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Problem A: Introducing Stress

A group of individuals recently purchased a flight to go to the International Space Station [1]. Each of them had to complete a rigorous training regime and demonstrate that they were capable of handling the physical and mental demands of space travel. When they arrived, they were expected to provide help and assistance to the astronauts who were at the station and the new crew members had a large number of tasks and experiments to complete.

The hectic schedule nearly overwhelmed the newly arrived guests, and the extra attention they required added to the stress felt by the existing crew. What can be done to ease this burden, yet result in a more efficient use of time for a flight crew? Before answering this question, a way to model the stress and capabilities of a flight crew must be created.

Develop a mathematical model of the stress and capabilities of a group of people. Assume that there is an existing group of people in place at the destination who are already under a great deal of pressure to complete their assigned tasks. The model should include the addition of a second group of capable people who arrive after undergoing the stress of a space launch and do not have prior exposure to the new environment. Given the expected stress levels over time what is the impact on the whole group?

Your model should be able to take a schedule for the whole group and then predict the impact on the group of people. You should identify what happens under different scenarios including the expectation of an immediate high level of productivity, a short period of rest followed by a sharp rise in a high level of productivity, and then a gradual increase from low to high levels of productivity. Which scenario results in the lowest stress and highest net productivity? Also, what should ground observers expect from small deviations from a given schedule?

Bibliography:

[1] “Pace of work put strain on private astronaut mission to ISS,” Jeff Faust, https://spacenews.com/pace-of-work-put-strain-on-private-astronaut-mission-to-iss/ . Last accessed 17 June 2022.

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Problem B: The Mechanics Of Suction Feeding

A common feeding method for a predatory fish is to quickly open its mouth to pull in water as well as prey animals into its mouth [1]. The resulting physics to model this phenomenon can be quite complicated, involving the interaction between the physical structure of the predator's mouth and the fluid mechanics associated with the moving water. Even the movement of the predator's mouth involves a complicated interaction between the anatomical structures of the mouth and head.

Prior to a large-scale investigation of the full dynamics, a preliminary examination of the potential forces that could possible occur will be conducted. Using Figure 1, in the overview of the phenomena [1], develop a mathematical model to mimic the movement of the jaw. Assume that the mouth parts have simple attachment points at their ends and ignore interactions with the fluid. As the mouth quickly opens where and when are the forces acting on the mouth parts the greatest? What are the potential limitations of the structure? Provide a rough estimate of the shortest time frame the mouth can open and close. Based on the timing what is the effective range and other limitations of this feeding technique? Focusing solely on the movement of the mouth how can your model be adapted in the next steps to create a more accurate representation of the movement of the mouth?

Bibliography

[1] Day, Steven W., Timothy E. Higham, Roi Holzman, Sam Van Wassenbergh, 2015. Morphology, Kinematics, and Dynamics: The Mechanics of Suction Feeding in Fishes. *Integrative and Comparative Biology*, 55(1): 21-35. https://doi.org/10.1093/icb/icv032 . Last accessed 14 July 2022.

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Problem C: People Ruin Everything

The presence of people has an impact on how animals behave. Many prey animals become less wary* and become less likely to engage in behaviors that reduce the risk of predation after repeated exposure to human activities [1]. The behaviors take time to change, but the introduction of people generally happens rapidly. What happens when a group of people enter a new area?

To explore this question, create a mathematical model of a system of animals that interact with each other and are exposed to human activity, and explore the trends over time. In this scenario humans should be quickly introduced into a system in which the animals have been in place for a long time. Your model should include the impact of behavioral changes over time and predict the long-term implications of what happens when prey animals have some of their antipredator responses muted.

The researchers who observed this phenomenon only examined the loss of traits over time for animals that live in urbanized areas. What happens when humans move out of the system? Would this result in an effective method to restore an ecosystem or has the damage already been done? Use your model to predict the overall impact in an established system in which humans quickly abandon the area.

* Thanks to Graham Atkinson for pointing out the fact that we had used “weary” when we really meant “wary.”

Bibliography

[1] Geffroy B., B. Sadoul, B.J. Putman, O. Berger-Ta, L. Z. Garamszegi, A. P. Møller *et al.* 2020. Evolutionary dynamics in the Anthropocene: Life history and intensity of human contact shape antipredator responses. *PLoS Biol.* 18(9): e3000818. https://doi.org/10.1371/journal.pbio.3000818 . Last accessed 16 June 2022.