed that in both species higher water temperature increased the intra marsupial and post marsupial development and decreased the survival of adult mysids. Hence, a shorter incubation period and high growth rates responsible for early reproduction. Laboratory reared *A. mitsukurii* also showed similar results [4]. The temperature dependency of incubation time is strongly agreeable with *A. mixta australis*, *T. tasmaniae* and *P. rufa* [4]. Further same conclusions have been discovered for temperature effect on survival and development time of *N. integer* [6].

Developmental time of each larval stages and the incubation time of *T. chiltoni* at each temperature was longer and each larval stages are larger in size than that of *T. novaezealandiae*. Thus, *T. novaezealandiae* reached maturity in a shorter time, at a smaller size than, *T. chiltoni*. Temperature had more effect on the growth rate of immature individuals than that of mature individuals. In both species decrease in growth rate was observed immediately before maturation. Rising temperatures accelerated the maturity of both species (*T. chiltoni*, 73–93 days at 13°C, 49–57 days at 23°C; *T. novaezealandiae*, 57–65 days at 13°C, 25–33 days at 23°C). Similar results reported for other mysids. In *N. intermedia* [1], *A. robusta* [8] and *A. mitsukurii* [4], growth rate as well as the maturity are strongly affected by the surrounding temperature.

At all temperatures, *T. chiltoni* had a significantly longer incubation period and post marsupial development than *T. novaezealandiae*. Thus, the generation time was longer in *T. chiltoni* than *T. novaezealandiae*. In both species, higher temperatures accelerated the development and resulted the shorter generation time.

For mysids in temperate countries, different seasonal cohorts are produced, such as *N. integer* and *N. americana* which occur in different estuaries produced three generations per year [12, 13]. Due to seasonal temperature variation from 10–25°C in Auckland region, seasonal cohorts were recognizable. In both species summer cohorts showed faster growth rate due to early maturation at higher temperatures. Therefore, summer cohorts have the shortest lifespan (*T. chiltoni*, 6–7 months; *T. novaezealandiae* 4–5 months) due to their accelerated growth in higher temperatures. The temperatures in early autumn (March) were observed to be as high as summer. Thus, the early autumn cohorts grow faster than the late autumn cohorts.

It was revealed in this study, that each seasonal cohort produce generations which overlapping with other cohorts. Thus, both species produced multiple broods and overlapping generations. However, the number of generations varied depending on their lifespan. The lifespan also varies according to the seasonal cohort depending on the temperatures.

Present study evidenced that both species produced five consecutive overlapping generations within their life span. Their longest life span was eight months for *T. chiltoni*, and seven months for *T. novaezealandiae*. The interesting fact is that the longer living mysids were born during autumn and winter. In *T. novaezealandiae* they were bone during mid-autumn to mid- winter while in *T. chiltoni* the longer living mysids were borne during mid-autumn to early winter.

Outcomes of other studies conducted in New Zealand give different view regarding the generations and life span of the present study. *T. chiltoni* populations in South Island (Lake Ellesmere), recognised to have at least two, possibly three generations per year [14] and those from Kaikorai lagoon, with only two generations per year [15]. *T. chiltoni* populations in North Island, Lakes Waahi and Waikare with at least three and possibly four generations per year [16]. Again, the present findings are contrast with [15] and reported *T. novaezealandiae* have three generations annually in Kaikorai lagoon. However, the present North Island study (Auckland) for *T. chiltoni* and *T. novaezealandiae*, recorded five consecutive overlapping generations, it is higher than other studies. On the other hand, in South Island localities, Kaikorai lagoon and Lake Ellesmere, winter temperatures were relatively low (>10°C) during winter and a cessation of breeding may take place in winter [13, 17], therefore, producing fewer generations than North Island populations. However, these studies in New Zealand showed contrasting results with present study, the main reason for this contrast was due to the fact those studies were mainly only field based. Furthermore, they did not consider the potential growth of individuals, the growth rate varies with the season as well as the growth rate differences in immature and mature stages. The present findings were based on both laboratory and field studies with the consideration of seasonal temperature differences. The laboratory experiments which recognized the growth rates of both species at different stages in different temperatures.

The chosen temperatures represent the seasonal water temperatures of study sites and the ambient temperatures in Auckland Region. Under natural conditions water temperature could change day and night and therefore cannot controlled as in laboratory conditions. Therefore, these predicted values obtained under the laboratory conditions might be slightly changed with difference in the temperature. Therefore, considering both wild mysids and laboratory culture together give a better output than considering a single factor as stand-alone.

In order to have an enhanced growth and survival, the tolerance level of temperature is most contributing factor to be considered. These results have important implications for conservation of mysid habitats in estuarine environment, particularly with respect to loss of riparian vegetation, hence shade, as a consequence of coastal development. Due to the findings of this research it is alarming to consider the effects of the global temperature will have on the survival of the minute crustaceans on earth.

5. Conclusion

Higher temperatures accelerated the growth rate, shorten the incubation period and decreased the survival of mysids. The accelerated the growth rate was always shown by the immature individuals and the temperature enhance the faster maturation. *Tenagomysis chiltoni* exhibited a longer incubation period than *T. novaezealandiae* at all temperatures. In addition to this, shorter generation time was also observed at higher temperatures. Both species showed multivoltine life cycles and produced up to five generations within their life time. Life span varied according to the seasonal cohort, shortest in summer and longest in winter. The maximum life span was eight months for *T. chiltoni*, and seven months for *T. novaezealandiae*. The individuals that were born during autumn and winter (autumn and winter cohorts) live longer than those born in summer and spring.

6. Acknowledgment

This project was funded by the Auckland University of Technology, Auckland, New Zealand. Dr. Steve O' Shea is hereby acknowledged for his support during my study.

7. References

1. Toda H, Takahashi M, Ichimura S. The effect of temperature on the post-embryonic growth of *Neomysis intermedia* Czerniawsky (Crustacea, Mysidacea) under laboratory conditions. Journal of Plankton Research, 1984; 6:647-662.
2. Baldo F, Taracido LJ, Arias AM, Drake P. Distribution and life history of the mysid *Rhopalophthalm*us mediterraneus in the Guadalquivir Estuary (SW Spain). Journal of Crustacean Biology, 2001; 21:961-972.
3. Johnston NM, Ritz DA, Fenton GE. Larval development in the Tasmanian mysids *Anisomysis mixta australis*, *Tenagomysis tasmaniae* and *Paramesopodopsis rufa* (Crustacea: Mysidacea). Marine Biology, 1997; 130:93-99.
4. Yamada H, Yamashita Y. Effects of temperature on inter moult period, growth rate and reproduction rate in *Acanthomysis mitsukurii* (Crustacea: Mysidacea*)*. Crustacean research, 2000; 29:160-169.
5. Winkler G, Greve, W. Laboratory studies of the effect of temperature on growth, moulting and reproduction in the co-occurring mysids Neomysis integer and Praunus flexuosus, Marine Ecology Progress Series, 2002; 235:177-18
6. Fockedey N, Ghekiere A, Bruwiere S, Janssen CR. Effect of salinity and temperature on the intra marsupial development of the brackish water mysid *Neomysis integer* (Crustacea: Mysidacea). Marine Biology, 2006; 48:1339-1356.
7. Mauchline J. The biology of mysids and euphausids. Advances in Marine Biology. New York: Acadamic Press Inc. (London), 1980.
8. Sudo H. Effect of temperature on growth, sexual maturity and reproduction of Acanthomysis robusta (Crustacea: Mysidacea) reared in the laboratory. Marine Biology, 2003; 143:1095-1107.
9. Rudstam LG. Hetherington AL, Mohammadian AM, Effect of Temperature on Feeding and Survival of Mysis relicta. Journal of Great Lakes Research. 1999; 25(2):363-371.
10. Paul S, Krkosek M, Probert K, Closs GP. Osmoregulation and survival of two mysid species of Tenagomysis in southern estuaries of New Zealand. Marine and Freshwater Research, 2013; 64:340-347. http://dx.doi.org/10.1071/MF12316.
11. Punchihewa NN. Reproductive biology and intra marsupial development of mysids in Auckland region, New Zealand. International Research Journal of Environmental Science. 2018; 7(9):28-35.
12. Mees J, Abdulkerim Z, Hamerlynck O. Life history, growth and production of Neomysis integer in the Westerschelde estuary (SW Netherlands). Marine Ecology Progress Series, 1994; 109:43-57.
13. Vinas MD, Ramírez FC, Mianzan HW. Annual population dynamics of the opossum shrimp Neomysis americana Smith, 1873 (Crustacea: Mysidacea) from an estuarine sector of the Argentine Sea. Scientia Marina. 2005; 69(4):493-502.
14. Waite RP. Food resource utilization by Tenagomysis chiltoni (Crustacea: Mysidacea). Unpublished MSc. Thesis, University of Canterbury, 1980.
15. Lill AWT, Closs GP, Savage C, Schallenberg M. Annual secondary production of two estuarine mysid species (Mysidacea: Mysidae) inhabiting an intermittently closed estuary, south-eastern New Zealand. New Zealand journal of marine and fresh water research. 2011; 62(7):823-834.
16. Kirk PD. The biology of the mysid shrimps of the lower Waikato area. M.Sc. thesis. University of Waikato, Waikato, 1983.
17. Wittmann KJ. Ecophysiology of marsupial development and reproduction in Mysidacea (Crustacea). Oceanography and Marine Biology, An Annual Review, 1984; 22:417-456.