World Journal of Aquaculture Research & Development

ISSN 2688-5581

Review Article

Kairomones: Interspecific Chemical Signalling System in Aquatic Ecosystems

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Abstract

The chemical signalling system constitutes the large sensory mechanism that mediates the behavioural and physiological responses in aquatic ecosystems. These chemical cues strongly affect the population structure, feeding and foraging strategies, and also govern the transfer of energy within and among ecosystems. Chemical cues are omnipresent and play different roles in freshwater and marine systems; however, their impacts are inadequately recognized. In this mini review, we have discussed the interspecific chemical cues known as kairomones especially fish kairomones. The role of kairomones in vertical migration of zooplanktons is also discussed.

Keywords: Heterospecifics; Predator-prey systems; Kairomone

Introduction

In order to pass the signal of auditory, visual, or chemical nature with conspecifics and heterospecifics, animals use a variety of means. The specific method used for communication between individuals depends largely upon the type of information being transferred and the medium available for transmission of the cue. Chemical cues serve as the primary vehicle for conveying information concerning impending predation risk in aquatic predator-prey systems. It is understood that to be effective, such cues should be easily identified by the recipient, easily transmitted in water and comprise an accurate index of predation risk. Pheromones are known since long in animal kingdom and are intraspecific signals for communication. Allomones are interspecies chemical signals bringing benefit to the signal-producing organism, whereas Kairomones are released in interspecific community for the benefit of the recipients of the chemical signal. Kairomones, when released, serve many benefits during interaction like establishing social hierarchies, finding a mate, and also for various interspecies defensive mechanisms [1,2]. Coined the term "Kairomone" (Gk. Kairos means opportunistic/exploitative) to describe "a trans specific chemical messenger, the adaptive benefit of which falls on the recipient rather than on the emitter".

According to Nordlund and Lewis (1976) whose redefinition was valid many years and is still used by several authors, a kairomone is "a substance, produced, acquired by, or released as a result of the activities by an organism, which, when it contacts an individual of another species in the natural context, evokes in the receiver a behavioural or physiological reaction adaptively favourable to the receiver but not to the emitter."

A kairomone is a chemical signal, released by an organism, during the interspecific interaction for the exclusive benefit of the other species, without benefitting the emitter. The production of such chemical cues is considered disadvantageous for producer by several researchers; however, it is believed that there may be some other unknown benefits which keep this evolutionary trait still functioning. The kairomone enhances the overall wellbeing of the recipient and while as differs from an allomone (it benefits the producer and harms the receiver) and a synomone (which benefits both producer and receiver). The kairomones gives the ecological signalling in two ways; they may indicate a food source for, or the presence of predator, the former of which is more common and later is less studied.

Classification of kairomones

The classification of kairomones based on how the receiver is benefitted results into four main groups:

Foraging kairomone: A kairomone used by the benefiting organism in the context of the location of food for the organism itself or its offspring.

Enemy-avoidance kairomone: A kairomone used by the benefiting organism to reduce the negative impact of a natural enemy.

Sexual kairomone: Pheromones mediating sexual attraction.

Aggregation kairomone: A kairomone released for attraction and/or arresting both sexes of receiver.

Classification according to the beneficial effect of the receiver

Primer kairomone: A kairomone inducing a physiological response in the benefiting organism.

Citation: Yousuf DJ, Phulia V, Bhat IA, Nazir MI, Rasool I, Raja-Adil HB et al. Kairomones: Interspecific Chemical Signalling System in Aquatic Ecosystems. World J Aquac Res Development. 2020; 2(1): 1007.

Publisher Name: Medtext Publications LLC

Manuscript compiled: April 06th, 2020

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Releaser kairomone: A kairomone inducing an immediate behavioural response in the benefiting organism.

Kairomones in an aquatic environment

The chemical cues have evolved as important signals in aquatic environments, due to absence of more effective visual and auditory senses. The primary sources of information in aquatic environments have been identified as visual and chemical cues that may induce short-term behavioural processes for both fishes (vertebrate) and rustacean (invertebrate) species. Under laboratory conditions in a freshwater fish, the acoustic cues have been demonstrated to elicit behavioural responses but the reliability of acoustic information may be limited under conditions of relatively high background noise, as can be felt in lotic (moving) systems. Again, under the laboratory conditions, organisms of same species (conspecific) differing in the ontogenic stage when exposed to damage-released chemical cues have been shown to elicit different responses, with similarly sized receivers demonstrating alarm or antipredator responses. Furthermore, in the same experimental conditions, larger receivers demonstrated behaviours consistent with foraging responses. The same mechanism was found in heterospecifics receivers hunting the same prey with similar predation risks as senders. On the other hand, heterospecifics receivers having larger size than the cue sender demonstrated foraging responses after exposure to damage-released chemical cues under both laboratory and field conditions.

Burks and Lodge (2002) while going through the literature on chemical cues found that in freshwater ecosystems, kairomones mediate majority of species interactions. They found that in freshwater fish and predacious insects act as senders, while as zooplankton follow the recipient task. Predacious insects may act both as receivers as well as senders of cues whereas; tadpoles act only as receivers of cues from predators. In order to locate a prey, predators use a variety of information sources, and likewise prey animals use various sources and tactics to locate and avoid the predator. In freshwater environments, the chemical signalling often plays a crucial role in such predator/prey interactions.

In aquatic ecosystems under variable physico-chemical conditions, kairomones are subjected to different environmental factors which can result into change in their chemical property. Under these factors, solar ultraviolet radiation has been found most effective to change the chemical moieties and their fate.

Fish kairomones

The different groups of freshwater fishes release chemical cues from the epidermis upon any mechanical damage, like a predation attack. It results into suite of antipredator or alarm responses in centrarchid, salmonid, cyprinid, cyprinodontiform, esocid and poeciliid species. Depending on the manner in which these chemicals are released, they may increase the predation pressure of receivers, which is not always the case with potentially misleading visual cues.

The various interspecific effects of fish kairomones include decrease in shredding activity of Gammarus pulex, increase in digging activity of Chironomid larvae, and movement of snails to protective covers. Fish kairomones result into development of deeper body in Crucian carp so as to avoid attacks by gape-limited piscivores. How kairomones act on the behaviour between fish and zooplankton is still debatable. The effect of fish kairomones on the acceptor (zooplankton) can be positive or negative. Vertical migration of plankton can be one of the induced factors of kairomones proved by mathematical a model [3] that helps zooplankton to maintain their population by avoiding over-predation [4] identified Tri Methyl Amine (TMA) as a major component of fish kairomone. They found that, whatever the inducing factor of vertical migration in zooplanktons maybe; it is produced only by fish in the presence of bacteria. In aquatic ecosystems fish and insects (mostly predacious) act largely as senders, while zooplankton behaves as receivers. Similarly, some other organisms, such as tadpoles act only as receivers of chemical cues from predators. In this complex system, predacious insects act as both receivers and senders of chemical cues from larger predators and to zooplanktons (especially Daphnia). While as, the responses of Daphnia to fish kairomones are quick and takes only few hours to reach their maximum value. It has been found that in presence of fish kairomones, daphnids immediately hide under macrophytes for at least 6 hours [5]. In nature, the fish population is present in most of the aquatic systems, and the rate of release of kairomone depends on the abundance of the fish population. It was established that kairomone is produced only by fish in the presence of bacteria [4].

The beneficial or detrimental effect of the fish kairomones has remained a debatable issue between researchers. Fish kairomones can reduce zooplankton growth and reproductive rates and extend its maturation time [6]. It is also known that kairomone reduces tolerance of zooplankton to environmental stress, such as starvation, high water temperature [7] and pesticide contamination [8]. Furthermore, a synergism in the effects of fish kairomones with food deficiency, low oxygen concentration and pesticide [9] has been observed. These studies suggest that fish kairomones might change zooplankton behaviour, morphology or some other characteristics and in this way change the animal's energy budget (energy loss or gain). On the other hand, some studies [9] described the life-history shifts as beneficial for Daphnia, because they avoid the predator risk by reducing the maturation size and in this way the offspring results into small adults [10] showed an attraction response in dotty back Pseudochromis fuscus, a predatory coral fish to chemical cues from already wounded prey damselfish, Pomacentrus amboinensis. It was found that the predator was more attracted to skin extracts of prey in good condition compared to prey in poor body condition. Moreover, in both the laboratory and field conditions it was found that the predator was able to differentiate between the prey sizes based on the cues from skin extracts. Similarly, [11] found the size-independent antipredator behaviours in an opportunistic predator, Hart's Rivulus Harti in response to conspecifics or heterospecifics chemical cues in and significant size-dependent trends against heterospecifics alarm cues from skin of Poecilia reticulate. Thus, it can be summarized here that the presence of multiple chemical cues indicating presence of known prey species will result in higher abundance of local predators.

Fish kairomone and phototactic swimming by daphnia in a lake

Predatory fish require a certain light intensity to attack their prey successfully. The Daphnia avoids the predatory pressure by moving into deeper water layers which are usually darker [12] showed that in Daphnia galeata × hyalina a chemical cue (kairomone) associated with juvenile perch (Perca fluviatile) changed the light-induced swimming responses. The bottom dwelling behaviour was observed in daphnids in presence of fish kairomone and showed the prompt response to changes in light intensity. Van Gool and Ringelberg (1998) found that the concentration of kairomone in water is used by Daphnia to determine the predation risk and swimming response in response to different environmental variables (like light). The cost benefit ratio of particular migration is determined by the food availability and kairomone concentration in a lake. One of the life history responses towards fish kairomones in Daphnia magna was hatching postponement of diapausing eggs (an embryonic resting stage) [13]. However, it could be that fish kairomones work as a positive signal for the hatching of diapausing eggs because the presence of fish often suppresses invertebrate predators and stabilizes the Daphnia population [14-18].

Abiotic influences over the action of kairomones

The abiotic factors that play a role in the delivery and reception of chemical cues include light, temperature, and hydrodynamics. The light and chemical cues from predators are known to work in tandem that triggers the vertical migration of Daphnia. Temperature also effects the action of kairomones and may also determine the costs and benefits of responding to kairomones from predators. For example, when D. ambigua was reared in presence of Chaoborus kairomones, it resulted into decrease of helmet size below 23˚C [7]. While as, at temperature above 28˚C, the mortality of large helmeted daphnids was increased. Thus, it explains the higher predation pressure of Daphnia in presence of predator chemical cues during summer.

Conclusion

The role of kairomones as chemical cues seems to be like a vicious circle which needs to be validated further. Once the researchers elucidate the chemistry of such cues, it can prove beneficial for the farm production of fish and other related species.

References

1. Chamero P, Leinders-Zufall T, Zufall F. From genes to social communication: molecular sensing by the vomeronasal organ. Trends Neurosci. 2012;35(10):597-606.
2. Brown Jr, William L, Thomas Eiser, Whittaker RH. Allomones and kairomones: transspecific chemical messengers. Bioscience. 1970;20(1):21.
3. Samanta S, Chakraborty S, Bhattacharya S, Chattopadhyay J. Fish kairomones, its benefits and detriments: A model-based study both from releaser and acceptor perspective. Ecological complexity. 2011;8(3):258-64.
4. Boriss H, Boersma M, Wiltshire KH. Trimethylamine induces migration of waterfleas. Nature. 1999;398(6726):382.
5. Lauridsen TL, Lodge DM. Avoidance by Daphnia magna of fish and macrophytes: Chemical cues and predator-mediated use of macrophyte habitat. Limnol Oceanogr. 1996;41(4):794-8.
6. Black AR, Dodson SI. Demographic costs of Chaoborus-induced phenotypic plasticity in Daphnia pulex. Oecologia. 1990;83(1):117-22.
7. Hanazato T. Effects of a Chaoborus-released chemical on Daphnia ambigua: Reduction in the tolerance of the Daphnia to summer water temperature. Limnol Oceanogr. 1991;36(1):165-71.
8. Hanazato T, Dodson SI. Complex effects of a kairomone of Chaoborus and an insecticide on Daphnia pulex. J Plankton Res. 1992;14(12):1743-55.
9. Hanazato T, Dodson SI. Synergistic effects of low oxygen concentration, predator kairomone, and a pesticide on the cladoceran Daphnia pulex. Limnol Oceanogr. 1995;40(4):700-9.
10. Lonnstedt OM, McCormick MI, Chivers DP. Well-informed foraging: damage-released chemical cues of injured prey signal quality and size to predators. Oecologia. 2012;168(3):651-8.
11. Elvidge CK, Ramnarine IW, Godin JG, Brown GE. Size mediated response to public cues of predation risk in a tropical stream fish. J Fish Biol. 2010;77(7):1632-44.
12. Ringelberg JB, FLIK BG, Lindenaar D, Royackers K. Diel vertical migration of Daphnia hyalina (sensu latiori) in lake Maarsseveen. part 1, Aspects of seasonal and daily timing. Archiv für Hydrobiologie. 1991;121(2):129-45.
13. Lass S, Vos M, Wolinska J, Spaak P. Hatching with the enemy: Daphnia diapausing eggs hatch in the presence of fish kairomones. Chemoecology 2005;15(1):7-12.
14. Wissel B, Freier K, Müller B, Koop J, Benndorf J. Moderate planktivorous fish biomass stabilizes biomanipulation by suppressing large invertebrate predators of Daphnia. Archiv für Hydrobiologie. 2000;149(2):177-92.
15. Brewer MC, Dawidowicz P, Dodson SI. Interactive effects of fish kairomone and light on Daphnia escape behavior. J Plankton Res. 1999;21(7):1317-35.
16. Burks RL, Lodge DM. Cued in: advances and opportunities in freshwater chemical ecology. J Chem Ecol. 2002;28(10):1901-17.
17. Nordlund DA, Lewis WJ. Terminology of chemical releasing stimuli in intraspecific and interspecific interactions. J Chem Ecol. 1976;2:211-20.
18. Van Gool E, Ringelberg J. Light-induced migration behaviour of Daphnia modified by food and predator kairomones. Anim Behav. 1998;56:741-7.