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噪声对鱼类的影响*

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摘要:【目的】了解噪声对鱼类的不同影响，为噪声对鱼类的影响提供较为系统的信息资料。【方法】在文献调查基础上，综述了不同类型噪声对鱼类听觉、行为和种群数量的影响。【结果】水体中常见的噪声来源有打桩、船舶、声呐/水下地震勘探等。噪声不但会对鱼类造成暂时性阈移或永久性阈移，而且还会使鱼类的集群行为、逃避行为以及捕食行为发生变化。可通过统计分析鱼类的死亡率和捕捞率来研究噪声对鱼类种群参数的影响。【结论】目前关于噪声对鱼类影响的研究还十分缺乏且有较大局限性，应加强研究野生环境下噪声对鱼类的影响。

关键词:噪声;鱼类听觉;鱼类行为;鱼类数量
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研究显示，全世界大概有 800 种鱼如金钱鱼(*Scatophagus argus*)、花鲈(*Lateolabrax maculatus*)、电鳐(*Malapterurus electricus*)、青石斑鱼(*Epinephelus awoara*)、鲶(*Silurus asotus*)等具有发声能力;噪声会干扰它们的发声行为[1-4]。鱼类种群不仅受到栖息地退化、化学污染、渔业发展等难以避免威胁，还受到各种噪声的威胁[5]。目前，噪声对鱼类的影响受到越来越多的关注，但精确的实验数据非常缺乏，以至于很少有人真正了解噪声对鱼类的影响。本文在综合调查已有相关文献的基础上，概述了不同类型的噪声对鱼类听觉、行为和数量的影响，为深入研究噪声对鱼类的影响提供较为系统的基础资料。

1 水体中常见的噪声来源

水体中常见的噪声来源有打桩、船舶、声呐、水下地震勘探等。

打桩在跨水桥梁、水上风电场、码头、水上油气平台等涉水工程建设过程中起到基础稳固作用[6-7]。打桩不仅是上述工程建设的必经阶段，也是噪声强度最大、持续时间最长的阶段之一[8]。打桩可分为两种类型:一类是冲击式打桩(Impact pile-driving)，使用液压泵驱动桩锤不断下落对桩柱施加冲击力将桩砸入地下;另一类是振动式打桩(Vibratory pile-driving)，使用旋转偏心块对桩施加交变力，通过振动将桩沉入地下[9]。不同类型的桩有着不同类型的特性，由此对鱼类生理也会造成不同影响如引起肝脏出血、鱼鳔破裂、内耳损伤等[10]。

船舶噪声是低频噪声源中最具代表性的噪声源，种类繁多，大小不一。船舶不仅是各类水体中的主要运输工具，也是影响海洋渔业健康发展的因素之一[11]。船舶噪声不止源于超级油轮、货船等大型船舶，也源于观光船、渔船等小型船舶。

声呐是利用声波在水中的传播特性，探测水中目标的方向、位置和特征的设备[12]，广泛应用于鱼雷制导、水雷引信、鱼群探测、水文测量等。

水下地震勘探是在人类水下资源利用过程中得到快速发展的海洋物理勘探技术，是对水下地质条件进行科学研究的重要手段。这一物探技术主要原理为:使用高分辨率的紧密探测仪收到炸药在水底浅井中爆炸所产生的反射波，并根据反射波的形状推断出水底的岩层深度以及构造状况，进而对水底各个断面做成剖面图，最终明确水底地质结构[13]。在水下地震勘探中，空气枪是主要震源[14]。不同类型的空气枪工作原理大体相同:空气经

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过空气压缩机压缩后进入气枪中,并达到一定压力;在工作时,气枪控制器控制电磁阀以打开气室,其中的高压气体迅速进入水中形成气泡,产生振动[15]。

2 噪声对鱼类的影响

2.1 噪声对鱼类听觉的影响

鱼类的听觉系统由耳、气鳃及其他外周附属结构和听觉中枢组成。由于鱼类内耳的感觉上皮有耳石,感觉上皮和耳石能在声波的作用下产生相对运动,从而会引起听觉神经的兴奋。鱼类这种在内耳中刺激感觉上皮和耳石以及将声能转换为相应电信号的基本机制和其他脊椎动物的有关机制是相同的。噪声对鱼类听觉组织的影响,可通过测定鱼类的暂时性阈移(Temporary threshold shift)和永久性阈移(Permanent threshold shift)来确定[16-17]。暂时性阈移指在噪声中暴露一定时间后发生的,但经过充分休息即可恢复的听阈升高;永久性阈移指在噪声中重复暴露而形成的不能恢复的听阈升高[18-19]。

将虹鳟(*Oncorhynchus mykiss*)和斑点叉尾鮰(*Ietalurus punetaus*)置于中频率声呐条件下,两种鱼均出现暂时性阈移增大;斑点叉尾鮰的暂时性阈移在 48 h 内恢复,但虹鳟的暂时性阈移在 48 h 后仍未恢复[20]。Scholik 等人[21-22]将黑头呆鱼(*Pimephales promelas*)置于小船和渡轮所产生的低频率噪声中连续刺激 2 h,结果表明该物种暂时性阈移增大。Smith 等人[23]将鲦(*Hemiculter lcucisculus*)置于船舶发动机噪声中刺激 2 h,结果也显示鲦的暂时性阈移增大。在这些研究中,经过刺激后的鱼听力随时间推移而逐渐恢复正常,听力恢复所需时间与所受噪声频率大小和刺激持续时间长短有关。

用空气枪发出的噪声对真鲷(*Pagrosomus major*)进行刺激,真鲷内耳听觉上皮的毛细胞受到大面积伤害[24]。此外,空气枪发出的噪声能使金鱼(*Carassius auratus*)、罗非鱼(*Oreochromis* spp.)、太阳鱼(*Lepomis gibbosus*)等鱼类出现永久性阈移[25-30]。由于不同种类鱼的听觉敏感度和可听频率范围有所差别,如金鱼能感受的频率上限可达 3 000 Hz 而大多数鱼类的听力敏感度较低;因此同一频率下的噪声会使不同鱼类出现不同的反应。

从上述有关鱼类听觉的多种行为和生理学研究可知,多数种类的鱼对噪声的反应与其他脊椎动物相同。此外,研究者还通过将鱼解剖后观察如肝脏、鱼鳔等非听觉组织中细胞的方式,检测了噪声对鱼类的影响[31]。例如,研究人员发现在美国旧金山奥克兰湾大桥建设过程中,打桩对桥周围的鱼类造成了肝脏充血、鱼鳔破裂、鱼体内部出血等不同程度的伤害[32]。

2.2 噪声对鱼类行为的影响

噪声对鱼类行为的影响,可通过观察大型养殖池中鱼的集群行为、逃避行为、捕食行为等来进行研究[33]。

Engas 等人[34-36]发现,拖网渔船、渡轮、小艇等船只的噪声可以改变鱼类的集群行为(如游泳速度、游泳方向和教育行为)。在船舶噪声存在的情况下,金枪鱼(*Thunnus thynnus*)有序的集群行为出现了混乱,个别的鱼独自游向水表面或者是水底[37]。Chapman 等人[38-39]研究发现空气枪射击所产生的噪声改变了大西洋鳕鱼(*Gadus morhua*)群体的分布状况,导致这一物种群体出现了深水行为。

Doksæter 等人[40]调查了大西洋鲱(*Clupea harengus*)在越冬时对声呐信号及虎鲸(*Orcinus orca*)吃食声音的行为反应。他们用回声探测仪来监控大西洋鲱在水中的行为,结果发现大西洋鲱没有远离声呐源的反应,而虎鲸吃食的声音则使这一物种出现了逃避反应。Pearson 等人[41]将鲑鱼(*Sebastes* spp.)置于空气枪所产生的噪声中刺激10 min,结果发现随着空气枪噪声水平的增大,鲑鱼选择远离空气枪噪声源向水底游去。此外,有研究表明大西洋鲱、大西洋鳕鱼、沙鳗(*Astroconger myriaster*)等鱼类在水中会远离船只[42]。

在自然条件下,噪声能干扰捕食中的鱼类,导致鱼类捕食效率降低[43]。Voellmy 等人[44]将三刺鱼(*Gasterosteus aculeatus*)置于船舶噪声和无声两种情况下观察该物种捕捉水蚤的情况。结果表明,三刺鱼在无声条件下每次能捕捉到同样数量的水蚤,而在船舶噪声条件下只能捕捉到少量藻类植物。

总之,用不同类型的噪声刺激鱼类会使鱼类产生不同的行为反应。这些行为反应的产生是因为鱼类和其他生物一样,也具有应激性。当鱼类在进行集群、摄食等行为时受到外界噪声干扰后,就会改变现有的状态而出现不同的反应。

2.3 噪声对鱼类种群参数的影响

噪声对鱼类种群参数的影响可通过在噪声环境下对鱼类发育周期中不同时期鱼的死亡率和捕捞率进行分析记录来加以研究[45-47]。

研究者用大西洋鳕鱼、大西洋鲱、花狼鱼(*Anarhichas minor*)进行鱼鳔共振实验,即在不同噪声频率下模拟海军声呐信号刺激这些鱼类[48-49]。实验结果显示:实验中除了因重复实验造成大西洋鲱死亡(死亡率为20%~30%)之外,噪声并没有导致其他鱼类死亡率明显上升。将这些鱼类继续喂养28 d,并观察它们的死亡情况和生长相关参数(如长度、体质量、身体健康状况)情况,结果显示处理组和对照组之间无统计学意义上的差异。即使研究中出现了一定的死亡率,但在野生环境中因声呐刺激造成的鱼类死亡数量远低于鱼类的正常死亡数量[50]。

在三维地震勘测期间,将40台海底地震仪沉置于水下使之呈长方形矩阵排列进行采集实,其中测出的回声丰度表示鱼的数量;结果显示鱼的数量在空气枪射击后减少了36%[51-53]。挪威一项研究表明,在空气枪矩阵排列附近,对青石斑鱼、大西洋鳕和黑线鳕(*Melanogrammus aeglefinus*)的捕获率降低到45%~70%;在操作结束5 d后,对上述鱼类捕获率仍没有恢复[54-56]。

3 结束语

水下噪声对鱼类的影响已经成为一个严重的生态问题。随着噪声水平逐步上升,必须在噪声对鱼类多样性和水下生态系统造成不可逆的损害之前对噪声进行管理。而到目前为止,大多数研究仅涉及笼养的鱼类。即使在少数研究中研究者通过水下拍摄或声呐观察到野生环境中生长的鱼类对声源的反应,但这远远不够。笼养条件下的鱼类在运动方面会受到一定限制。这不仅来自于笼壁的限制,而且也来自于生存空间狭小。笼养条件下的鱼类会感知到笼子的存在,这很有可能改变鱼类对噪声刺激的反应。在野外条件下,鱼类会通过快速远离噪声源响应感知到的噪声;而在笼中条件下是不可能做到上述行为的——鱼类会因为不能移动太远而没有明显的响应。因此,当前最重要的工作是加强研究野生环境下噪声对鱼类的影响。

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Animal Sciences

Influence of Noise on Fish

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Abstract: [**Purposes**]In order to understand the different effects of noise on fish, to provide systematic information for the effect of noise on fish. [**Methods**]On the basis of literature survey, this paper has summarized the influence of different types of noises on fish hearing, behavior and population quantity. [**Results**]Common sources of noise in water include piling, ships, sonar and underwater seismic exploration etc. Noise can not only cause temporary threshold shift or permanent threshold shift to fish, but also change the cluster behavior, escape behavior and predatory behavior of fish. The effects of noise on fish population parameters can be studied by statistical analysis of fish mortality and fishing rates. [**Conclusions**]At present, the research on the impact of noise on fish is still very scarce and has great limitations, the effect of noise on fish in wild environment should be strengthened.

Keywords: noise; fish hearing; fish behavior; fish quantity

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