Harmonious coexistence: ethical issues arising from studies on improving plant pollination with micro-drone swarms, while safeguarding insect populations and fostering human health

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Brief description of context

The decline in bee populations is linked to climate change, impacting their health through altered flowering times, rising temperatures, extreme weather, pesticide exposure, and higher Carbon Dioxide levels. These issues harm their habitats, colony health and pollen quality, jeopardising their crucial role in crop pollination and biodiversity. Natural pollinators, particularly bees, are critical to global agriculture, food production, and human health. They enhance the production of essential food groups, such as fruits, vegetables, and nuts, which are vital for nutrition [1]. Garibaldi et al (2022) identified four pathways linking pollinator health and human health: nutrition, medicine provisioning, mental health, and environmental quality. The global increase in human populations and food demand, combined with the declining bee populations, presents significant challenges for human health [2]. Smith et al. (2022) modelled the global health impacts of insufficient pollination. A decline of 3-5% in global fruit, vegetable, and nut production due to decreased wild pollinators led to an estimated 427,000 deaths yearly from insufficient healthy food consumption and associated diseases [3]. Low-income countries particularly suffer significant income and crop yield losses from pollinator deficits. The decline in bee populations poses a risk to global food production; to address this issue, robotic pollinators (pollibots) are being created to assist the pollination process. This case study explores the ethical considerations surrounding the development and use of pollibots to enhance pollination, while also protecting natural pollinators and promoting human health.

Discussion of ethical issues

An artificial band-aid or the solution. California produces 80% of global almonds, generating $10.4 billion annually [4]. To sustain production, honeybees are transported across the U.S., with 70% of commercial honeybees used for almond pollination [4]. Declining bee populations necessitate importing bees, which can disrupt Californian ecosystems by increasing competition with indigenous bees. Additionally, this transportation of bees means they are not pollinating their original habitats, leading to losses for those local ecosystems. Our research aims to develop pollibots for almond pollination, reducing environmental impacts and competition with indigenous bees while supporting natural ecosystems [5]. Robotic pollinator prototypes consist of small drones with GPS, high-resolution cameras, and artificial intelligence for autonomous navigation and pollination. Successful instances include a manually controlled drone that pollinated Japanese lilies and BloomX's AI-driven robotic pollinator linked to mobile apps for efficient blueberry and avocado production [4][6]. However, challenges like economic feasibility and scalability still exist.

Dependence on technology. The reliance on pollibots raises concerns about the potential neglect of natural pollinator conservation efforts. Integrating pollibots into traditional farming could enhance pollination efficiency and increase crop yields. However, this reliance on technology may diminish the focus on conserving natural pollinators like bees, impacting cultural relationships with them. Over-dependence on technology could make agriculture systems vulnerable to technical failures and cyber-attacks, reducing food production resilience for future generations. It may also divert resources from essential conservation initiatives, harming biodiversity and ecosystem health. Additionally, the environmental impact of metal, plastic and the lithium battery used in creating pollibots poses risks, as these materials could enter the food chain, through animal consumption or crop absorption, and be harmful to humans and wildlife. It is essential to balance technological progress with ecosystem preservation to maintain biodiversity and respect cultural values tied to natural pollinators.

Biodiversity. The introduction of pollibots may disrupt ecosystems and reduce plant diversity if they prioritise agricultural crops, potentially harming natural pollinators. While pollibots could support crop diversity, reduce pesticide use, and enhance cross-pollination, they are not a substitute for natural pollinators. The focus of private companies on cash crops could neglect wild plants, harming wildlife food sources and exacerbating the decline of natural bees. This reduction in plant diversity could disrupt ecosystems, negatively affecting other species reliant on varied plants. In summary, while pollibots may boost agricultural productivity, they could unintentionally harm biodiversity by detracting from conservation efforts for natural pollinators and diverse flora.

Equity and access. Access to robotic pollinator technology may be limited to wealthier regions or large-scale agricultural operations, raising ethical concerns around equity and access [7]. High development costs could disadvantage small-scale farmers who might struggle to compete with larger operations that can afford advanced technologies, worsening economic disparities in agriculture [8]. Unequal technology distribution may create geographic disparities in productivity, causing growth in some regions while others stagnate or decline in the absence of natural pollinators [7]. This could widen the gap between high and low-middle income areas, exacerbating global inequities in food security, economic stability, and health, especially in resource-poor regions reliant on agriculture [8]. Addressing these challenges requires thoughtful development and distribution policies to ensure equitable access for all farmers, promoting fairness and preventing further disparities.

Long-term ecological consequences. Pollibots are being tested in simulation environments so it will take years to establish if they would be capable of sustaining global food production, with investment costs of infrastructure, hardware repair and maintenance posing significant hurdles [9]. Moving forward there is a need to evaluate the carbon footprint of pollibots throughout their life cycle, from production to disposal, while exploring eco-friendly alternatives [10]. Researchers should proactively address potential long-term environmental impacts in the early stages of development [10]. Alternatives to pollibots, such as managed pollinators (e.g. honeybees), wind pollination, self-pollinating crop varieties and manual pollination, though beneficial, have weaknesses including vulnerability, unpredictability and the need for significant human labour. Pollibots could alleviate some of the weaknesses of these alternative solutions and be used in combination with them to enhance food security and support climate resilience. Further research is needed to evaluate the long-term risks and benefits and health effects of pollibots. This research must address social, security, and privacy concerns. Roboticists should leverage collective intelligence and expert collaboration for sustainable pollination strategies.

Conclusions and recommendations

Recommendation one: balance human-centred and interspecies design thinking. The robotic community should expand its focus from simply solving problems to enhancing human-robot interactions while valuing insect pollinators for their intrinsic importance. Price (2023) suggests viewing pollinator loss through a multispecies justice lens, emphasising their role in food security. Researchers are encouraged to develop robotic pollinators that support natural pollinators and promote sustainable agriculture looking at human-robot-bee-biodiversity interactions. Although the efficacy of nonhuman-centred design in robotics is uncertain, exploring it highlights the vulnerability of natural pollinators [11]. A holistic policy approach integrating environmental, agricultural, and technological aspects is essential for enhancing biodiversity. The long-term focus should balance ecological benefits with human needs, aiming for robotic pollinators to support both agricultural productivity and ecological health for sustainable outcomes.

Recommendation two: develop responsibility by design practices. To maximise the benefits of robotic pollinators, it is essential to implement a concept known as "responsibility by design." This approach weaves ethical and sustainability principles into every stage of the development and deployment of these technologies. It aims to ensure that the use of robotic pollinators enhances food production while safeguarding biodiversity and public health. Key aspects of this approach include sustainability in design, which involves a thorough assessment of the environmental and social impacts of robotic pollinators. Additionally, design ethics play a crucial role in co-creating solutions alongside the communities that may be affected. This ensures transparency, inclusivity, and collaboration across various disciplines. Achieving this cultural shift necessitates training for all stakeholders involved. This training should focus on ecodesign, accessibility, and the recognition of multispecies rights. By embracing these practices, we can develop robotic pollinators that not only improve agricultural productivity but also align with sustainability and ethical standards.

Concluding remarks. Pollibots may help address food security challenges linked to dwindling natural pollinators and climate change. Their design must consider biodiversity and ecological impacts. Recommendations aim to ensure these robotic pollinators benefit human health, natural pollinators, and sustainability initiatives.

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