10龄及14龄中国鲎和圆尾鲎头胸甲宽度与体重的回归分析

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摘要:为了研究鲎形体与体重之间的关系,进一步探讨其生长特性,分别测定了中国鲎(*Tachypleus tridentatus*)和圆尾鲎(*Carcinoscorpius rotundicauda*)14龄成鲎和10龄幼鲎及不同性别的形态参数(头胸甲宽度及体重)。结果表明,中国鲎和圆尾鲎14龄成鲎和10龄幼鲎以及雌、雄的头胸甲宽度与体重均表现为正相关($R^2>0.88$);10龄中国鲎和圆尾鲎异速生长曲线的斜率-回归系数b分别为2.2263和2.1883,而14龄成鲎的回归系数b分别为3.1551和2.6501;10龄和14龄雌、雄中国鲎的b值分别为2.2314(♀)、1.9626(♂)和3.2295(♀)、2.8674(♂),10龄和14龄雌、雄圆尾鲎的b值分别为2.5342(♀)、1.9547(♂)和2.7791(♀)、2.1803(♂),b值均大于1,表明体重增长率大于头胸甲宽度的增长率,处于正生长期,且雌鲎的异速生长率均大于雄鲎;F检验表明,中国鲎和圆尾鲎10龄及14龄不同性别的头胸甲宽度与体重存在极显著的线性关系($P<0.01$)。

关键词:中国鲎;圆尾鲎;回归系数;头胸甲宽度;体重
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中国鲎(*Tachypleus tridentatus*)和圆尾鲎(*Carcinoscorpius rotundicauda*)为我国仅有的2种鲎,隶属于节肢动物门(Arthropoda)、有螯亚门(Chelicerta)、肢口纲(Merostomata)、剑尾目(Xiphosura)、鲎科(Tachypleidae),已有2亿多年的历史,是名副其实的"活化石"(Lamsdell et al, 2013)。目前,世界现存的鲎分为2亚科、3属、4种,美洲鲎亚科(Subfamily Limulinae)仅1属、1种,即美洲鲎(*Limulus polyphemus*);鲎亚科(Subfamily Tachypleinae)分为蝎鲎属和鲎属,由3种亚洲鲎组成,分别为蝎鲎属的圆尾鲎(*C. rotundicauda*)和鲎属的中国鲎(*T. tridentatus*)与南方鲎(*T. gigas*)。鲎具有极高的经济价值和科研价值,其壳可入药(洪水根, 2011),从鲎血中提取的鲎素不仅能快速检测出生物体内的毒素(Levin & Bang 1968; Pei et al, 2013),还能有效地抑制菌体(Watanabe et al, 2013)、肿瘤(谢海伟等, 2013;Wang et al, 2013)及病毒的活性;鲎独特的视神经功能使之成为仿生学重要的模式生物(Thomson 1963; Evert,1969);而独特的蓝色血液与早期三叶虫阶段的特殊发育,也使之成为生物进化及动物生理研究的重要材料(Nossa et al, 2013)。鲎的价值虽然很高,但是随着环境的恶化与人为捕捞的加剧,其资源量急剧减少,需加大保护力度(Hajeb et al, 2009a;2009b;Kamaruzzaman et al, 2011)。

国内外学者在鲎的生物学方面进行了相关研究(Sekiguchi et al, 1988a;洪水根, 2011;Nossa et al, 2013);而有关圆尾鲎的研究相对较少(吕林兰等, 2006)。有学者通过野外试验(Rudloe 1981; Botton et al, 2003)及实验室饲养实验(Sekiguchi et al, 1988a; Lee & Morton, 2005)对比了鲎的生长特性;研究发现,幼鲎摄食情况可以通过增重率来衡量,认为其生长指标-头胸甲宽度及体重的测量和比较分析尤为重要(Lee & Morton, 2005);而异速生长(对生物体部位间不同关系的研究)提供了重要的增长信息,反映出鲎种群生长发育的不均匀性(Sahu & Dey, 2013)。目前,生物学家已经用此方法来评估生物群体的生长特性(Sekiguchi et al, 1976;1978);中国鲎和圆尾鲎的生长速度与头胸甲宽之间的关系还未见报道,因此本文拟通过探究不同年龄中国鲎和圆尾鲎头胸甲宽与体重的关系,以期为其生物学研究提供基础数据。

1 材料与方法

1.1 实验材料

实验用10龄及14龄中国鲎与圆尾鲎均来自于广西合浦县西场镇邻近海域,按年龄大小分别养殖,

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并用黄色透明的塑料标签(10 mm × 5 mm)用超强力胶水标记于蛏的腹甲左面,分别放入 4 个塑料容器内(30 cm × 45 cm × 30 cm),每日更换盐度为 28 的新鲜海水,养殖方法参考 Lee & Morton(2005)。

1.2　形态观察与测量

圆尾蛏和中国蛏外部形态特征有着明显的区别,圆尾蛏的头胸甲圆弧状,背面散布有微小的刺,腹甲后端背面正中有小隆起,后半部腹面两侧长有白毛,端面大体呈圆形,剑尾表面无小刺;而中国蛏的背面圆突,腹面凹陷,剑尾酷似三角刮刀。首先根据其外部形态特征将圆尾蛏和中国蛏进行分类,并做好标记。

将不同的蛏洗涤干净并用滤纸擦拭干后进行头胸甲宽度、体长及体重的测量。通过数显游标卡尺测量蛏的头胸甲宽度和体长,通过电子天平称量其体重,并分别记录其不同性别的生理指标。

1.3　数据分析

利用软件 SPSS17.0 进行统计分析,Excel 2003 进行线性回归;对不同性别和类别蛏的体重与头胸甲宽度进行回归分析,获得异速生长曲线的斜率 - 回归系数 b(体重的 log 值与前体宽度的 log 值)及截距,并对回归系数进行 F 检验。

2　结果

参照 Sekiguchi 等(1988a;1988b)和 Chiu & Morton (2004)的分龄标准,对中国蛏与圆尾蛏个体的生理指标进行统计分析(表 1)。结果表明,10 龄和 14 龄中国蛏的平均头胸甲宽度和体重数值均比圆尾蛏的大,说明中国蛏比圆尾蛏的生长速度快。分别绘制 10 龄、14 龄不同性别中国蛏与圆尾蛏头胸甲宽度间隔内体重增加量的平滑曲线及数据转换为对数后的线性回归分析(表 2),体重及头胸甲宽度均在直线附近分布,并获得了异速生长曲线的斜率 - 回归系数 b;其中,中国蛏 10 龄幼蛏的回归系数 b 为 2.2263,截距为 -2.8140(图 1);14 龄成蛏的回归系数达到最高,为 3.1551,截距为 -4.4605(图 2);圆尾蛏 10 龄幼蛏的回归系数 b 为2.1883,截距为 -2.8337(图 3);14 龄成蛏的回归系数 b 为 2.6501,截距为 -3.3773(图 4)。

表 1　10 龄和 14 龄中国蛏及圆尾蛏的头胸甲宽度与体重

Tab.1　Prosomal width and body weight of 10th and 14th instars of *T. tridentatus* and *C. rotundicaudath*

种 类	龄期	数量/只	头胸甲宽度/mm	平均宽度/mm	体重范围/g	平均体重/g
中国蛏	10	27	46.09 ~ 55.44	52.01 ± 0.49	7.66 ~ 12.05	10.18 ± 0.21
中国蛏	14	23	122.08 ~ 156.36	137.69 ± 1.85	136.58 ~ 290.60	196.92 ± 8.76
圆尾蛏	10	10	46.78 ~ 52.42	49.07 ± 0.52	6.82 ~ 8.24	7.52 ± 0.14
圆尾蛏	14	42	112.66 ~ 143.53	126.08 ± 1.40	108.76 ~ 215.64	156.59 ± 4.70

表 2　中国蛏与圆尾蛏头胸甲宽度对数与体重对数的回归分析

Tab.2　Relationship of log values of prosomal width and body weight of *T. tridentatus* and *C. rotundicauda*

种 类	龄期	回归方程	R^2	P
中国蛏	10	$y = 2.2263x - 2.8140$	0.9610	< 0.01
中国蛏	14	$y = 3.1551x - 4.4605$	0.9513	< 0.01
圆尾蛏	10	$y = 2.1883x - 2.8337$	0.9651	< 0.01
圆尾蛏	14	$y = 2.6501x - 3.3773$	0.9445	< 0.01

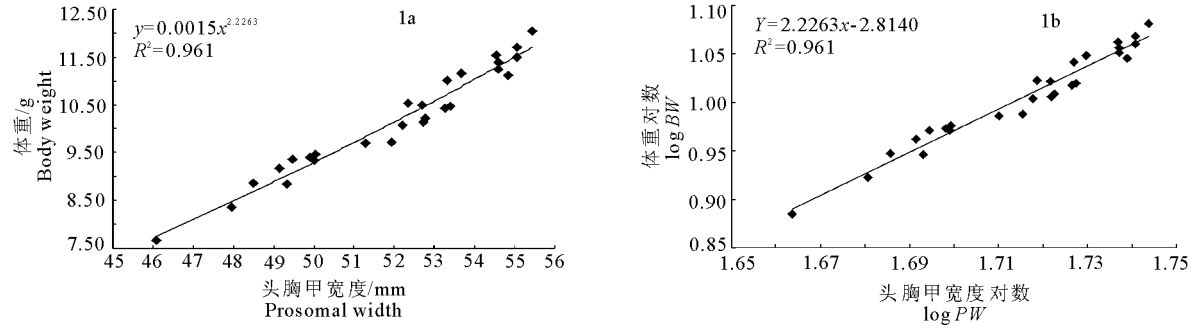

图 1　10 龄中国蛏体重与头胸甲宽度(1a)及其对数(1b)关系

Fig.1　Relationship between body weight and prosomal width(1a) and relationship of log values of prosomal width and body weight (1b) of the 10th instar of *T. tridentatus*

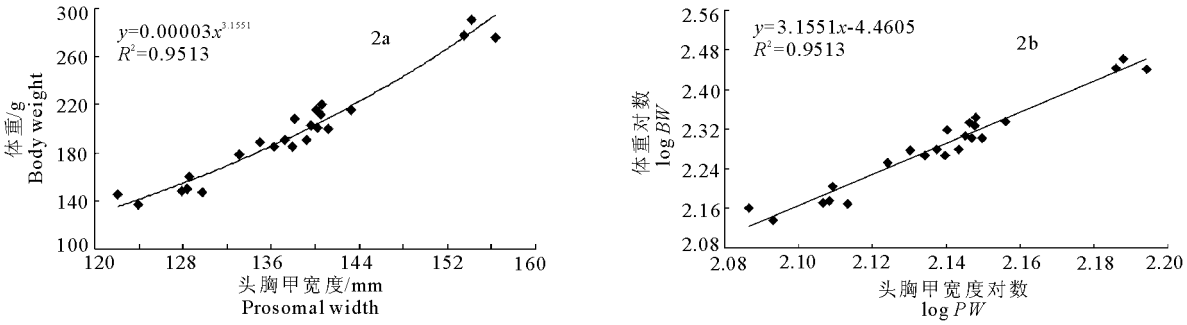

图 2 14 龄中国螨体重与头胸甲宽度(2a)及其对数(2b)关系

Fig. 2 Relationship between body weight and prosomal width(2a) and relationship of log values of prosomal width and body weight (2b) of the 14th instar of *T. tridentatus*

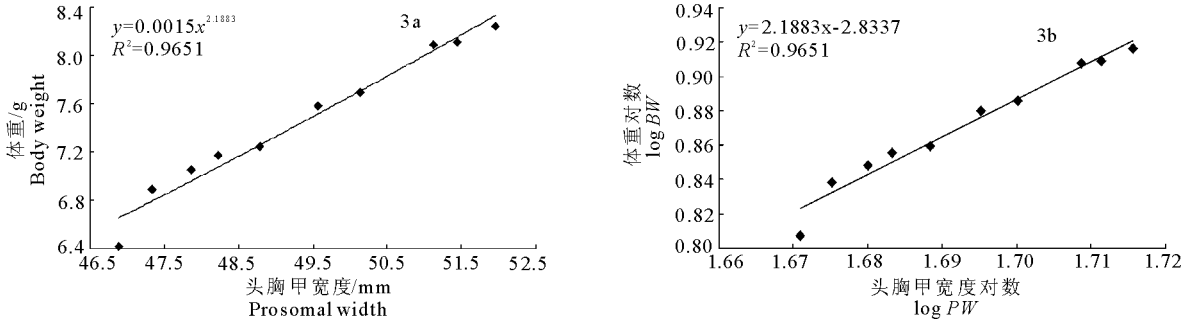

图 3 10 龄圆尾螨体重与头胸甲宽度(3a)及其对数(3b)关系

Fig. 3 Relationship between body weight and prosomal width(3a) and relationship of log values of prosomal width and body weight (3b) of the 10th instar of *C. rotundicauda*

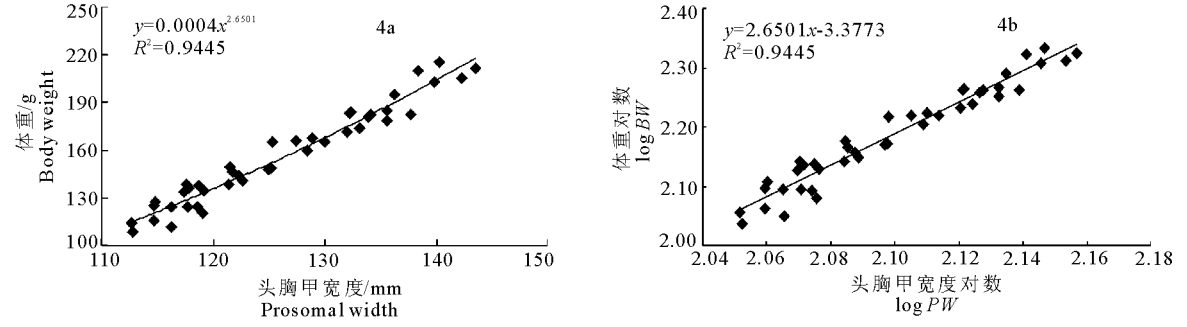

图 4 14 龄圆尾螨体重与头胸甲宽度(4a)及其对数(4b)关系

Fig. 4 Relationship between body weight and prosomal width(4a) and relationship of log values of prosomal width and body weight (4b) of the 14th instar of *C. rotundicauda*

不同性别中国螨与圆尾螨头胸甲宽度与体重测量数据见表3,线性回归关系见图5~8。对其异速生长情况进行分析发现,10 龄中国螨雌螨回归系数(截距)为 2.2314(−2.8180),雄螨为 1.9626(−2.3680);14 龄中国螨雌螨的回归系数(截距)为3.2295(−4.6131),雄螨为2.8674(−3.8553);圆尾螨 10 龄幼雌螨回归系数(截距)为2.5342(−3.4176),雄螨为1.9547(−2.4352);14 龄圆尾螨雌螨为 2.7791(−3.6498),雄螨为 2.1803(−2.3744)(表4)。初步认为不同类别、不同性别及不同年龄螨的头胸甲宽度和体重之间存在一定的线性关系,通过进一步回归系数的 F 检验,发现中国螨和圆尾螨 10 龄及 14 龄不同性别螨的头胸甲宽度与体重存在极显著的线性关系($P<0.01$)。

表 3　不同性别中国蚕和圆尾蚕的头胸甲宽度与体重

Tab. 3　Prosomal width and body weight of different sexes of *T. tridentatus* and *C. rotundicauda*

种类	龄期	性别	数量/只	头胸甲宽度/mm	平均宽度/mm	体重范围/g	平均体重/g
中国蚕	10	雌	12	47.94 ~ 55.44	53.41 ± 0.69	8.36 ~ 12.05	10.91 ± 0.30
		雄	15	46.09 ~ 53.39	50.89 ± 0.54	7.66 ~ 10.47	9.60 ± 0.20
	14	雌	10	138.15 ~ 154.17	143.12 ± 1.83	200.30 ~ 290.60	224.65 ± 10.23
		雄	13	122.08 ~ 156.36	133.51 ± 2.42	136.58 ~ 276.38	175.60 ± 10.08
圆尾蚕	10	雌	5	47.34 ~ 51.96	50.29 ± 0.84	6.89 ~ 8.24	7.78 ± 0.25
		雄	5	46.88 ~ 50.13	48.38 ± 0.54	6.42 ~ 7.69	7.11 ± 0.20
	14	雌	23	112.66 ~ 129.97	120.21 ± 1.10	108.76 ~ 167.15	135.83 ± 3.69
		雄	19	117.61 ~ 143.53	133.18 ± 1.72	137.45 ~ 215.64	181.72 ± 5.22

表 4　不同性别中国蚕和圆尾蚕头胸甲宽度对数与体重对数的回归分析

Tab. 4　Relationship of log values of prosomal width and body weight of different sexes of *T. tridentatus* and *C. rotundicauda*

种类	龄期	性别	回归方程	R^2	P
中国蚕	10	雌	$y = 2.2314x - 2.8180$	0.9678	< 0.01
		雄	$y = 1.9626x - 2.3680$	0.9541	< 0.01
	14	雌	$y = 3.2295x - 4.6131$	0.9145	< 0.01
		雄	$y = 2.8674x - 3.8553$	0.9461	< 0.01
圆尾蚕	10	雌	$y = 2.5342x - 3.4176$	0.9248	< 0.01
		雄	$y = 1.9547x - 2.4352$	0.9951	< 0.01
	14	雌	$y = 2.7791x - 3.6498$	0.8797	< 0.01
		雄	$y = 2.1803x - 2.3744$	0.9231	< 0.01

3　讨论

3.1　中国蚕和圆尾蚕的研究进展

尽管有关蚕的研究已经进行了 1 个世纪,由于在实验室内人工繁育受精卵至成蚕的难度太大(Sekiguchi et al,1988a;1988b; Chatterji 1994),有关蚕具体的寿命、确切的蜕皮次数及龄期鉴定等问题至今仍未得到解决(Tanacredi & John, 2001; Carmichael et al,2003);最好的蚕生长测定方法就是跟踪调查自然环境下个体从孵化至成熟的整个过程(Sekiguchi et al,1988a),但这个方法太不切实际。除了通过直接测量已蜕皮个体(Carmichael et al, 2003)或是蜕皮的形态指标外(Shuster,1958;

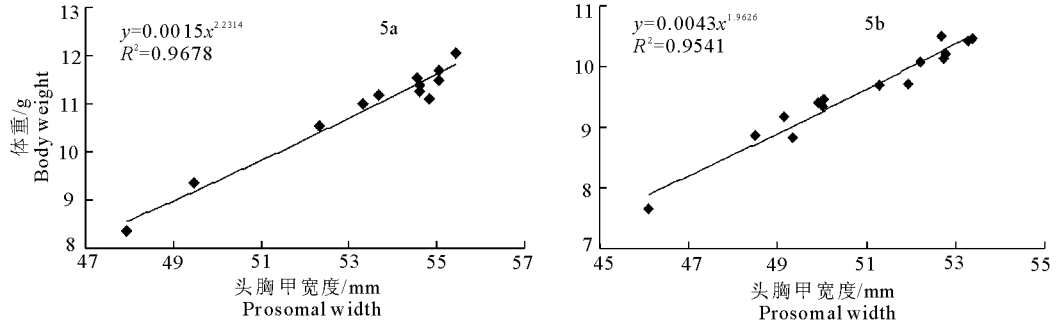

图 5　10 龄中国蚕雌蚕(5a)和雄蚕(5b)体重与头胸甲宽度的关系

Fig. 5　Relationship between body weight and prosomal width of females(5a) & males(5b) of 10th instar of *T. tridentatus*

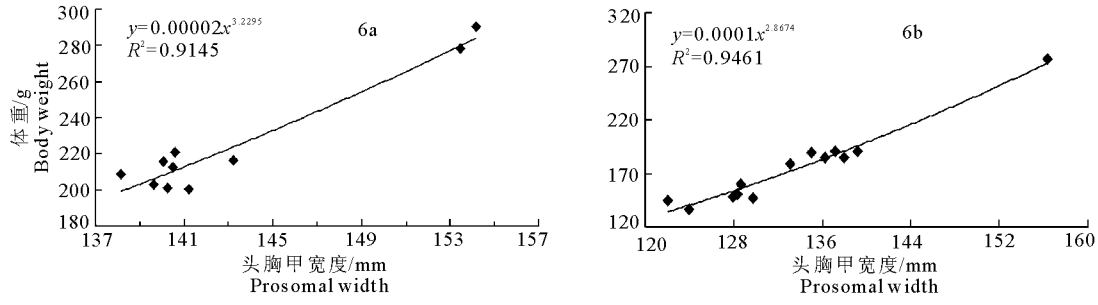

图 6　14 龄中国蚕雌蚕(6a)和雄蚕(6b)体重与头胸甲宽度的关系

Fig. 6　Relationship between body weight and prosomal width of females(6a) & males(6b) of 14th instar of *T. tridentatus*

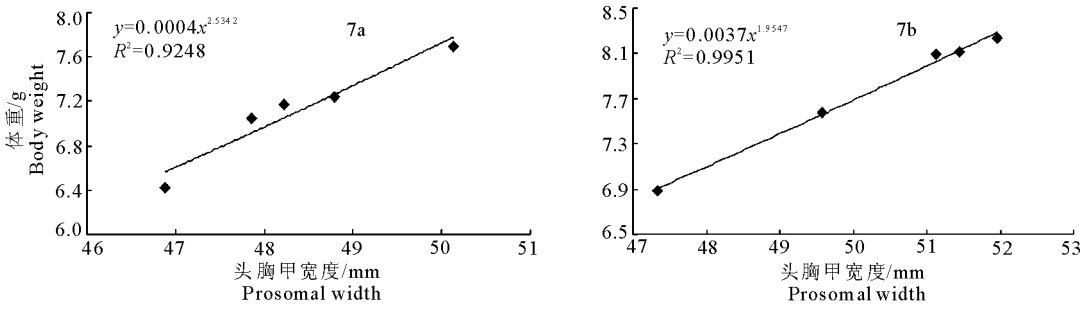

图7 10 龄圆尾蝗雌蝗(7a)和雄蝗(7b)体重与头胸甲宽度的关系

Fig. 7 Relationship between body weight and prosomal width of females(7a) & males(7b) of 10th instar of *T. tridentatus*

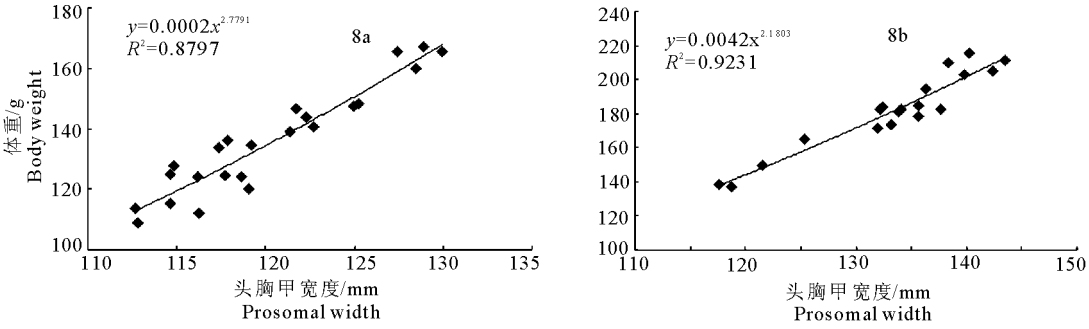

图8 14 龄圆尾蝗雌蝗(8a)和雄蝗(8b)体重与头胸甲宽度的关系

Fig. 8 Relationship between body weight and prosomal width of females(8a) & males(8b) of 14th instar of *T. tridentatus*

1982),对中国蝗和圆尾蝗生长率的直接测定也逐步在实验室内展开。

3.2 不同地区及不同种群蝗的生长评价指标

本研究发现,10 龄幼蝗与 14 龄成蝗的中国蝗和圆尾蝗头胸甲宽度与体重间均表现为正相关(相关系数R^2 >0.88;图 1 -4),并获得了异速生长曲线的斜率 - 回归系数 b;其中,中国蝗 10 龄幼蝗的回归系数 b 为 2.2263,截距为 -2.8140;14 龄成蝗的回归系数达到最高,为 3.1551,截距为 -4.4605;圆尾蝗 10 龄幼蝗的回归系数 b 为2.1883,截距为 -2.8337;14 龄成蝗的回归系数 b 为 2.6501,截距为 -3.3773。根据 Shuster(1958)报道的蝗生长评价指标方法,当 b >1 意味着正生长,即体重增长率大于头胸甲宽度增长率;反之亦然,b <1 意味着负生长,即体重增长率小于头胸甲宽度增长率;b = 1 为等速生长。以回归系数对中国蝗与圆尾蝗的异速生长进行评价时发现,本实验中 10 龄及 14 龄的圆尾蝗和中国蝗的 b 值均大于 1,意味着体重增长率大于头胸甲宽度的增长率,因此所以认为其处于正生长期;这一结论与不同地区及不同种群的研究结果一致。Chatterji 等(1988)对印度孟加拉邦蝗的研究发现,该地圆尾蝗(*C. rotundicauda*)的 b 值(截距)为 3.89(-0.61);Vijayakumar 等(2000)对 137 只南方蝗进行了形态测量与回归分析,得出体重增长率要高于头胸甲宽度的增长率,相关系数 r =0.92;Morton & Lee(2003)计算得出香港中国蝗 b 值(截距)为 2.48(-3.25);Lee & Morton(2005)对从香港沙滩中采样获取的头胸甲宽度在 17.1 ~ 91.1 mm(6 ~12 龄)的中华蝗幼蝗及圆尾蝗幼蝗进行测定,获得了头胸甲宽度与湿重的回归系数 b 值为 2.9682,截距为 -4.07,决定系数 R^2 为 0.9485;由于样本龄期及所处环境的差异,所以回归系数 b 与本实验结果略有差异。Zadeh 等(2009)测得马来西亚 1 ~7 龄圆尾蝗头胸甲宽度与体重的 b 值为 2.6727,R^2 为 0.9974;1 ~6 龄南方蝗幼蝗的 b 值为 2.4845,R^2 为 0.9894。

3.3 不同地区及不同种群蝗回归系数的性别差异

除不同地区以及不同种群的回归系数有差异外,b 值还会随性别的不同而有变化。本研究发现,10 龄雌、雄中国蝗 b 值为 2.2314 和 1.9626,14 龄的 b 值为 3.2295 和 2.8674;10 龄雌、雄圆尾蝗 b 值为 2.5342 和 1.9547,14 龄的 b 值为2.7791和2.1803。研究数据表明,不同种类、不同龄期的雌蝗异速生长率均大于雄蝗,成蝗的异速生长率大于幼蝗,这一结

果与以往的研究相同。Chatterji(1994)得出印度南方鲎(*T. gigas*)雌雄成鲎的 b 值(截距)分别为 2.90(-4.05)和 2.55(-3.29),且成鲎体重的增加量大于雌鲎壳长的立方,大于雄鲎壳长的平方;Chiu & Morton (2003)得到的香港中国鲎 b 值均较低,雌雄鲎分别为 2.13 和 1.89,而雌雄香港圆尾鲎的 b 值分别为 2.69 和 2.00,并确定了香港中国鲎的回归系数 b 与年龄的关系;Ismail 等(2011)对马来西亚珍多海滩与珍拉丁海滩的南方鲎头胸甲宽度与体重关系进行了比较,得出珍多海滩采集的雄鲎 b 值(截距)为 1.1923 (1.0145),雌鲎为 2.0408 (0.2069),珍拉丁海滩采集的雄鲎为 1.8474 (0.2283),雌鲎为3.0172(-1.1385),表明雌鲎体重增加速度是前体宽度增长速度的 3 倍。

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Regression Analysis between Prosomal Width and Body Weight of 10th and 14th Instar Stages of *Tachypleus tridentatus* and *Carcinoscorpius rotundicauda*

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Abstract: To investigate the relationship of body size and body weight of *T. tridentatus* and *C. rotundicauda*, the morphometric parameters including prosomal width and body weight were measured for males and females in 10th and 14th instar stages. The allometric analysis revealed that both 10th and 14th instars of *T. tridentatus* and *C. rotundicauda* exhibited a very high degree of positive correlation between prosomal width and body weight ($R^2 > 0.88$). The regression coefficient (b) for *T. tridentatus* and *C. rotundicauda* in 10th instar were 2.2263, 2.1883, and 3.1551, 2.6501 for 14th instar, respectively. The "b" values for females (♀) and males (♂) of *T. tridentatus* were 2.2314(♀, 10th), 1.9626(♂, 10th), 3.2295(♀, 14th), 2.8674(♂, 14th), and the values for *C. rotundicauda* were 2.5342(♀, 10th), 1.9547(♂, 10th), 2.7791(♀, 14th), 2.1803(♂, 14th) respectively, indicating that the weight gain was faster than the growth of prosomal width and females showed stronger positive allometry than males. Meanwhile, F test results showed that significant linear relationship was observed between the prosomal width and body weight of 10th and 14th instars of *T. tridentatus* and *C. rotundicauda* of both sexes($P < 0.01$).

Key words: *Tachypleus tridentatus*; *Carcinoscorpius rotundicauda*; regression coefficient; prosomal width; body weight