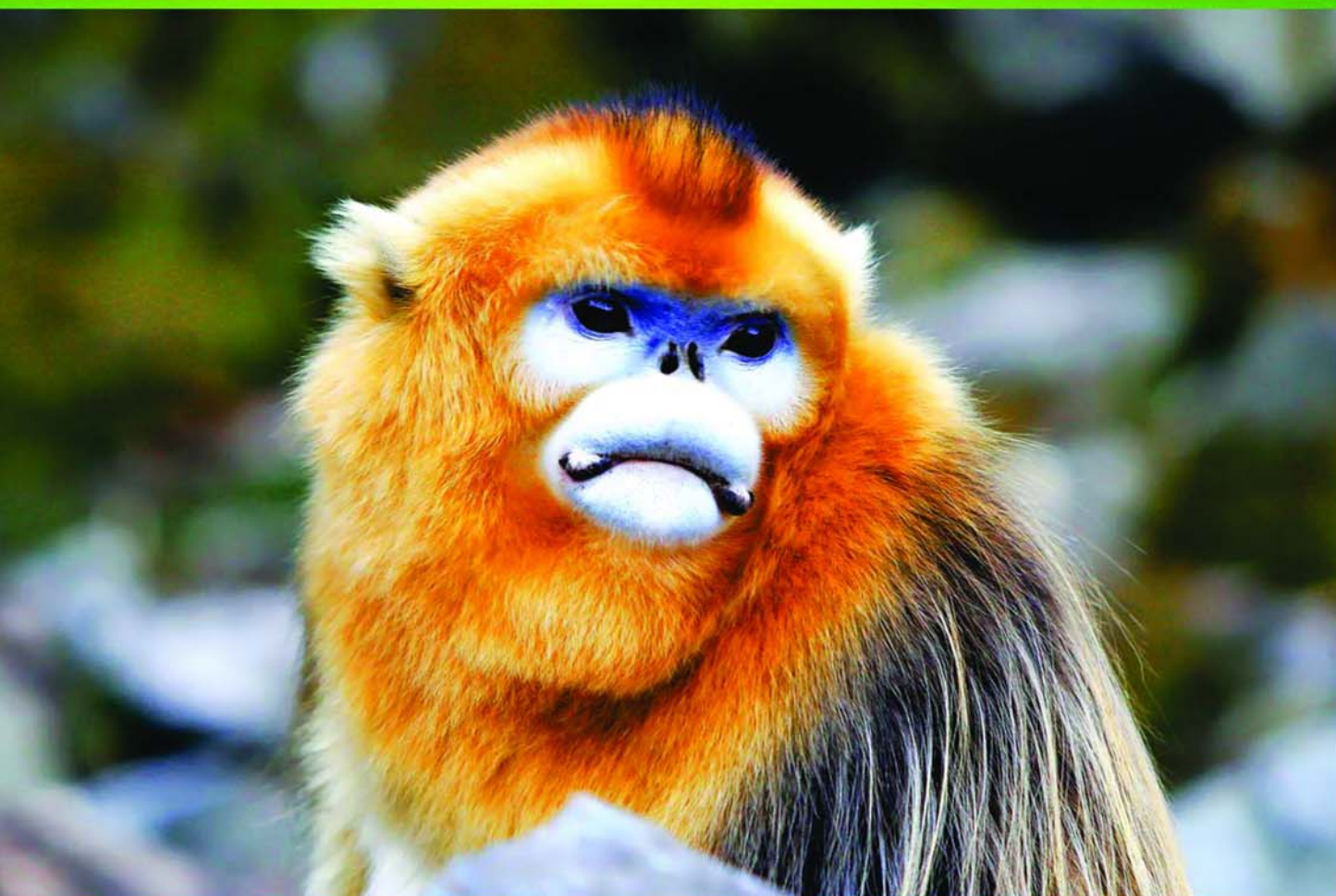


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封面图说: 雄视——中国的金丝猴有川、黔、滇金丝猴三种,此外还有越南和缅甸金丝猴两种。金丝猴是典型的森林树栖动物,常年栖居于海拔 1500—3300m 的亚热带山地、亚高山针叶林、针阔叶混交林,常绿落叶阔叶混交林中,随着季节的变化,只在栖息的生境中作垂直移动。川金丝猴身上长着柔软金色长毛,十分漂亮。个体大,嘴角处有瘤状突起的是雄性金丝猴的特征。川金丝猴只分布在中国的四川、甘肃、陕西和湖北省。属国家一级重点保护、CITES 附录一物种。

彩图提供: 陈建伟教授 国家林业局 E-mail: cites.chenjw@163.com

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沉积再悬浮颗粒物对马氏珠母贝摄食 生理影响的室内模拟

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摘要: 采用实验生态学方法室内模拟研究了不同浓度沉积再悬浮颗粒物对马氏珠母贝清滤率、摄食率、吸收率的影响。结果表明: (1) 水体中总悬浮颗粒物对马氏珠母贝清滤率的影响极显著 ($P < 0.01$)。总悬浮颗粒物由低浓度 (12.6 mg/L) 趋高浓度 (500 mg/L) 时, 马氏珠母贝的清滤率呈现峰值变化规律。与总悬浮颗粒物浓度 50 mg/L 时的最大清滤率 ($1.12 \text{ L} \cdot \text{个体}^{-1} \cdot \text{h}^{-1}$) 比较, 悬浮颗粒物浓度为 500 mg/L 时, 清滤率达最小值 ($0.17 \text{ L} \cdot \text{个体}^{-1} \cdot \text{h}^{-1}$), 其清滤率降幅达 85%。这表明在高浓度悬浮颗粒物的水环境下, 贝类受到环境胁迫, 其生理和自身摄食机制受到限制, 引起摄食减少和机体损伤。马氏珠母贝类的清滤率 (CR) 与总悬浮颗粒物浓度 (TPM) 之间的关系可表达为: $CR = -0.701 + 1.627 \times \text{TPM} - 0.463 \times \text{TPM}^2 + 0.036 \times \text{TPM}^3$ ($R^2 = 0.928$)。 (2) 水体中总悬浮颗粒物对马氏珠母贝摄食率的影响极显著 ($P < 0.01$)。马氏珠母贝的摄食率随着总悬浮颗粒物浓度的升高而增加, 在 50 mg/L 时达最大值 (38.28 mg/h), 当总悬浮颗粒物浓度超过 50 mg/L 时, 摄食率反而下降, 在总悬浮颗粒物浓度为 500 mg/L 时, 降为最小值 (16.22 mg/h), 摄食率降幅为 58%。随着悬浮颗粒物浓度的增加, 马氏珠母贝摄食率受到的影响小于清滤率受到的影响。马氏珠母贝类的摄食率 (IR) 与总悬浮颗粒物浓度 (TPM) 之间的关系可表达为: $IR = -46.631 + 70.957 \times \text{TPM} - 18.385 \times \text{TPM}^2 + 1.367 \times \text{TPM}^3$ ($R^2 = 0.907$)。 (3) 水体中总悬浮颗粒物对马氏珠母贝吸收率影响极显著 ($P < 0.01$)。总悬浮颗粒物由低浓度 (12.6 mg/L) 趋高浓度 (500 mg/L) 时, 马氏珠母贝的吸收率呈逐渐下降趋势, 在总悬浮颗粒物 12.6 mg/L 时, 马氏珠母贝的吸收率最大 (48.57%), 而总悬浮颗粒物 500 mg/L 时, 马氏珠母贝的吸收率最小 (8.56%)。马氏珠母贝的吸收率 (AE) 与总悬浮颗粒物浓度 (TPM) 之间的关系可表达为: $AE = 52.189 + 0.132 \times \text{TPM} - 3.111 \times \text{TPM}^2 + 0.316 \times \text{TPM}^3$ ($R^2 = 0.976$)。
关键词: 马氏珠母贝; 沉积再悬浮颗粒物; 清滤率; 摄食率; 吸收率

Effect of suspended sediment on the feeding physiology of *Pinctada martensii* in laboratory

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Abstract: *Pinctada martensii*, one of the important species for marine pearl culture, has brought about high economic and social benefits for the coastal communities. In this study, the effect of suspended sediment particles on the feeding physiology (clearance rate CR, ingestion rate IR and absorption efficiency AE) was investigated by adopting the measures of experimental ecology in laboratory to provide both insight into tolerance of *P. martensii* to environmental changes and guidelines for healthy culturing of *P. martensii*. The results were as followed: (1) The total suspended particle had significant effect on clearance rate of *P. martensii* ($P < 0.01$), with peak value of clearance rate of *P. martensii* occurred as

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the total suspended particle varying from 12.6 to 500 mg/L. Compared with the maximum value of $1.12 \text{ L} \cdot \text{ind}^{-1} \cdot \text{h}^{-1}$ at a concentration of 50 mg/L, the clearance rate of *P. martensii* reached the minimum value of $0.17 \text{ L} \cdot \text{ind}^{-1} \cdot \text{h}^{-1}$ at a concentration of 500 mg/L, decreased by 85%. The relationship of the clearance rate and the total suspended particle could be expressed by a function as: $CR = -0.701 + 1.627 \times \text{TPM} - 0.463 \times \text{TPM}^2 + 0.036 \times \text{TPM}^3$ ($R^2 = 0.928$). (2) The total suspended particle had significant effect on ingestion rate of *P. martensii* ($P < 0.01$), the ingestion rate of *P. martensii* increased with increasing suspended particle concentration from 12.6 to 50 mg/L and decreased with suspended particle concentration above 50 mg/L, with the maximum value of 38.28 mg/h at a concentration of 50 mg/L. However, the ingestion rate of *P. martensii* reached the minimum value of 16.22 mg/h at a concentration of 500 mg/L, which reduced to 58% compared with a concentration of 50 mg/L. This showed that the ingestion rate of *P. martensii* was less affected in contrast to the clearance rate, implying *P. martensii* was able to reduce clearance rate for maintaining relatively stable ingestion rate with increasing suspended particle concentration to maintain normal energy balance and to adapt to change of environment. The relationship between the ingestion rate and the total suspended particle could be described by a function as: $IR = -46.631 + 70.957 \times \text{TPM} - 18.385 \times \text{TPM}^2 + 1.367 \times \text{TPM}^3$ ($R^2 = 0.907$). (3) The absorption efficiency of *P. martensii* decreased from 48.57% to 8.56% with increasing suspended particle concentration from 12.6 to 500 mg/L. This suggested that the organic content decrease with increasing suspended particle concentration, causing reduction of the absorption efficiency of *P. martensii*. The relationship of the absorption efficiency and the total suspended particle could be described by a function as: $AE = 52.189 + 0.132 \times \text{TPM} - 3.111 \times \text{TPM}^2 + 0.316 \times \text{TPM}^3$ ($R^2 = 0.976$).

Key Words: *Pinctada martensii*, suspended sediment particle, clearance rate, ingestion rate, absorption efficiency

在浅海养殖水域,由于高流速的洪水、低潮潮汐、风浪活动和间歇性暴雨事件,极易引起沉积颗粒物再悬浮^[1]。沉积颗粒物的再悬浮过程引起了总悬浮颗粒物和颗粒有机物的增加,然而,由于悬浮颗粒物中较高比例的无机物的稀释效应导致悬浮颗粒物中颗粒有机物相对含量显著减少^[1-2],因此,沉积颗粒物再悬浮过程对海洋滤食性贝类可供摄食的食物颗粒物的数量和质量产生显著的影响^[3-5]。尽管悬浮颗粒物中包含滤食性贝类重要食物来源的颗粒有机物^[6],但是,沉积再悬浮颗粒物的浓度的日益增加已经对滤食性贝类产生负面影响^[7]。研究表明,悬浮颗粒物中的粉沙和粘土浓度的增加显著增加贝类假粪的产生,极大减少了可供摄食藻类的数量,同时对贝类的鳃造成损伤^[8-10]。双壳贝类长期暴露在较高浓度悬浮颗粒物的海水中,将导致供贝类生长和繁殖的能量的减少,进而对贝类种群产生有害影响^[11]。因此,沉积颗粒物的再悬浮过程不仅对水域的理化性质产生影响,而且直接影响滤食性贝类摄食生理生态和行为反应^[12]。

马氏珠母贝 (*Pinctada martensii* (Dunker)) 是我国进行海水珍珠养殖的重要种类,隶属于瓣鳃纲 (Lamellibranchia), 翼形亚纲 (Pteromorpha), 珍珠贝目 (Pterioida), 珍珠贝科 (Pteriidae), 主要分布于我国两广、海南、台湾等热带、亚热带海域。近几年,由于种质退化、环境恶化、人为因素等原因,珍珠质量及产量出现滑坡,已引起政府及各研究机构高度的重视,对此开展研究包括马氏珠母贝的选育^[13]、群体内遗传多样性^[14-15]、种群内自繁及种群杂交^[16-17]等侧重于种质退化方面;此外,随着养殖海区自身污染和陆源污染导致浅海养殖海区环境恶化或老化,使海水中沉积再悬浮颗粒物的浓度呈逐渐升高趋势,因养殖环境悬浮颗粒物中的浮泥在贝体表面的沉积极易引起多毛类寄生虫病(俗称黑心肝病或黑壳病)的暴发,已造成该贝出现了不同程度的死亡现象^[18]。多年来,沉积再悬浮颗粒物对贝类摄食生理的影响一直为研究的热点问题,国外学者研究了不同浓度悬浮颗粒物对欧洲鸟尾蛤 (*Cerastoderma edulis*)^[19]、贻贝 (*Mulinia edulis*)^[20]、海螂 (*Mya arenaria*)^[21]、长牡蛎 (*Crassostrea gigas*)^[12]、江珧 (*Atrina zelandica*)^[11]的摄食行为和摄食生理的影响,国内学者探讨了沉积再悬浮颗粒物对栉孔扇贝 (*Chlamys ferrerii*)、紫贻贝 (*Mytilus edulis*) 和菲律宾蛤仔 (*Ruditapes philippinarum*) 摄食生理的影响^[22]。马氏珠母贝作为我国湛江流沙湾珍珠养殖的重要贝类,随着养殖历史的长久和规模的日益增大,因海水中沉积再悬浮颗粒物浓度增大给该贝带来的负面影响受到广泛关注。因此,研究沉积再悬浮

颗粒物对马氏珠母贝摄食生理的影响,对于深层次理解该贝抵抗不良环境的能力显得十分必要。本研究通过模拟浅海沉积颗粒物再悬浮事件,以马氏珠母贝为材料,探讨沉积再悬浮颗粒物对该贝清滤率、摄食率和吸收率的影响,期望揭示该贝对环境变化的耐受力,为浅海贝类健康养殖提供理论依据。

1 材料和方法

1.1 沉积再悬浮颗粒物

采集湛江流沙湾马氏珠母贝筏式养殖区的表层底泥(<2 cm),按照宋强等^[22]方法,将底泥在 60 °C 下烘干至恒重,冷却干燥后,研磨,用 200 目筛绢过筛,保留的颗粒物粒径小于 76 μm。

1.2 实验用贝

实验所用马氏珠母贝于 2010 年 3—4 月采自湛江流沙湾近海珍珠贝养殖区,挑选无损伤个体,洗刷去除表面的附着物,在广东海洋大学海水经济无脊椎动物实验室暂养 7d,实验贝类的生物学数据见表 1。暂养期间自然海水盐度为 28.6—29.1,水温 25.4—26.6 °C, pH 值 8.12—8.35, DO>5 mg/L, NH₄⁺-N <0.05 mg/L, 24 h 充气,每天投喂小球藻(*Chlorella* sp.)和亚心形扁藻(*Platymonas subcordiformis* (Wille) Hazen),日换水 2 次,每次换水 1/2。实验前 24 h 停止投喂饵料,挑选健康的个体进行实验。实验前将贝类放入实验水体适应 1 h。

表 1 马氏珠母贝的生物学测定

Table 1 Biological measurement of *Pinctada martensii*

种类 Species	壳长/mm Shell length	壳高/mm Shell height	干组织重/g Dry tissue weight	干壳重/g Dry shell weight	肥满度/% Rich fitting
马氏珠母贝 <i>Pinctada martensii</i>	57.13±3.368	62.24±4.251	1.57±0.027	11.62±0.648	13.51

1.3 方法

1.3.1 实验设计

实验装置采用宋强等^[22]方法,实验期间,调节充气量使悬浮颗粒物悬浮均匀。海水体积 100 L,海水理化因子同暂养条件。实验设置的悬浮颗粒物浓度分别为 50、100、200、300、400、500 mg/L 6 个实验组和 1 个低浓度海水组(12.6 mg/L,砂滤海水),每组设置 3 个重复组。每个水槽放置马氏珠母贝 10 个。实验各浓度组设置对照组,对照组水槽中不放置贝类,以消除沉降的影响。为消除昼夜摄食节律对实验结果的影响,实验在 9:00 和 21:00 各进行 1 次,取两个时间点的平均值。实验持续 6 h 后,从各个实验组和对照组分别取水样 500 mL,用于分析实验水槽中悬浮颗粒物的变化情况,同时从各个实验组收集贝类排泄的粪便和假粪,用 GF/C 玻璃纤维滤纸抽滤,滤干后-20 °C 下储备以备分析。用游标卡尺测量马氏珠母贝的壳长、壳高和壳宽,用解剖刀将软体部与壳分开,在 80 °C 烘干至恒重,称干壳质量和干组织质量。

1.3.2 悬浮颗粒物浓度的计算

悬浮颗粒物浓度的计算采用海水中总悬浮颗粒物和颗粒有机物来作为测定指标^[23]。TPM 和 POM 测定的方法如下:用经过蒸馏水清洗并在马福炉中灼烧(450 °C) 6 h 后称重(W_0)并标记好的玻璃纤维滤纸(GF/C Whatman,孔径 1.2 μm)抽滤 500 mL 的水样,所滤物用 0.5 mol/L 的甲酸铵(约 10 mL)漂洗掉盐分后在 110 °C 下烘干至恒重,称重(W_{110});再在 450 °C 马福炉中灼烧 6 h 后称重(W_{450})。称量用 SARTORIUS-BS110S 电子天平(精确到 0.1 mg)。按以下公式计算 POM 和 TPM 的值:

$$\text{POM} = W_{110} - W_{450}; \text{TPM} = W_{110} - W_0$$

粪便和假粪中的 TPM 和 POM 测定方法同上。

1.3.3 清滤率、滤食率和吸收效率的计算公式

(1)清滤率(Clearance rate CR),按 Coughlan^[24]的公式:

$$\text{CR} = V \times (\ln C_0 - \ln C_t) / (N \times T)$$

式中, C_0 、 C_t 分别为实验开始和 T 时间时水体颗粒物浓度(mg/L); V 为实验海水体积(L); T 为实验持续时间(h); N 为实验贝个体数。

(2) 摄食率(Ingestion Rate, IR), 按 MacDonald^[25] 的公式:

$$IR = CR \times C_0 - PPF$$

式中, PPF 为单位时间内排出的假粪量。

(3) 吸收效率(Absorption Efficiency, AE), 一般按 Conover^[26] 的公式:

$$AE = (F - E) / [(1 - E) \times F] \times 100\%$$

式中, F 为水体中颗粒有机物的含量(POM/TPM), E 为粪便中有机物的含量(POM/TPM)。考虑到贝类在滤食过程中产生相当数量的假粪, 本文采用宋强等^[22] 的计算公式:

$$AE = (OIR - OER) / OIR$$

式中, OIR 为贝类在单位时间内摄食的有机物量, OER 为贝类在单位时间内排出粪便的有机物量。

1.4 数据处理

为了消除实验中个体差异对马氏珠母贝生理指标的影响, 将实验数据转换为 1 g 标准下的数据进行比较。转换用以下公式:

$$S_s = (1/W_e)^b \times S_e$$

式中, S_s 为标准动物(1 g)的生理指标; S_e 为实验情况下生理指标(清滤率、摄食率)的实测值; W_e 为实验贝软体部干重; b 为重量指数, 取值 0.62^[27]。

数据统计采用 SPSS13.0 进行单因素方差(ANOVA)分析, 作图采用 EXCEL2003。

2 结果

2.1 沉积再悬浮颗粒物对马氏珠母贝清滤率的影响

如图 1 所示, 总悬浮颗粒物由低浓度(12.6 mg/L)趋高浓度(500 mg/L)时, 马氏珠母贝的清滤率呈峰值变化。其中, 在总悬浮颗粒物浓度为 50 mg/L 时, 该贝清滤率达最大值($1.12 \text{ L} \cdot \text{个体}^{-1} \cdot \text{h}^{-1}$), 随着总悬浮颗粒物浓度继续增加清滤率开始下降, 其中, 在悬浮颗粒物浓度为 500 mg/L 时, 清滤率降为最小值($0.17 \text{ L} \cdot \text{个体}^{-1} \cdot \text{h}^{-1}$), 清滤率降幅为 85%。方差分析表明, 水体中总悬浮颗粒物对马氏珠母贝清滤率影响极显著($P < 0.01$)。马氏珠母贝的清滤率(CR)与总悬浮颗粒物浓度(TPM)之间的线性函数关系为:

$$CR = -0.701 + 1.627 \times \text{TPM} - 0.463 \times \text{TPM}^2 + 0.036 \times \text{TPM}^3 \quad (R^2 = 0.928)$$

2.2 沉积再悬浮颗粒物对马氏珠母贝摄食率的影响

如图 2 所示, 在总悬浮颗粒物浓度为 12.6—50 mg/L, 马氏珠母贝的摄食率随着总悬浮颗粒物浓度的升高而增加, 在 50 mg/L 时达最大值(38.28 mg/h), 当总悬浮颗粒物浓度超过 50 mg/L 时, 摄食率反而下降, 在总悬浮颗粒物浓度为 500 mg/L 时, 降为最小值(16.22 mg/h), 摄食率降幅为 58%。方差分析表明, 水体中总悬浮颗粒物对马氏珠母贝摄食率影响极显著($P < 0.01$)。马氏珠母贝类的摄食率(IR)与总悬浮颗粒物浓度(TPM)之间的线性函数关系为:

$$IR = -46.631 + 70.957 \times \text{TPM} - 18.385 \times \text{TPM}^2 + 1.367 \times \text{TPM}^3 \quad (R^2 = 0.907)$$

2.3 沉积再悬浮颗粒物对马氏珠母贝吸收率的影响

由图 3 可知, 总悬浮颗粒物由低浓度(12.6 mg/L)趋高浓度(500 mg/L)时, 马氏珠母贝的吸收率呈逐渐下降趋势。其中, 在总悬浮颗粒物 12.6 mg/L 时, 马氏珠母贝的吸收率最大(48.57%), 而总悬浮颗粒物 500 mg/L 时, 马氏珠母贝的吸收率最小(8.56%)。方差分析表明, 水体中总悬浮颗粒物对马氏珠母贝吸收率影响极显著($P < 0.01$)。马氏珠母贝的吸收率(AE)与总悬浮颗粒物浓度(TPM)之间的线性函数关系为:

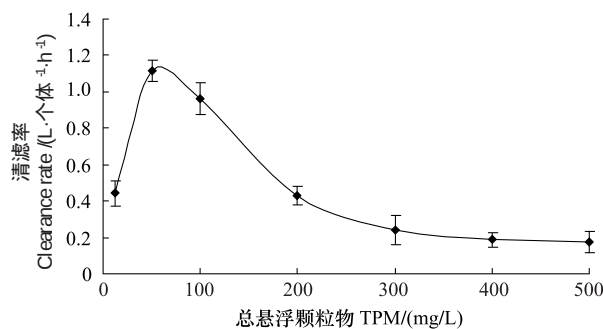


图 1 总悬浮颗粒物对马氏珠母贝清滤率的影响

Fig. 1 Effects of different suspended sediment concentration on the clearance rate of *Pinctada martensii*

$$AE = 52.189 + 0.132 \times \text{TPM} - 3.111 \times \text{TPM}^2 + 0.316 \times \text{TPM}^3 \quad (R^2 = 0.976)$$

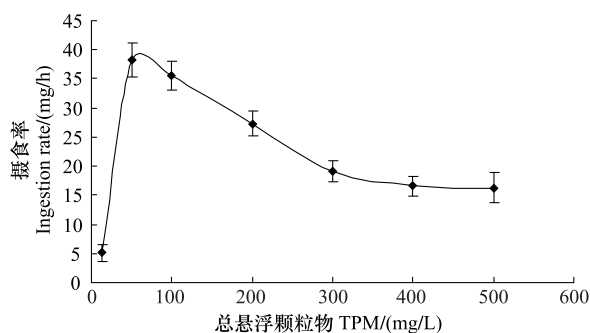


图2 总悬浮颗粒物对马氏珠母贝摄食率的影响

Fig.2 Effects of different suspended sediment concentration on the ingestion rate of *Pinctada martensii*

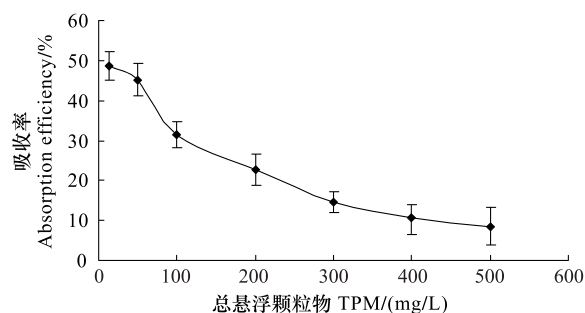


图3 总悬浮颗粒物对马氏珠母贝吸收率的影响

Fig.3 Effects of different suspended sediment concentration on the absorption efficiency of *Pinctada martensii*

3 讨论

中国沿海在夏季多风,沿海水域极易发生再悬浮^[28]。流沙湾位于湛江雷州半岛西南部,是中国“南珠”的主要养殖区,每年夏秋间常为大风暴的多发季节,风暴卷起海底泥沙易导致水体形成高浓度的悬浮颗粒物。水体中过多的泥沙颗粒会给滤食性贝类带来负面影响,如鳃丝损失、摄食量降低和增加对疾病的易感性等^[29]。本实验中作者采集马氏珠母贝筏式养殖区的表层底泥,按宋强等^[22]方法制备悬浮颗粒物,虽然烘干泥样中一些成分可能由于挥发或变性损失而与现场再悬浮颗粒物中某些组分略有差异,但是通过该方法制备悬浮颗粒物作为室内模拟研究是可行的。此外,选择9:00和21:00各进行1次实验,每次持续6h,实验数据取两个时间点的平均值,以尽量减小昼夜摄食节律引起的实验误差。研究表明,水体中形成过高浓度的悬浮颗粒物对马氏珠母贝的清滤率、摄食率和吸收率产生了一定的负面效应,这与Ellis^[11]、宋强等^[22]的实验结果一致。

清滤率反映了贝类的滤水能力,是调节摄食行为的重要组成要素和获取能量的重要机制,其明显受到水体中食物数量和质的影响^[30]。实验结果表明,在实验设置的悬浮颗粒物浓度范围内(12.6—500 mg/L),马氏珠母贝的清滤率随悬浮颗粒物浓度的增加而升高,当悬浮颗粒物浓度为50 mg/L时,该贝清滤率达最大值,然后,随着总悬浮颗粒物浓度继续增加,该贝清滤率开始下降。目前,国内外许多学者研究表明,在一定悬浮颗粒物浓度范围内,滤食性贝类的清滤率与悬浮颗粒物浓度呈正相关,而超过某一浓度,清滤率随悬浮颗粒物浓度的增加而下降。例如, Ellis^[11]、Barillé^[12]、Igesias^[19]的研究表明,当仅仅投喂自然沉积再悬浮颗粒物时,贝类的清滤率在60—100 mg/L范围内与总悬浮颗粒物浓度成正比;当浓度超过100 mg/L时,清滤率随浓度的增加而降低;宋强等^[22]研究表明,总悬浮颗粒物由低浓度趋高浓度时,栉孔扇贝、菲律宾蛤仔和紫贻贝3种滤食性贝类的清滤率均呈峰值变化。其中,栉孔扇贝和菲律宾蛤仔在50 mg/L时清滤率达到最大值,而紫贻贝在100 mg/L时清滤率达到最大值。本研究中,马氏珠母贝的清滤率在不同浓度悬浮颗粒物下呈现的峰值变化规律与上述研究结论相类似,而不同贝类在取得最大清滤率时的悬浮颗粒物浓度略有不同,说明不同贝类对悬浮颗粒物的耐受能力有差异,这可能与不同贝类的生活环境以及贝类自身的生理条件有关。与悬浮颗粒物浓度50 mg/L比较,当悬浮颗粒物浓度超过200 mg/L,马氏珠母贝清滤率降幅61.6%,在悬浮颗粒物浓度为500 mg/L时,清滤率降幅为85%。这是因为在高浓度悬浮颗粒物的水环境下,贝类受到环境胁迫,其生理和自身摄食机制受到限制,引起摄食减少和机体损伤,水体环境历史条件和贝类自身生理条件决定了贝类对悬浮颗粒物质量和数量潜在的摄食量^[31-32]。此外,水体中悬浮颗粒物浓度过高,增加的悬浮泥沙含量会明显增加假粪的产量和贝类能量的消耗,减少对食物的摄食并损伤贝类的鳃^[11]。

摄食率是反映滤食性贝类生理状况的一项动态指标,它直接受到贝类所处环境的生物和非生物因子的影

响,诸如海水的温度、盐度、流速、悬浮颗粒物的数量和质量等^[33]。本实验结果表明,水体中总悬浮颗粒物对马氏珠母贝摄食率影响极显著。在总悬浮颗粒物浓度为 12.6—50 mg/L,马氏珠母贝的摄食率随着悬浮颗粒物浓度的升高而呈现峰值变化规律,其中,悬浮颗粒物为 50 mg/L 时清滤率达最大值,当总悬浮颗粒物浓度超过 50 mg/L 时,摄食率反而下降,在总悬浮颗粒物浓度为 500 mg/L 时,降为最小值。这与清滤率的变化趋势一致。与几种附着生活型的滤食性贝类比较表明,马氏珠母贝的最大摄食率与栉孔扇贝相似,而明显小于紫贻贝^[22],这可能与不同贝类的生活环境有关,马氏珠母贝和栉孔扇贝生活在透明度较大的海区^[34],而紫贻贝能长期生活在浊度较高的水体中,对不利环境的适应能力较强^[35]。与悬浮颗粒物浓度 50 mg/L 比较,当悬浮颗粒物浓度超过 200 mg/L,马氏珠母贝摄食率降幅 28.6%,在悬浮颗粒物浓度为 500 mg/L 时,摄食率降幅为 58%。分析表明,在悬浮颗粒物浓度超过一定数值时,马氏珠母贝摄食率降低幅度小于清滤率,该贝摄食率受到的影响小于清滤率受到的影响。这是贝类为了维持正常的能量平衡和适应外界环境的变化,随水体中悬浮颗粒物浓度的增加,降低清滤率从而保持相对稳定的摄食率^[36]。滤食性贝类通过摄食有机物质和选择性排出假粪来适应水体中悬浮颗粒物质量和数量的变化^[37],在高浓度悬浮颗粒物情况下,通过调节摄食率,降低清滤率可防止颗粒物过多地滞留于鳃上,这是对不良条件的一种反应^[8]。

关于悬浮颗粒物对吸收率的影响研究已经有了相关报道。许多学者对硬壳蛤(*Mercenaria mercenaria*)^[38]和欧洲鸟尾蛤^[19]以及栉孔扇贝、紫贻贝和菲律宾蛤仔^[22]的研究结果表明,随着悬浮颗粒物浓度的增高,水体中有机质的含量降低,贝类对再悬浮颗粒物的吸收效率也降低。在本实验中,水体中总悬浮颗粒物浓度对马氏珠母贝吸收率影响极显著,总悬浮颗粒物由低浓度(12.6 mg/L)趋高浓度(500 mg/L)时,马氏珠母贝的吸收率呈逐渐下降趋势,这可能由于实验水槽中总悬浮颗粒物浓度增加而沉积速率增大,有机物通过吸附等原因使其比例减少,进而对再悬浮颗粒物的吸收效率也降低。本研究结果支持了上述研究结论。MacDonald 等^[21]对海螂和麦哲伦扁圆扇贝(*Placopecten magellanicus*)的研究结果表明,随着总悬浮颗粒物的质量(颗粒物中有机物含量)的增加,这两种贝类的吸收率都有明显的增加。可以看出,在贝类的吸收率和饵料的质量(饵料中有机物的含量)之间有着很密切的关系。因此,可以利用这一关系来增加海区饵料中有机物的含量,从而达到增加海区马氏珠母贝养殖容量的目的。

References:

- [1] Navarro J M, Widdows J. Feeding physiology of *Cerastoderma edule* in response to a wide range of seston concentrations. *Marine Ecology Progress Series*, 1997, 152: 175-186.
- [2] Wong W H, Cheung S G. Feeding behavior of green mussel, *Perna viridis* (L.): responses to variation in seston quantity and quality. *Journal of Experimental Marine Biology and Ecology*, 1999, 236(2): 191-207.
- [3] Hawkins A J S, Smith R F M, Bayne B L, Héral M. Novel observations underlying the fast growth of suspension-feeding shellfish in turbid environments: *Mytilus edulis*. *Marine Ecology Progress Series*, 1996, 131: 179-190.
- [4] Urrutia M B, Iglesias J I P, Navarro E, Prou J. Feeding and absorption in *Cerastoderma edule* under environmental conditions in the bay of Marennes-oleron (Western France). *Journal of the Marine Biology Association of the United Kingdom*, 1996, 76(2): 431-50.
- [5] Navarro J M, Labarta U, Fernández-Reiriz M J, Velasco A. Feeding behavior and differential absorption of biochemical components by the infaunal bivalve *Mulinia edulis* and the epibenthic *Mytilus chilensis* in response to changes in food regimes. *Journal of Experimental Marine Biology and Ecology*, 2003, 287(1): 13-35.
- [6] Grant J. The relationship of bioenergetics and the environment to the field growth of cultured bivalves. *Journal of Experimental Marine Biology and Ecology*, 1996, 200(1/2): 239-256.
- [7] Jorgensen C B. Bivalve filter feeding revisited. *Marine Ecology Progress Series*, 1996, 142: 287-302.
- [8] Navarro E, Iglesias J I P, Ortega M M. Natural sediment as a food source for the cockle *Cerastoderma edule* (L.): effect of variable particle concentration on the feeding, digestion and the scope for growth. *Journal of Experimental Marine Biology and Ecology*, 1992, 156(1): 69-87.
- [9] Willows R I. Optimal digestive investment: a model for filter feeders experiencing variable diets. *Limnology and Oceanography*, 1992, 37(1): 829-847.
- [10] Iglesias J I P, Urrutia M B, Navarro E, Alvarez-Jorna P, Larretxea X, Bougrier S, Heral M. Variability of feeding processes in the cockle

- Cerastoderma edule* (L.) in response to changes in seston concentration and composition. *Journal of Experimental Marine Biology and Ecology*, 1996, 197(1): 121-143.
- [11] Ellis J, Cummings V, Hewitt J, Thrush S, Norkko A. Determining effects of suspended sediment on condition of a suspension feeding bivalve (*Atrina zelandica*): results of a survey, a laboratory experiment and a field transplant experiment. *Journal of Experimental Marine Biology and Ecology*, 2002, 267(2): 147-174.
- [12] Barillé L, Prou J, Héral M, Razet D. Effects of high natural seston concentrations on the feeding, selection, and absorption of the oyster *Crassostrea gigas* (Thunberg). *Journal of Experimental Marine Biology and Ecology*, 1997, 212(2): 149-172.
- [13] He M X, Shi J H, Lin Y G, Jiang Y P. Studies on growth traits of first generation of selective line of *Pinctada martensii* Dunker. *Journal of Tropical Oceanography*, 2006, 25(1): 19-22.
- [14] Qu N N, Gong S Y, Huang G J, Yu D H. Genetic diversity of three cultured populations of Chinese pearl oyster *Pinctada fucata* using microsatellite DNA. *Journal of Hydroecology*, 2009, 2(4): 89-93.
- [15] Jiang Y P, He M X, Lin Y G. Genetic Diversity of a Cultured Population on *Pinctada Martensii* Dunker by ISSR Marker. *Marine Science Bulletin*, 2007, 26(5): 62-66.
- [16] Wang A M, Ding X L, Deng F J, Ye L, Yan B. The genetic diversity of the first filial generation from matings and crosses of two wild populations (Daya Bay, Guangdong and Sanya, Hainan) in *Pinctada martensii* (Dunker). *Marine Fisheries Research*, 2003, 24(4): 19-24.
- [17] Wang A M, Yan B, Ye L, Lan G B, Zhang G D, Du X D. Comparison on main traits of F1 from matings and crosses of different geographical populations in *Pinctada martensii*. *Journal of Fisheries of China*, 2003, 27(3): 200-206.
- [18] Liang F L, Liu Y, Deng C M, Mao Y. Survey on polychaete verminosis in farmed pearl oyster (*Pteria penguin*) in Liusha Bay, Leizhou, Guangdong. *Marine Fisheries Research*, 2007, 28(2): 84-89.
- [19] Iglesias J I P, Navarro E, Jorna P A, Armentia I. Feeding, particle selection and absorption in cockles *Cerastoderma edule* (L.) exposed to variable conditions of food concentration and quality. *Journal of Experimental Marine Biology and Ecology*, 1992, 162(2): 177-198.
- [20] Velasco L A, Navarro J M. Energetic balance of infaunal (*Mulinia edulis* King, 1831) and epifaunal (*Mytilus chilensis* Hupé, 1854) bivalves in response to wide variations in concentration and quality of seston. *Journal of Experimental Marine Biology and Ecology*, 2003, 296(1): 79-92.
- [21] MacDonal B A, Bacon G S, Ward J E. Physical responses of infaunal (*Mya arenaria*) and epifaunal (*Placopecten magellanicus*) bivalves to variations in the concentration and quality of suspended particles II. Absorption efficiency and scope for growth. *Journal of Experimental Marine Biology and Ecology*, 1998, 219(1/2): 127-141.
- [22] Song Q, Fang J G, Liu H, Zhang J H, Wang L L, Wang W. Studies on the effects of suspended sediment on the feeding physiology of three suspension-feeding bivalves. *Marine Fisheries Research*, 2006, 27(4): 21-28.
- [23] Kuang S H, Fang J G, Sun H L, Li F. Seasonal variation of filtration rate and assimilation efficiency of scallop *Chlamys farreri* in Sanggou Bay. *Oceanologia et Limnologia Sinica*, 1996, 27(2): 194-199.
- [24] Coughlan J. The estimation of filtering rate from the clearance of suspensions. *Marine Biology*, 1969, 2(4): 356-385.
- [25] MacDonald B A, Ward J E. Variation in food quality and particle selectivity in the sea scallop *Placopecten magellanicus* (Mollusca: Bivalvia). *Marine Ecology Progress Series*, 1994, 108: 251-264.
- [26] Conover R J. Assimilation of organic matter by zooplankton. *Limnology and Oceanography*, 1966, 11(3): 338-345.
- [27] Bayne B L, Newell R C. Physiological energetics of marine mollusks//Saleuddin A S M, Wilbur K M, eds. *The Mollusca*. Vol 4: Physiology, Part 1. New York: Academic Press, 1983: 407-515.
- [28] Booth J G, Miller R L, McKee B A, Leathers R A. Wind induced bottom sediment resuspension in a microtidal coastal environment. *Continental Shelf Research*, 2000, 20(7): 785-806.
- [29] Leverone J R. Growth and survival of caged adult bay scallops (*Argopecten irradians concentricus*) in Tampa Bay with respect to levels of turbidity, suspended solids and chlorophyll A. *Florida Science*, 1995, 58(2): 216-227.
- [30] Hawkins A J S, Fang J G, Pascoe P L, Zhang J H, Zhang X L, Zhu M Y. Modelling short-term responsive adjustments in particle clearance rate among bivalve suspension-feeders: separate unimodal effects of seston volume and composition in the scallop *Chlamys farreri*. *Journal of Experimental Marine Biology and Ecology*, 2001, 262(1): 61-73.
- [31] Shin P K S, Yau F N, Chow S H, Tai K K, Cheung S G. Response of the green-lipped mussel *Perna viridis* (L.) to suspended solids. *Marine Pollution Bulletin*, 2002, 45(1/12): 157-162.
- [32] Hewitt J E, Pilditch C A. Environmental history and physiological state influence feeding responses of *Atrina zelandica* to suspended sediment concentration. *Journal of Experimental Marine Biology and Ecology*, 2004, 306(1): 95-112.
- [33] Bao Y B, You Z J. The present researching status of ingestion rate's influence factors of marine suspension-feeding shellfish. *Marine Fisheries Research*, 2006, 27(1): 76-80.

- [34] Wang R C, Wang Z P. Science of Marine Shellfish Culture. Qingdao: Ocean University of China Press, 2008: 184, 268.
- [35] Kiørboe T, Møhlenberg F, Nøhr O. Feeding, particle selection and carbon absorption in *Mytilus edulis* in different mixtures of algae and resuspended bottom material. *Ophelia*, 1980, 19(2): 193-205.
- [36] Wong W H, Cheung S G. Feeding behaviour of the green mussel, *Perna viridis* (L.): responses to variation in seston quantity and quality. *Journal of Experimental Marine Biology and Ecology*, 1999, 236(2): 191-207.
- [37] Bayne B L. The physiology of suspension feeding by bivalve mollusks: an introduction to the plymouth "TROPHEE" workshop. *Journal of Experimental Marine Biology and Ecology*, 1998, 219(2): 1-19.
- [38] Bricelj V M, Malouf R E. Influence of algal and suspended sediment concentrations on the feeding physiology of the hard clam *Mercenaria mercenaria*. *Marine Biology*, 1984, 84(2): 155-165.

参考文献:

- [13] 何毛贤, 史兼华, 林岳光, 姜因萍. 马氏珠母贝选育子一代生长特性研究. *热带海洋学报*, 2006, 25(1): 19-22.
- [14] 曲妮妮, 龚世园, 黄桂菊, 喻达辉. 合浦珠母贝 3 个养殖群体遗传多样性的微卫星分析. *水生态学杂志*, 2009, 2(4): 89-93.
- [15] 姜因萍, 何毛贤, 林岳光. 马氏珠母贝群体内遗传多样性的 ISSR 分析. *海洋通报*, 2007, 26(5): 62-66.
- [16] 王爱民, 丁小雷, 邓凤娇, 叶力, 阎冰. 马氏珠母贝大亚湾和三亚野生种群内自繁及种群间杂交一代的 RAPD 分析. *海洋水产研究*, 2003, 24(4): 19-24.
- [17] 王爱民, 阎冰, 叶力, 兰国宝, 张栋国, 杜晓东. 马氏珠母贝不同地理种群内自繁和种群间杂交子一代主要性状的比较. *水产学报*, 2003, 27(3): 200-206.
- [18] 梁飞龙, 刘永, 邓陈茂, 毛勇. 广东雷州流沙湾养殖企鵝珍珠贝多毛类寄生虫病的调查. *海洋水产研究*, 2007, 28(2): 84-89.
- [22] 宋强, 方建光, 刘慧, 张继红, 王玲玲, 王巍. 沉积再悬浮颗粒物对 3 种滤食性贝类摄食生理的影响. *海洋水产研究*, 2006, 27(4): 21-28.
- [23] 匡世焕, 方建光, 孙慧玲, 李锋. 桑沟湾栉孔扇贝不同季节滤水率和同化率的比较. *海洋与湖沼*, 1996, 27(2): 194-199.
- [33] 包永波, 尤仲杰. 海洋滤食性贝类摄食率影响因子研究现状. *海洋水产研究*, 2006, 27(1): 76-80.
- [34] 王如才, 王昭萍. 海水贝类养殖学. 青岛: 中国海洋大学出版社, 2008: 184, 268.

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