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Mothership and multi-tender routing: an optimisation framework for coral deployment under bathymetric constraints

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Abstract: Effective large-scale reef restoration depends on planning vessel logistics to deliver corals to pre-determined target locations in bathymetry-constrained waters. The critical path, representing the longest weighted path, is used to quantify deployment trip duration. We minimize deployment trip duration by utilizing a coordinated fleet (Gonzalez-R et al. 2020) comprising a carrier vessel (mothership) that hosts several small vessels (tenders) used for coral deployment, while considering fleet utilization and obstacle avoidance for depth-constrained vessels.

We present a routing optimisation framework that integrates: (1) capacity-constrained k-means (Macqueen 1967) to cluster target deployment locations into tender workloads; (2) shortest-path routing with obstacle avoidance using nearest neighbour greedy heuristics (Bellmore and Nemhauser 1968), 2-opt local search (Croes 1958) and A* (Hart et al. 1968); (3) mothership waypoint improvement, representing tender launch and retrieval locations, using gradient descent (Cauchy 1847); and (4) iterative solution improvement using simulated annealing metaheuristics (Kirkpatrick et al. 1983). We consider two case studies in the Great Barrier Reef, representing potential deployment scenarios with distinct spatial characteristics, benchmarked against expert elicited manual plans. To assess robustness, we simulate stochastic disturbances that restrict target location availability mid-deployment, forcing reactive resequencing and reallocation. Results are compared with simulations under perfect prior information. Sensitivity of tender fleet configuration specifications (number and capacity) highlight logistical trade-offs and inform investment decisions in differing fleet compositions.

We provide a bathymetry-dependent routing formulation that coordinates a mothership and multiple tenders, utilizing a hybrid optimisation strategy and a reactive robustness protocol for weather-based disruptions. The scalable framework is directly applicable to reef restoration and accommodates the inclusion of additional constraints for other marine operations to support decision-makers in pre-deployment operational planning.

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