A STRATEGIC APPROACH TO MARINE PROTECTED AREAS BASED ON LARVAL CONNECTIVITY IN THE LOMBOK STRAIT

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INTRODUCTION

- Despite progress in establishing MPAs, global coverage is still below the **10% CBD 2020 target**. **Ecological connectivity**, including larval dispersal and energy flow, is **crucial for ensuring the effectiveness of MPAs**[1].
- **Frigate tuna** (Auxis thazard) is a **key fishery resource** in West Nusa Tenggara (1,626 tons in Lombok Barat, 2022). However, **CPUE has declined by arround 7.8%** annually **due to overfishing and a lack of seasonal regulation**, threatening local livelihoods and industry[2].
- **The biophysical larval dispersal model** (MITgcm + OceanParcels) provides robust **estimates of larval connectivity**. This approach supports evidence-based MPA network design for ecologically and economically important species like Auxis thazard[3].

METHODOLOGY

Model framework:
- OceanParcels (3D Lagrangian particle tracking)

Fieldset:
- horizontal velocity (u, v), vertical velocity (w), temperature (T) from MITgcm hydrodynamics results

Resolutions:
- Horizontal: ~1/150° ≈ 750 m
- Vertical with 44 layers < 274 m

Release points:
- 3,823 (unevenly distributed across 20 MPAs)

Pelagic larval duration (PLD):
- 36 days

Vertical habitat range:
- 3.5–200 m

Release duration:
- 121 consecutive days

Simulation runtime:
- 152 days total

Total particles:
- 925,166

The following MPAs are included in the analysis:

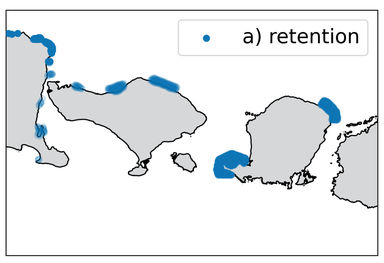
- Nusa Penida
- Situbondo
- Buleleng
- Karangasem
- Gili Sulat & Lawang
- Gili Air
- Bali Barat
- Gili Tangkok
- Banyuwangi
- Gili Balu
- Perancak
- Kuta Selatan
- Bali Selatan
- Serangan
- Tatar Sepang
- Melaya
- Benoa Bay
- Panjang Island
- Semawang
- Kramat

$$X(t+\Delta t) = X(t) + \int_{t}^{t+\Delta t} \vec{V}(x,\tau)d\tau + \Delta X_b(t)$$

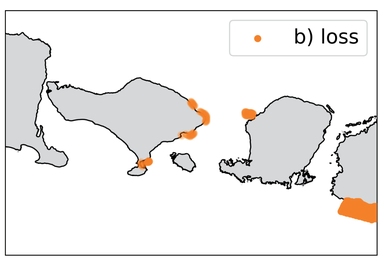
Lagrangian particle advection scheme, where particle position is updated from the local velocity field and an additional stochastic term.

Larval trajectories were summarized into **transition matrices and analyzed as weighted, directed graphs** using **NetworkX** (v2.5.1). Key metrics included retention, loss, and beaching rates, source–sink indices, and betweenness centrality to assess the ecological role of each MPA.

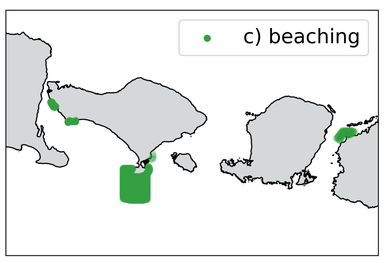
RESULTS



High retention (larval refugia)
Recommendation:
Prioritize local sustainability zones to secure recruitment and community-based fisheries.

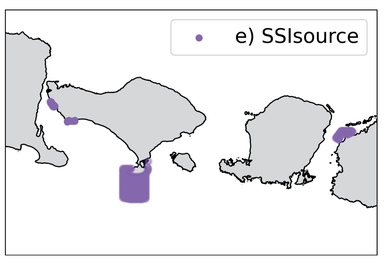


High loss/export (major larval donors)
Recommendation:
Manage as regional larval sources, requiring strict protection to maintain spillover.

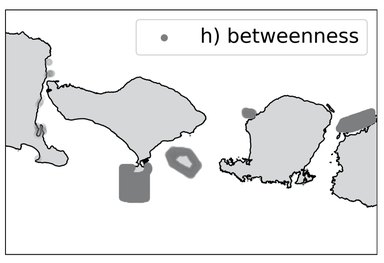


High beaching (coastal spillover sites)
Recommendation:
Support small-scale fisheries and regulate coastal harvest to avoid overexploitation.

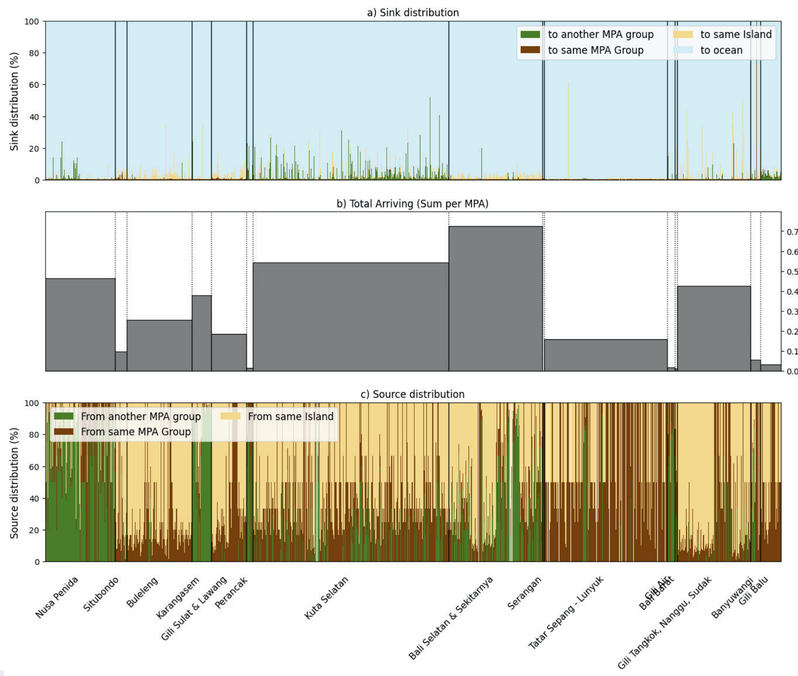
Strong sink MPAs (SSIsink)
Recommendation:
Ensure fisheries regulations align with high dependency on external larval input.



Strong source MPAs (SSIsource)
Recommendation:
Manage as regional seed banks for larval dispersal, with priority monitoring.

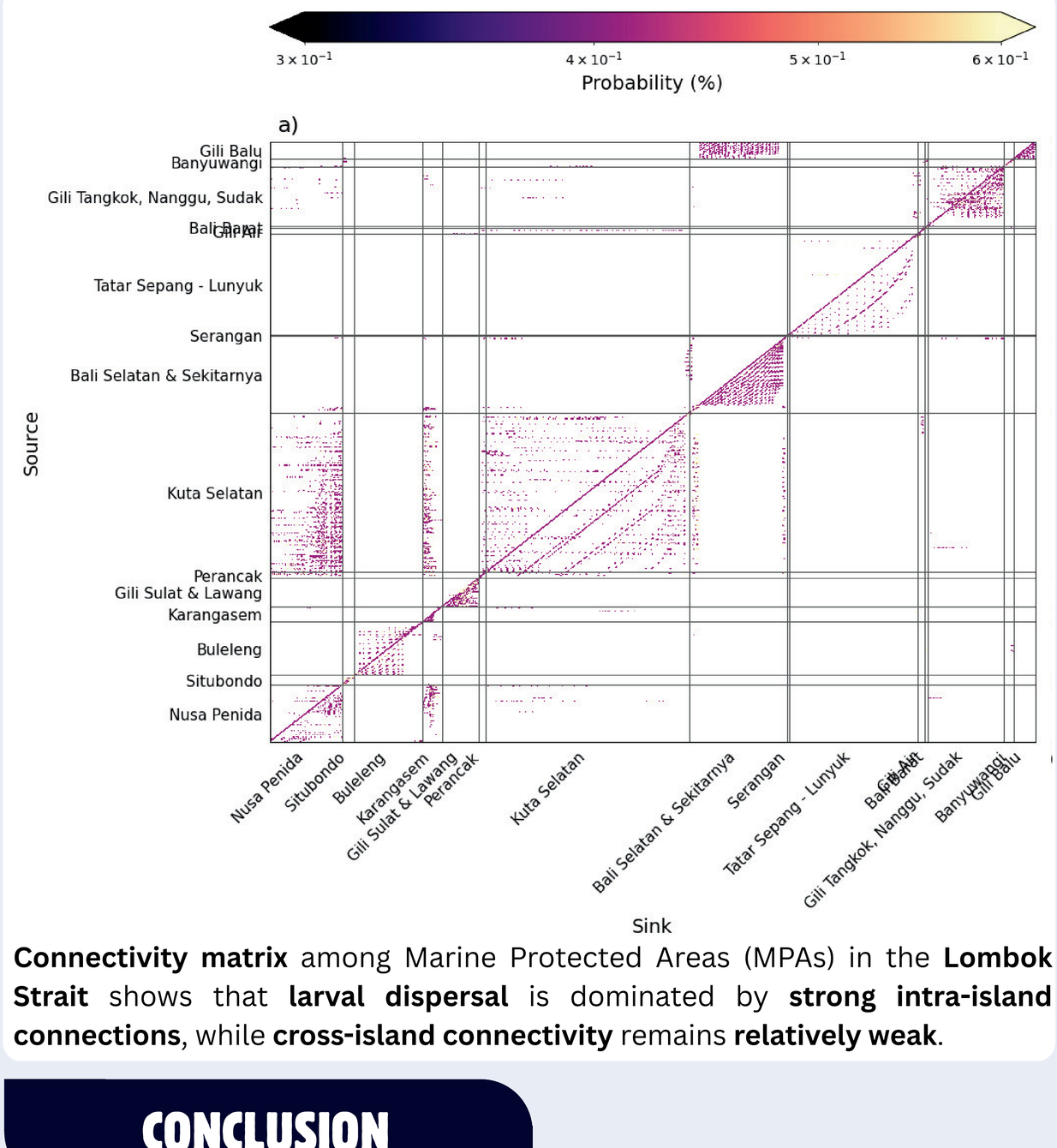


Key corridors/connectors (high betweenness)
Recommendation: ensure connectivity is not disrupted by local stressors.



Most particles were exported to the open ocean (>90%), with only limited retention or exchange among MPAs. Arrival rates were highest in Bali Selatan, South Kuta, Karangasem, and Nusa Penida.

Source contributions varied, with MPAs such as Karangasem and Nusa Penida acting as inter-island sources, while Buleleng and Situbondo were mainly supplied by nearby groups.



Connectivity matrix among Marine Protected Areas (MPAs) in the **Lombok Strait** shows that **larval dispersal** is dominated by **strong intra-island connections**, while **cross-island connectivity** remains **relatively weak**.

CONCLUSION

- **Certain MPAs function as donors and connectors, critical for sustaining regional connectivity.**
- **Findings highlight that designing MPA networks must account for connectivity roles, not only area size, to ensure ecological resilience and sustainable fisheries for species such as Auxis thazard.**

References:

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3. Assis, J., Tyberghein, L., Bosch, S., et al. Bio-ORACLE v2.0: Extending marine data layers for bioclimatic modelling. Global Ecology and Biogeography, 30(1): 258–266 (2021).

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