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FISH FOREVER

Marine Reserve Design

Marine Reserve Network Design Guidelines

Rare
Rare is the leading behavior change organization in conservation. Rare specializes in identifying proven locally-led solutions and work with partners and communities worldwide to bring these solutions to a regional and national scale.

FishForever
Fish Forever is Rare's community-led solution to revitalize coastal marine habitats, such as coral reefs, mangroves and seagrasses, protect biodiversity, andsecure the livelihoods of fisher households and their communities. It uses an innovative approachto address coastal overfishing—by empowering communities through clear rights, strong governance, local leadership, and participatory management—that protects essential fish habitat and regulates fishing activities.

Cover photograph: © George Stoyle/ Rare

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INTRODUCTION

Fish Forever's reserve design approach develops networks of reserves across multiple communities that reflect ecological connectivity and provide optimal conditions for species recovery and sustainability, while providing both economic and ecological benefits in adjacent fishing grounds. To maximize the ecological and fisheries benefits, reserve networks will protect critical habitats, avoid threats of habitat degradation, incorporate larval connectivity, and account for adult movement patterns. Local involvement and engagement in the selection and designation of these areas is critical to their long-term success. Reserves established and implemented within individual communities will contribute to a regional network allowing these areas to collectively protect and restore ecosystems that are critical for fisheries recovery.

This approach will achieve the following overarching goals:

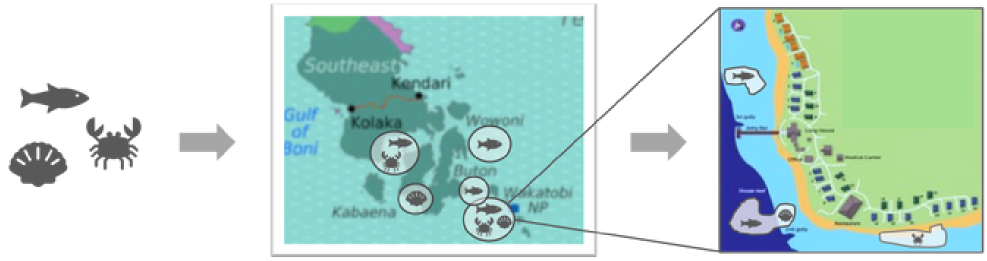
- Develop ecologically relevant reserve networks on a regional scale to serve as planning tools for Rare sites
- Prioritize sites for program implementation that are well connected through larval dispersal and adult movement
- Link Rare sites with other large-scale spatial planning efforts
- Maximize catch within managed access area
- Rebuild or sustain fish populations targeted by fishers
- Rebuild or sustain herbivorous fish populations
- Facilitate climate resilience
- Restore or sustain ecosystem function
- Increase or stabilize fisher income

RESERVE DESIGN PROCESS OVERVIEW

The reserve network design approach is centered around three key topics:

1) species selection,
2) population connectivity and
3) reserve placement.

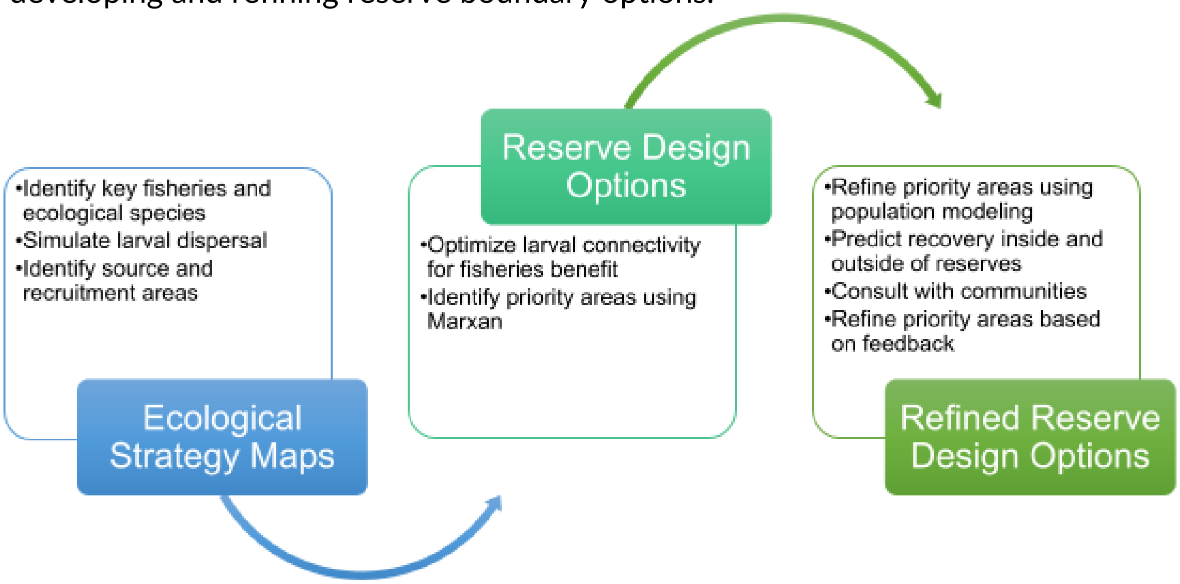
The image below summarizes data inputs, critical processes, and main outputs. The first step of this process is to engage with the community to identify key ecological and commercial species. The reserve network will be optimized for these species. The second step is to identify ecological priority areas that are interconnected, support high larval density, and/or serve as larval sources or sinks. The third step will map out strategically sized and placed site-level reserves that are connected through larval dispersal and adult movement and balance both conservation and fisheries goals.



Key Questions	*What species should we protect and what is the optimal reserve size?*	*How are the areas that support these populations connected to each other?*	*Where are the optimal areas for collective and effective protection?*
Data Inputs	• Ecologically and commercially important species • Species home range and life cycle	• Larval and spawning traits • Habitat maps • Ocean currents	• Model targets • Catch/abundance data • Fishing grounds • Current spatial management • Pollution and threat areas • Habitat Maps • Population growth parameters
Critical Processes	Participatory community and fisheries assessment	• Larval dispersal modeling • Regional management body discussions	• Marxan • Metapopulation modeling • Community management body discussions
Main Outputs	List of prioritized species Fishing grounds	Map of priority areas for regional ecological connectivity	Reserve boundary options with catch predictions

RESERVE DESIGN PROCESS IN DETAIL

Below is a detailed look at the reserve design process focusing on ecological strategy maps and developing and refining reserve boundary options.

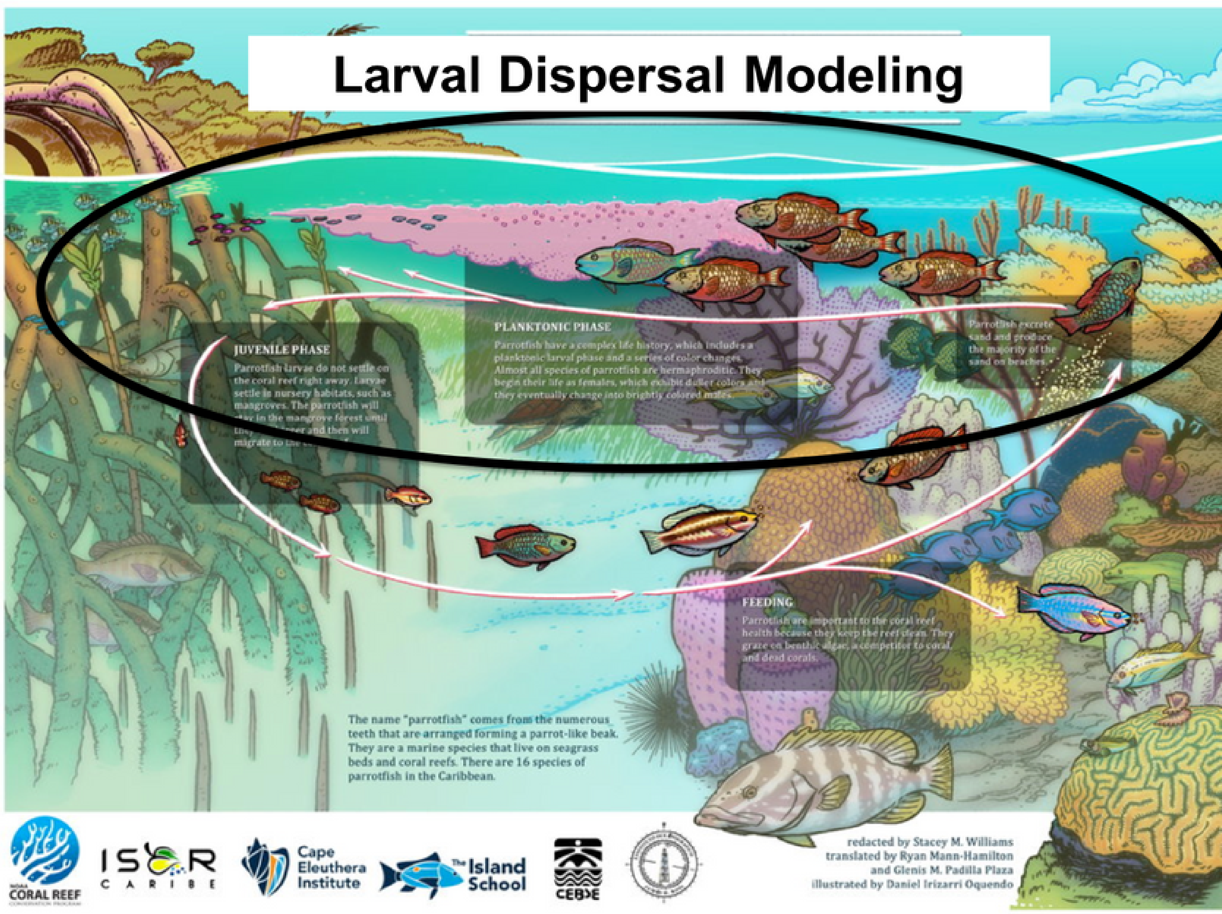


REGIONAL ECOLOGICAL PRIORITY ZONES

Regional scale reserve network planning begins with identifying ecological priority zones that are key areas for connectivity and critical habitat for the priority species identified by the communities. Ecological connectivity is primarily driven by ocean currents and larval behavior.

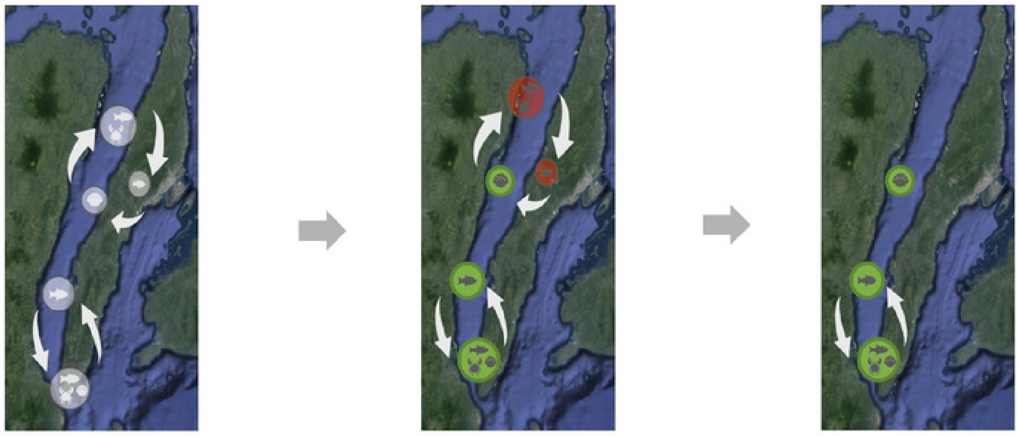
Larval dispersal modeling uses these components to predict the movement of marine larvae across the seascape and identify pathways that link adult populations. The image below illustrates an example of a fish as is moves through the following lifecycle:

1) Spawning
2) Egg fertilization
3) Larval development in the open ocean for a period of time (pelagic larval duration)
4) Larval settlement in specific habitats
5) Juvenile development in nurseries or juvenile habitat
6) Migration to adult habitat (not all species migrate to a different habitat as adults)



Our reserve design process models the movement of larval through the first four stages of this lifecycle. Identifying areas where larvae settle is critical for designing an effective reserve network. Through larval dispersal modeling and a reserve placement optimization tool developed by the Capturing Coral Reef & Related Ecosystem Services (CCRES) project, we will highlight priority reserve locations that are likely to support fish populations that are self-replenishing, import larvae from other areas, and export larvae to fishing ground. These areas serve as a master plan for a predefined region and can be used to prioritize sites for program implementation.

Larval dispersal modeling and optimization will identify, and cluster key areas as shown in the connectivity assessment stage below. Once the locations and connectivity patterns are determined, country teams can conduct a feasibility assessment to exclude locations where community conflict, policies or development that hinder implementation and adoption of a regional network. The regional network map highlighting ecological priority zones that are associated with supportive communities will serve as a discussion document for country teams to take to key decision makers and obtain commitments for protecting these areas.



Connectivity Assessment

- Identify key areas that are connected through larval dispersal of ecologically and commercially important species.

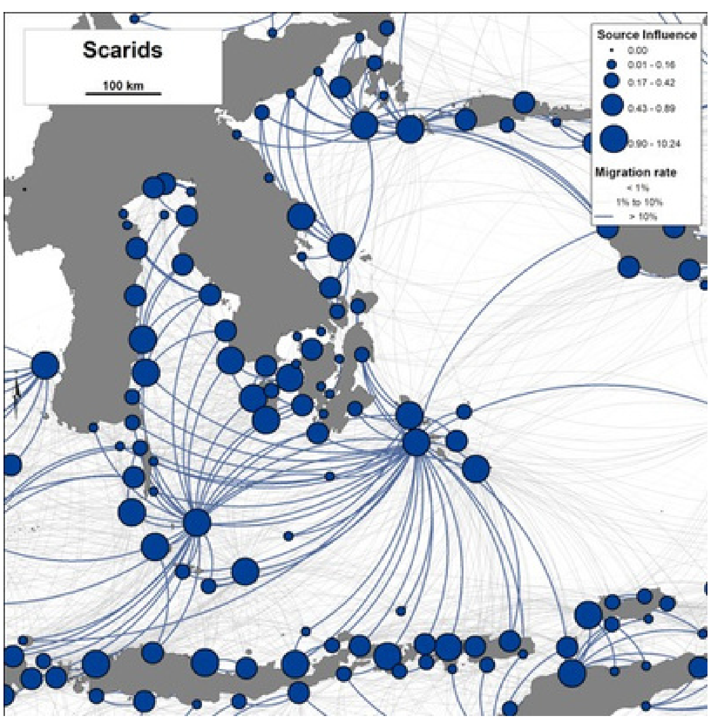
Feasibility Assessment

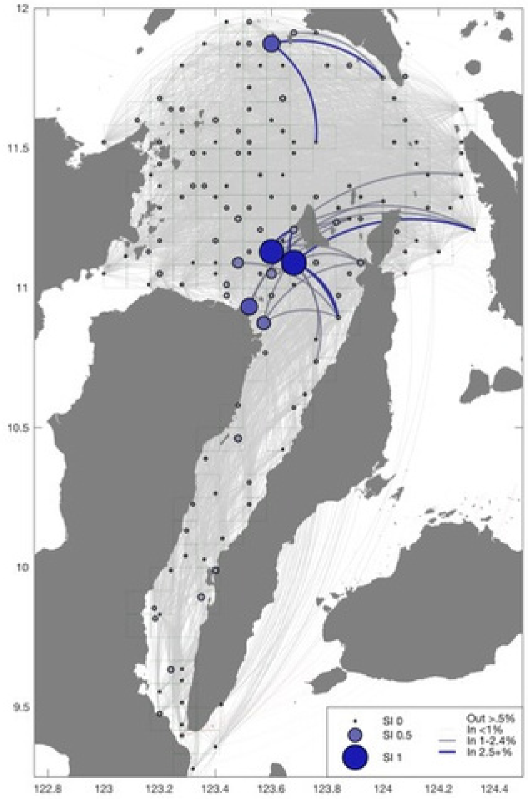
- Identify communities that facilitate or hinder regional operationalization i.e. enabling policy, partner relations, social conflict and coastal development plans.

Regional Network

- Select communities for inclusion in the regional network. Discuss the network with key decision makers and obtain commitments for protection.

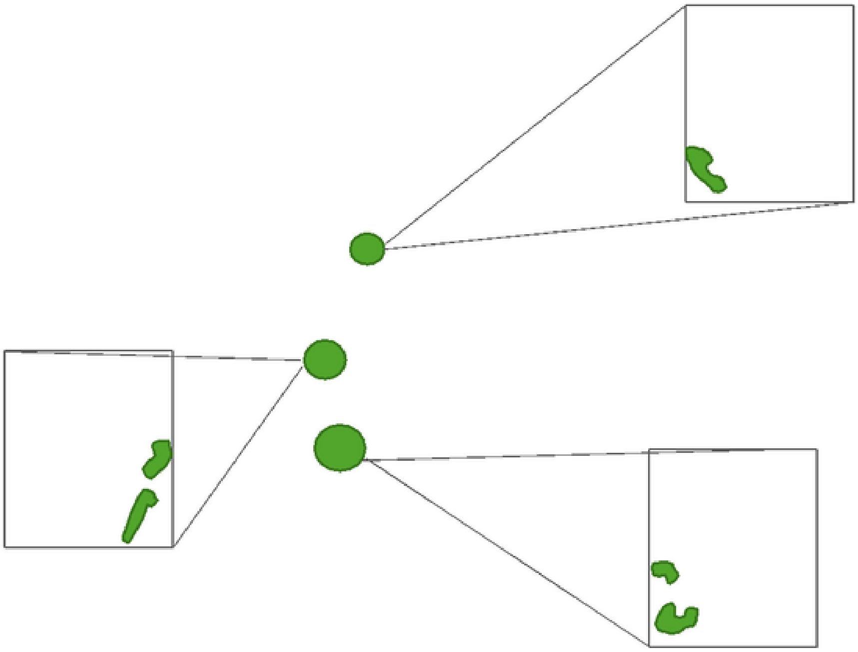
SAMPLE ECOLOGICAL PRIORITY AREAS





RESERVE NETWORK DESIGN OPTIONS

The last stage of reserve design development identifies reserve boundary options that are within the key priority areas and balance fisheries and conservation objectives. This is accomplished by running Marxan, a widely used decision support software for conservation planning, to select areas that satisfy predetermined objectives and targets (see below). Marxan produces thousands of potential design options. Metapopulation modeling is used to choose the Marxan options that best facilitate the persistence of key species and maximize fisheries yield. The final outputs will provide predictions of population recovery within the reserve and catch within fishing areas. We suggest choosing 5 options for discussion with community leaders, but country teams can request as many as they deem necessary.



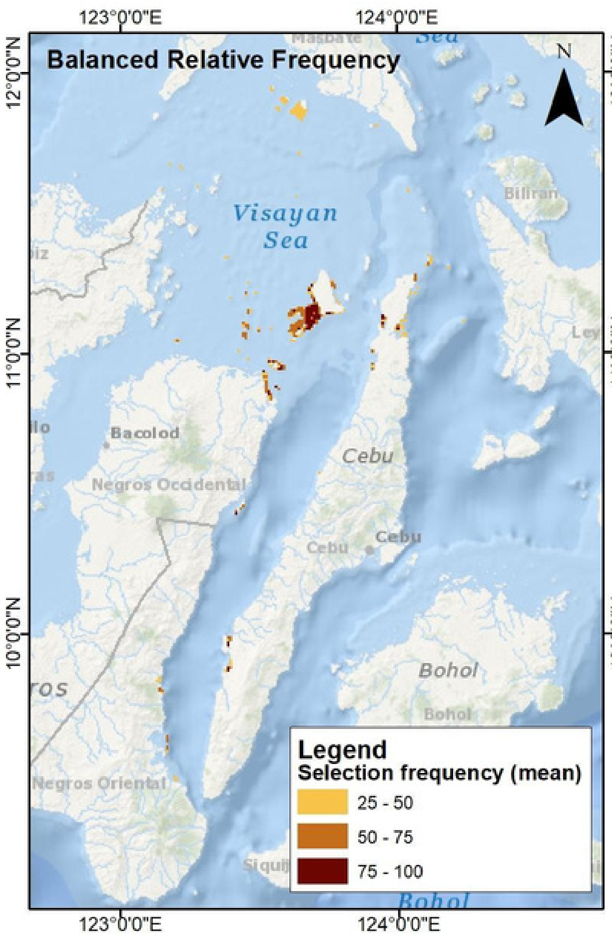
RESERVE NETWORK OBJECTIVES AND TARGETS

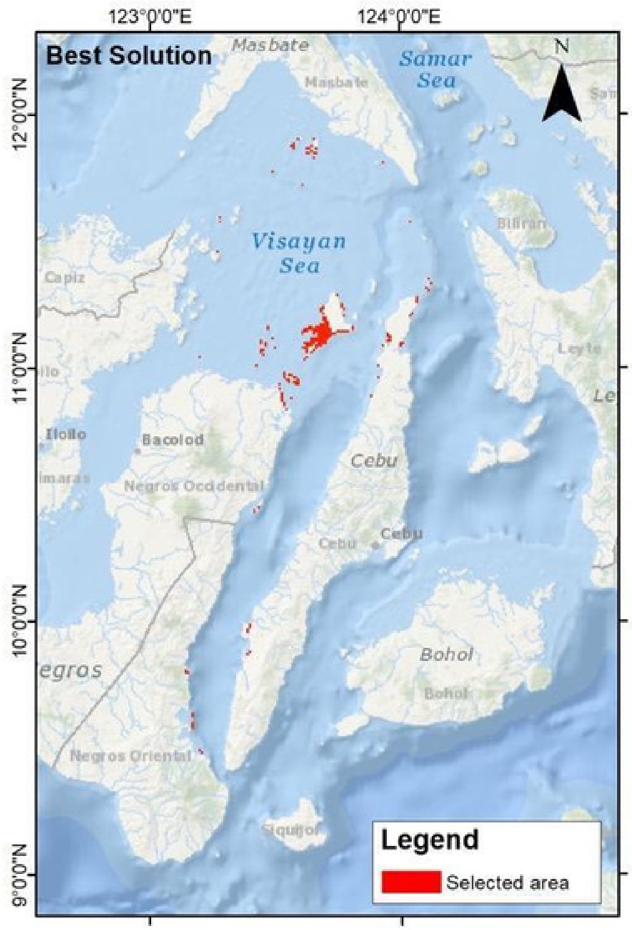
Priority	Objective	Target
Fixed	Protect all stages of lifecycle	Protect 20% of adjacent key habitats (coral, mangrove, seagrass)
Fixed	Minimize outside threats	Avoid high pollution areas, area of large infrastructure, and major tourist areas
Fixed	Protect key spawning areas for those fish that aggregate	Protect 100% of spawning aggregation sites
1	Optimize larval connectivity to facilitate fish population recovery inside reserves and within fishing areas	Prioritize areas that balance larval import to reserve areas and export to fishing areas
2	Maximize biodiversity in reserves	Prioritize areas with high fish and coral functional diversity

SAMPLE FINAL OUTPUTS

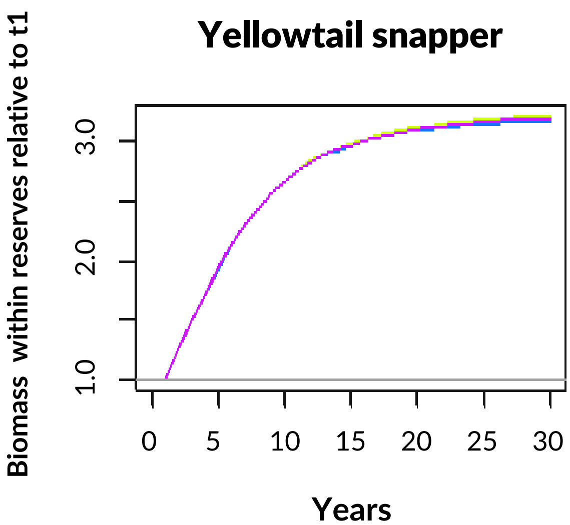
Solution frequency Map: Overlays all reserve design options across a region onto one map. This highlights areas that are consistently chosen as key areas.

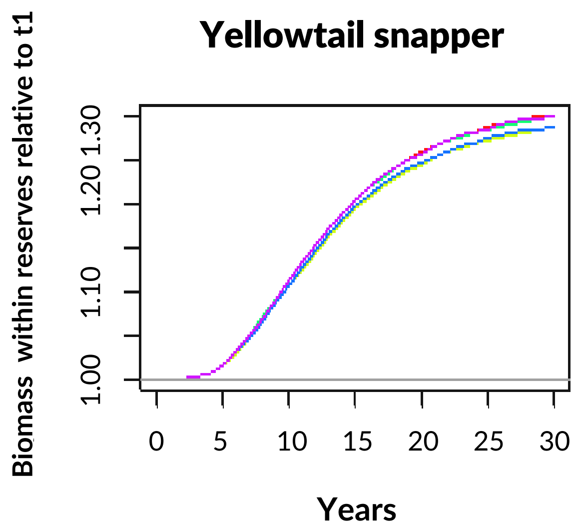
Individual Solution Maps: Each reserve design option can be discussed individually. These maps will be accompanied by graphs showing catch predictions over time.





Recovery Curves: Population modeling will result is predictions of fish population recovery over time both inside and outside the reserves. The recovery curves will represent relative biomass increase over time.





DATA COLLECTION

The table below details the data needed for each step in the reserve design process. Data collection will be a collaborative effort between the Rare country teams, the Rare Arlington team, and external partners.

Design Component	Detail needed	Rational	Sources
Participatory	Species of commercial and ecological importance	Reserve networks will be developed for important fisheriesa nd/or ecological species. The network can be designed to benefit multiple species where appropriate.	Community workshops
	Fishing Grounds	Fishing grounds will be overlaid on the ecological priority areas to assess reserve costs and identify areas to be avoided	Community workshops
	Threats to the fishery	Threats to the fishery (industrial fishers, development, pollution, climate change, development, etc) will be used to identify areas to avoid and goals for the reserve network.	Community workshops
	Critical habitats for each stage of species lifecycle	Nursery habitat, larval settlement habitat, adult feeding and spawning habitat, and spawning aggregation locations.	Community workshops, Literature review, local NGOs, local universities, local governments
	Uses of marine resources	Reserve related benefits to the ways in which the community uses the marine resources will be communicated and maximized	Community workshops
	Marine spatial plans/Existing MPA locations	Existing reserves will be identified and incorporated into the model.	Community workshops, local governments/NGOs
	Territorial water boundaries	Territorial waters will be identified and incorporated into the model.	Community workshops, local governments/NGOs
Habitat	Major habitat types (coral, mangrove, seagrass)	Replicates of all habitats used by juveniles and adults of target species will be protected within the reserve network.	Literature review, local government databases, consultants, local NGOs
Land Use	Land development	Land development results in ecosystem threats such as pollution, sedimentation, increased population size, increased fishing pressure, and habitat destruction. Reserve networks should be designed to minimize these threats.	Literature review, local government databases, consultants, local NGOs, global databases
	River outputs and associated pollutants	River runoff with high levels of sedimentation, nutrients, and pollutants contributes to degraded habitats. These areas should be avoided when designing a reserve network.	Literature review, local government databases, consultants, local NGOs, global databases

Ecological Data	Target species abundance/biomass Habitat health: Benthic Cover preferably at the species leve Species distribution modeling	Estimating effects of a reserve network is most accurate when baseline data is obtained prior to implementation. This data can describe regional or more localized trends in species abundance or biomass and habitat health.	Literature review, local universities, local NGOs, local governments
Larval Dispersal	Ocean current patterns	Ocean currents can transport larvae across long distances or facilitate larval retention within a localized area.	Universities, biophysical modeler
	Pelagic larval duration	The time that the target species spends in the water column during the larval stage. This is one factor that influences the distance that the larvae will travel before settling.	Literature review
	Vertical Migration	Measurement of position within the water column throughout the pelagic larval duration. Vertical movement within the water column influences dispersal trajectory.	Literature review
	Settlement habitat	Preferred habitat type for larval settlement will be used to identify all potential settlement locations in the biophysical model.	Literature review
	Adult (release habitat)	Preferred habitat for adult spawning will be used to identify all potential spawning locations in the biophysical model.	Literature review
	Mortality rate	Natural larval mortality rate will be used in the biophysical model to estimate the number of larvae that survive to settlement.	Literature review
	Spawning time and location	Timing, frequency, and location in the water column of spawning events will be used in the biophysical model to determine release parameters.	Literature review
Adult Movement	Home range	Area used by the target species during normal daily activities will be used to identify optimal areas for protection as well as spillover benefits.	Literature review
Population Model	Survival	We will use known relationships between total length L and age a (von Bertalanffy growth), and between egg production or fecundity (f) and L, to estimate egg production at a given age. K, L∞ and t0 are the von Bertalanffy parameters for, respectively, growth rate, asymptotic length (mm) and age at which individual would be length 0 (yr). α and β are parameters for the fecundity-at-length relationship.	Literature review
	Fecundity		Literature review

ROLES AND RESPONSIBILITIES

<table>
<tr><th></th><th>What</th><th>Who</th></tr>
<tr><td rowspan="8">Data Collection</td><td>Identify target species</td><td rowspan="7">Participatory workshops, Country teams</td></tr>
<tr><td>Map fishing grounds</td></tr>
<tr><td>Map existing protected areas/marine spatial plan</td></tr>
<tr><td>Define conservation goal</td></tr>
<tr><td>Define goals for the fishery, and identify perceived threats</td></tr>
<tr><td>Map critical habitats for each stage of target species lifecycle</td></tr>
<tr><td>Identify high pollution areas (development, river outputs, etc)</td></tr>
<tr><td>Collate biological/population data for target species (abundance, catch, fish behavior, ocean currents, population parameters)</td><td>External Design team, Country teams</td></tr>
<tr><td rowspan="2">Map Regional Ecological Priority Zones</td><td>Model larval dispersal patterns</td><td rowspan="2">External Design team</td></tr>
<tr><td>Identify key ecological areas that connected through larval dispersal or are self-recruiting</td></tr>
<tr><td>Regional Stakeholder Consultation</td><td>Obtain commitments for protection from key decision makers</td><td>Country Teams</td></tr>
<tr><td rowspan="4">Map Reserve Network Design</td><td>Model adult movement patterns</td><td rowspan="4">External Design team</td></tr>
<tr><td>Model population growth – Use underwater survey data or OurFish data for baseline population estimate</td></tr>
<tr><td>Integrate pollution areas, existing marine spatial plans, movement, growth, community goals and perceived threats into a spatially explicit model</td></tr>
<tr><td>Predict population recovery and spillover</td></tr>
<tr><td>Community Stakeholder Discussion</td><td>Discuss reserve placement options and select final reserve design. Identify optimal managed access areas around the final reserve design.</td><td>Country Teams</td></tr>
<tr><td>Monitor and Evaluate MA-R</td><td>Monitor fish biomass and habitat using underwater visual surveys. Monitor fish catch using OurFish. Evaluate response of fish populations inside reserve and in managed access areas.</td><td>Country Teams/Arlington</td></tr>
<tr><td>Adaptive Fisheries Management</td><td>Modify fisheries management plan as needed in response to changes in fish populations or habitat.</td><td>Country Teams/Arlington</td></tr>
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