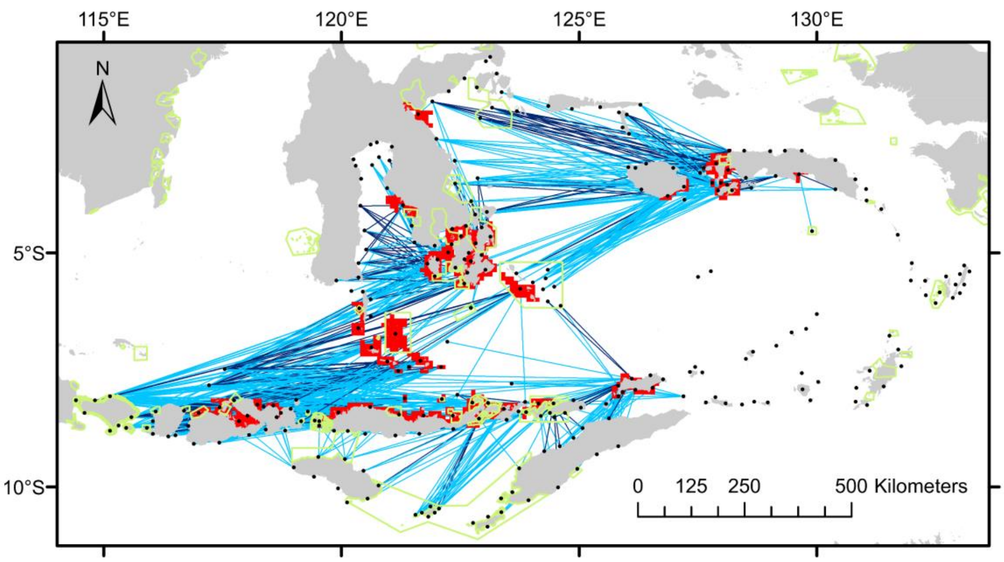
Incorporating larval dispersal into marine protected area design

The issue

Following decisions on the total coverage of marine protected areas (MPAs) (see policy brief – how much to protect?), decision makers need to identify high priority locations for MPA enforcement. Standard MPA design methods are focused on habitat representation, identifying a target proportion (e.g. 30%) of different habitat types that can be protected for a minimum economic cost. However, this method ignores a critical ecological process –the dispersal of marine larvae by ocean currents. Many marine animals produce millions of eggs and larvae that drift in the ocean for days, weeks or even months until they settle in shallow coastal habitats. Settlement habitats range from being close to home, to sometimes being 10s-100s of kilometres away from spawning locations. By incorporating data on larval dispersal into the MPA design process, MPAs can help optimize dynamic interactions between population recovery, larval production and the connectivity between protected and unprotected populations. This is a prerequisite to support more efficient biodiversity conservation and the sustainability of productive fisheries.

The evidence

In collaboration with conservation and fisheries practitioners, a novel, transparent and flexible MPA design approach was developed to reconcile various possible management objectives by integrating three important attributes of larval dispersal: (1) local larval retention (the number of larvae retained locally in MPAs), (2) import-connectivity (the number and diversity of larvae transported into MPAs from other areas), and (3) export-connectivity (the number and diversity of larvae transported from MPAs to unprotected locations). The approach was tested based on multiple realistic dispersal patterns, different types of threats to marine populations, and different management objectives. The outcomes demonstrate consistently more efficient biodiversity conservation and fisheries management, encouraging future applications specifically where management tools other than MPAs are not feasible.



The best MPA network to protect biodiversity and support fisheries persistence on coral reefs in the Sunda Banda seascape, Indonesia. Candidate MPAs in red cover 30% of all coral reef habitat, balancing efficient protection from local threats and desirable dispersal characteristics. Blue lines highlight strong (light) and very strong (dark) connectivity between MPAs and putative fishery hotspots. Green lines denote officially declared MPAs. © Krueck et al, Ecological Applications.

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Examples of possible management objectives and associated treatments of larval dispersal information

Management objective	Retention of larvae in MPAs	Import of larvae into MPAs	Export of larvae from MPAs
Local biodiversity conservation	**Yes**	Yes (if uncontrolled stressors threaten local persistence)	**No**
Biodiversity conservation in and outside of MPAs	**Yes**	See above	**Yes** (MPAs should support threatened populations)
Support fisheries productivity	**Yes**	See above	**Yes** (MPAs should supply important fishing grounds with many larvae)
Support long-term fisheries persistence	**Yes**	See above	**Yes** (many MPAs should supply important fishing grounds with larvae)

Frequently asked questions

1) Is formal training and prior MPA design experience required to use the approach?
We recommend participation in a formal training course on advanced MPA design currently offered by Dr Nils Krueck (University of Queensland, Australia) and the World Wildlife Fund (WWF) Indonesia. Prior experience with the standard MPA design software MARXAN is desirable. However, basic training in conservation planning and MARXAN applications can be part of the advanced MPA design course.

2) What kind of data do we need to apply this MPA design approach?
Larval dispersal is often measured by using biophysical models. Modelling data is available from different sources, including, for example, the Coral Triangle Atlas (http://ctatlas.reefbase.org/). If no data is available for the planning region, publicly accessible models can be used to simulate representative examples of larval dispersal trajectories. Publicly accessible models include ConnIe 2 (http://www.csiro.au/connie2/) and Marine Geospatial Ecology Tools (http://mgel.env.duke.edu/mget). For more comprehensive customized simulations, university groups with relevant expertise in larval dispersal modelling might need to be contracted.

3) Can the dispersal optimization approach be integrated with standard MARXAN applications?
Yes, formal training on advanced MPA designs teaches participants alternative options to integrate the optimization of larval dispersal with standard MPA design objectives, such as habitat representation.

4) What is the level of uncertainty that conservation and fisheries will benefit?
Alignments of measured and simulated larval dispersal are still rare, but there is increasing evidence that simulations correctly estimate both the strength and direction of larval dispersal. We recommend using both standard and advanced MPA design methods in order to specify any potential trade-offs in MPA placement. In many cases, there will be sufficient flexibility to meet all management objectives, including those for larval dispersal, based on multiple alternative MPA network configurations. This situation allows users to make informed decisions on MPA placements even if there is considerable uncertainty about conservation and fisheries benefits.

Further information

Krueck NC, Ahmadia GN, Green A, Jones GP, Possingham HP, Riginos C, Treml EA, Mumby PJ (2017) Incorporating larval dispersal into MPA design for both conservation and fisheries. Ecological Applications 27(3): 925-41.