EXPERIMENTAL EVIDENCE FOR THE DISRUPTION OF PREDATOR-PREY INTERACTIONS BY CHEMICAL POLLUTION

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Abstract
Predator-prey relationships are complex and chemical communication plays an important role. The role of chemical communication between *Scorpaena porcus* and *Pomatoschistus* spp. was assessed including the added effects of a herbicide. Tank trials featured living free-roaming and confined *S. porcus* as well as a maquets. This allowed for manipulations of cues perceived by the prey. Trials were performed in chemically polluted and unpolluted seawater. *Pomatoschistus* spp. assessed predation threats using multiple sources of information. Kairomones of *S. porcus* were detected by the prey, yet simultaneous visual and olfactory cues resulted in stronger anti-predator responses. Glyphosate disrupted predator-prey interactions.This work was supported by the Croatian Science Foundation under the project COREBIO (3107).

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Predator-prey relationships have long been in the focus of biological and ecological research. In predator-prey relationships the most effective prey investment is to prevent detection and attack [1]. A prerequisite is to know where the predator is located and read its condition and behaviour by using multiple cues, at least visual and chemical. Chemical cues provide information that visual cues cannot and studies have shown that fish respond to chemical cues without an additional visual cue [2]. Glyphosate is one of the most frequent contaminants in surface, ground and drinking water. It is widely used in the world and very mobile in water and air. Its application is likely to accelerate in the future. The negative effects of pesticides in marine organisms are varied. Glyphosate has been shown to cause changes in acetylcholinesterase (AChE) activity. Changes in AChE activity are known to induce an alteration in prey location, predator avoidance, and orientation towards food [3].

The following hypotheses motivated our reasearch: 1. The predator *Scorpaena porcus* is perceived as threat by the prey *Pomatoschistus* spp. and provokes anti-predator behaviour. 2. Chemical cues of the predator provoke anti-predator behaviour in the prey. 3. The combination of chemical and visual cues of the predator result in a stronger anti-predator reaction in the prey than each cue by itself. 4. Concentrations of the herbicide glyphosate in sea water which are below the EU limit alter the behaviour of prey towards their predator. To test these hypotheses, we conducted a multifactorial indoor tank experiment. We observed prey responses to the predator under normal and polluted seawater conditions, under presence of only chemical, only visual, and both predator cues, and within environments offering zwo types of habitat, seagrass and open sand.

Concerning the behavior of prey to predator in normal ambient seawater the following results can be summarized: 1. The degree of prey activity decreased and its motionlessness increased in the presence of predator cues compared to their absence. This is consistent with the prediction that increased motion increases the risk of being detected. 2. Prey habitat choice showed no clear pattern. In daytime, when the predator was in the seagrass, prey preferred the bare sand. Pooling data from day and night suggests that prey more often finds itself in the same habitat as the predator. At night localization of the predator may be best achieved by staying closeby. 3. The prey responded differently to confined predators, seen and smelled, than to the maquet-predators which are visible but odorless. Prey did detect and react to kairomones of the predator and responded with significantly higher immobility and distance to the predator when odors were present. 4. When visual cues were presented by a living but constrained predator giving off no chemicals, the prey kept a greater diatance from the predators than to the a maquet and prey was also more likely to aggregate. Thus prey does respond to visual cues alone. 5. Presentation of both predator cues resulted in further increases in the distances between predator and prey and in more prey aggregation. However, there were no differences in the amount of activity level comparing single cue and double cue treatments.
Concerning the prey behaviour in polluted (glyphosate) water, the following results can be summarized: 1. When a very low concentration of glyphosate was added to the seawater, the prey kept a larger distance to a predator with chemical cues only than to predators offering visual and chemical cues. With only visual cues present, prey kept a larger distance to the predator in the treatment featuring the higher glyphosate concentration (EU exposure limit) than in the treatments featuring either unpolluted seawater or lower glyphosate concentration. Thus, with a higher glyphosate concentration, prey may have increased overall vigilance. 2. While there always was a regular pattern of aggregation and dispersion of prey in all glyphosate-free treatments, no pattern of aggregation/dispersion was found for any of the glyphosate treatments. This total lack of regular bahavioral patterns in the glyphosate treatments suggests that prey is not behaving normally. 3. While overall activity levels of prey in the glyphosate treatments are similar to those in the unpolluted treatments, half of the glyphosate trials resulted in a significantly higher proportion of motionless prey when under predator presence compared to the no-predator treatment. Prey in all trials featuring unpolluted seawater showed a consistent reduction in activity during the presence of predators.

We conclude that *Scorpeana porcus* and *Pomatoschistus* ssp. show classic predator prey interactions, with the prey altering aggregation patterns, distance to the prey, activity levels and habitat choice in response to the various predator presentations. Both, visual and chemical cues are important and solicit different responses in the prey. Furthermore, prey which is confronted with predators in water polluted with the herbicide glyphosate, show markedly altered predator responses compared to being in unpolluted water. Prey keeps a larger distance from the predator which is potentially an outcome of significantly higher overall activity levels. This „hyperactivity“ may also be responsible for the lack of the regular patterns of aggergation and dispersal in all polluted treatments.

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