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中文题名	玻尔兹曼方程模拟鱼等水生动物游动数学模型及工程应用
英文题名	Mathematical Model and Application for Aquatics Movements based on Boltzmann Equation
中文关键词	江豚,中华鲟,数量分布,过水工建筑物,栖息地选择
英文关键词	Yangtze finless porpoise, Chinese sturgeon, distribution, bypass efficiency, habitat selection
中文文摘	鱼类等水生动物，是河流、湖泊等生态环境中不可缺少的一部分。近年来，人工修建的水利工程建筑物改变了传统的江湖关系，对鱼类等水生动物造成非常大的影响。洄游性和半洄游性动物的洄游路线被截断，大批物种隔断在水利工程建筑物上下游，物种之间的基因交流减少，生物多样性进一步减弱；水利工程建筑物对河道的截流也使得上下游的水文条件发生改变，使得鱼类等水生动物原有的栖息地消失，新的栖息地出现，极大地影响了水环境生态系统。已有的鱼类等水生动物游动行为的研究模型大多建立在拉格朗日框架上，计算工作量极大，且多为经验模型。难以在河流流域中模拟其游动过程，进而难以分析其栖息地状况，且传统的栖息地评价模型的核心大多为统计学理论，又缺乏对研究对象本身行为的分析。本文从水生动物个体行为出发，分析其运动时在水体中的受力情况，建立了其游动行为的玻尔兹曼方程，并将其它影响因素作为源项处理，求解后得到其数量分布公式。公式中的相关变量包括流速、其身体与水流方向之间的夹角、水深、水温、底质和含沙量等，物种相关变量包括身体侧表面积、对流速变化的感应能力和克流能力。建立的鱼类等水生动物行为模型能够良好的反映其与流速、水深和水温等环境因素的偏好关系，同时因为模型涉及鱼类等水生动物在水中游动的受力情况，使得模型能够准确的模拟研究对象在水中的行为模式，并与水动力模型和泥沙输移模型良好耦合，适用于各种尺度的研究区域。此外由于模型中涉及多个表征生物物种的参数，模型对于各种研究对象也有着广泛的适用性。模型被应用到江豚通过水工建筑物模拟和中华鲟栖息地选择模拟等实际工作中，分别研究鄱阳湖拟建水利枢纽工程对江豚洄游行为的影响和三峡水利枢纽工程不同下泄流量对中华鲟栖息地的影响。模型结果表明，鄱阳湖的拟建水利枢纽工程对江豚的洄游行为有一定的影响，不同水文年优化调度后江豚的通过率最大可达 90%以上，修建水利枢纽工程前后鄱阳湖内的江豚分布规律改变不大；不同的上游来流流量下中华鲟的数量分布区别巨大，当流量处于 20000m3/s 到 30000m3/s 之间时最适合中华鲟栖息。因此，模型可以为生态环境的保护和修复工作提供重要的参考。
外文文摘	The aquatic animals are the indispensable elements of the ecological environment in the natural rivers and lakes. For the past decades, thousands of hydraulic buildings have been constructed, which altered the river lake relationship and significantly affectly the aquatic animals. Migratory and semi migratory animals have been blocked downstream the dams. The gene exchanges between species have reduced, alone with the biodiversity. The channel closures caused by the hydraulic buildings have also changed the hydrologic conditions of the adjacent regions. The original habitats of the aquatic animals dispearred and new ones emerged, which has greatly impacted the ecological system of water environment.Plenty of movement models and habitat evaluation models have been developed to solve the above issues. However, most of the previous movement models are built on the Lagrangian framework with empirical basis and huge amount of computational work, which can be hardly applied on simulating the movment procedure in the entire basin of a river, as well as the habitat condition of the auqtic animals, while the previous habitat evaluation models are mostly generated from the statistic data and lack of studies on the behavior performance of the aquatic animals. In this paper, the individual behaviors of the aquatic animals were anyalyzed, as well as the stress states of the individuals' swimming behavior. Noticing that aquatic animals can be treated as particles compared with the size of the computational grids, the souce items of the Boltzmaan equation was deformed so that the distribution function of the simulated aquatic animals was obtained. The distribution fuction has connection with the environmental variables such as flow velocity, angles between the object's orientation and flow direction, water depth, water temperature, substrate and sediment concentration, as well as the specie related variables such as

	wetted area, capabilities to sense the flow alteration and resist flow drags. The movement model built on the distribution function is able to reflect the velocity, depth and temperature preferences of the most of the aquatic animals. Meanwhile, stress state of the individuals was fully considered, which makes the model provide accuate results on simulating the movement of groups of the aquatic animals. The model can be perfectly coupled with hydrodynamic and sediment transport models, which means the scale of the study region is no more a constraint. What’s more, the model can be applied on most of aquatic species due to the involvement of multiple specie related parameters.The model was then applied on the simulations of migration behavior of the Yangtze finless porpoise and habitat selection of the Chinse sturgeon. The influnces of the scheduled hydraulic construction in the Poyang Lake to the porpoises were discussed, alone with the influnces of different impoundment schemes of the Three Gorges Dam on the sturgeons. The application results indicated that, the scheduled hydraulic construction has little impact on the migration of the porpoises. By reasonalble optimization, the pass rates of different hydrological years may maintain above 90% after the dam was built. The distributions of porposes inside the lake also have little changes. Obvious differences exist on the distribution of Chinese sturgeon with different upstream discharges. Discharge between 20000m3/s and 30000m3/s is optimum for the Chinese sturgeon to live and spawn. For conclusion, both of the migration model and habitat selection model can provide important references to the protection and restoration of the ecological environment.
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