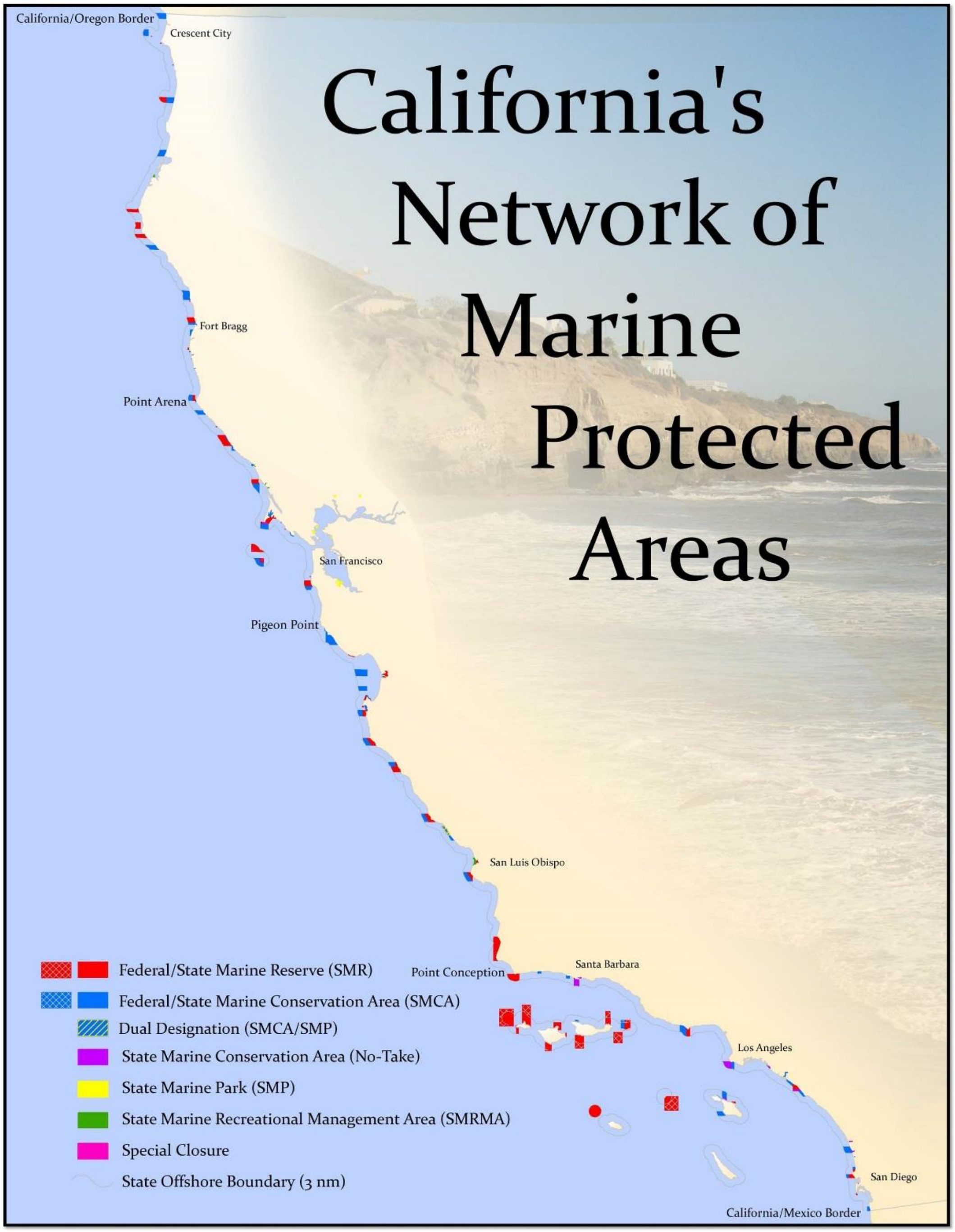
Proceedings of the Marine Protected Area Site Selection Workshop

January 12, 2018
Long Marine Lab, University of California, Santa Cruz



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Acknowledgements

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Executive Summary

California's marine protected areas (MPAs) were designed to function as a cohesive and ecologically connected network, pursuant to the Marine Life Protection Act (MLPA).[1] The MLPA also requires that the network be monitored to evaluate progress towards meeting the MLPA goals and to inform adaptive management.[2] As a first step, the state implemented Phase 1 of the Statewide MPA Monitoring Program (2007 – 2018) to conduct regional baseline monitoring near the time of MPA implementation. Baseline monitoring established a comprehensive benchmark of ecological and socioeconomic conditions across the state, and provided an important set of data against which future MPA performance can be measured.[3] Building on Phase 1, the California Department of Fish and Wildlife (CDFW) and California Ocean Protection Council (OPC) are developing priorities and strategies for Phase 2, statewide long-term monitoring. A Statewide MPA Monitoring Action Plan (Action Plan) is now under development by CDFW and OPC to prioritize MPA index sites, and ecological and socioeconomic indicators for long-term monitoring, and to help guide cost-effective spending and funding for future monitoring projects. The Action Plan will aggregate monitoring recommendations presented in Phase 1 regional MPA monitoring plans and technical reports with novel quantitative and expert informed approaches for long-term monitoring.

On January 12, 2018, CDFW and OPC convened a workshop titled "Marine Protected Area Site Selection" with collaborating researchers to discuss and develop recommendations and a shared understanding to inform the development of the Action Plan, including approaches for long-term monitoring design, detecting potential MPA effects, and predicting MPA effectiveness over time. Workshop participants identified core priorities for integrating discussed approaches to inform the Action Plan, and important next steps. Presentations and topics centered around:

1) Incorporating MPA design features and long-term monitoring datasets into site selection criteria
2) Monitoring that accounts for fisheries sustainability and ecosystem integrity goals
3) Using the state space integration projection model (SSIPM) to estimate fishing mortality rates to set expectations for population responses
4) Using spatial point process models for benthic visual survey and sampling design
5) Continued facilitation of a Regional Oceanographic Modeling System (ROMS) to estimate network connectivity

[1] California Fish and Game Code (FGC) §2850-2863.
[2] FGC §2853(c)(3). See also FGC §2852(a) and §2856(a)(2)(H).
[3] CDFW. (2016). California Marine Life Protection Act Master Plan for Marine Protected Areas. Adopted by the California Fish and Game Commission on August 24, 2016.

Overview

California has adopted a two-phase approach to MPA monitoring through the Statewide MPA Monitoring Program to track the ecological and socioeconomic conditions across the MPA network. Regional baseline monitoring (Phase 1) established a comprehensive benchmark of ecological and socioeconomic conditions at or near the time of MPA implementation in each of four regions across the state, including the central coast, north central coast, south coast, and north coast (Table 1). Phase 1 monitoring occurred from 2007 – 2018, and included 37 state-funded regional projects across the state (Table 1).

Table 1. Phase 1 regional baseline monitoring, including the number of regional projects, data collection period, analysis and sharing information period, and initial 5-year management review.

Coastal Region	Number of Projects	Collect Data	Analyze, Synthesize & Share Information	5-year Management Review
Central	5	2007 - 2010	2010 - 2013	2013
North Central	11	2010 - 2012	2012 - 2016	2016
South	10	2011 - 2013	2013 - 2017	2017
North	11	2014 - 2016	2016 - 2018	2018

Beginning in 2016, California is now designing and implementing statewide long-term monitoring (Phase 2) to reflect current priorities and management needs across agencies and mandates. Since it is unfeasible to monitor every one of California's MPAs each year, due to limitations of cost and time, the MLPA calls for "*monitoring, research, and evaluation at selected sites to facilitate adaptive management of MPAs…*".[4] Therefore, planning for Phase 2 includes drawing from Phase 1 to stitch together data and priorities on a statewide scale. Building long-term datasets at monitoring index sites using practical, cost-efficient, and standardized ecological indicators over sufficient time and geographic scale is necessary to evaluate MPA network performance, inform adaptive management decisions, and ensure that the MPA network is meeting the goals of the MLPA. To help further guide implementation of Phase 2 monitoring and cost-effective spending, CDFW and OPC are developing the Action Plan, beginning in early 2018 and anticipated for completion by Fall 2018 (Figure 1).

[4] FGC §2853(c)(3)

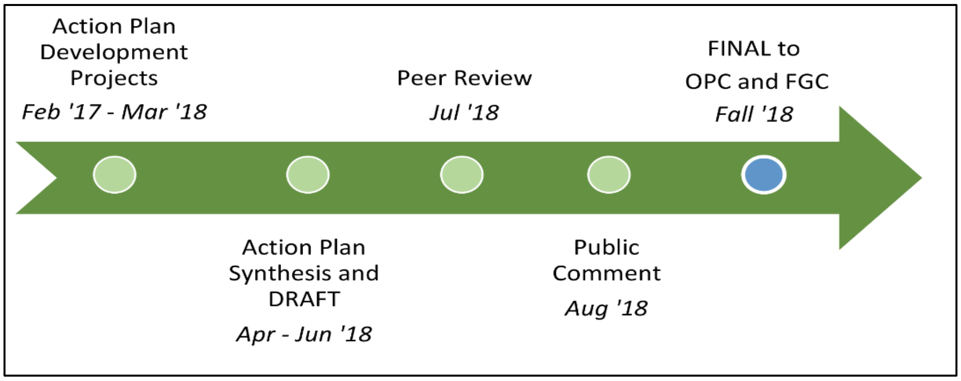

Figure 1. Draft timeline for Action Plan development and review.

The Action Plan will:

1) Be developed in a manner that is scientifically rigorous and builds on the local knowledge, capacity, and unique considerations from the MPA planning process and Phase 1 monitoring.
    a. E.g., MPA science design features, "State of the Region" summary reports[5,6,7,8] and CDFW's management recommendations regarding the first five years of regional MPA implementation,[9] and final technical reports for each of the 37 individual regional baseline projects.[10]
2) Incorporate quantitative and expert informed approaches to help prioritize MPA index sites, ecological and socioeconomic indicators, and other sampling design criteria for Phase 2.
    a. E.g., University of California, Santa Cruz (UCSC) ROMS to estimate network connectivity, and analyses by University of California, Davis (UCD)/CDFW post-doctoral researchers and California Ocean Science Trust (OST) science integration fellows
3) Guide cost-effective spending and funding for future monitoring projects.

Presentations and topics discussed at the January 12, 2018 "MPA Site Selection Workshop" included: [11]

- CDFW's MPA design features and monitoring matrices (Appendix B)
- Monitoring California's MPA network based on multiple objectives for adaptive management (Appendix C)
- Estimating values of local fishing mortality: Needed for both fisheries (Marine Life Management Act; MLMA) and MPAs (MLPA) (Appendix D)
- Spatial point process model for benthic visual survey and sampling design (Appendix E)
- Continued development of the UCSC ROMS to estimate network connectivity

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[5] OST and CDFW. (2013). *State of the California Central Coast: Results from Baseline Monitoring of Marine Protected Areas 2007-2012*. California, USA. February 2013. 45 p.
[6] OST and CDFW. (2015). *State of the California North Central Coast: A Summary of the Marine Protected Area Monitoring Program 2010-2015*. California, USA. November 2015. 26 p.
[7] OST, CDFW, and OPC. (2017). *State of the California South Coast: Summary of Findings from Baseline Monitoring of Marine Protected Areas, 2011-2015*. California, USA. March 2017. 60 p.
[8] CDFW, OST, and OPC. (2017). *State of the California North Coast: Summary of Findings from Baseline Monitoring of Marine Protected Areas, 2013-2017*. California, USA. November 2017. 32 p.
[9] Available on CDFW's website: https://www.wildlife.ca.gov/Conservation/Marine/MPAs/Research-And-Monitoring.
[10] Available on California Sea Grant's website: https://caseagrant.ucsd.edu/ongoing-projects/mpa-baseline-programs#ResearchSummaries.
[11] See Appendix A for a more complete list of presentations and topics discussed, and workshop purpose/objectives.

1. CDFW's MPA Design Features and Monitoring Matrices

CDFW has developed matrices and an associated interactive mapping tool to facilitate the process of selecting and prioritizing long-term monitoring sites. Using a points-based system, CDFW demonstrated how priority MPAs were identified using key MPA design features (MPA Features Matrix) and information on historical monitoring conducted within MPAs prior to implementation (MPA Monitoring Matrix). The MPA Features Matrix includes criteria that were identified and evaluated during the MLPA Initiative public planning process such as core science design guidelines (e.g., size, habitat representation and replication, levels of protection, etc.;[12] as well as proximity to Areas of Special Biological Significance, and whether MPAs had a historical protected area within its boundaries) (Table 2).

Table 2. Example of records in the MPA Features Matrix. Abbreviations: level of protection (LOP), Areas of Special Biological Significance (ASBS).

MPA Name	MPA Size	MPA Size points	Rocky Shores-0.60 Linear Miles	Level of Protection	LoP Multiplier	ASBS % of MPA	ASBS points	Historic v. current size	Historic MPA LoP	TOTAL POINTS
Sea Lion Cove SMCA	0.2	0	1	mod low	0.2	0%	0.0	0.00	0	1.2
Saunders Reef SMCA	9.4	1	1	mod low	0.2	12%	0.1	0.00	0	2.3
Del Mar Landing SMR	0.2	0	1	very high	1	38%	0.4	0.41	0	2.8
Stewarts Point SMCA	1.2	0	1	low	0	0%	0.0	0.00	0	1.0
Stewarts Point SMR	24.1	2	1	very high	1	0%	0.0	0.00	0	4.0
Salt Point SMCA	1.8	0	1	mod low	0.2	0%	0.0	0.68	0	1.9
Gerstle Cove SMR	0.0	0	0	very high	1	84%	0.8	0.87	0	1.7
Russian River SMRMA	0.4	0	0	very high	1	0%	0.0	0.00	0	0.0
Russian River SMCA	0.8	0	0	mod	0.4	0%	0.0	0.00	0	0.0
Bodega Head SMR	9.3	1	1	very high	1	3%	0.0	0.05	1	4.1
Cluster - Bodega Head SMCA / Bodega Head SMR	21.7	2	1	mod high	0.6	1%	0.0	0.02	0.5	4.1
Bodega Head SMCA	12.3	1	0	mod high	0.6	0%	0.0	0.00	0	1.0
Estero Americano SMRMA	0.1	0	0	very high	1	0%	0.0	0.00	0	0.0

The MPA Monitoring Matrix includes sampling history for long-term monitoring efforts targeting specific ecosystems, that were uniformly and consistently conducted statewide prior to MLPA implementation, including:

- Rocky intertidal monitoring (Multi-Agency Rocky Intertidal Network biodiversity and fixed plot data),
- Nearshore (0-30 meter [m]) subtidal and kelp forest monitoring (PISCO and Reef Check California [RCCA] SCUBA data), and
- Mid-depth (30-100 m) remotely operated vehicle (ROV) monitoring (CDFW and Marine Applied Research and Monitoring [MARE])

The years of prior monitoring were tabulated as a time series for a single site within each MPA, and a multiplier was added to each MPA to account for the number of monitoring effort types occurring in each of the three target ecosystems (Table 3).

[12] See Appendix A, Section 4.3 of CDFW. (2016). California Marine Life Protection Act Master Plan for Marine Protected Areas. Adopted by the California Fish and Game Commission on August 24, 2016.

Table 3. Example of records in the MPA Monitoring Matrix. Abbreviations: rocky intertidal monitoring (RIM), kelp forest monitoring (KFM), mid-depth remotely operated vehicle monitoring (ROV).

MPA Name	RIM: PISCO Diversity	RIM: PISCO Fixed	KFM: RCCA	KFM: PISCO	ROV	Monitoring History Points	Monitoring Multiplier	TOTAL POINTS
Sea Lion Cove SMCA	3	12	3	2	0	20	2	40
Saunders Reef SMCA	2	2	0	3	1	8	3	24
Del Mar Landing SMR	2	3	0	2	0	7	2	14
Stewarts Point SMCA	0	0	0	2	0	2	1	2
Stewarts Point SMR	1	0	0	2	1	4	3	12
Salt Point SMCA	1	2	1	2	0	6	2	12
Gerstle Cove SMR	2	3	12	0	0	17	2	34
Russian River SMRMA	0	0	0	0	0	0	0	0
Russian River SMCA	1	1	0	0	0	2	1	2
Bodega Head SMR	7	17	0	0	4	28	2	56
Cluster - Bodega Head SMCA / Bodega Head SMR	3.5	8.5	0	0	4	16	2	32
Bodega Head SMCA	0	0	0	0	4	4	1	4
Estero Americano SMRMA	0	0	0	0	0	0	0	0

A third matrix (All Rankings Matrix) was presented which combines final scores from the MPA Features and MPA Monitoring Matrices. The All Rankings Matrix allows for sorting and filtering of either the MPA Features or Monitoring matrices individually and/or a combination of both to observe how MPAs compare against each other on both a regional and statewide basis (Table 4). Lastly, CDFW demonstrated a mapping tool designed to help visualize the matrices in a more user-friendly format. In conjunction with other quantitative tools and approaches presented at the workshop (described in the following topics), the matrices and mapping tool will help facilitate long-term MPA monitoring site selection and a likely probability of detecting an ecosystem response to protection over time.

Table 4. Example of records in the MPA Monitoring Matrix.

MPA Name	Statewide MPA Features	Statewide MPA Monitoring	Statewide Combo	Regional MPA Features	Regional MPA Monitoring	Regional Combo
Sea Lion Cove SMCA	Group 4	Group 4	Group 4	Group 4	Group 2	Group 3
Saunders Reef SMCA	Group 4	Group 4	Group 4	Group 3	Group 3	Group 3
Del Mar Landing SMR	Group 4	Group 4	Group 4	Group 4	Group 3	Group 4
Stewarts Point SMCA	Group 4	Group 4	Group 4	Group 4	Group 4	Group 4
Stewarts Point SMR	Group 2	Group 4	Group 3	Group 1	Group 3	Group 2
Salt Point SMCA	Group 4	Group 4	Group 4	Group 4	Group 3	Group 4
Gerstle Cove SMR	Group 4	Group 4	Group 4	Group 4	Group 2	Group 3
Russian River SMRMA	Group 4	Group 4	Group 4	Group 4	Group 4	Group 4
Russian River SMCA	Group 4	Group 4	Group 4	Group 4	Group 4	Group 4
Bodega Head SMR	Group 2	Group 3	Group 3	Group 1	Group 1	Group 1
Cluster - Bodega Head SMCA / Bodega Head SMR	Group 3	Group 4	Group 4	Group 3	Group 2	Group 3
Bodega Head SMCA	Group 4	Group 4	Group 4	Group 3	Group 4	Group 4
Estero Americano SMRMA	Group 4	Group 4	Group 4	Group 4	Group 4	Group 4

2. Monitoring California's MPA Network Based on Multiple Objectives for Adaptive Management

UCD/CDFW post-doctoral researcher Katie Kaplan is leading the collaborative development of an approach for:

a) Timeline of expected fished population responses to California's MPAs: To inform adaptive management, Kaplan et al. are setting expectations for species responses to MPAs and comparing those expectations to long-term monitoring data, in order to assess if MPAs are performing as expected. Determining a clear timeline for expectations can aid in the development of a monitoring program that evaluates expectations over realistic time frames for assessing populations responses to MPAs. Kaplan and Yamane et al. are working on projecting a timeline of fished population responses to MPAs, including 19 species to date (see Table 5 and Topic #3 below).

Table 5. Species selected to project a timeline of responses to MPAs.

Common name	Species name	Family	Maximum Age (years)[13]
Cabezon	*Scorpaenichthys marmoratus*	Cottidae	13
Kelp greenling	*Hexagrammos decagrammus*	Hexigrammidae	18
Kelp rockfish	*Sebastes atrovirens*	Scorpaenidae	20
California scorpionfish	*Scorpaena guttata*	Scorpaenidae	21
Black & yellow rockfish	*Sebastes chrysomelas*	Scorpaenidae	22
Lingcod	*Ophiodon elongatus*	Hexigrammidae	25
Gopher rockfish	*Sebastes carnatus*	Scorpaenidae	30
Olive rockfish	*Sebastes serranoides*	Scorpaenidae	30
Brown rockfish	*Sebastes auriculatus*	Scorpaenidae	34
Kelp bass	*Paralabrax clathratus*	Serranidae	34
Blue rockfish	*Sebastes mystinus*	Scorpaenidae	44
Black rockfish	*Sebastes melanops*	Scorpaenidae	50
Bocaccio	*Sebastes paucispinis*	Scorpaenidae	50
California sheephead	*Semicossyphus pulcher*	Labridae	53
Copper rockfish	*Sebastes caurinus*	Scorpaenidae	57
Vermillion rockfish	*Sebastes miniatus*	Scorpaenidae	60
Yellowtail rockfish	*Sebastes flavidus*	Scorpaenidae	64
China rockfish	*Sebastes nebulosus*	Scorpaenidae	79
Red sea urchin	*Mesocentrotus franciscanus*	Strongylocentrotidae	> 100 [14]

[13] Maximum reported age for the finfish species, according to FishBase (version 10/2017). http://www.fishbase.org.
[14] Tagging studies reveal that red sea urchins are long-lived, with large individuals possibly living beyond 100 years; according to Kalvass, P., Rogers-Bennett, L., Barsky, K., and C. Ryan. (2003). Red sea urchin. In: *Status of the Fisheries Report: An Update through* 2003 (Eds. Ryan, C. and M. Patyten). California Department of Fish and Game, Marine Region. p. 9-1 to 9-14.

Responses depend, in part, on the level of fishing mortality prior to MPA implementation. An age-structured population model was applied to assess the time required to reach final abundance (i.e., maximum MPA effect) for each fished species, and the length of time of a potential transient response was assessed using two different connectivity assumptions, an open and closed population model for each fished species. Additionally, populations with variable recruitment were assessed to provide a confidence interval around expected population responses with stochasticity considered. Preliminary estimated timelines are highly variable by species and their associated life history characteristics. For example, preliminary results indicate cabezon which have a maximum age of 13 years, may take 7 years to reach final abundance; while china rockfish which have a maximum lifespan of 79 years, may take 40 years to reach final abundance.

b) <u>Identifying community level metrics</u>: To identify indicators of community structure and function, a subsampling method was applied that correlates subsets of species to the full set of known species in the community. This method calculates the dissimilarities (using the Bray-Curtis dissimilarity index) for all pairs of sites sampled along the California coast for a given habitat monitored, and then determines the links between sites to assess relationships in space. The minimum number of species that correlate at 95% to the full set of species can then be selected as indicators of community structure (i.e., the minimum number of species to predict 95% of the full community effect). This minimum list of species can be subsequently compared with previous indicators identified from key MPA design aspects (e.g., species likely to benefit lists developed by the MLPA Science Advisory Team[15]) and supporting documents from Phase 1 baseline monitoring (e.g., regional MPA monitoring plans and baseline technical reports), to effectively learn and adapt on previous work moving forward.

c) <u>Integrated tiered approach to inform development of the Action Plan</u>: A tiered approach to identify indicator species can be based on (Figure 2):

- Level of harvest: Species that are directly targeted for harvest or commonly in bycatch or indirectly damaged by fishing methods,
- Life history traits and vulnerability to fishing pressure: Species that may be more vulnerable to fishing pressure and benefit more from protection based on life history traits such as limited adult home range, long life span, and low fecundity,
- Indicators of community structure and function: Species role in the ecosystem as ecological interactors, biogenic habitat, or level of trophic importance, and
- Broad-scale metrics from scientific literature and expert input (e.g., biodiversity and climate change indicators).

[15] See Appendix A, Section 4.3 of CDFW. (2016). California Marine Life Protection Act Master Plan for Marine Protected Areas. Adopted by the California Fish and Game Commission on August 24, 2016.

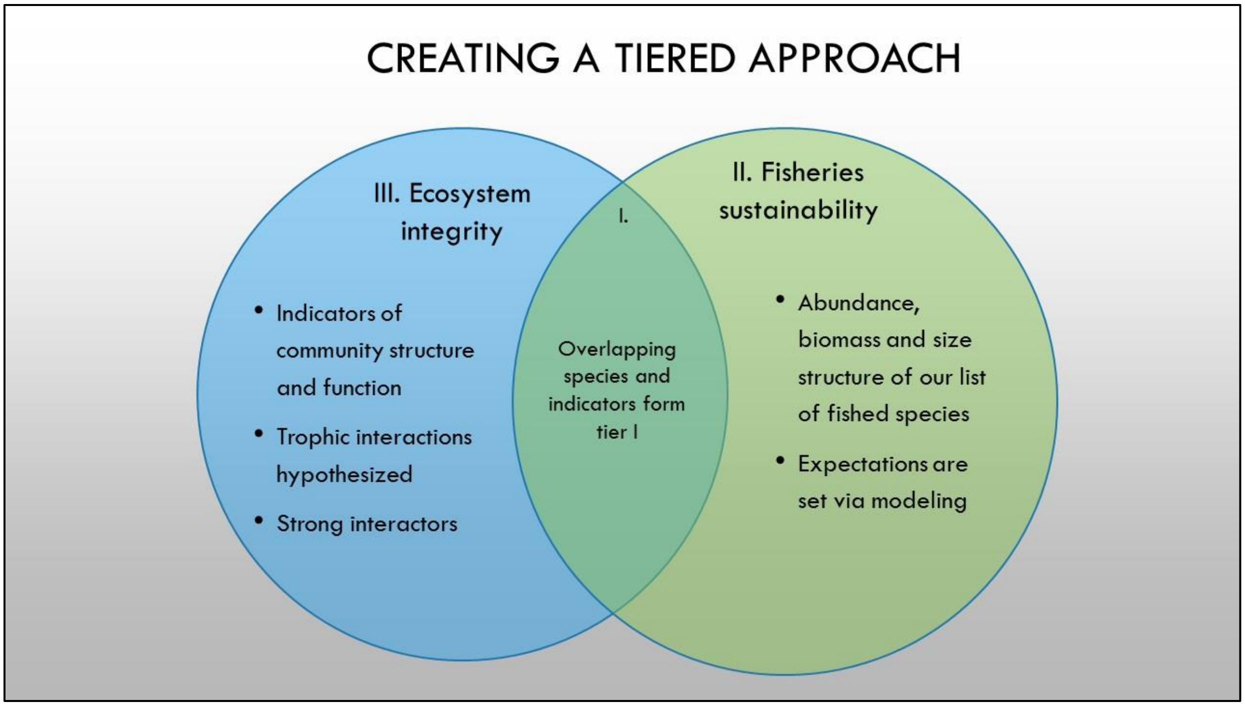

Figure 2. Conceptual schematic for creating an integrated tiered approach to identify indicator species. Tiers are defined in the "Key Outcomes and Next Steps" section.

3. Estimating Values of Local Fishing Mortality: Needed for Both Fisheries (MLMA) and MPAs (MLPA)

UCD/CDFW post-doctoral researcher Lauren Yamane is leading the collaborative development of an approach to estimate fishing pressure prior to MPA implementation to provide a better understanding of which species are likely to benefit from protection, and where MPA monitoring would most likely detect the greatest recovery due to protection. Original estimates used blue rockfish as the model indicator species at central coast sites,[16] while recent work has expanded to include south coast sites and more model species. A key challenge for this type of work is getting sufficiently large sample sizes and long data time-series lengths. The following tiered approach was used to determine fishing pressure and inform management decisions:

a) <u>Data-rich scenario</u>: This scenario applies to species and sites for which the SSIPM can be applied to estimate local fishing mortality rates (local F). Yamane et al. are estimating pre-MPA local F using the SSIPM applied to fisheries-independent data (e.g., PISCO, RCCA) for fished species (Table 5). This scenario is useful for identifying indicator species that may be appropriate for evaluation purposes. In general, it is expected that areas with greater historic fishing pressure would yield the highest biomass increases in response to MPAs. Higher local F generally correlates to increased truncation of size structure and therefore an increased ability to detect the filling in of size structure (Figure 3). Species characteristics resulting in the most precise estimates of local F include lower natural mortality (M) rates

[16] Blue rockfish is the most abundant monitored species, and has a long data time-series length of 9 years pre-MPA implementation.

(higher M can lead to underestimates of local F and greater error), a growth rate (k) exceeding M (e.g., k>M), and fished in early life history stages.

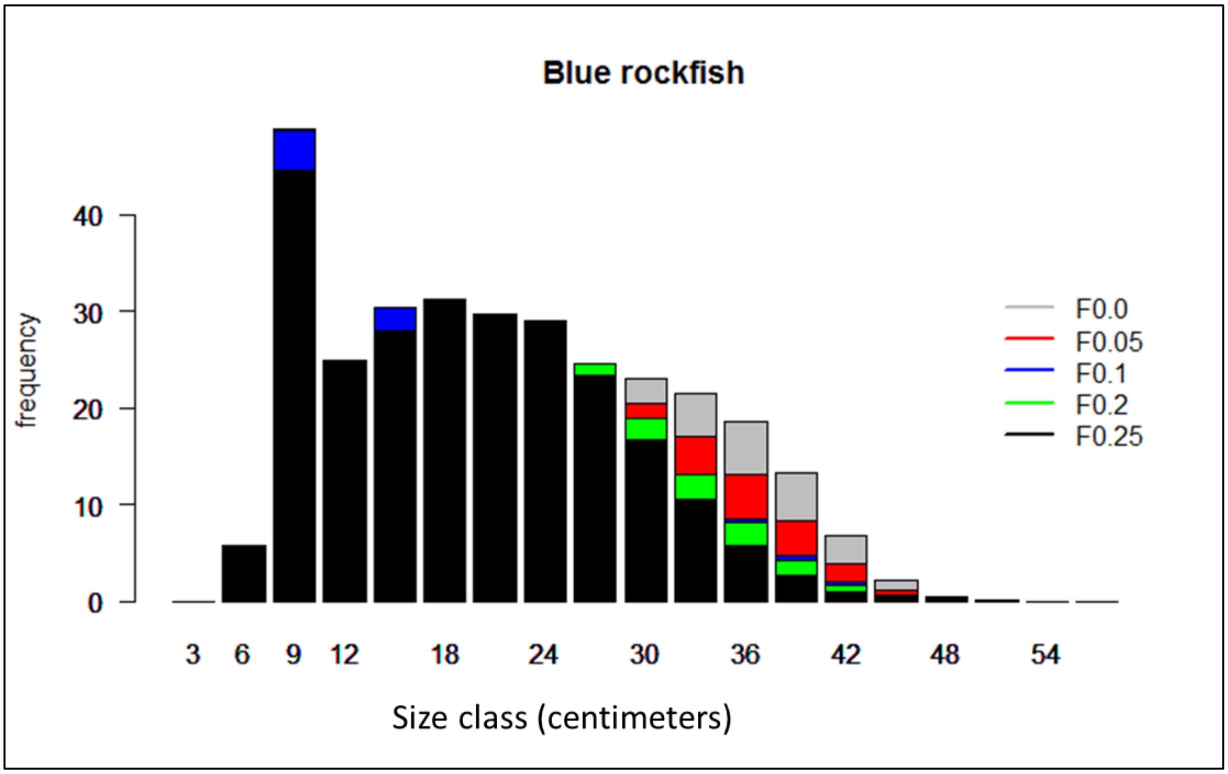

Figure 3. An example of the filling in of size structure for blue rockfish as local F increases.

Preliminary results indicate data-rich species with the most reliable estimates of local F based on biological characteristics include rockfishes (blue, vermillion, copper, yellowtail, kelp, china) and red sea urchin; and those with the least reliable estimates of local F are California scorpionfish, lingcod, cabezon, and kelp greenling. In addition, sites with larger sample sizes (i.e., number of fish lengths recorded per MPA and time step) and longer data time-series lengths lead to greater precision of local F estimates.

b) <u>Data-moderate scenario</u>: For those species and datasets which are not conducive for use with the SSIPM (e.g., important recreational species such as lingcod, cabezon, California scorpionfish, and kelp bass), Yamane et al. are estimating more general historical fishing effort across the state with fisheries-dependent data at relatively fine spatial scales. A primary example was presented by Olivia Rhoades, OST fellow, who is completing an analysis of relative historical fishing effort of private and rental skiff fisheries at a one minute of latitude by one minute of longitude scale using CDFW California Recreational Fisheries Survey data. The project will describe the level of relative fishing effort applied by recreational fishing boats throughout California from 2006 to 2011. This scenario is useful for informing site selection that may be appropriate for evaluation purposes.

c) <u>Data-poor scenario</u>: This scenario applies to sites where data-rich or data-moderate information is not available (e.g., the California north coast). Yamane et al. are estimating regional proxies for historical fishing (e.g., proxies such as distance to port, and using data-rich cases to understand data-poor cases), which is potentially useful for informing site selection.

4. Spatial Point Process Model for Benthic Visual Survey and Sampling Design

UCD/CDFW post-doctoral researcher Nick Perkins is leading the collaborative development of approaches to analyze and integrate an extensive ROV dataset collected by CDFW and MARE, including:

a) <u>Methods for analyzing ROV data</u>: Statistical analysis of ROV data is challenging due to data collection along transects and not accounting for spatial autocorrelation, which can lead to bias and errors. However, analysis approaches are rapidly evolving which may lead to robust estimates of species abundance. For example, Perkins et al. are exploring the use of spatial point process models to estimate species abundances within ROV sites and across subtidal rocky reef habitats (e.g., Bodega Head, Año Nuevo, and Pillar Point being developed as case studies). These models incorporate bathymetry-derived covariates (e.g., depth, slope, curvature, rugosity, and other substrate and habitat complexity layers at varying scales) combined with species presence/absence data (Figure 4). This approach can be compared with outputs from other approaches such as design-based estimates, non-spatial generalized linear models and generalized additive models.

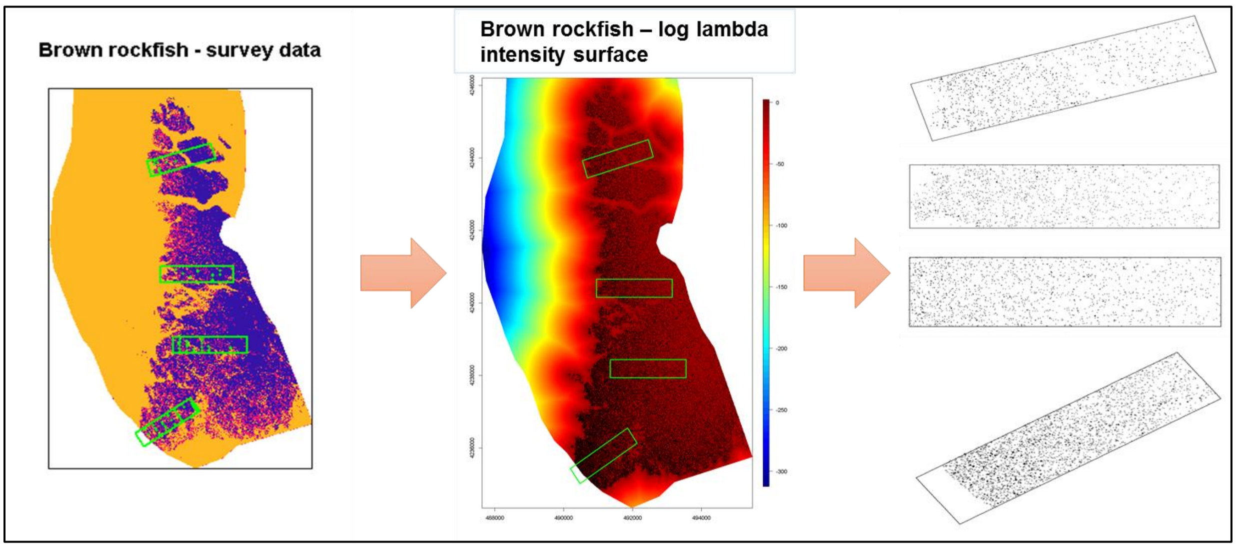

Figure 4. An example of using a spatial point process model to account for the occurrence of brown rockfish individuals in the Bodega Head area (left image), the intensity (i.e., number) of brown rockfish expected to occur in the area given the weighting of covariates (middle image), and predicted abundance across the area (right image).

b) <u>ROV sampling and survey design:</u> To ensure ROV sampling designs provide high enough statistical power to detect changes, Perkins et al. are incorporating outputs from spatial point process models (see Topic #4a above) to simulate species distributions across sites. These simulations will allow testing of the various sampling designs and levels of effort to evaluate and improve precision of surveys. Also, simulations of changing abundance and/or size distributions through time (e.g., using model species and data time-series of expected MPA recovery being worked on by Kaplan and Yamane et al.) will allow exploration of the interaction between sampling design and the statistical power needed to detect change. This will allow the trade-offs between sampling effort and an expected timeline to detect predicted changes to be explored.

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c) <u>Eco-regionalization of subtidal communities:</u> Previous work has demonstrated that incorporating bioregions into analyses can improve estimates of species recovery, such as providing higher statistical power to detect MPA effects. By using ROV and SCUBA datasets, oceanographic (e.g., sea surface temperatures and indices, fronts, chlorophyll a, etc), and habitat data (1 kilometer cells); Perkins et al. are developing a regions of common profile (RCP) model to identify which species contribute most out of species groupings and important environmental drivers. The RCP model may be potentially useful for informing site selection by incorporating sampling effects, deriving data-driven maps of eco-regions across the state, and placing MPAs and reference sites in a broader environmental context. For example, the RCP model may aid developing expectations for whether bioregions with similar species assemblages and environmental drivers have similar MPA responses, and whether there is potential to link changes in communities and environmental conditions over time (and ensure MPA and reference sites are comparable over time).

5. Continued Development of a Regional Oceanographic Modeling System to Estimate Network Connectivity

UCSC researchers Pete Raimondi and Mark Carr are tailoring a ROMS to evaluate larval connectivity of rocky intertidal, shallow rocky reef/kelp forest (0-30m), and deep rock (30-100 m) habitats. The ROMS simulates the movement of planktonic larvae from each 5 kilometer cell under different temporal scenarios with respect to dispersal times (planktonic larval durations [PLDs]) and oceanographic conditions, and can be used to determine the effect of PLD on source-sink dynamics, including the relative contribution of larval production and degree of connectivity (Figure 5).

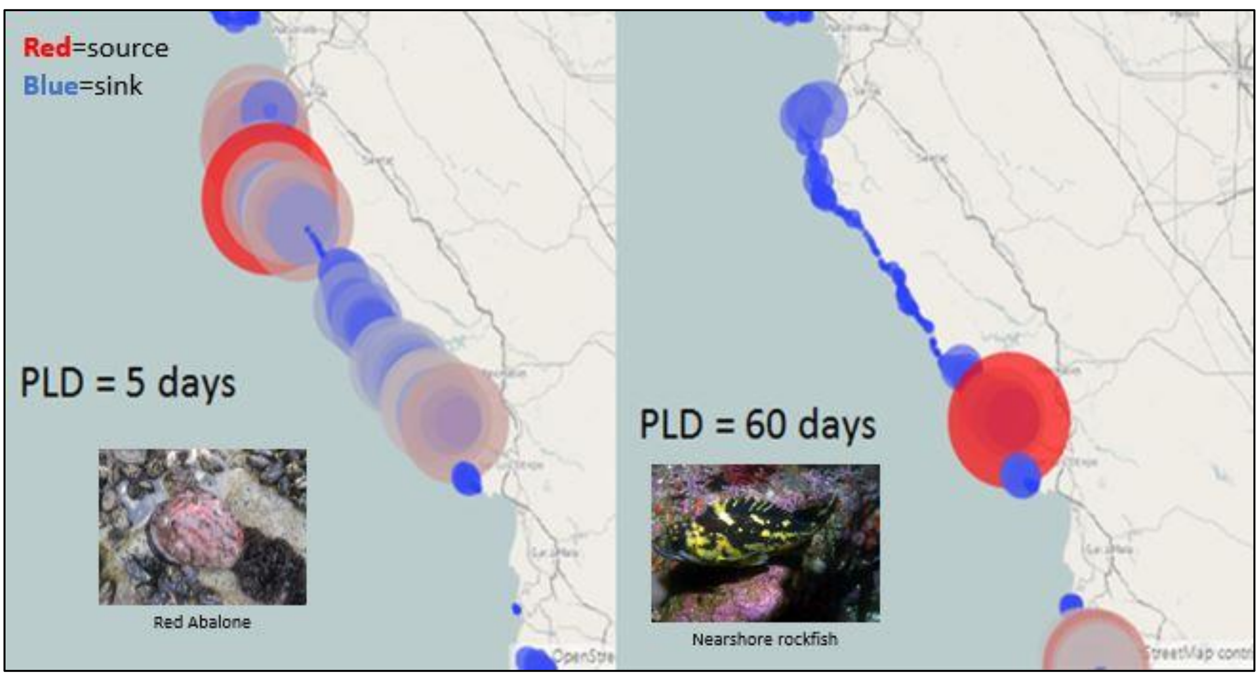


Figure 5. Preliminary results demonstrating the effect of PLD on regional connectivity in central California shallow 0-30m rocky reef/kelp forest habitat for species with a short PLD of 5 days, such as red abalone (left), and species with a longer PLD of 60 days, such as nearshore rockfishes (right). Bubble size indicates the degree of connectivity between cells (i.e., relative effect/contribution for larval production), with larger bubbles indicating areas of greater connectivity (i.e., source populations). Red bubbles represent larval sources, and blue bubbles represent larval sinks.

Several modifications and improvements were made to the ROMS since a focused ROMS workshop in August 2017.[17] First, in collaboration with CDFW, the mapping and habitat data used in the ROMS has been improved by filling in the shallow, nearshore 0-15m depth seafloor (“white zone”) along the entire California coast with interpolated data (encompasses a 50-500m wide band of previously unmapped seafloor). Other small or missing areas of unmapped seafloor are now complete. In addition, the topology of ROMS cell relative to MPA boundaries was edited allowing better analysis of MPA vs. non-MPA sites. Continued development of the ROMS includes evaluating the current sensitivity of the model (i.e., determine what counts as a connected link), incorporating various levels of protection and geomorphological attributes, and expanding habitat inputs (particularly from Oregon and Mexico).

Key Outcomes & Next Steps

The key outcome is that the January 12, 2018 workshop, convened by CDFW and OPC, provided an important venue to discuss, inform, and facilitate a variety of long-term monitoring approaches and analyses underway. Using these approaches and analyses, the Action Plan will have prioritized long-term monitoring metrics and sites, and guide resource allocation for Phase 2. Workshop participants also determined a tiered approach for determining indicator species, first based on a classification scheme using three groupings: *Group 1* includes fished species exhibiting SSIPM high predictability and high response, *Group 2* includes fished species exhibiting SSIPM high and medium predictability, high response, and/or a commercially and recreationally important species, and *Group 3* includes ecologically important species.[18] Identifying these groups helped inform a tiered species prioritization method developed following the workshop. Identifying select indicators species will be based on the following three tiers:

- **Tier 1**: Species that experience some level of take, may be good MPA indicators due to certain life history traits, and play a role in ecosystem function.
- **Tier 2**: Species that experience some level of take and may be good MPA indicators.
- **Tier 3**: Species that experience no level of take, but play a role in ecosystem function.

Next steps include vetting species lists through a peer review process, and incorporating expert input. Additionally, UCD/CDFW post-doctoral researchers are tasked with generating estimates of local F for 19 species to see how well they perform by February – early March 2018. Workshop participants will continue to discuss and resolve the tiered approach for determining indicator species, such as fleshing out the vulnerability aspect of *Group 3*. Finally, CDFW was tasked with providing insights for current questions regarding the ROMS model, including:

- Is bioregional representation necessary?
    - o CDFW response: Yes. It is important to have good coverage of priority MPAs for long-term monitoring in each bioregion.
- Should regional representation be proportional or not?

[17] CDFW. (2017). *Proceedings of the Regional Ocean Model System Overview Workshop*. University of California, Santa Cruz, August 10-11, 2017. 17 pages.
[18] Identifying *Group 3* species should primarily focus on whether they are functionally important (e.g., high interaction strength, habitat forming, have direct effects on community structure), but also on whether they are vulnerable (e.g., susceptible to climate change, environmental, and fishing impacts).

  - CDFW response: Our current approach is to pick a representational set of MPAs in each bioregion so that tier 1 MPAs are distributed relatively evenly across the entire network.
- Should a particular metric be developed to gauge the relative importance of individual locations to supplying propagules to MPAs, to SMRs, or to cells in general?
  - CDFW response: To start, we would like to see the supply to cells in general. Once we have the results we can target specific locations inside and outside MPAs.
- Should there be a mix of index sites that include places that are characterized as sources, as sinks, and/or a combination of both sources and sinks?
  - CDFW response: Ideally, we will prioritize a mix of both sources and sinks in any given region.

Appendix A: Workshop Agenda

Marine Protected Areas Site Selection Workshop

January 12, 2018; 8 AM to 4 PM

Long Marine Lab, UC Santa Cruz
Classroom 118, Center for Ocean Health
115 McAllister Way, Santa Cruz CA 95060

Workshop Purpose/Objectives:

- Inform the development of MPA site selection for Statewide Monitoring Action Plan. To this effect:
  - Receive updates on analytical approaches to spatial sampling design
  - Discuss and identify the best approaches for detecting MPA effects and predict effectiveness through monitoring
  - Develop recommendations for integrating discussed approaches to inform the Statewide MPA Monitoring Action Plan

Time	ITEM	PRESENTER
8:00 AM	Introductions and Workshop Purpose	Becky Ota Cyndi Dawson
8:15	Presentation and Discussion: update on MLPA Initiative planning and habitat matrix and interactive map	Amanda Van Diggelen
8:45	Presentation and Discussion: update on Regional Oceanographic Modeling System	Peter Raimondi
9:05	Presentation and Discussion: update on spatial point process model for benthic visual survey and sampling design	Nick Perkins
9:25	Presentation and Discussion: update on state space integration projection model	Lauren Yamane
9:45	Presentation Discussion: approaches for monitoring species responses to MPAs and community level metrics	Katie Kaplan
10:05	BREAK	
10:20	Group Discussion and Brainstorm: integration of information	All (plenary)
12:00 PM	LUNCH (lunch will be brought in; bring $10 cash for food)	
12:30	Continued Group Discussion and Brainstorm	All (plenary)
2:15	BREAK	
2:30	Continued Group Discussion and Brainstorm	All (plenary)
3:30	Overview, reflections, and next steps	Becky Ota
4:00	Adjourn	

OCEAN PROTECTION COUNCIL

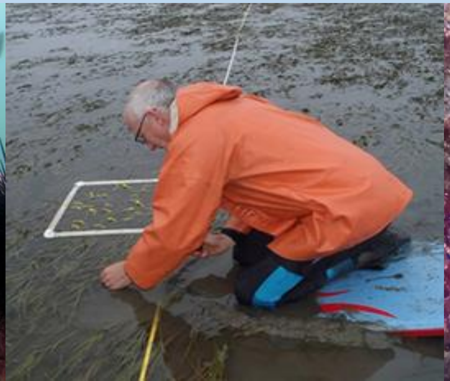
(Appendix B)
CDFW's MPA Features and Monitoring Matrices

CALIFORNIA
MARINE
PROTECTED
AREAS

Amanda Van Diggelen, Environmental Scientist
MPA Site Selection Workshop, Santa Cruz, CA
January 12, 2018








Matrices

1) Key Marine Protected Areas (MPA) Design Features

- MPA size
- Habitat thresholds
- Level of protection (LOP)
- Areas of Special Biological Significance (ASBS)
- Historical MPAs

MPA Name	MPA Size	MPA Size points	Rocky Shores-0.60 Linear Miles	Level of Protection	LoP Multiplier	ASBS % of MPA	ASBS points	Historic v. current size	Historic MPA LoP	TOTAL POINTS
Sea Lion Cove SMCA	0.2	0	1	mod low	0.2	0%	0.0	0.00	0	1.2
Saunders Reef SMCA	9.4	1	1	mod low	0.2	12%	0.1	0.00	0	2.3
Del Mar Landing SMR	0.2	0	1	very high	1	38%	0.4	0.41	0	2.8
Stewarts Point SMCA	1.2	0	1	low	0	0%	0.0	0.00	0	1.0
Stewarts Point SMR	24.1	2	1	very high	1	0%	0.0	0.00	0	4.0
Salt Point SMCA	1.8	0	1	mod low	0.2	0%	0.0	0.68	0	1.9
Gerstle Cove SMR	0.0	0	0	very high	1	84%	0.8	0.87	0	1.7
Russian River SMRMA	0.4	0	0	very high	1	0%	0.0	0.00	0	0.0
Russian River SMCA	0.8	0	0	mod	0.4	0%	0.0	0.00	0	0.0
Bodega Head SMR	9.3	1	1	very high	1	3%	0.0	0.05	1	4.1
Cluster - Bodega Head SMCA / Bodega Head SMR	21.7	2	1	mod high	0.6	1%	0.0	0.02	0.5	4.1
Bodega Head SMCA	12.3	1	0	mod high	0.6	0%	0.0	0.00	0	1.0
Estero Americano SMRMA	0.1	0	0	very high	1	0%	0.0	0.00	0	0.0

Matrices

2) MPA Monitoring

- Rocky Intertidal (RIM)
  - Partnership for the Interdisciplinary Study of Coastal Oceans (PISCO)
- Kelp Forest (0-30m; KFM)
  - Reef Check California (RCCA)
  - PISCO
- Mid-depth rock (30-100m; ROV)
  - Department of Fish and Wildlife
  - Marine Applied Research and Monitoring

MPA Name	RIM: PISCO Diversity	RIM: PISCO Fixed	KFM: RCCA	KFM: PISCO	ROV	Monitoring History Points	Monitoring Multiplier	TOTAL POINTS
Sea Lion Cove SMCA	3	12	3	2	0	20	2	40
Saunders Reef SMCA	2	2	0	3	1	8	3	24
Del Mar Landing SMR	2	3	0	2	0	7	2	14
Stewarts Point SMCA	0	0	0	2	0	2	1	2
Stewarts Point SMR	1	0	0	2	1	4	3	12
Salt Point SMCA	1	2	1	2	0	6	2	12
Gerstle Cove SMR	2	3	12	0	0	17	2	34
Russian River SMRMA	0	0	0	0	0	0	0	0
Russian River SMCA	1	1	0	0	0	2	1	2
Bodega Head SMR	7	17	0	0	4	28	2	56
Cluster - Bodega Head SMCA / Bodega Head SMR	3.5	8.5	0	0	4	16	2	32
Bodega Head SMCA	0	0	0	0	4	4	1	4
Estero Americano SMRMA	0	0	0	0	0	0	0	0

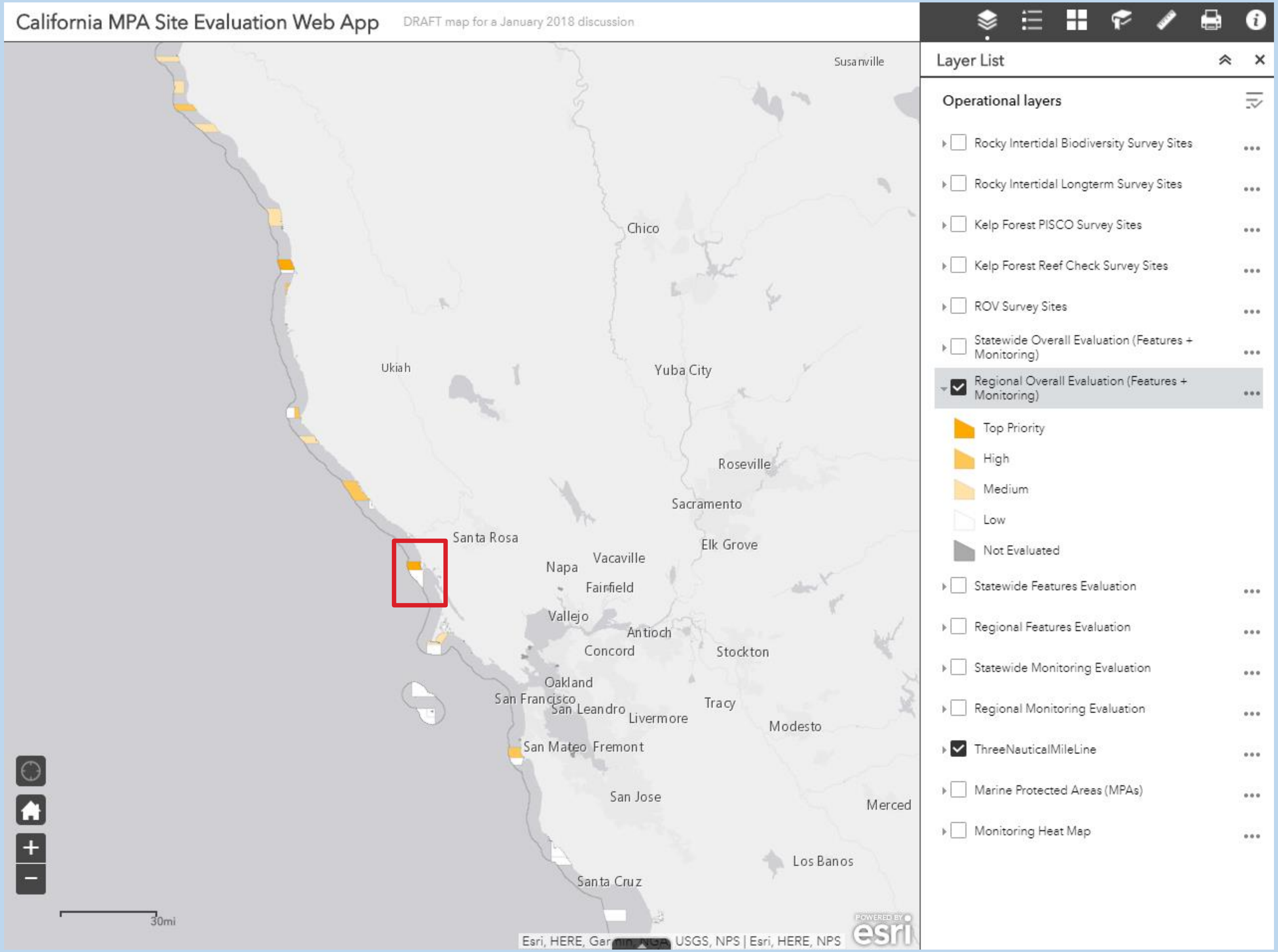
Matrices

1) MPA Features + 2) MPA Monitoring = 3) All Rankings

- Final MPA siting priorities

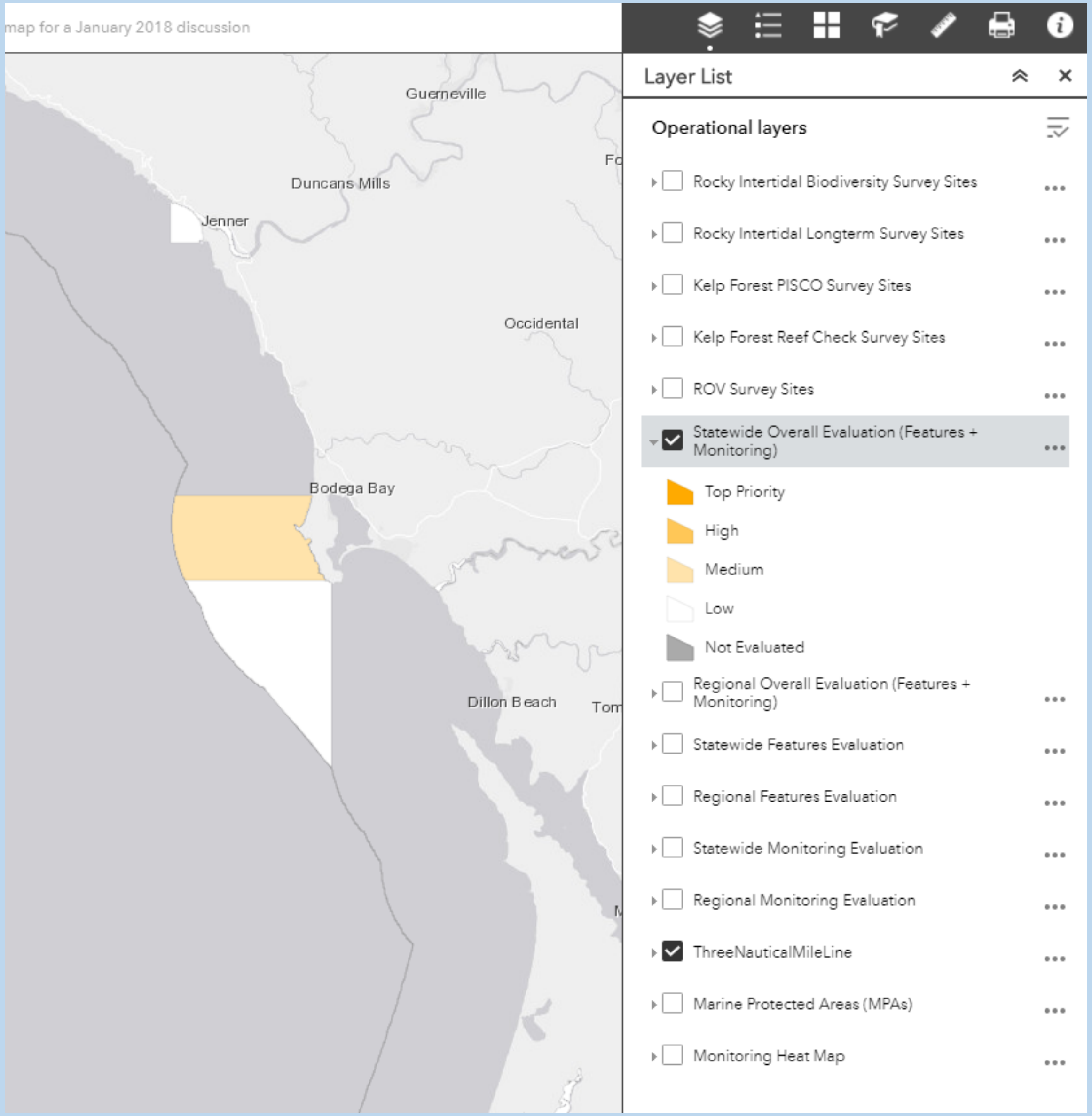
MPA Name	Statewide MPA Features	Statewide MPA Monitoring	Statewide Combo	Regional MPA Features	Regional MPA Monitoring	Regional Combo
Sea Lion Cove SMCA	4 Low	4 Low	4 Low	4 Low	2 High	3 Medium
Saunders Reef SMCA	4 Low	4 Low	4 Low	3 Medium	3 Medium	3 Medium
Del Mar Landing SMR	4 Low	4 Low	4 Low	4 Low	3 Medium	4 Low
Stewarts Point SMCA	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low
Stewarts Point SMR	2 High	4 Low	3 Medium	1 Priority	3 Medium	2 High
Salt Point SMCA	4 Low	4 Low	4 Low	4 Low	3 Medium	4 Low
Gerstle Cove SMR	4 Low	4 Low	4 Low	4 Low	2 High	3 Medium
Russian River SMRMA	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low
Russian River SMCA	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low
Bodega Head SMR	2 High	3 Medium	3 Medium	1 Priority	1 Priority	1 Priority
Cluster - Bodega Head SMCA / Bodega Head SMR	3 Medium	4 Low	4 Low	3 Medium	2 High	3 Medium
Bodega Head SMCA	4 Low	4 Low	4 Low	3 Medium	4 Low	4 Low
Estero Americano SMRMA	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low

Interactive Mapping Tool



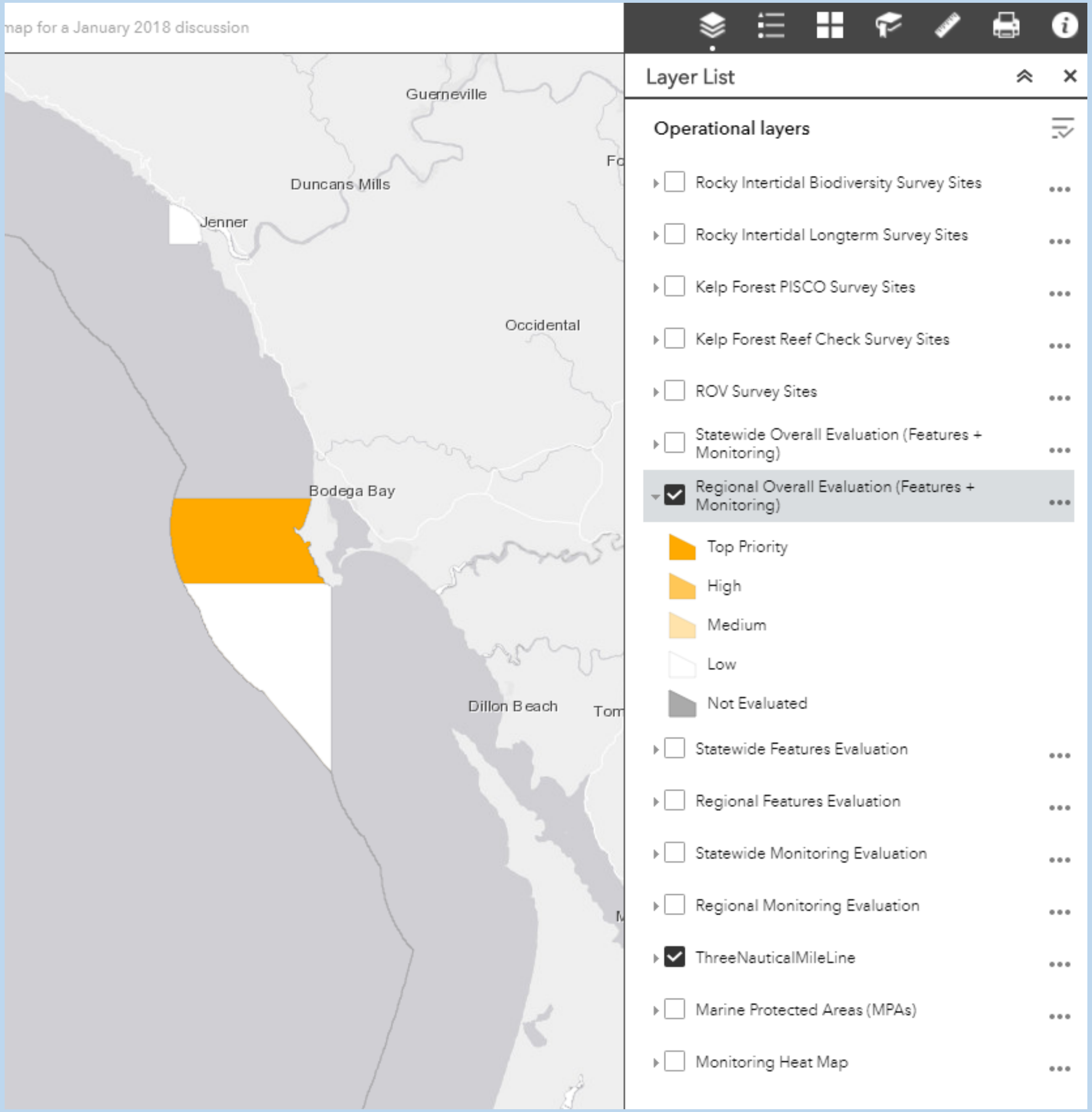
Mapping Tool and Matrix

MPA Name	Statewide Features	Statewide Monitoring	Statewide Combo
Sea Lion Cove SMCA	4 Low	4 Low	4 Low
Saunders Reef SMCA	4 Low	4 Low	4 Low
Del Mar Landing SMR	4 Low	4 Low	4 Low
Stewarts Point SMCA	4 Low	4 Low	4 Low
Stewarts Point SMR	2 High	4 Low	3 Med
Salt Point SMCA	4 Low	4 Low	4 Low
Gerstle Cove SMR	4 Low	4 Low	4 Low
Russian River SMRMA	4 Low	4 Low	4 Low
Russian River SMCA	4 Low	4 Low	4 Low
Bodega Head SMR	2 High	3 Med	3 Med
Cluster - Bodega Head SMCA / Bodega Head SMR	3 Med	4 Low	4 Low
Bodega Head SMCA	4 Low	4 Low	4 Low
Estero Americano SMRMA	4 Low	4 Low	4 Low



Mapping Tool and Matrix

MPA Name	Regional Features	Regional Monitoring	Regional Combo
Sea Lion Cove SMCA	4 Low	2 High	3 Med
Saunders Reef SMCA	3 Med	3 Med	3 Med
Del Mar Landing SMR	4 Low	3 Med	4 Low
Stewarts Point SMCA	4 Low	4 Low	4 Low
Stewarts Point SMR	1 Priority	3 Med	2 High
Salt Point SMCA	4 Low	3 Med	4 Low
Gerstle Cove SMR	4 Low	2 High	3 Med
Russian River SMRMA	4 Low	4 Low	4 Low
Russian River SMCA	4 Low	4 Low	4 Low
Bodega Head SMR	1 Priority	1 Priority	1 Priority
Cluster - Bodega Head SMCA / Bodega Head SMR	3 Med	2 High	3 Med
Bodega Head SMCA	3 Med	4 Low	4 Low
Estero Americano SMRMA	4 Low	4 Low	4 Low



Potential Sites Example

CONFIDENTIAL
Do Not Distribute

IMPORTANT: ALWAYS SORT THIS A TO Z AFTER OTHER FILTERS ARE USED IN ORDER TO LOOK AT PRIORITIES BY REGION

	B	C	D	E	F	G	H	I	K	L	M	O	P	Q	R	
1	MPA Name	Region	MPA Groupin	MPA Survey Group	MPA typ	Final_Monitoring Priority STATEWIDE (Priority=top 10; high=top 20, medium=top 40; low=remaining)	Final_MPA Features Priority STATEWIDE (Priority=top 10; high=top 20, medium=top 40; low=remaining)	Final_Combo Priority STATEWIDE (Priority=Priority & Priority; High= Priority & High or High & High; Medium= High & Med or Med & Med; Low= Med & Low or Low & Low)	Final_Monitoring Priority REGIONAL (Priority=top 2; high=top 5, medium=top 15; low=remaining)	Final_MPA Features Priority REGIONAL (Priority=top 2; high=top 5, medium=top 15; low=remaining)	Final_Combo Priority REGIONAL (Priority=Priority & Priority; High= Priority & High or High & High; Medium= High & Med or Med & Med; Low= Med & Low or Low & Low)	ROV Monitoring	KF Monitoring	RI Monitorin		Site Selection Justification
8	Cluster - Point Arena SMCA / Point Arena SMR	2 North Central	Cluster	NCC1	Coastal	4 Low	3 Medium	4 Low	3 Medium	3 Medium	3 Medium	Yes	Yes	Yes		This cluster is limited for SMR vs SMC
9	Point Arena SMCA	2 North Central	Single	NCC1	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	No		This SMCA will only support ROV rese location and monitor only the SMR si
10	Sea Lion Cove SMCA	2 North Central	Single	NCC1	Coastal	4 Low	4 Low	4 Low	2 High	4 Low	3 Medium	No	Yes	Yes		Small MPA adjacent to an SMR that p based kelp forest and rocky intertidal
11	Salt Point SMCA	2 North Central	Single	NCC2	Coastal	4 Low	4 Low	4 Low	3 Medium	4 Low	4 Low	No	Yes	Yes		Chose this site since it closes the gap this is a potential site that can be swit
12	Gerstle Cove SMR	2 North Central	Single	NCC2	Coastal	4 Low	4 Low	4 Low	3 Medium	4 Low	4 Low	No	Yes	Yes		Same as row 11 information
13	Bodega Head SMR	2 North Central	Single	NCC3	Coastal	3 Medium	2 High	3 Medium	1 Priority	1 Priority	1 Priority	Yes	No	Yes		This is the highest ranking MPA in the region, but doesnot have any KFM d
14	Cluster - Bodega Head SMCA / Bodega Head SMR	2 North Central	Cluster	NCC3	Coastal	4 Low	3 Medium	4 Low	2 High	3 Medium	3 Medium	Yes	No	Yes		The Bodega cluster will be useful for comparison
15	Bodega Head SMCA	2 North Central	Single	NCC3	Coastal	4 Low	4 Low	4 Low	4 Low	3 Medium	4 Low	Yes	No	No		The SMCA is primarily offshore and d ROV
16	Montara SMR	2 North Central	Single	NCC4	Coastal	4 Low	3 Medium	4 Low	2 High	2 High	2 High	Yes	Yes	Yes		This MPA has had previous monitorin closes the spacing difference betwe
17	Cluster - Pillar Point SMCA / Montara SMR	2 North Central	Cluster	NCC4	Coastal	4 Low	3 Medium	4 Low	3 Medium	2 High	3 Medium	Yes	Yes	No		May consider droppping the cluster a as a medium priority in the region
18	Pillar Point SMCA	2 North Central	Single	NCC4	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	No		Same as row 17 information
19	Natural Bridges SMR	3 Central	Single	CC1	Coastal	2 High	4 Low	3 Medium	3 Medium	4 Low	4 Low	No	Yes	Yes		This site will help close the spacing g has KRM data available as well; this s
20	Carmel Bay SMCA	3 Central	Single	CC2	Coastal	1 Priority	4 Low	3 Medium	1 Priority	3 Medium	2 High	Yes	Yes	Yes		Adjacent to an SMR that prohibits tak forest and rocky intertidal monitoring;
21	Point Lobos SMR	3 Central	Single	CC2	Coastal	1 Priority	2 High	2 High	1 Priority	3 Medium	2 High	Yes	Yes	Yes		This is a highest state priority site; the allow for SMR vs SMCA ROV compar
22	Cluster - Point Lobos SMCA / Point Lobos SMR	3 Central	Cluster	CC2	Coastal	2 High	2 High	2 High	3 Medium	3 Medium	3 Medium	Yes	Yes	Yes		The Pt Lobos cluster will be useful for KFMcomparison
23	Point Lobos SMCA	3 Central	Single	CC2	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	No		The SMCA is offshore and doesn't h
24	Point Sur SMR	3 Central	Single	CC3	Coastal	1 Priority	2 High	2 High	2 High	3 Medium	3 Medium	Yes	Yes	Yes		This is a highest state priority site; ha
25	Cluster - Point Sur SMCA / Point Sur SMR	3 Central	Cluster	CC3	Coastal	3 Medium	2 High	3 Medium	3 Medium	2 High	3 Medium	Yes	Yes	Yes		The Pt Sur cluster will be useful for a comparison
26	Point Sur SMCA	3 Central	Single	CC3	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	No		The SMCA is offshore and doesn't h recommend using this cluster and jus
27	Piedras Blancas SMR	3 Central	Single	CC4	Coastal	2 High	1 Priority	2 High	2 High	2 High	2 High	Yes	Yes	Yes		This SMR has all three types of monit oceanogrpahic linkages between Po
28	Cluster - Piedras Blancas SMCA / Piedras Blancas SMR	3 Central	Cluster	CC4	Coastal	4 Low	1 Priority	3 Medium	4 Low	1 Priority	3 Medium	Yes	Yes	Yes		This cluster is limited for SMR vs SMC
29	Piedras Blancas SMCA	3 Central	Single	CC4	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	No		The SMCA is offshore and doesn't h
30	Point Buchon SMR	3 Central	Single	CC5	Coastal	3 Medium	3 Medium	3 Medium	3 Medium	3 Medium	3 Medium	Yes	Yes	Yes		This SMR has all three types of monit
31	Cluster - Point Buchon SMCA / Point Buchon SMR	3 Central	Cluster	CC5	Coastal	4 Low	2 High	3 Medium	4 Low	2 High	3 Medium	Yes	Yes	Yes		Recommend keeping this cluster to s
32	Point Buchon SMCA	3 Central	Single	CC5	Coastal	4 Low	4 Low	4 Low	4 Low	4 Low	4 Low	Yes	No	Yes		Flagging for Sara: this is an offshore
33	Campus Point SMCA	4 South	Single	SC1	Coastal	1 Priority	1 Priority	1 Priority	2 High	3 Medium	3 Medium	Yes	Yes	Yes	3	Monitoring data for all three survey m
34	Harris Point SMR	4 South	Single	SC2	Coastal	1 Priority	1 Priority	1 Priority	1 Priority	1 Priority	1 Priority	Yes	Yes	Yes	3	Monitoring data for all three survey m justify site selection
35	Anacapa Island SMCA	4 South	Single	SC3	Coastal	3 Medium	4 Low	4 Low	3 Medium	4 Low	4 Low	Yes	Yes	No	2	Does not have RIM data available bu to date:

Questions?

Amanda Van Diggelen
Amanda.VanDiggelen@wildlife.ca.gov

(Appendix C)

MONITORING CALIFORNIA'S MPA NETWORK BASED ON MULTIPLE OBJECTIVES FOR ADAPTIVE MANAGEMENT

JANUARY 12TH, 2018

MPA WORKSHOP

OUTLINE

- I. INTRODUCTION
- II. MLPA GOAL: FISHERIES SUSTAINABILITY
  - RESPONSE OF AN OPEN POPULATION
  - RESPONSE OF A CLOSED POPULATION
- III. MLPA GOAL: ECOSYSTEM STRUCTURE, FUNCTION INTEGRITY
  - DIRECT EFFECTS: TARGETED SPECIES THAT ALSO PLAY A STRONG ROLE IN ECOSYSTEM STRUCTURE/FUNCTION
  - INDIRECT EFFECTS: SPECIES IMPACTED BY FISHED SPECIES (I.E. FOOD WEB DYNAMICS)
  - INDICATORS OF COMMUNITY STRUCTURE THAT ARE NOT AFFECTED BY FISHED SPECIES (I.E. HABITAT FORMING SPECIES)
  - BROAD-SCALE METRICS FROM THE LITERATURE (BIODIVERSITY INDICATORS)
- IV. PUTTING IT ALL TOGETHER INTO ONE APPROACH

DESIGNING AND IMPLEMENTING A MONITORING PLAN FOR ADAPTIVE MANAGEMENT

- FIRST STEP IS TO DETERMINE EXPECTATIONS OF SPECIES RESPONSES TO MPAS
- THEN LONG-TERM MONITORING EVALUATES IF EXPECTATIONS WERE MET

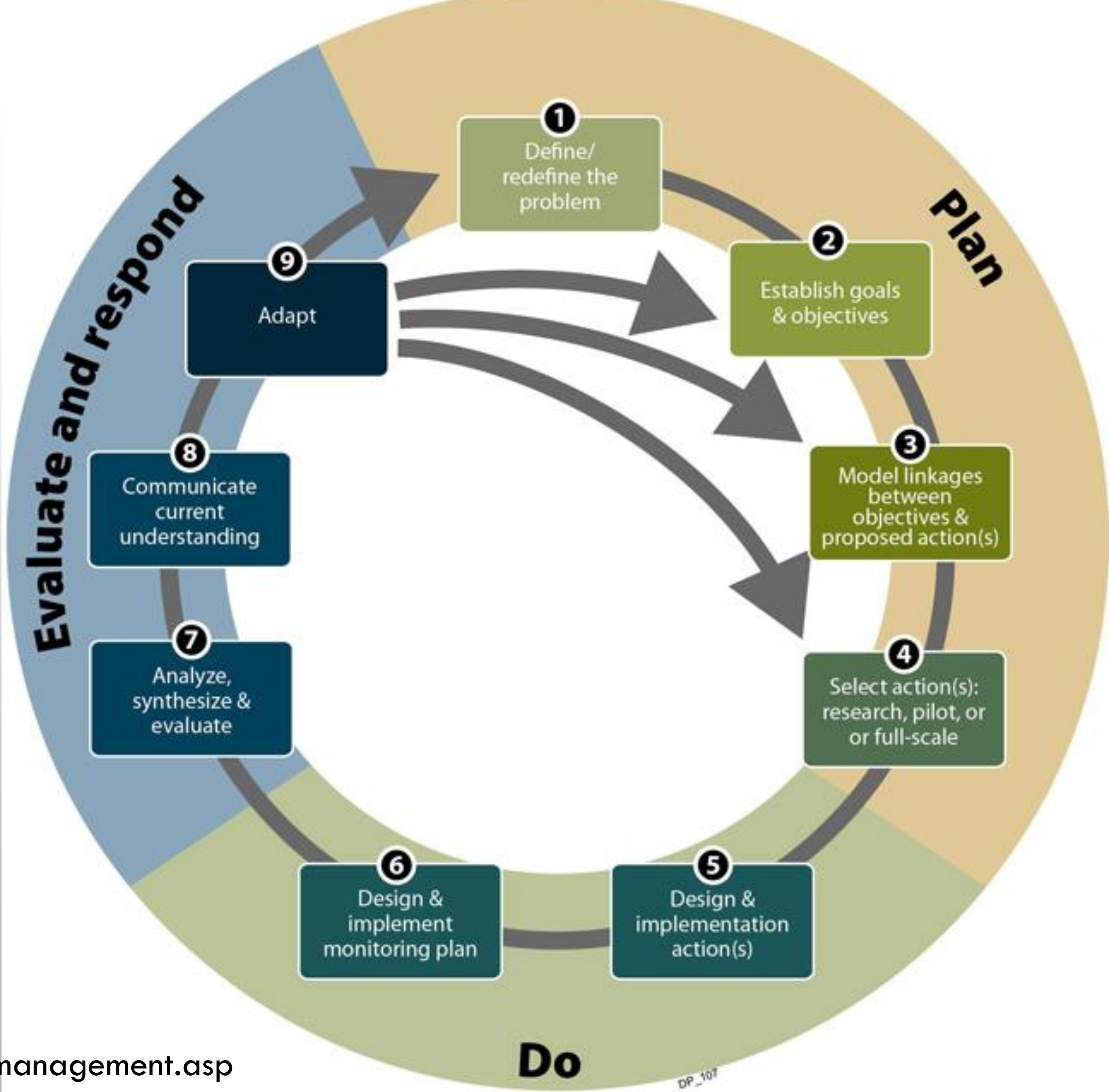


Figure credit: http://www.dfg.ca.gov/erp/adaptive_management.asp

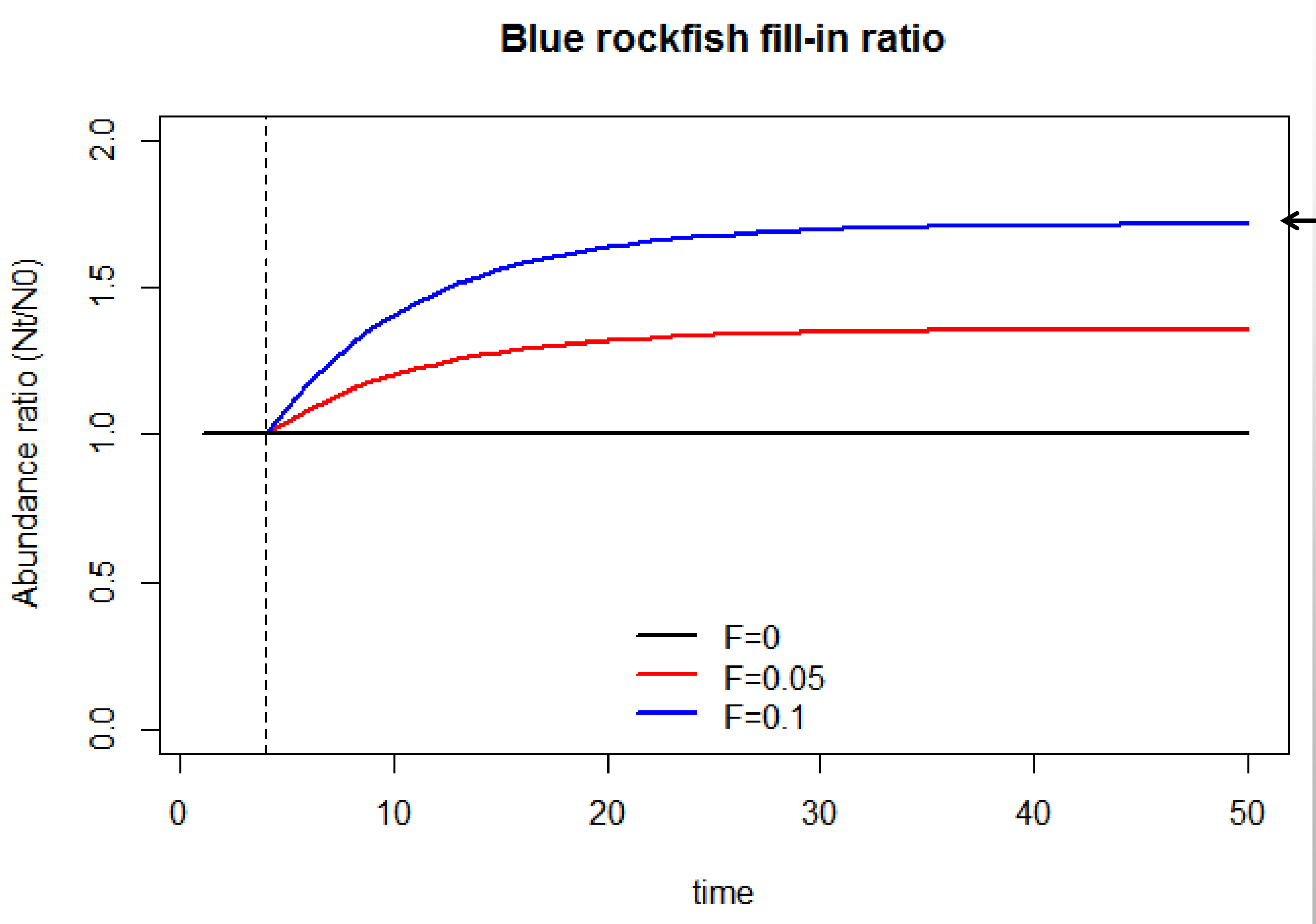
OBJECTIVES

- PROBLEM: EXISTING WORK ON MONITORING SELECTED TOO MANY SPECIES AND INDICATORS TO MONITOR WITHOUT A CLEAR DIRECTION FOR PRIORITIZATION GIVEN A LIMITED BUDGET
- SOLUTION: PROVIDE A METHOD FOR PRIORITIZING INDICATORS BASED ON OVERLAPPING OBJECTIVES OF THE MLPA

RESPONSES OF FISHED POPULATIONS TO THE IMPLEMENTATION OF THE MLPA

- APPROACH: PROJECT TIMELINE OF FISHED SPECIES RESPONSES TO MPAS
- RESPONSES DEPEND ON LEVEL OF FISHING MORTALITY BEFORE MPA IMPLEMENTATION
  - LAUREN IS USING SSIPM MODEL TO GET SPATIALLY EXPLICIT FISHING MORTALITY RATES
- CURRENTLY ASSESSING TIMELINE OF FISHED POPULATION RESPONSES BASED ON FISHING MORTALITY RATES USED IN STOCK ASSESSMENTS FOR THE 90S AND 2000S

Final responses depend of prior fishing



$$\left\{ \frac{M+F}{M} \right.$$

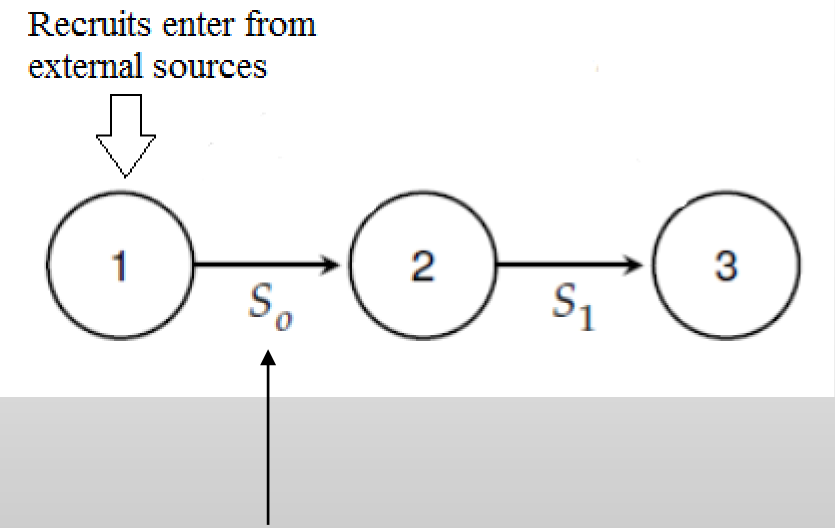
Natural mortality rate → M

Fishing mortality rate → F

MODELING AN OPEN POPULATION

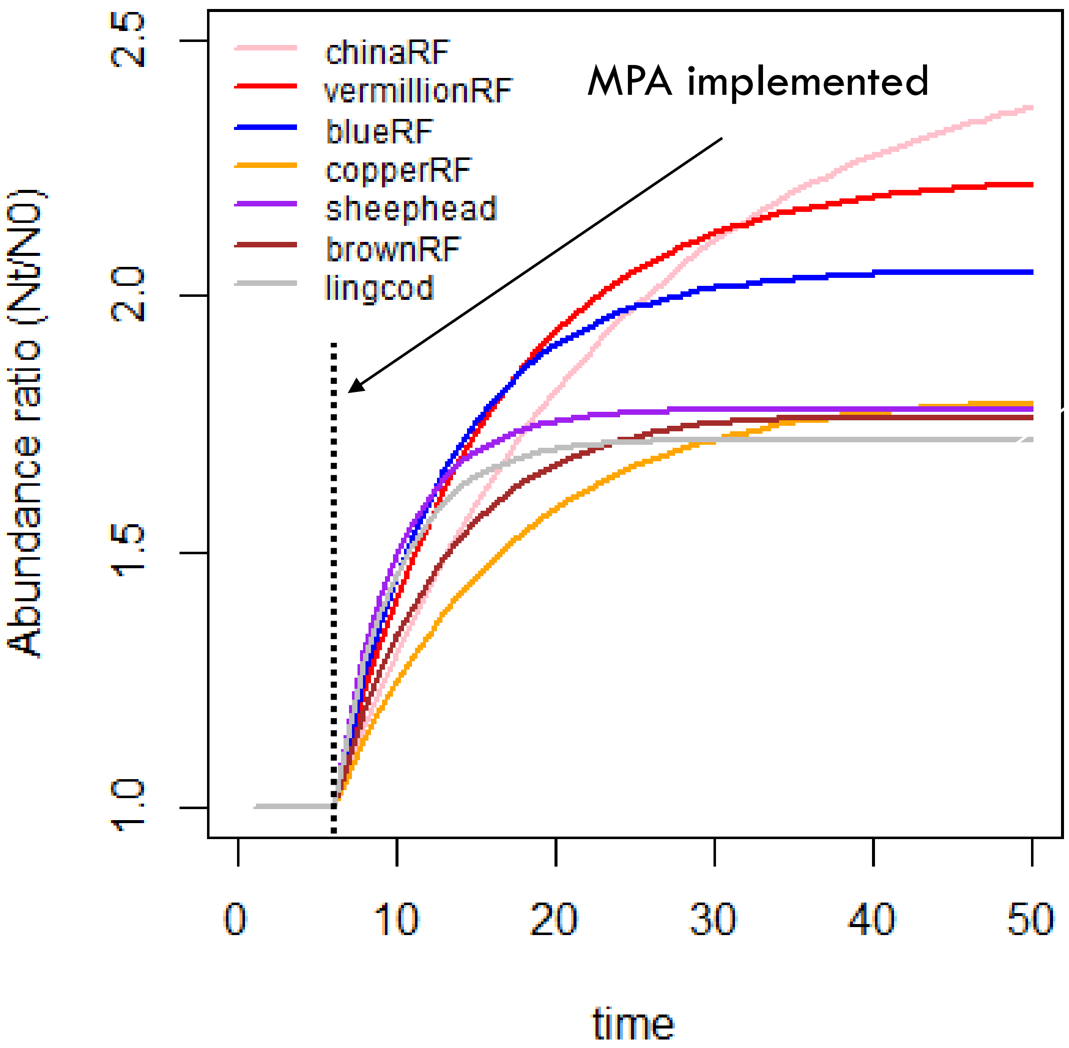
- CONSTRUCT LESLIE MATRIX
- CONSTANT RECRUITMENT ADDED TO THE POPULATION
  - CAN ADD VARIABILITY TO RECRUITMENT
- TO DETERMINE THE POPULATION RESPONSE WE REMOVE F (FISHING MORTALITY) AND SEE HOW THE ABUNDANCE CHANGES OVER TIME

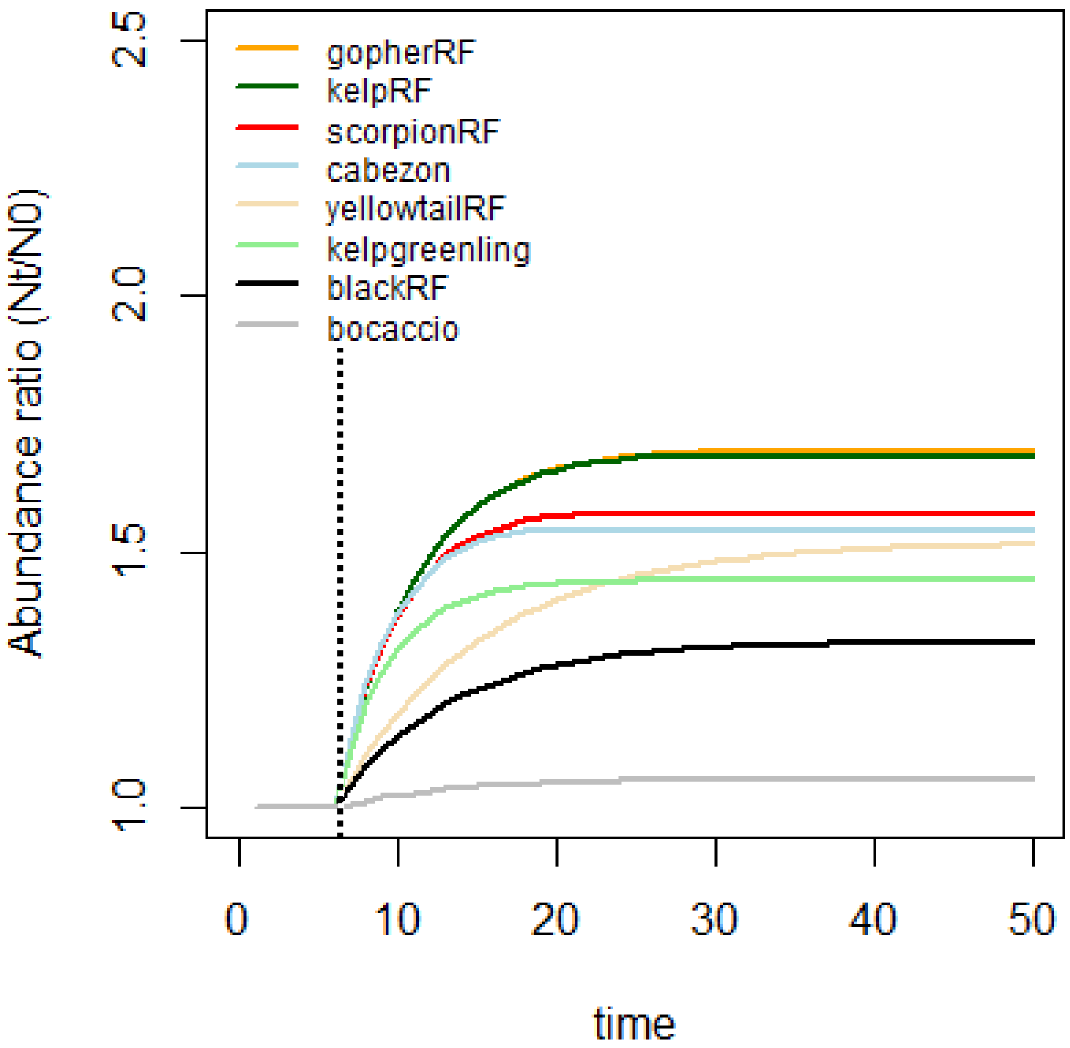
$$\mathbf{N}_{t+1} = \mathbf{A}\mathbf{N}_t + \mathbf{R},$$



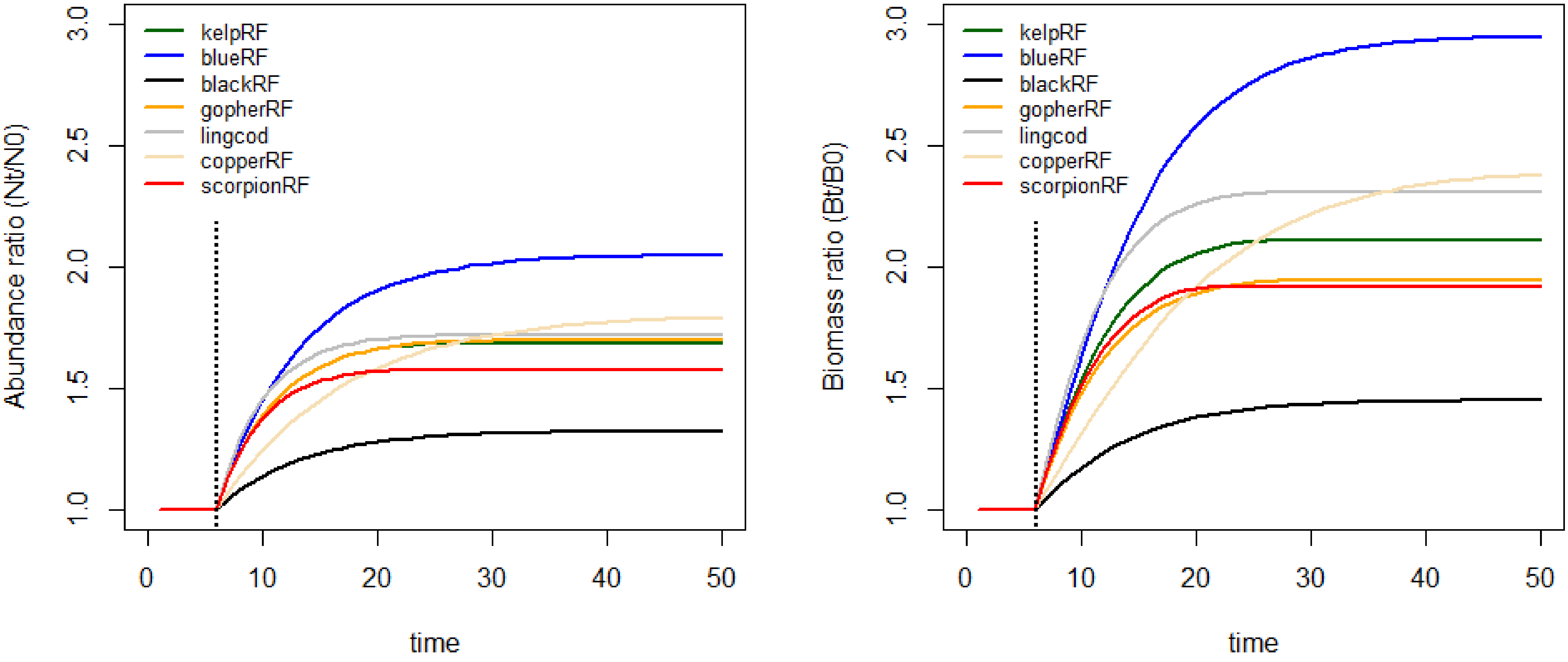
Survivorship to the next age class is based on the fishing mortality (F) and natural mortality rate (M)

MODELING MPA RESPONSES: ABUNDANCE CHANGES OVER TIME FOR AN OPEN POPULATION

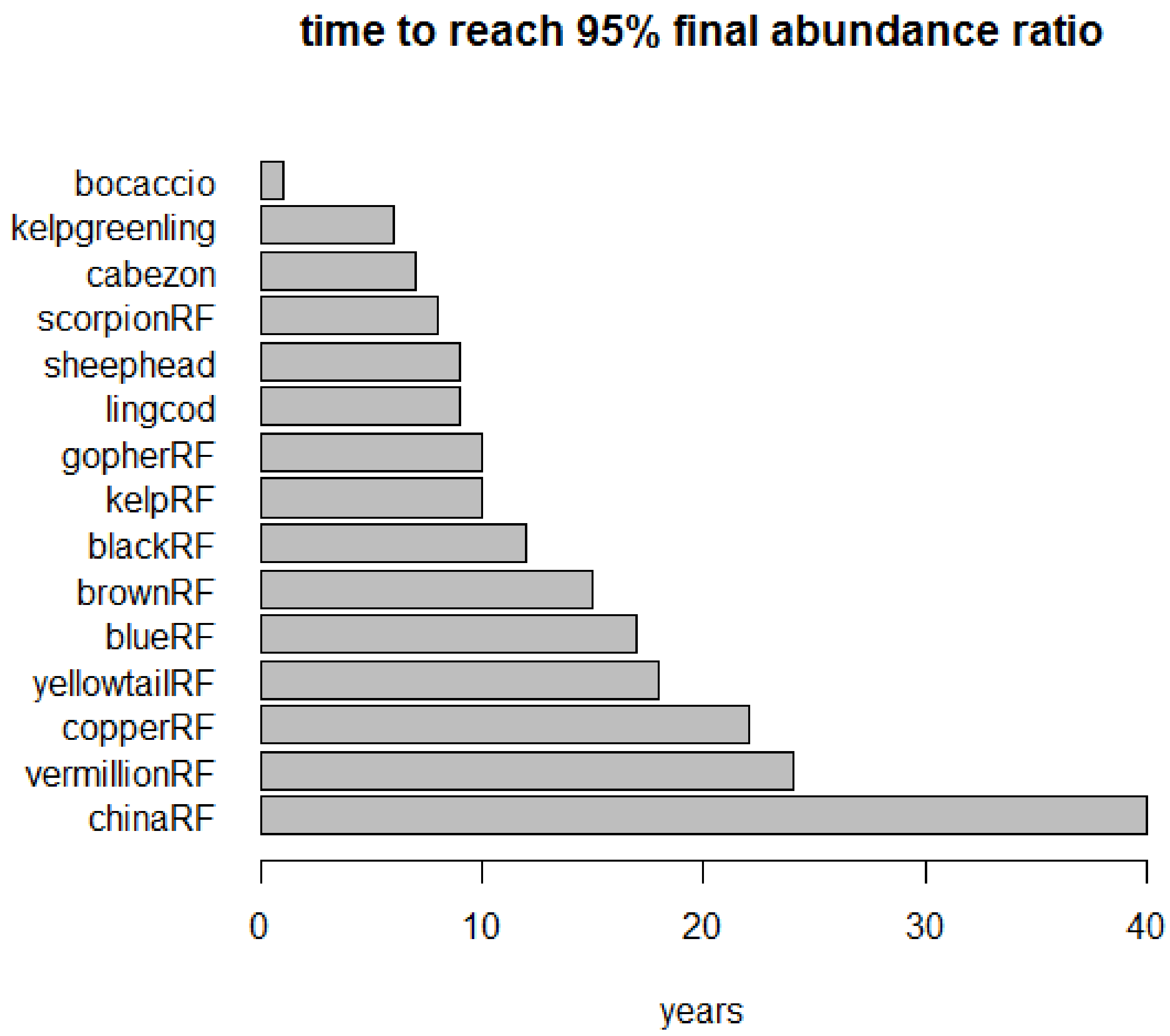


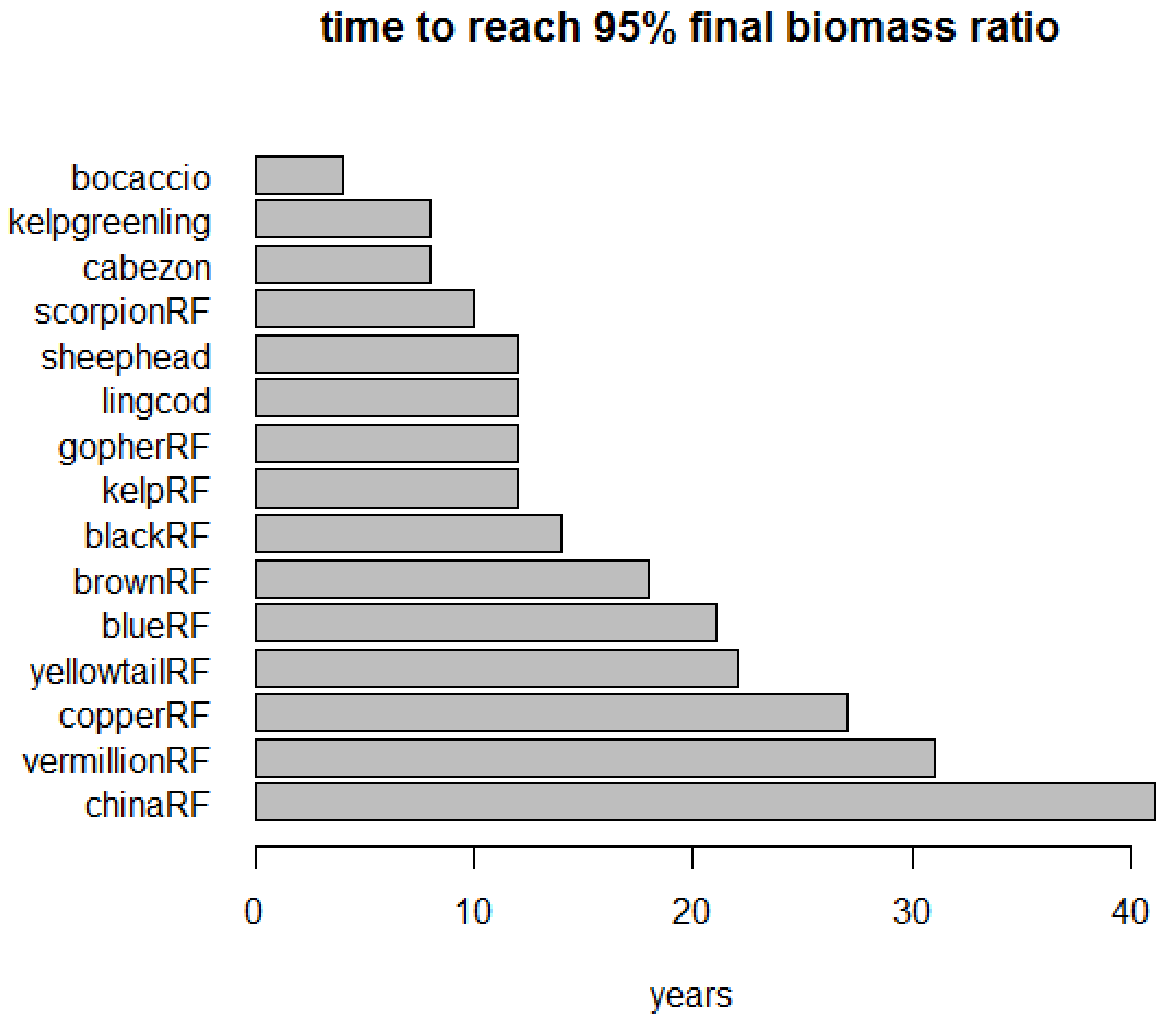


BIOMASS RATIO INCREASE IS GREATER THAN ABUNDANCE

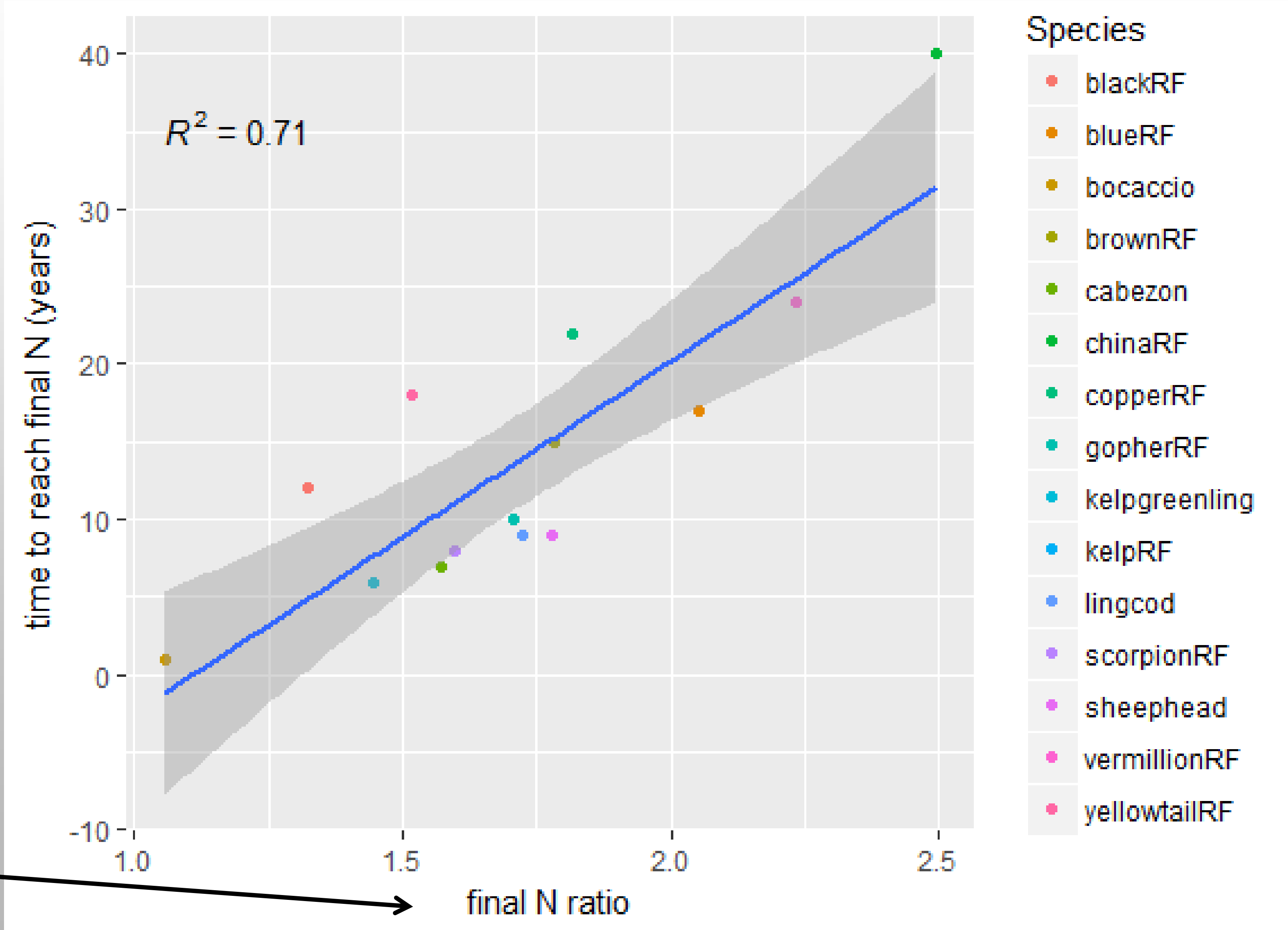


TIMELINES FOR ABUNDANCE AND BIOMASS USING OPEN POPULATION DETERMINISTIC MODEL



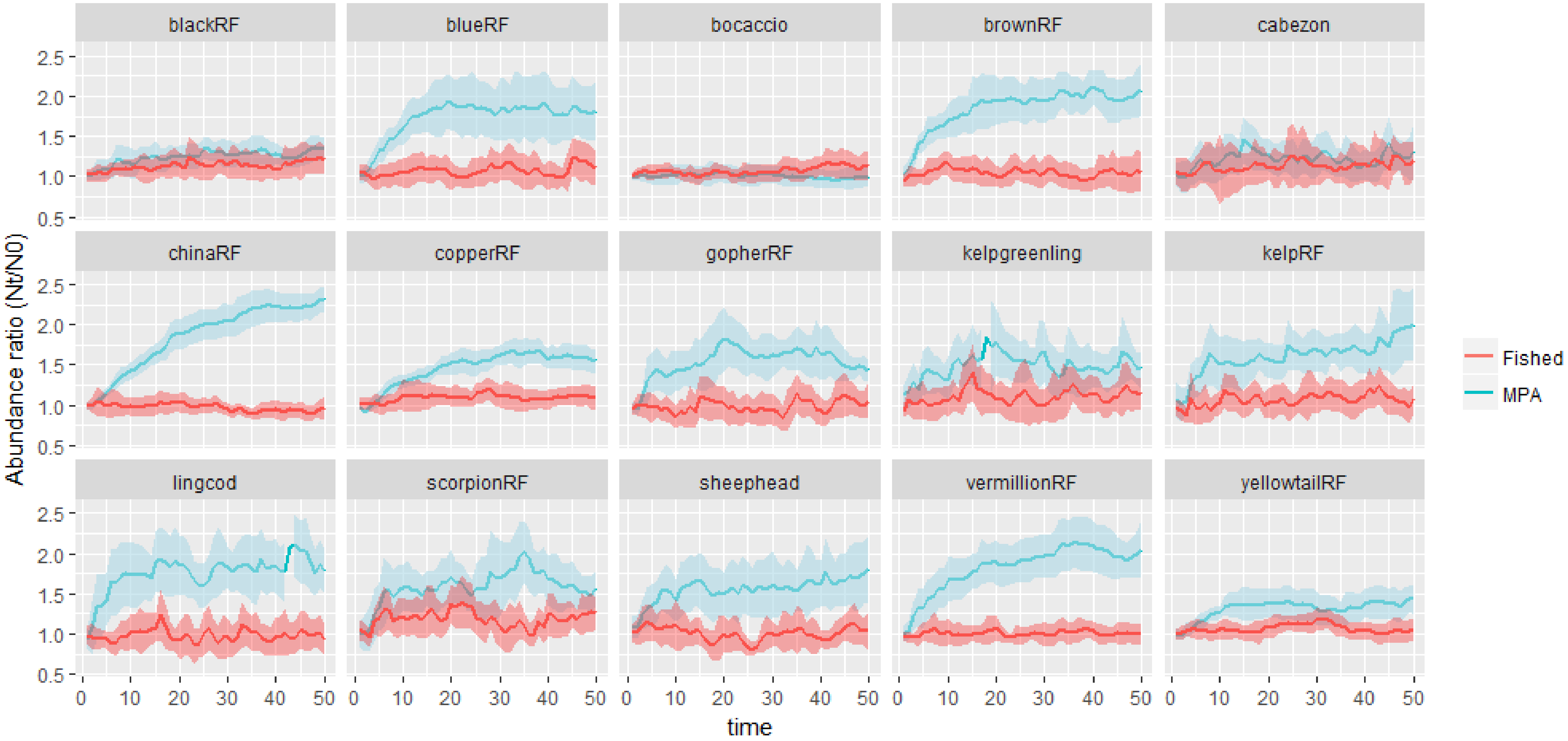


TIME TO REACH FINAL ABUNDANCE IS CORRELATED TO THE FINAL ABUNDANCE RATIO

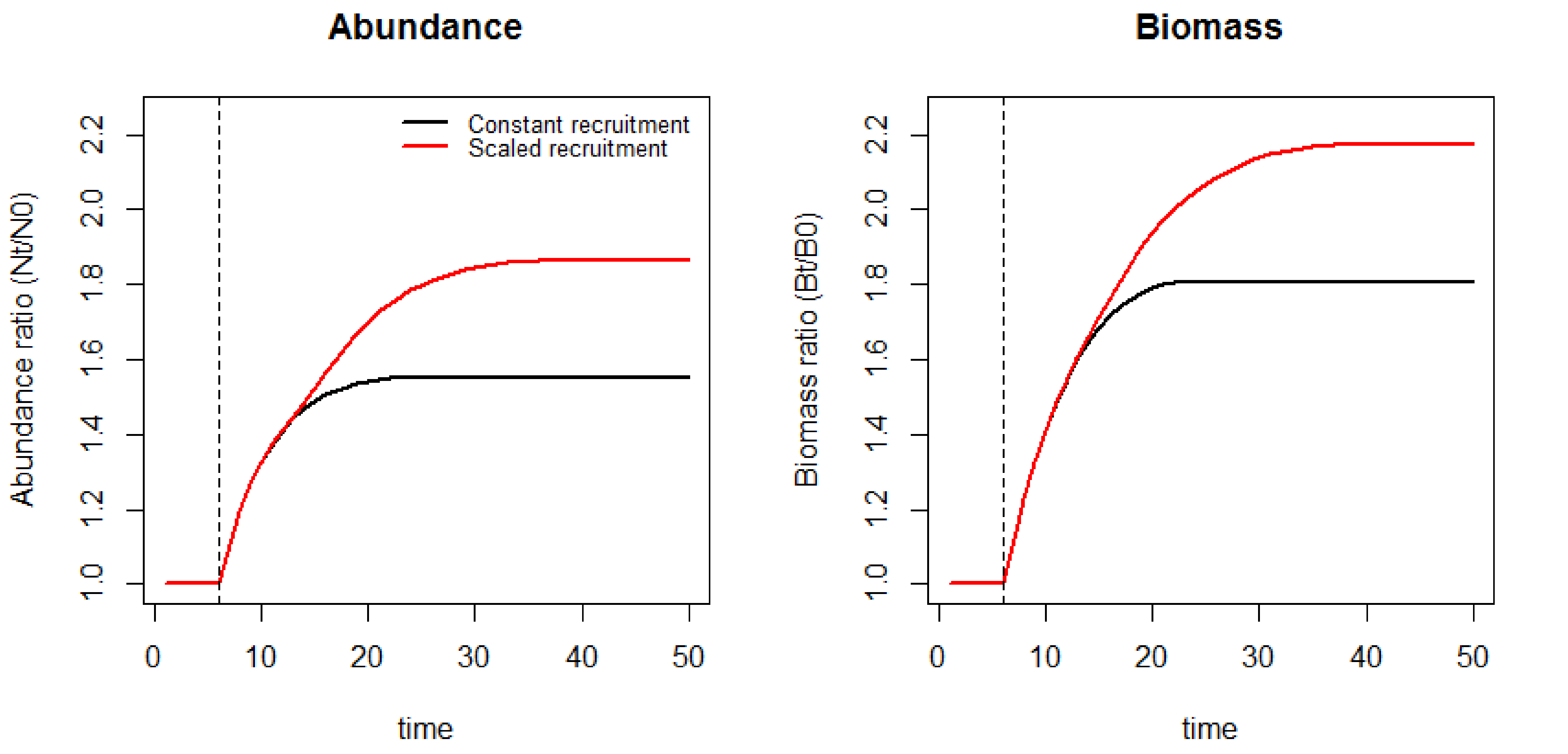


$$\frac{M+F}{M}$$

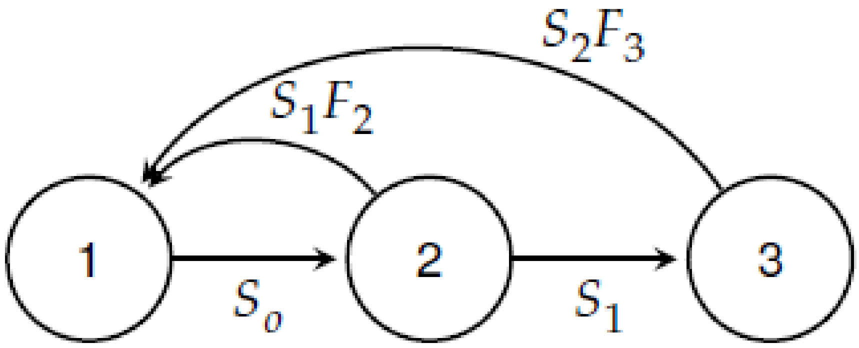
MODELING STOCHASTICITY IN RECRUITMENT (preliminary result)



MODELING RESPONSE RATIOS WITH CHANGES IN RECRUITMENT DUE TO MPA IMPLEMENTATION

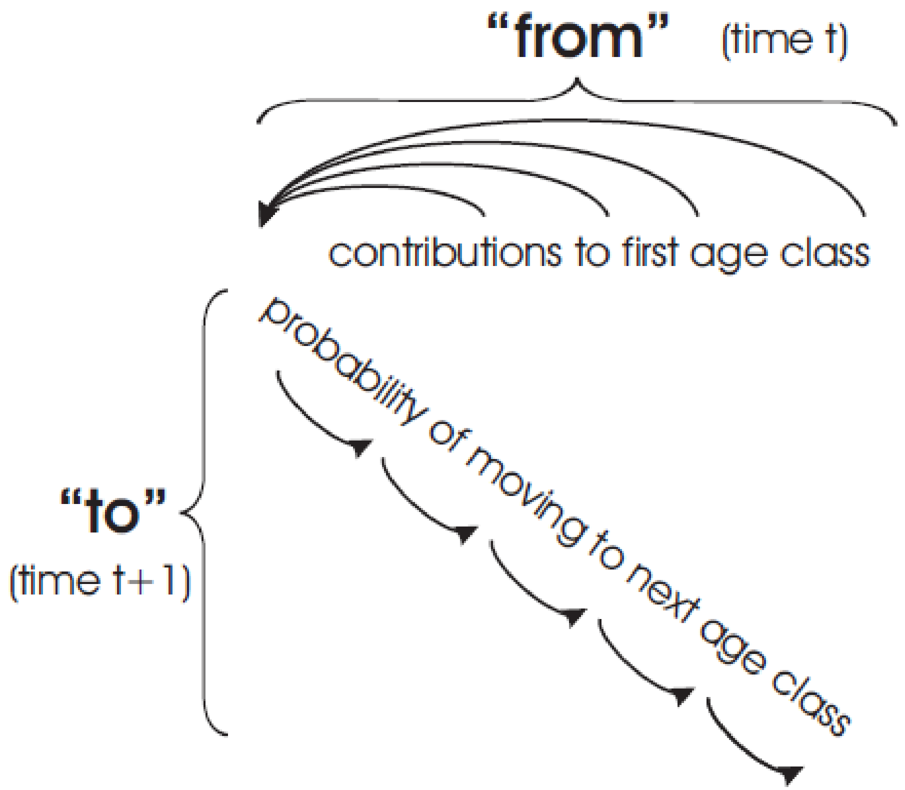


MODELING A CLOSED POPULATION



- CAN DETERMINE TIME SCALE OF TRANSIENT RESPONSE
- STEP1: DETERMINE STABLE AGE DISTRIBUTION FOR FISHED POPULATION
- STEP 2: DETERMINE RATIOS OF INCREASE ONCE FISHING MORTALITY IS REMOVED

$$\mathbf{N}_{t+1} = \mathbf{A}\mathbf{N}_t,$$

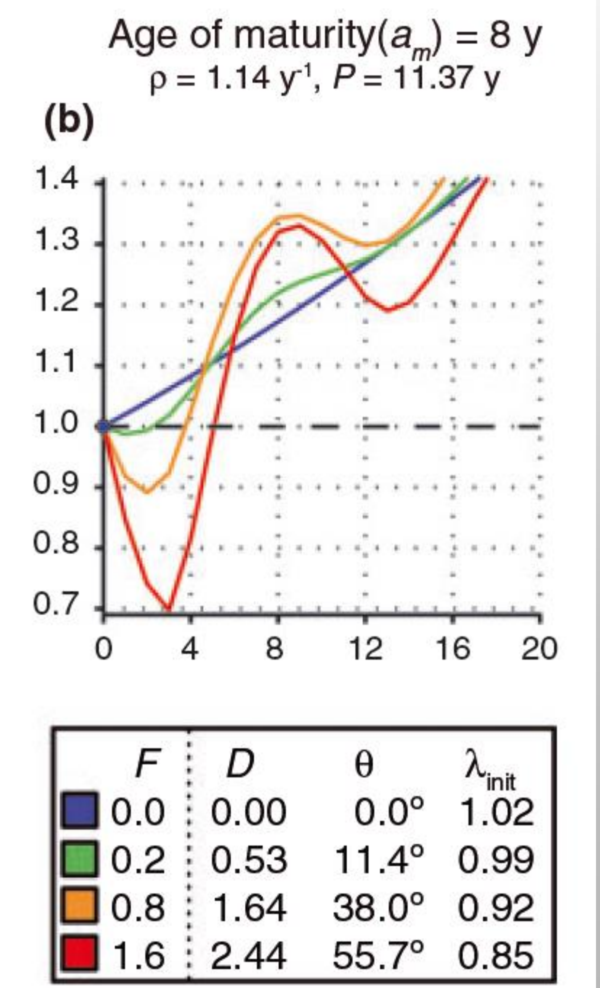


DETERMINING TRANSIENT RESPONSES FOR A CLOSED POPULATION

- THE TRANSIENT RESPONSE OF THE CLOSED POPULATION IS A SINE WAVE OF THE PERIOD (P), THAT DIES OUT AS DAMPING RATIO (RHO)

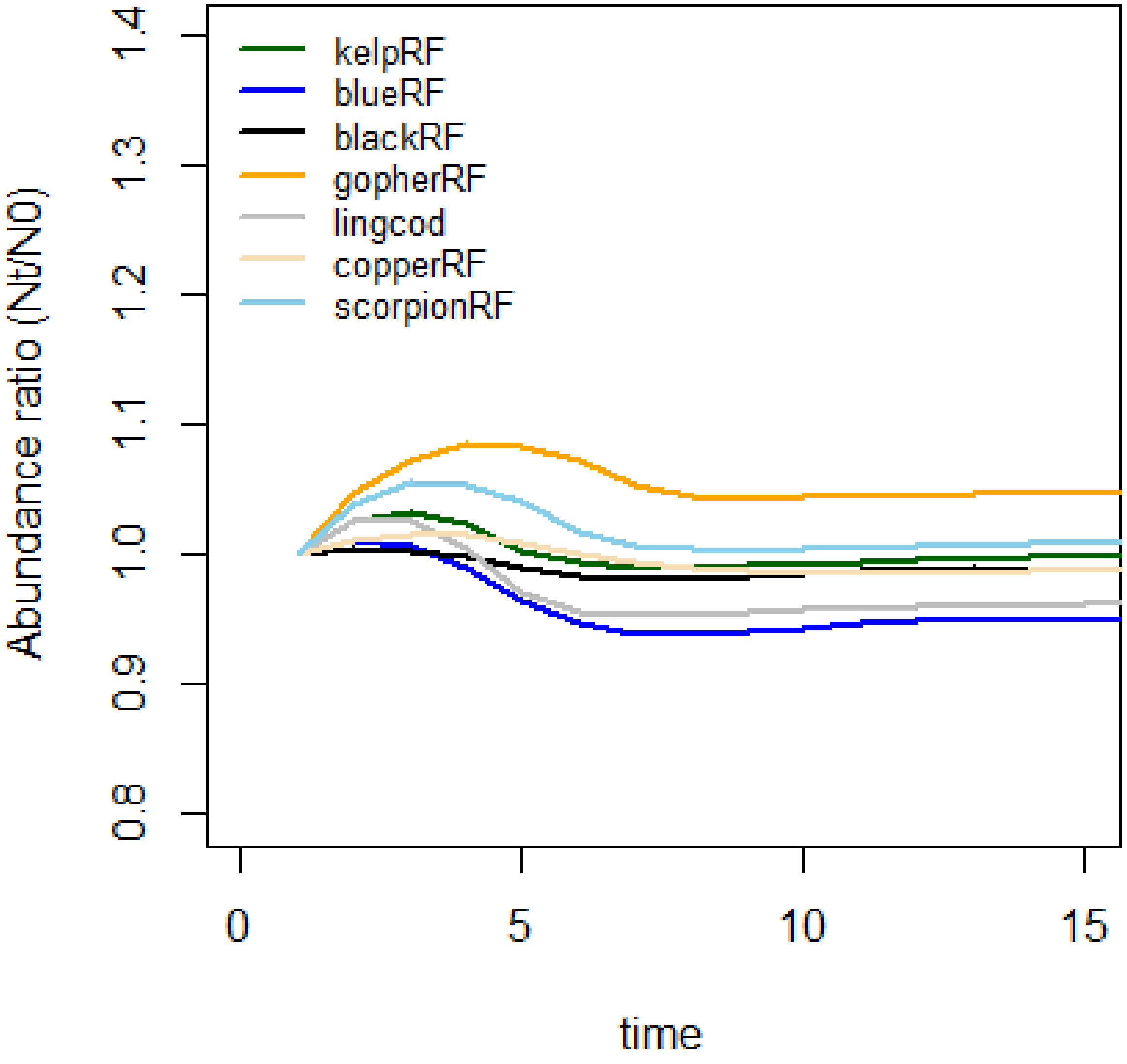
$$\rho \approx \lambda_1 / |\lambda_2|$$

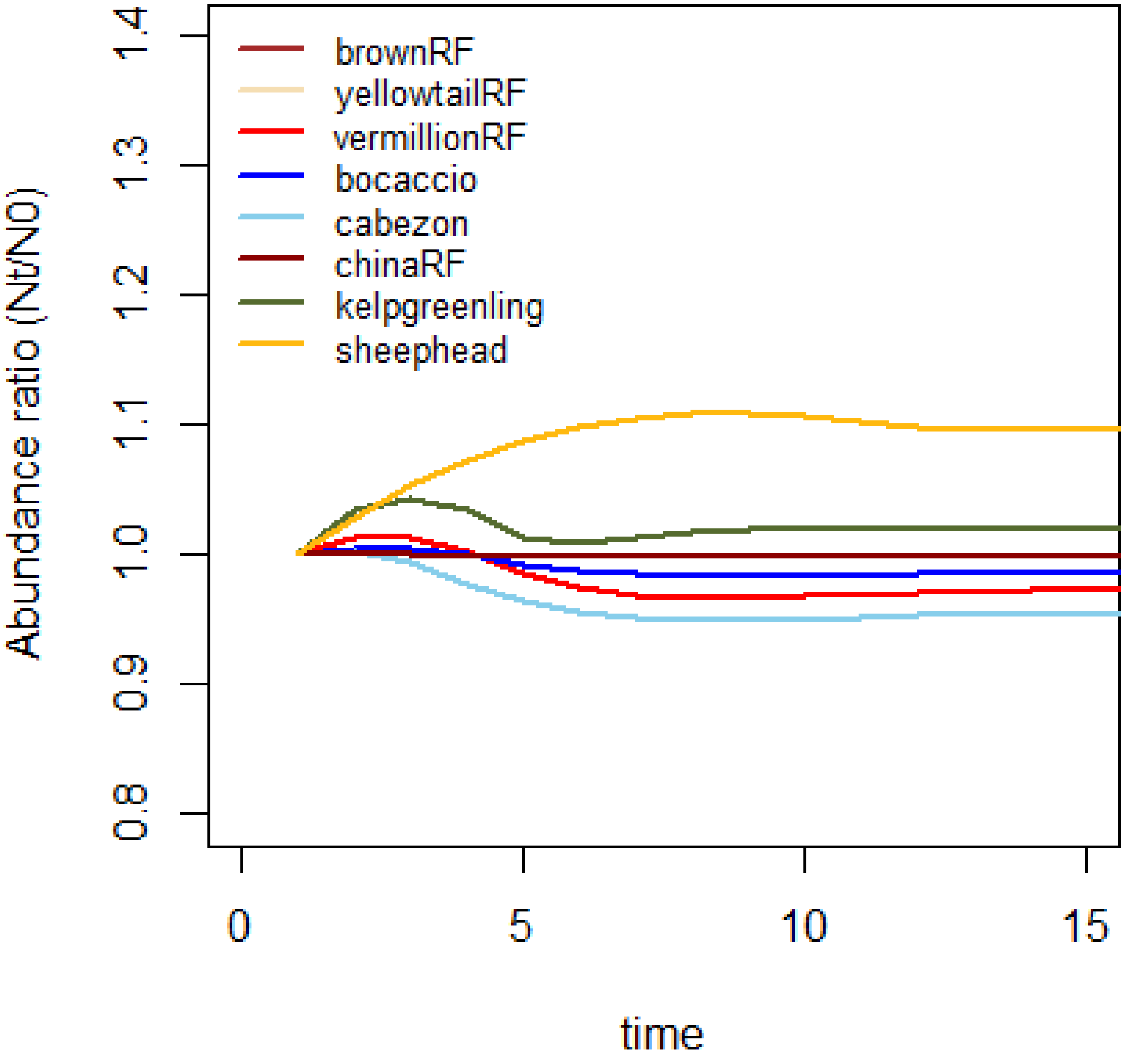
$$P = 2\pi / \arctan\left(\frac{\mathrm{Im}(\lambda_2)}{\mathrm{Re}(\lambda_2)}\right)$$



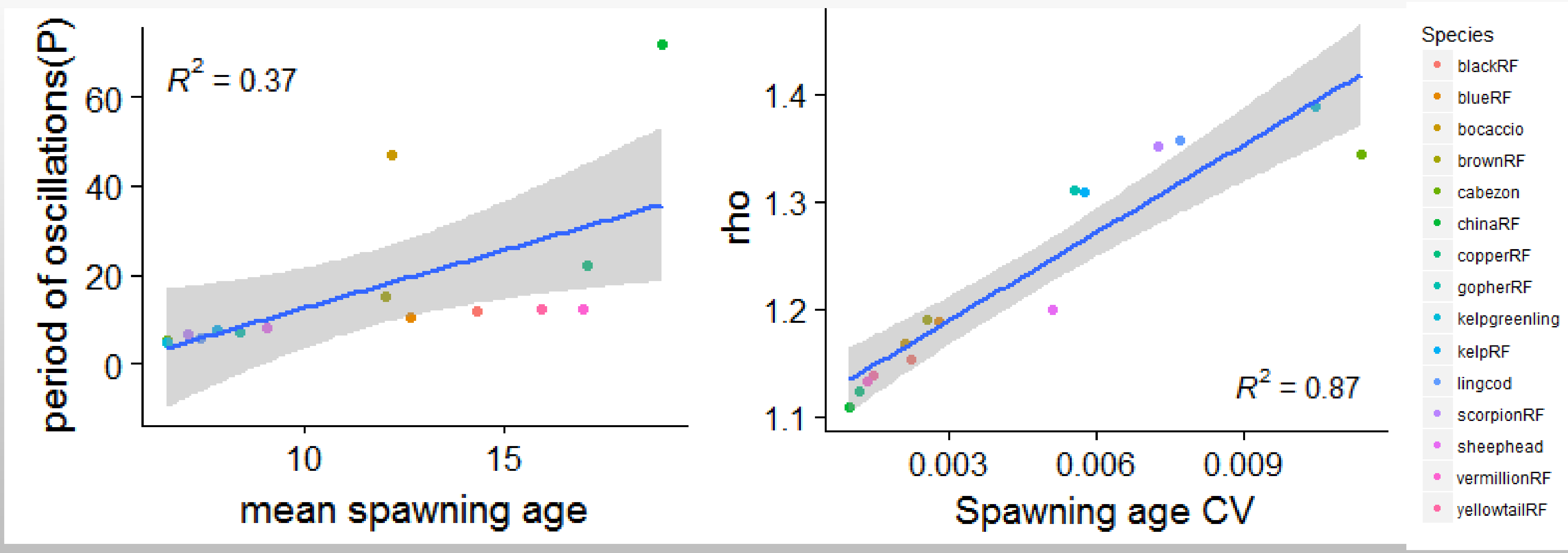
White et al. 2013

CLOSED POPULATIONS HAVE OSCILLATORY TRANSIENT DYNAMICS

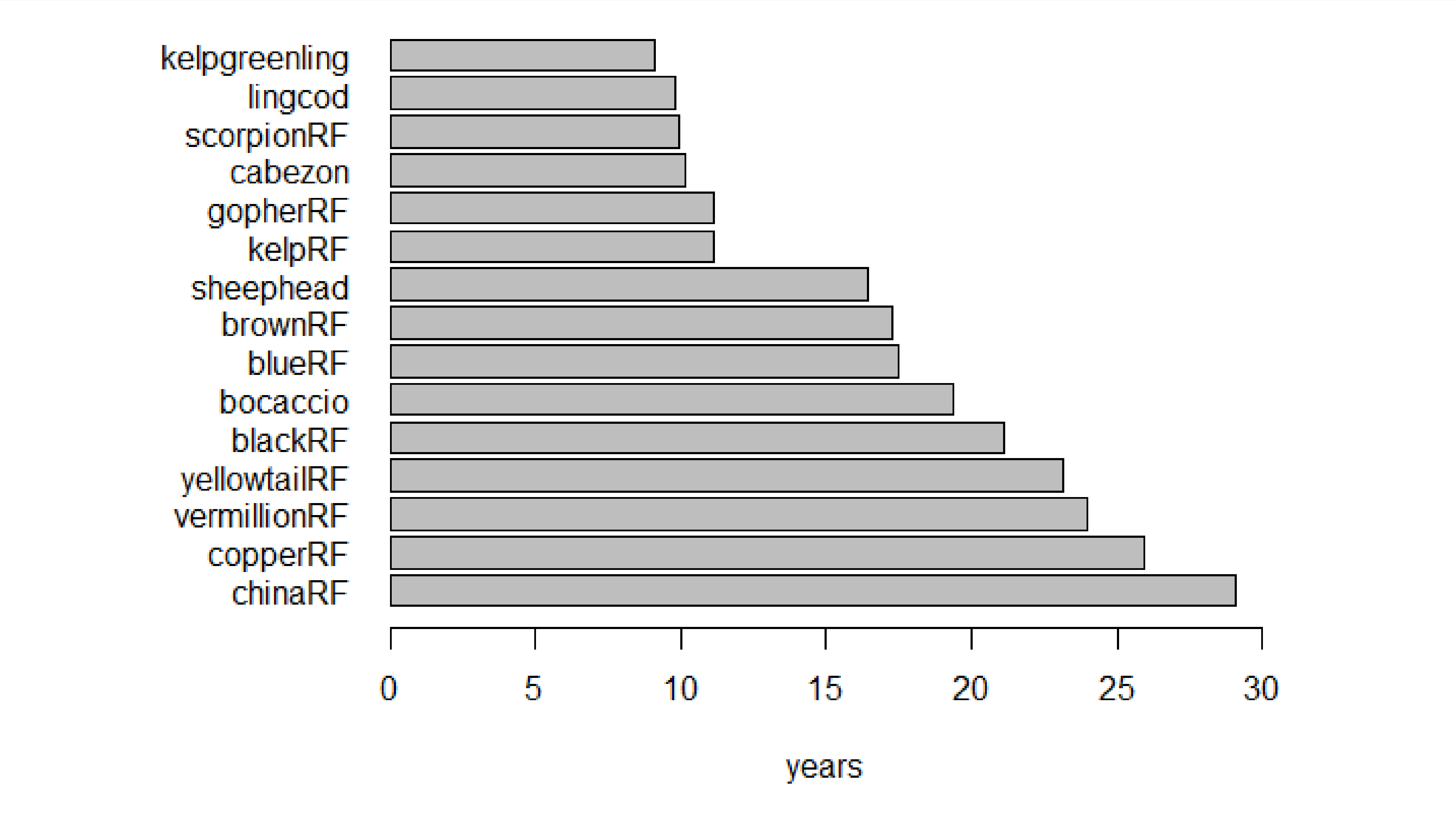




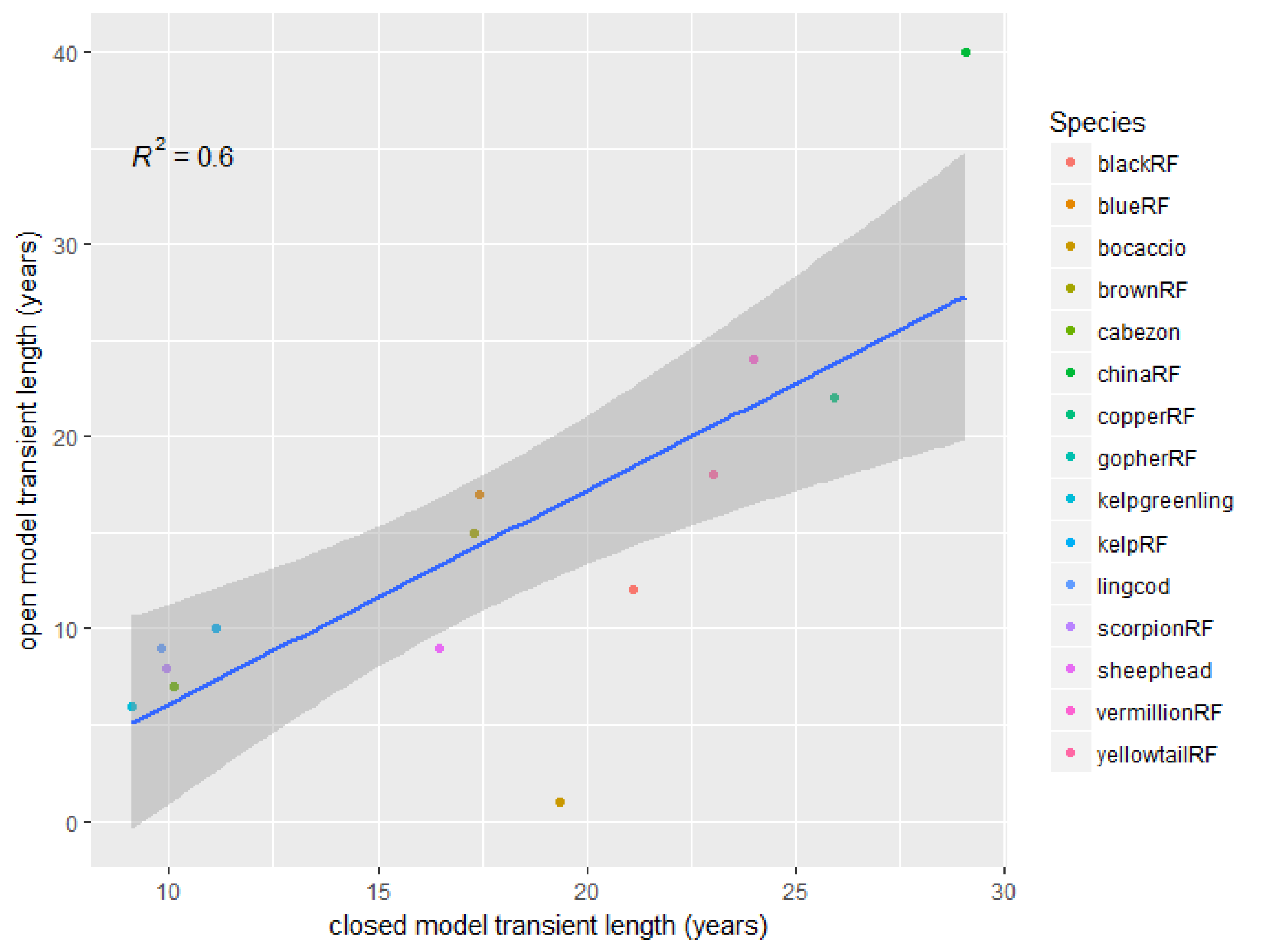
GENERAL TRENDS OF TRANSIENT RESPONSE METRICS BASED ON LIFE HISTORIES



LENGTH OF TRANSIENCE IN CLOSED POPULATION CASE



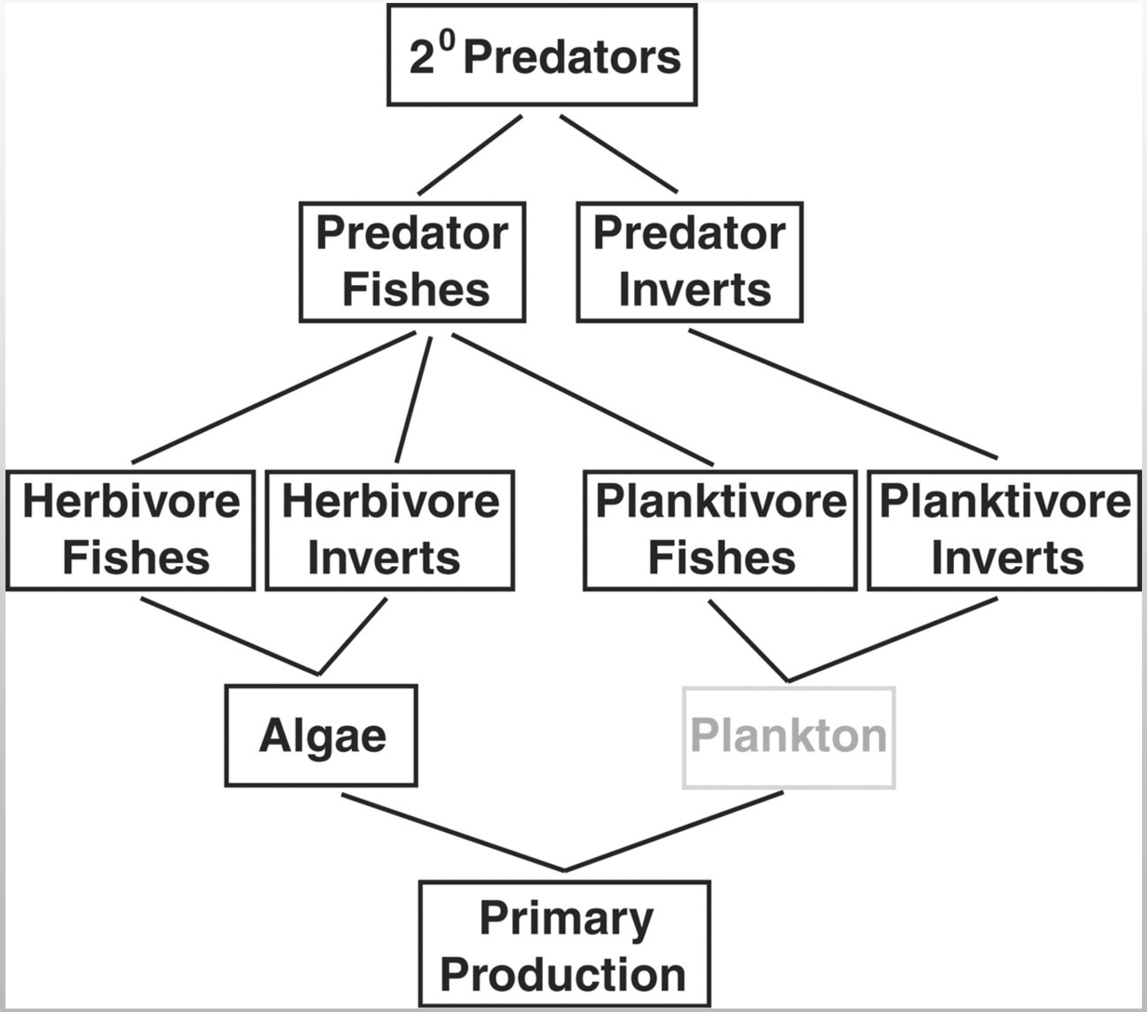
OPEN POPULATION V. CLOSED POPULATION LENGTH OF TRANSIENT PERIODS



PART II: ECOSYSTEM STRUCTURE, FUNCTION AND INTEGRITY GOAL

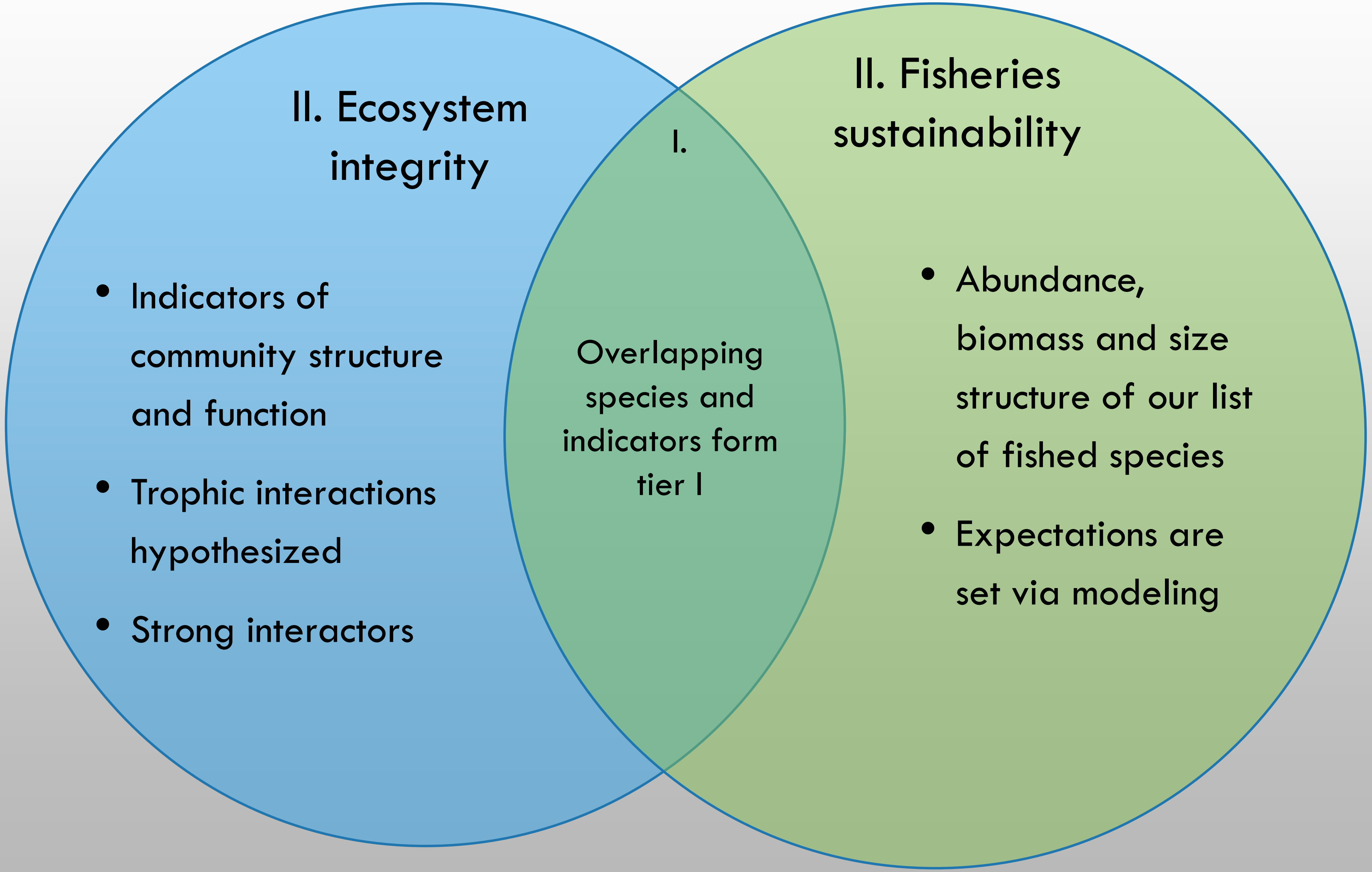
INDICATORS BASED ON:

- I. DIRECT EFFECTS: TARGETED SPECIES THAT ALSO PLAY A STRONG ROLE IN ECOSYSTEM STRUCTURE/FUNCTION
- II. INDIRECT EFFECTS: SPECIES IMPACTED BY FISHED SPECIES (I.E. FOOD WEB DYNAMICS)
- III. INDICATORS OF COMMUNITY STRUCTURE THAT ARE NOT AFFECTED BY FISHED SPECIES (I.E. HABITAT FORMING SPECIES)
- IV. BROAD-SCALE METRICS FROM THE LITERATURE (BIODIVERSITY INDICATORS)



Halpern et al. 2006

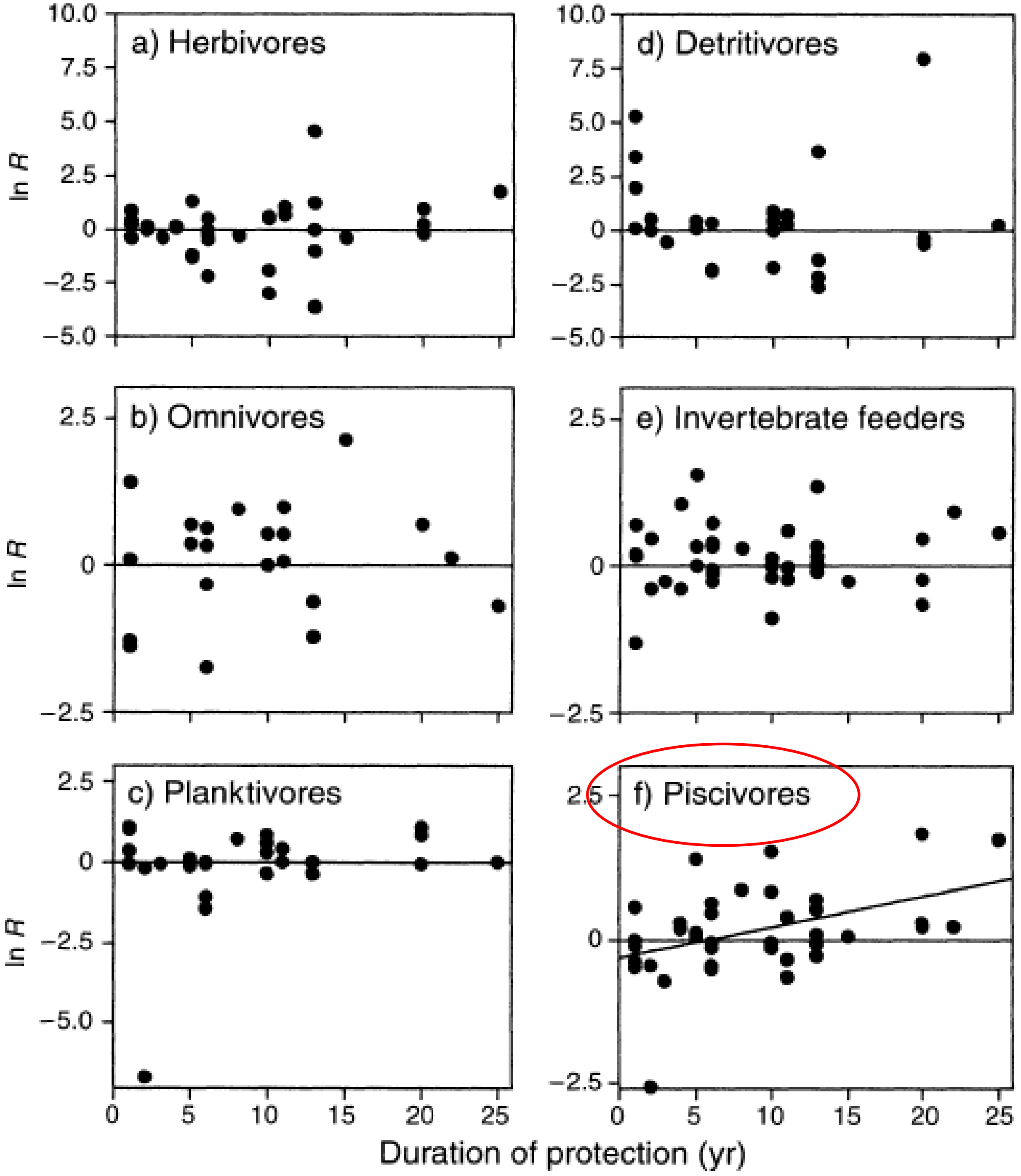
CREATING A TIERED APPROACH



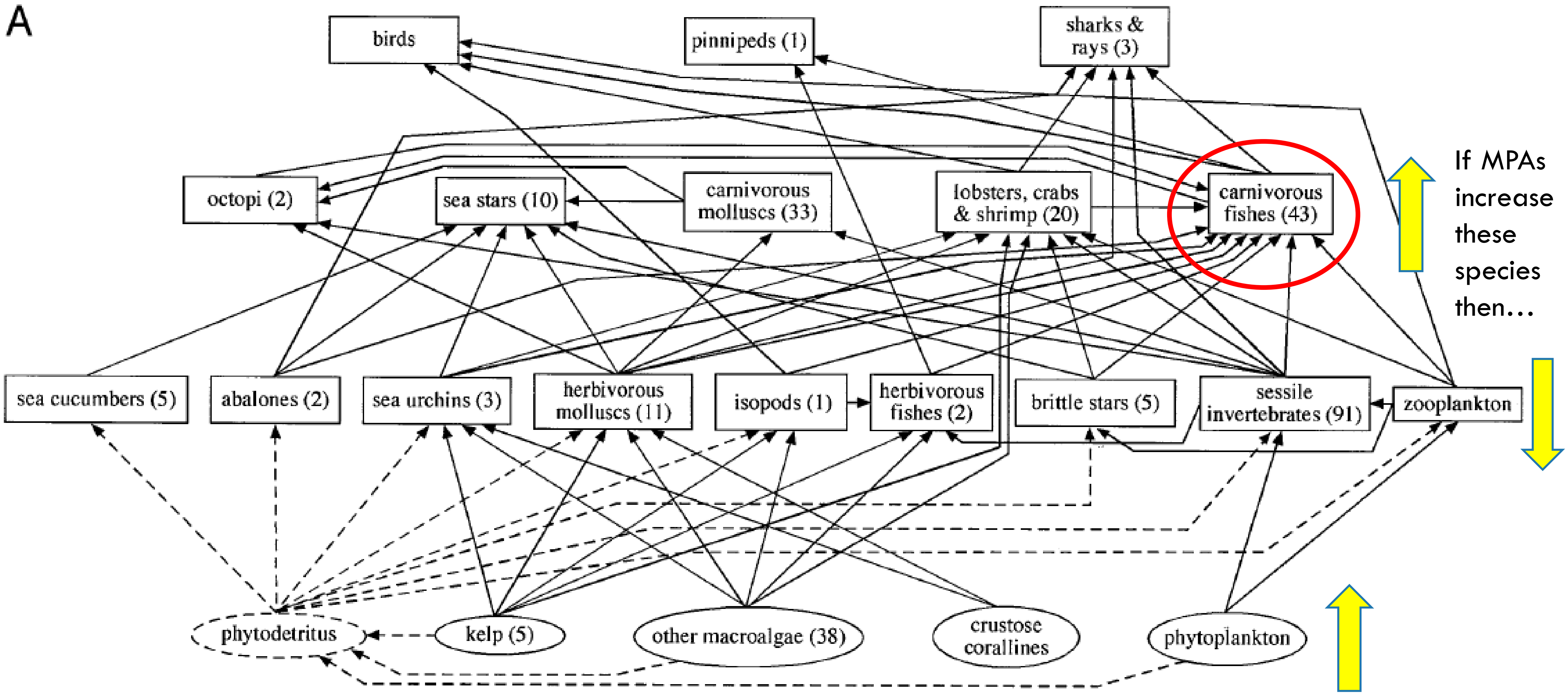
II. INDIRECT EFFECTS: TROPHIC LEVELS SHOW DIFFERENT RESPONSES TO MARINE RESERVES

- INCREASING POSITIVE EFFECTS FOR HIGHER TROPHIC LEVELS
- MARINE RESERVES EFFECTIVE IN INCREASING **ABUNDANCES** OF EXPLOITED SPECIES AND RESTORING COMMUNITY STRUCTURE, THOUGH CHANGES OCCUR THROUGH A SERIES OF TRANSIENT STATES OVER LONG TIME FRAMES

Micheli, F; Halpern, BS; Botsford, LW; and Warner, RR. 2004



II. INDIRECT EFFECTS: DYNAMICS OF A KELP FOREST ECOSYSTEM



If MPAs increase these species then…

Babcock et al. 2010:

Average indirect effect is 13 years or longer

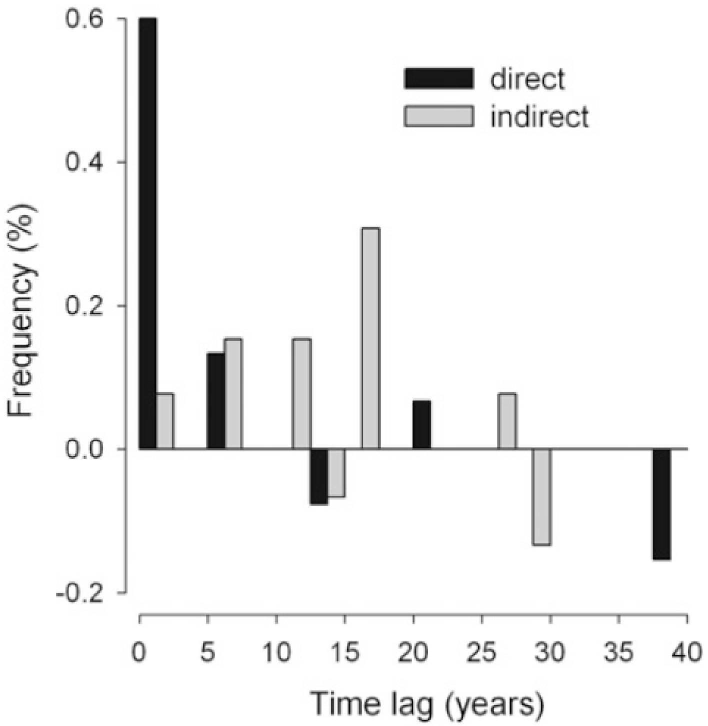
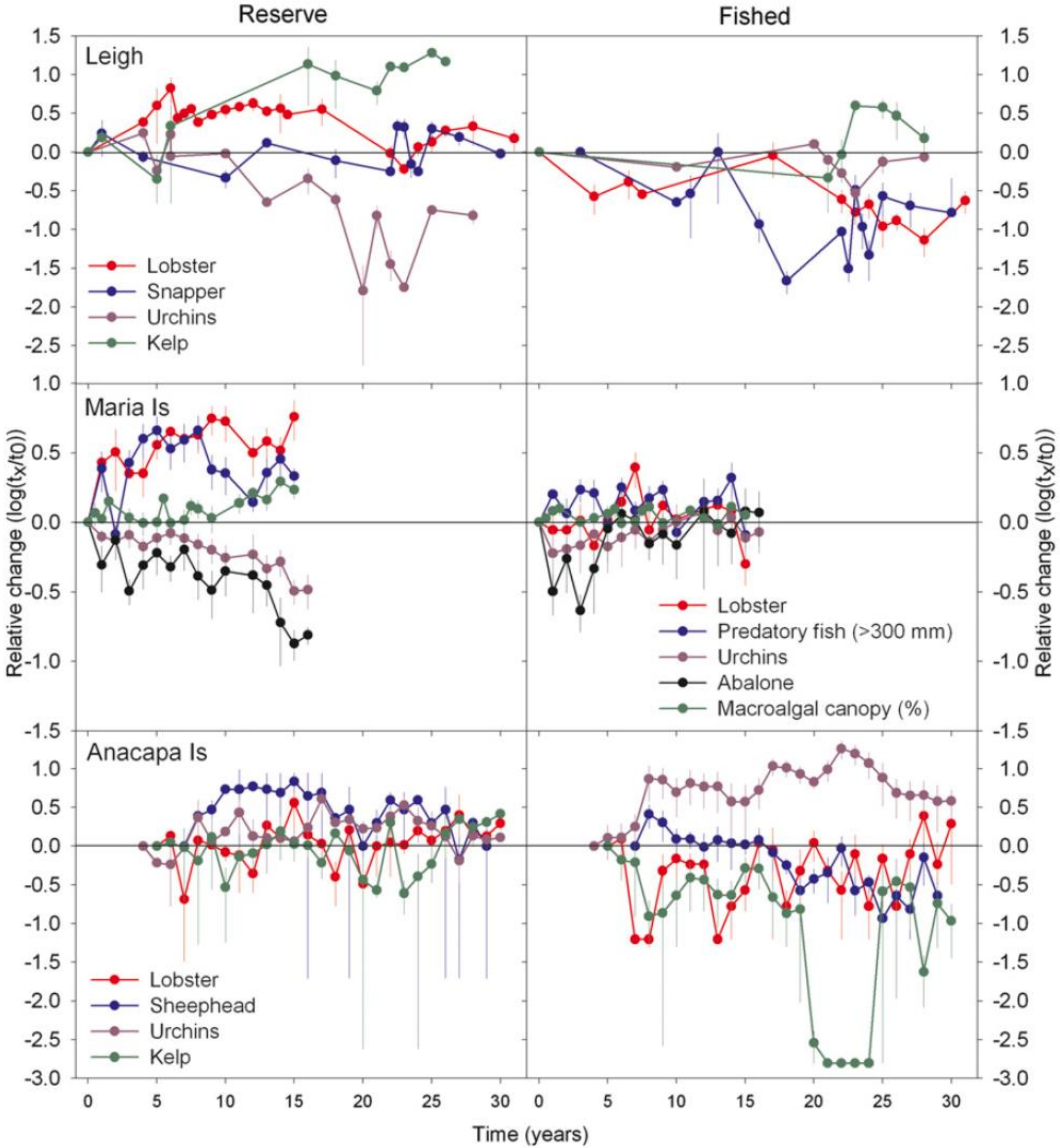


Fig. 3. Time to first detection of direct and indirect responses to marine reserve protection. Positive data indicate the proportion of observed species displaying direct and indirect effects, negative values indicate taxa for which no effect was observed. *n* = 28.



III. INDICATORS OF COMMUNITY STRUCTURE

- APPROACHES
  - DETERMINE SUBSET OF COMMUNITY INDICATORS THAT CORRELATE TO FULL COMMUNITY
  - COMPARE TO REGIONAL MONITORING PLANS INDICATOR/FOCAL SPECIES LIST

APPROACH

Raw data - >300 species

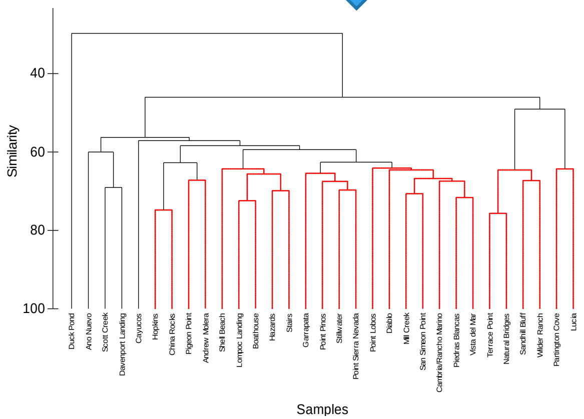
	anthopleura s	bossiella spp	chthamalus s	c
Pigeon Point	4.4151E-2	6.7442E-2	0.12998	
Ano Nuevo	0.10622	3.7556E-2	9.1993E-2	
Scott Creek	8.0553E-2	0.12305	0.13154	
Davenport Landing	0.10003	8.1677E-2	8.9473E-2	
Sandhill Bluff	7.5512E-2	2.6698E-2	0.17302	
Wilder Ranch	2.8296E-2	6.3271E-2	0.12005	
Terrace Point	3.8028E-2	2.689E-2	0.27024	

Start with all species

Similarity matrix

	Pigeon Point	Ano Nuevo	Scott Creek	Davenport L
Pigeon Point				
Ano Nuevo	58.102			
Scott Creek	55.827	57.16		
Davenport Landing	53.051	62.838	69.044	
Sandhill Bluff	35.721	42.813	50.279	53.62

Calculate similarity/dissimilarity for all pairs of sites



Link sites to assess relationships in space or time

APPROACH

Raw data - >300 species

	anthopleura s	bossiella spp	chthamalus s	c
Pigeon Point	4.4151E-2	6.7442E-2	0.12998	
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Similarity matrix

	Pigeon Point	Ano Nuevo	Scott Creek	Davenport L
Pigeon Point				
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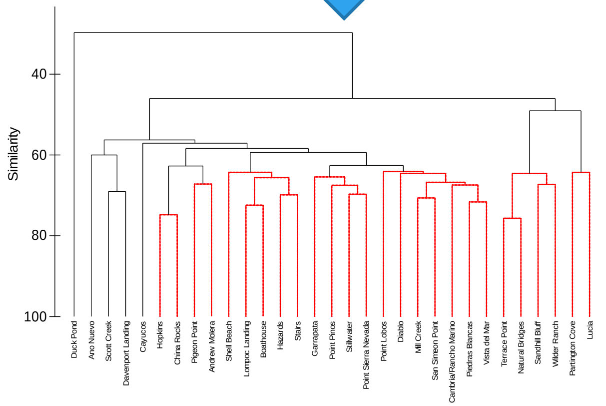
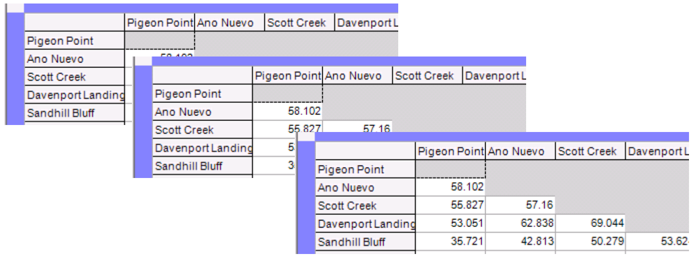


Create random subsets of species
(e.g. sets of 100, 99, 98, ….3, 2, 1species)

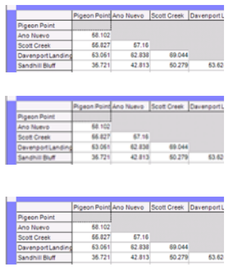
Similarity matrices (millions of combinations)



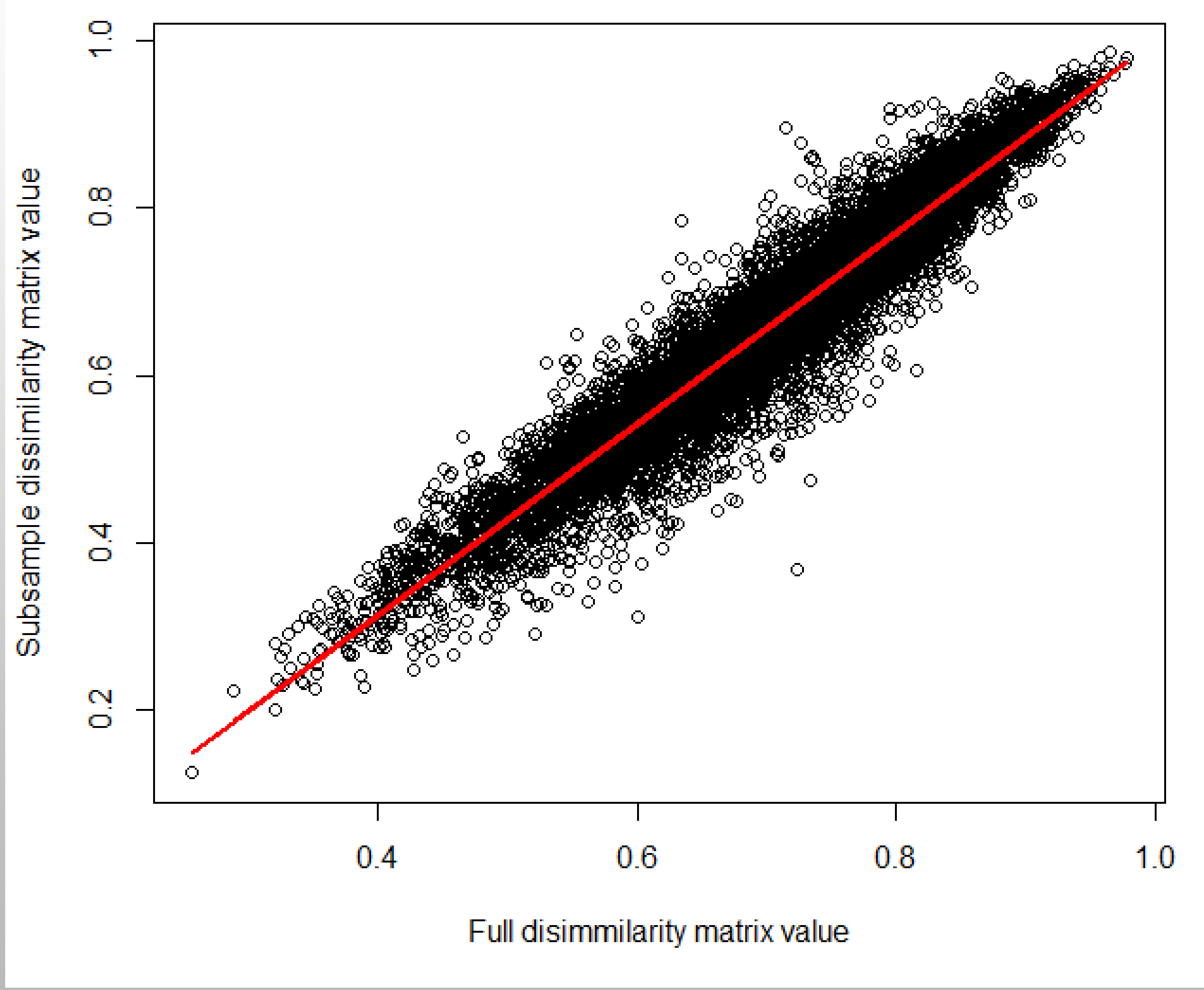
Compare fit of original matrix (all species) to new (reduced # species) matrices

	Pigeon Point	Ano Nuevo	Scott Creek	Davenport L
Pigeon Point				
Ano Nuevo	58.102			
Scott Creek	55.827	57.16		
Davenport Landing	53.051	62.838	69.044	
Sandhill Bluff	35.721	42.813	50.279	53.62

VS



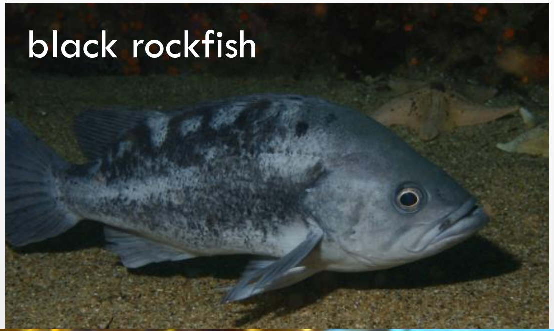
COMPARE REDUCED MODEL TO FULL MODEL

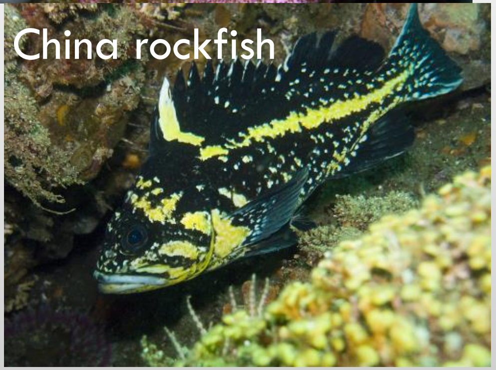


Bray-Curtis dissimilarity matrix for all site pairs

III. KELP FOREST COMMUNITY INDICATORS

Species with 95% correlation to full list
Chromis punctipinnis
Oxyjulis californica
Sebastes mystinus
Sebastes melanops
Sebastes atrovirens
Sebastes carnatus
Sebastes chrysomelas
Sebastes nebulosus
Sebastes serranoides
Embiotoca jacksoni
Embiotoca lateralis





III. Rocky intertidal sedentary species

Species with 95% correlation to full list

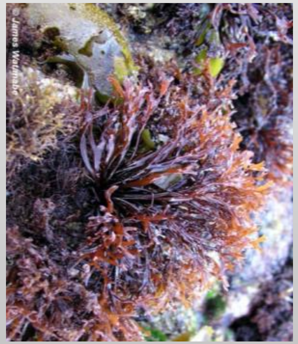
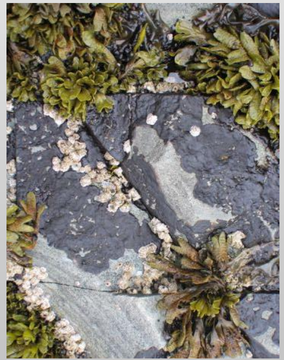
- *Balanus glandula*
- *Blue green algae callothrix*
- *Chondracanthus canaliculatus*
- *Chthamalus dalli/fissus*
- *Corallina spp*
- *Egregia menziesii*
- *Endocladia muricata*
- *Fucus spp*
- *Gelidium coulteri*
- *Mastocarpus spp*
- *Mazzaella cordata /Mazzaella splendens*
- *Odonthalia floccosa*
- *Petrocelis*
- *Phragmatopoma sabellaria spp*
- *Phyllospadix scouleri*
- *Phyllospadix torreyi*
- *Silvetia compressa*
- *Tetraclita rubescens*
- *Ulva.spp/Enteromorpha.spp/Monostroma.spp*







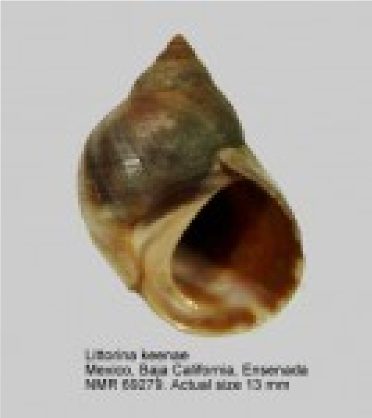




III. MOBILE INTERTIDAL SPECIES

Species with 95% correlation to full list
Periwinkle (*Littorina keenae*)
Checkered periwinkle (*Littorina plena scutulata*)
Littorina spp
Lottia austrodigitalis digitalis
Small limpet
Pisaster ochraceus



II. COMPARISON: KELP FOREST INDICATORS SELECTED IN REGIONAL MONITORING PLANS

Central coast example

ECOSYSTEM FEATURE ASSESSMENT

Key Attribute	Indicator/Focal Species
Biogenic Habitat: Macroalgal assemblage	Areal extent of surface kelp canopy (e.g., *Macrocystis pyrifera, Nereocystis luetkeana*)
	Number of kelp stipes: ➢ Bull kelp (*Nereocystis luetkeana*) ➢ Giant kelp (*Macrocystis pyrifera*), stipes per plant
Trophic Structure: Omnivorous Invertebrates	Density & size structure of focal species: ➢ Black abalone (*Haliotis cracherodii*) ➢ Purple sea urchin (*Strongylocentrotus purpuratus*) ➢ Red abalone (*Haliotis rufescens*) ➢ Red sea urchin (*Strongylocentrotus franciscanus*)
Trophic Structure: Detritivorous Invertebrates	Density & size structure of sea stars (e.g., *Patiria miniata*)
Trophic Structure: Predatory Invertebrates	Density & size structure of sea stars (e.g., *Pisaster* spp., *Pycnopodia helianthoides*)
Trophic Structure: Planktivorous fishes	Density & size structure[1] of blue rockfish (*Sebastes mystinus*)
Trophic Structure: Omnivorous fishes	Density & size structure[1] of focal species: ➢ Black & yellow rockfish (*Sebastes chrysomelas*) ➢ Cabezon (*Scorpaenichthys marmoratus*) ➢ Gopher rockfish (*Sebastes carnatus*) ➢ Kelp rockfish (*Sebastes atrovirens*) ➢ Painted greenling (*Oxylebius pictus*) ➢ Striped seaperch (e.g., *Embiotica lateralis*) ➢ Black perch (e.g., *Embiotica jacksoni*)
Trophic Structure: Piscivorous fishes	Density & size structure[1] of focal species: ➢ Black rockfish (*Sebastes melanops*)

FINAL KELP AND SHALLOW ROCK INDICATORS FOR COMMUNITY STRUCTURE SELECTED FROM COMBINATION OF METHODS

Indicators from subsample matrices	South coast regional list	Central coast regional list	North coast regional list
blacksmith (*Chromis punctipinnis*)	Giant kelp (*Macrocystis pyrifera*)	Bull kelp (*Nereocystis luetkeana*)	Stalked kelp (*Pterygophora californica*)
Señorita (*Oxyjulis californica*)	Red sea urchin (*Strongylocentrotus franciscanus*)	Sea stars (*Patiria miniata*)	California sea cucumber (*Parastichopus californicus*)
Blue rockfish (*Sebastes mystinus*)	Purple sea urchin (*Strongylocentrotus purpuratus*)	Painted greenling (*Oxylebius pictus*)	
Black rockfish (*Sebastes melanops*)	Spiny lobster (*Panulirus interruptus*)	Striped seaperch (*Embiotica lateralis*)	
Kelp rockfish (*Sebastes atrovirens*)	California sheephead (*Semicossyphus pulcher*)	Black perch (*Embiotica jacksoni*)	
Gopher rockfish (*Sebastes carnatus*)	Kelp bass (*Paralabrax clathratus*)	Copper rockfish (*Sebastes caurinus*)	
Black-and-yellow rockfish (*Sebastes chrysomelas*)	Cabezon (*Scorpaenichthys marmoratus*)	Lingcod (*Ophiodon elongatus*)	
China rockfish (*Sebastes nebulosus*)	Kellet's whelk (*Kelletia kelletii*)	Sea otters (*Enhydra lutris*)	
Olive rockfish (*Sebastes serranoides*)	Sea stars (*Pisaster spp., Pycnopodia helianthoides*)		
Black surfperch (*Embiotoca jacksoni*	Abalone (*Haliotis spp.*)		
Striped surfperch (*Embiotoca lateralis*)	Giant keyhole limpet (*Megathura crenulata*)		
	Wavy turban snail (*Megastraea undosa*)		

TIERED APPROACH: KELP AND SHALLOW ROCK HABITAT FISH SPECIES

II. Ecosystem structure/function

- Blacksmith
- Señorita
- Blue rockfish
- Black rockfish
- Kelp rockfish
- Gopher rockfish
- Black-and-yellow RF
- China rockfish
- Olive rockfish
- CA sheephead
- Kelp bass
- Copper rockfish
- Lingcod
- Black perch
- Striped seaperch
- Painted greenling
- Cabezon

I.

- Blue rockfish
- Black rockfish
- Kelp rockfish
- Gopher rockfish
- Black & yellow RF
- CA sheephead
- Kelp bass
- Copper rockfish
- Lingcod
- Kelp bass
- Olive rockfish
- Cabezon

II. Fisheries sustainability

- Kelp rockfish
- Blue rockfish
- Black rockfish
- Gopher rockfish
- Lingcod
- Copper rockfish
- Scorpion rockfish
- Brown rockfish
- Yellowtail rockfish
- Vermillion rockfish
- Bocaccio
- Cabezon
- China rockfish
- Kelp greenling
- CA sheephead
- Kelp bass
- Olive rockfish
- Black & yellow RF

IV. BROAD-SCALE COMMUNITY LEVEL METRICS AND BIODIVERSITY INDICATORS

Table 2. Indicators of community-level response to marine protected area establishment recommended for use by managers.

Category	*metric (s)*
Biomass	total biomass
Abundance	total abundance & log normal μ
Dominance	McNaughton & relative dominance
Evenness	eCDF slope
Rarity	log skew
Richness	log series α
Diversity	Shannon & Simpson diversity

Soykan et al. 2015

HOW TO FOCUS ASSESSMENT OF ECOSYSTEM CONDITION?

- HIRE FIELD STAFF THAT ARE EXPERTS IN SPECIES IDENTIFICATION WHO CAN MONITOR EVERYTHING AT KEY SITES?
  - METRICS FOR EVENNESS, RICHNESS, RARITY ETC. WILL REQUIRE INTENSIVE MONITORING EFFORT
- FOCAL SPECIES LISTS CAN BE USED TO GUIDE CITIZEN SCIENCE PROGRAMS AND/OR ANALYSIS OF KEY SPECIES OF INTEREST?
  - FULL LIST OR SUBSET OF INDICATOR SPECIES?

DISCUSSION QUESTIONS

- SHOULD WE MONITOR COMMUNITY INDICATORS SUCH AS HABITAT-FORMING SPECIES THAT ARE NOT DIRECTLY IMPACTED BY MPAS?
  - IS IT AN OBJECTIVE OF THE MPA MONITORING PROGRAM TO EVALUATE BROADER ECOLOGICAL PATTERNS AND CHANGE INDEPENDENT OF MPA EFFECTS?

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(Appendix D)

Estimating Local Values of F: Needed for both Fisheries (MLMA) and MPAs (MLPA)

Lauren Yamane

Local fishing mortality provides a way to integrate MLMA and MLPA for adaptive management

Fishing mortality (F) = instantaneous rate of mortality due to fishing

- Has a direct effect on population dynamics! Which means you can set expectations of population response

MLMA : Stock assessments often include only broad, regional estimates of fishing mortality (F)

- Spatial heterogeneity in F can influence yield (Ralston and O'Farrell 2008)
- Lobster FMP identifies F as an EFI of the highest priority:

*"**F directly links to the MLMA objectives** (Table 5-1), to **reference points** determined or used by the FMP models, and to **any control rule** described by the FMP."*

MLPA : Expect greater biomass increases for MPAs/species with high historical F

Tiered methods to determine fishing pressure

Data-rich: Estimating pre-MPA local F with SSIPM

- Fit PISCO/Reef Check size data to model
- First step: When does the model produce reliable estimates of F?
- Estimated local F's (Central Coast; future focus: South Coast)

Data-moderate: Estimate fine-scale historical fishing effort with fisheries-dependent data

- Use spatially-explicit CRFS data (2006-present) to visualize fishing effort across state
- Private/rental boats (future focus: party boats)

Data-poor: Use regional proxies for historical fishing

Use data-rich to inform data-poor?

Management decisions informed by fishing pressure analyses

Data-rich: Estimating local F with SSIPM

- Biological characteristics = *Who* to monitor? Done — **Indicator species**
- Sample size = *How many* to monitor? In progress
- Time series length = *How much* and *where* to monitor? In progress — **Site selection**

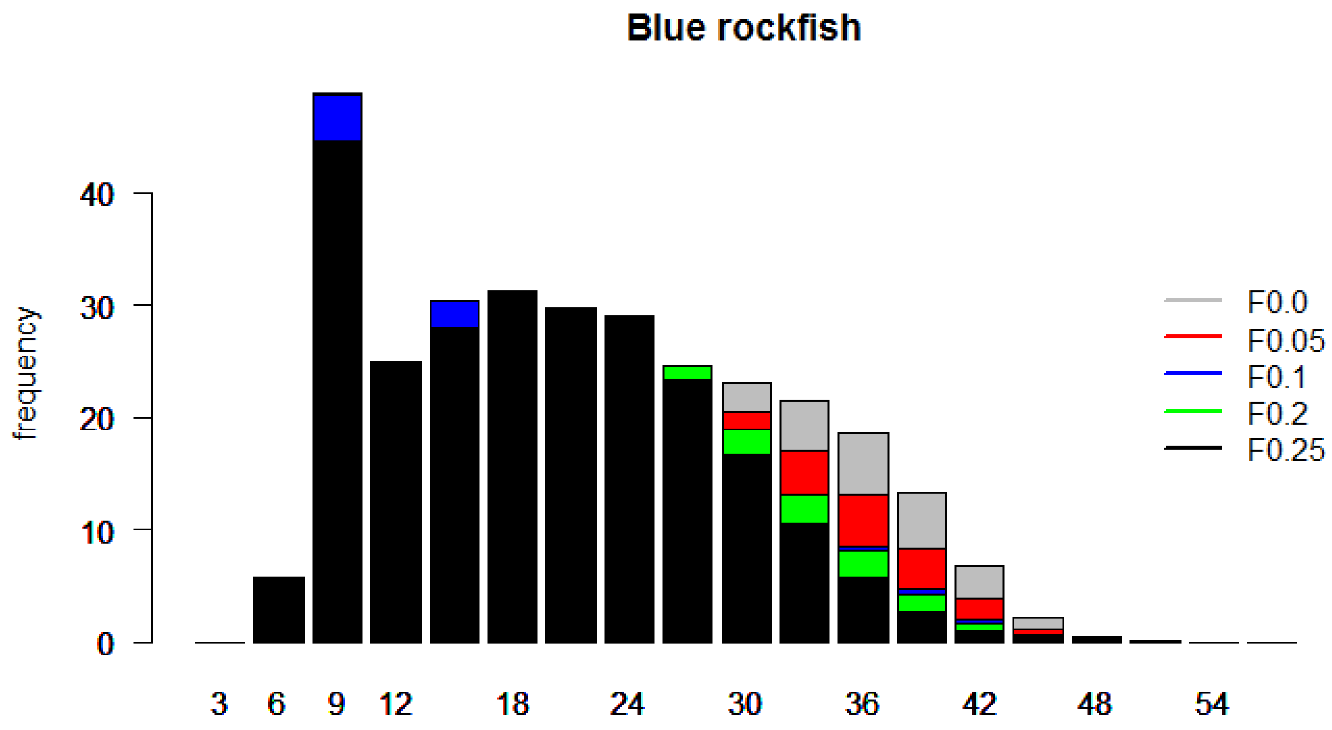
Data-moderate: Estimate fine-scale historical fishing effort — **Site selection** Olivia Rhoades

- Can't plug these in to Katie's estimates of fill-in rates
- *Who* and *where* to monitor

Data-poor: Regional proxies of historical fishing effort

- Best guess on *where* to monitor (North Coast) Still needed **Site selection**

Reminder: higher F's mean greater truncation of size structure and greater ability to detect fill-in response



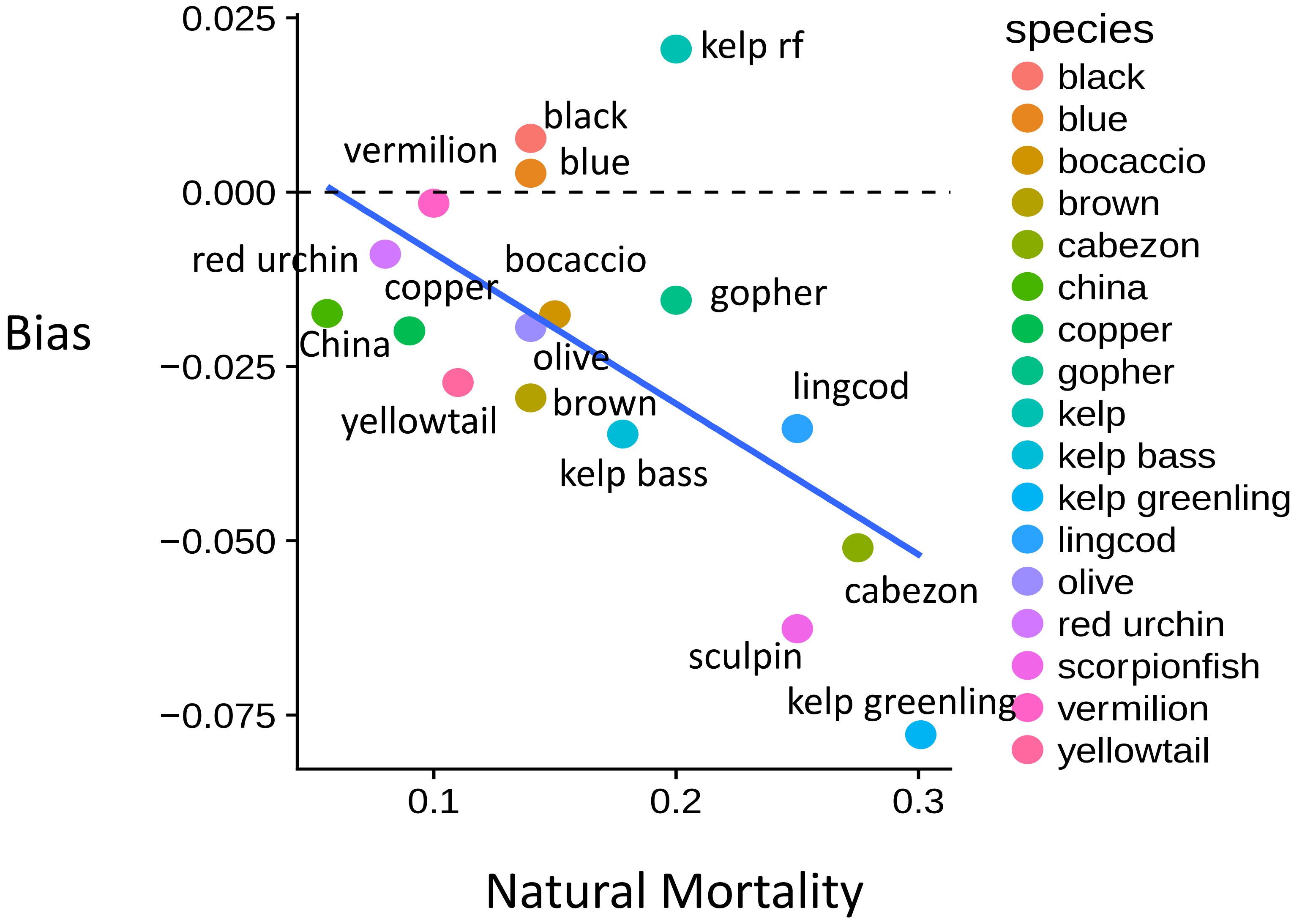
Size class

Linf	38.15
K	0.172
t0	-1.145
M	0.14
Lmat	27.086
Lfish	21.02
Recruit size	4
YOY	<10

Every species has different biological characteristics

As natural mortality increases model underestimates F

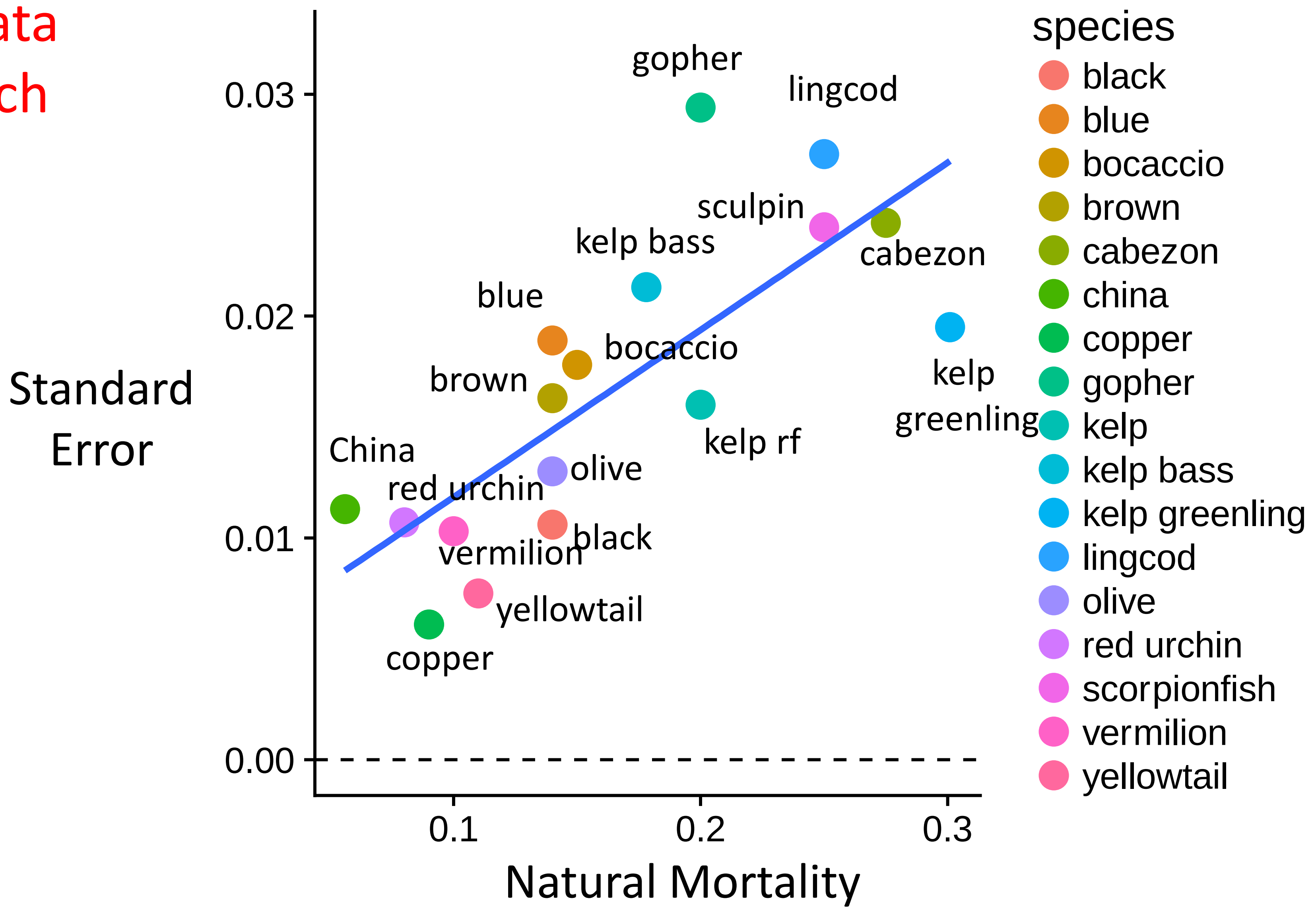
Data Rich



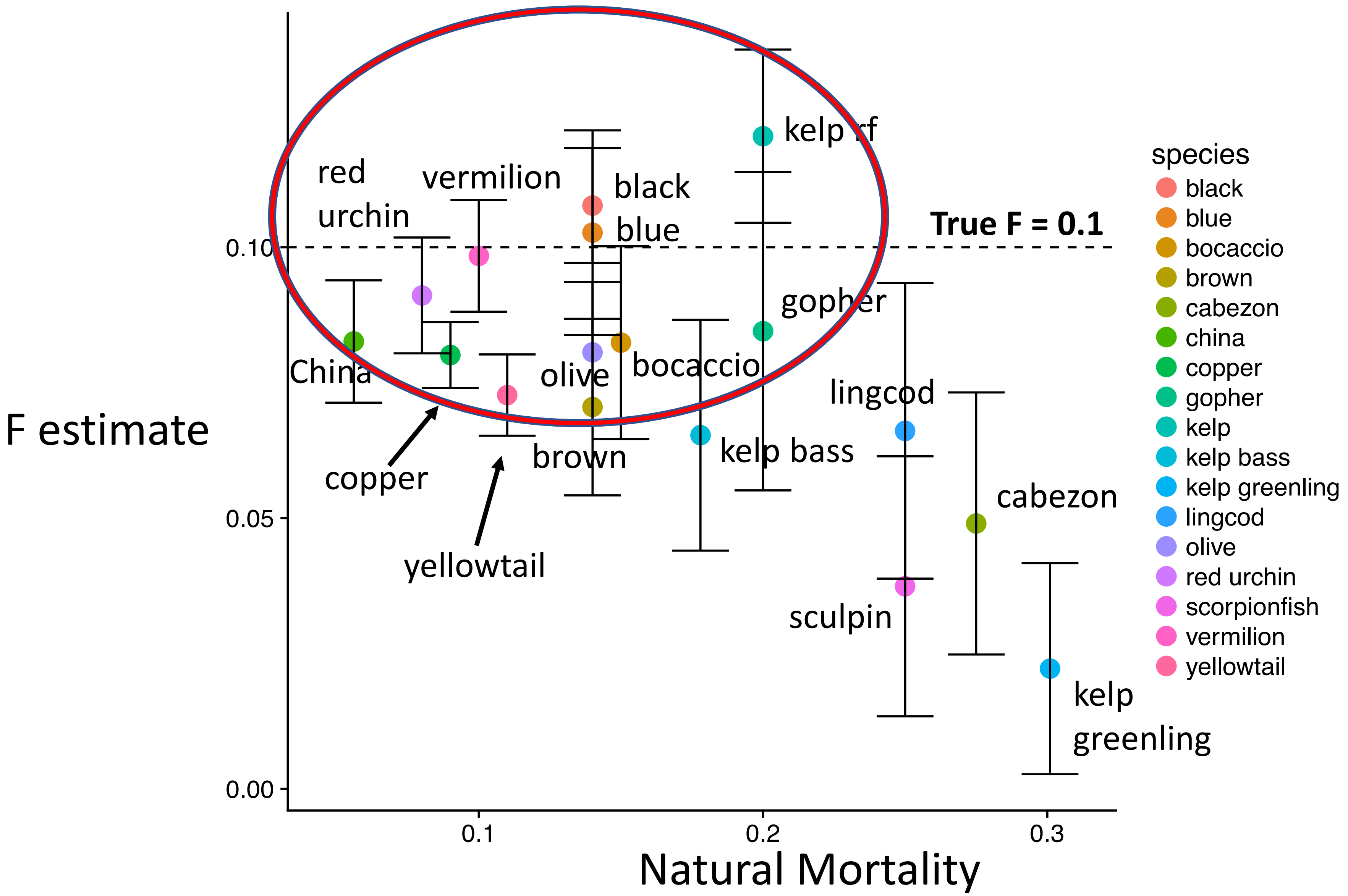
F=0.1

… and error increases

Data Rich

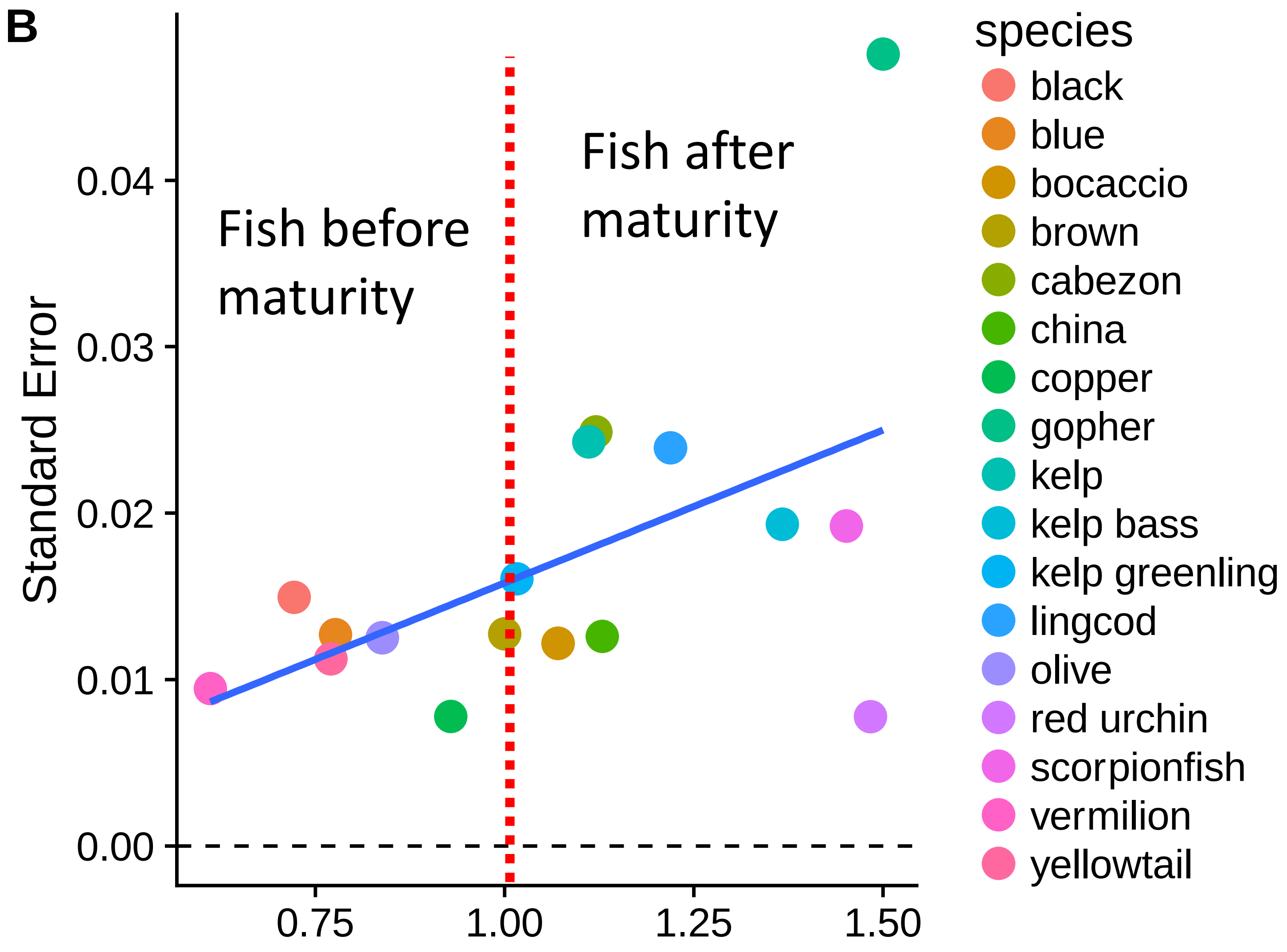


F=0.1


F estimate
Natural Mortality
0.00
0.05
0.10
0.1
0.2
0.3
True F = 0.1
red
urchin
vermilion
black
blue
kelp rf
gopher
China
olive
bocaccio
lingcod
copper
yellowtail
brown
kelp bass
cabezon
sculpin
kelp
greenling
species
black
blue
bocaccio
brown
cabezon
china
copper
gopher
kelp
kelp bass
kelp greenling
lingcod
olive
red urchin
scorpionfish
vermilion
yellowtail

Precision of F estimate increases if species is fished earlier

Data
Rich



Length when fished: Length at maturity

Overall: what species characteristics enhance estimate of the local fishing mortality?

Species with:

- Lower natural mortality (M) rates
- A growth rate exceeding the natural mortality rate (e.g., k>M)
- Fished early in life history

Which species would enable more reliable local F estimates based on biological characteristics?

Data Rich

<u>Worse choices</u>

- CA Scorpionfish
- Lingcod
- Cabezon
- Kelp greenling

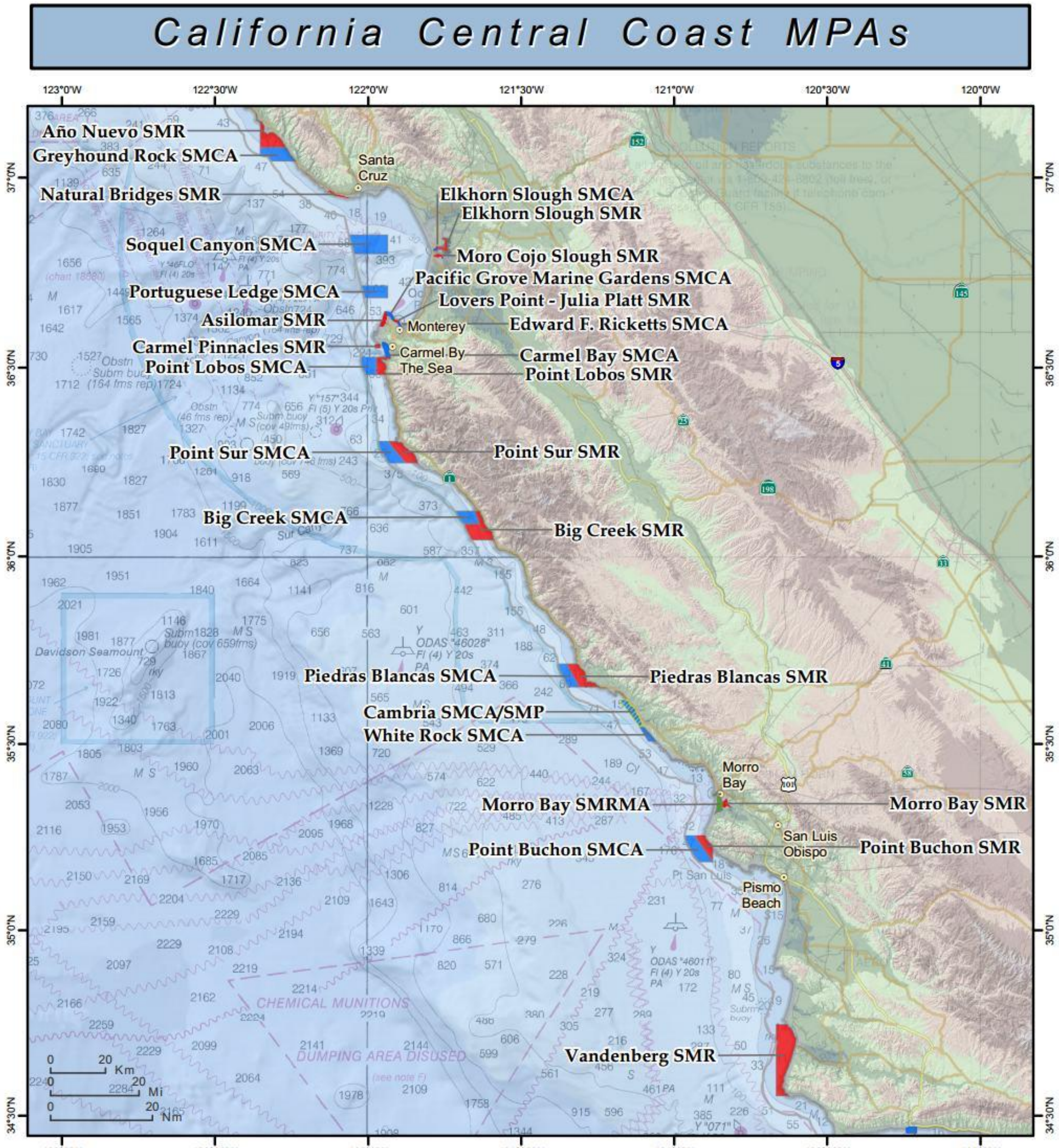
<u>Better choices</u>

- Blue rockfish
- Vermilion rockfish
- Copper rockfish
- Yellowtail rockfish
- Kelp rockfish
- China rockfish
- Red urchin

Where model has been applied to data to estimate local F so far

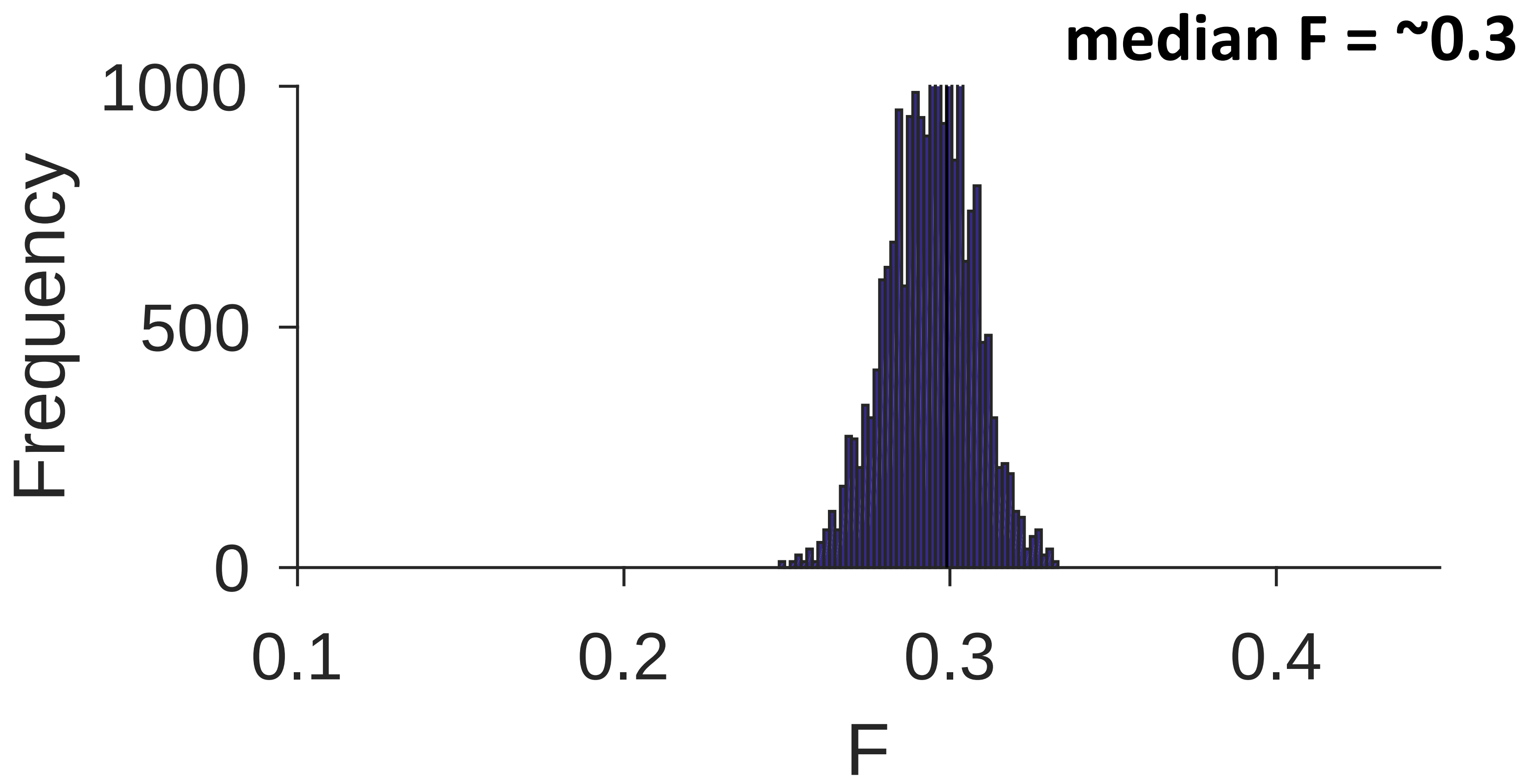
Central Coast:

- Copper, Black-and-Yellow, Blue, Olive/Yellowtail complex at 4 different MPAs (appeared most abundant of the "better choices")
- Blue most reliable F estimates
- Olive/Yellowtail complex may be too complicated given different movement patterns of two species



Blue Rockfish at Vandenberg SMR : F estimate

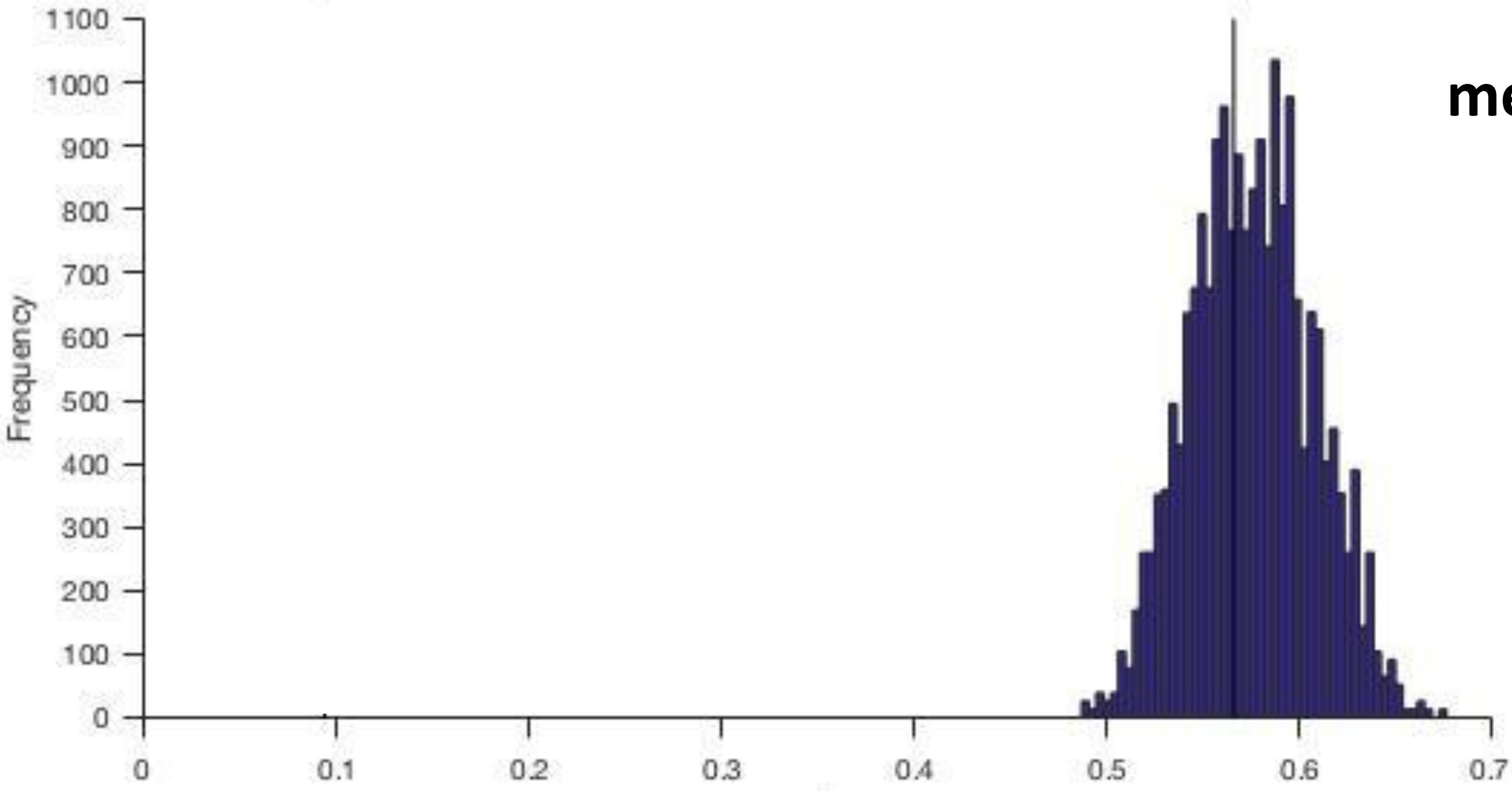
Data
Rich



Blue rockfish seems to be a model indicator species for understanding MPA responses
(other projections of responses for blue rockfish at other Central Coast MPAs by Nickols et al., in prep)

Blue Rockfish at Natural Bridges SMR (Santa Cruz) : F estimate

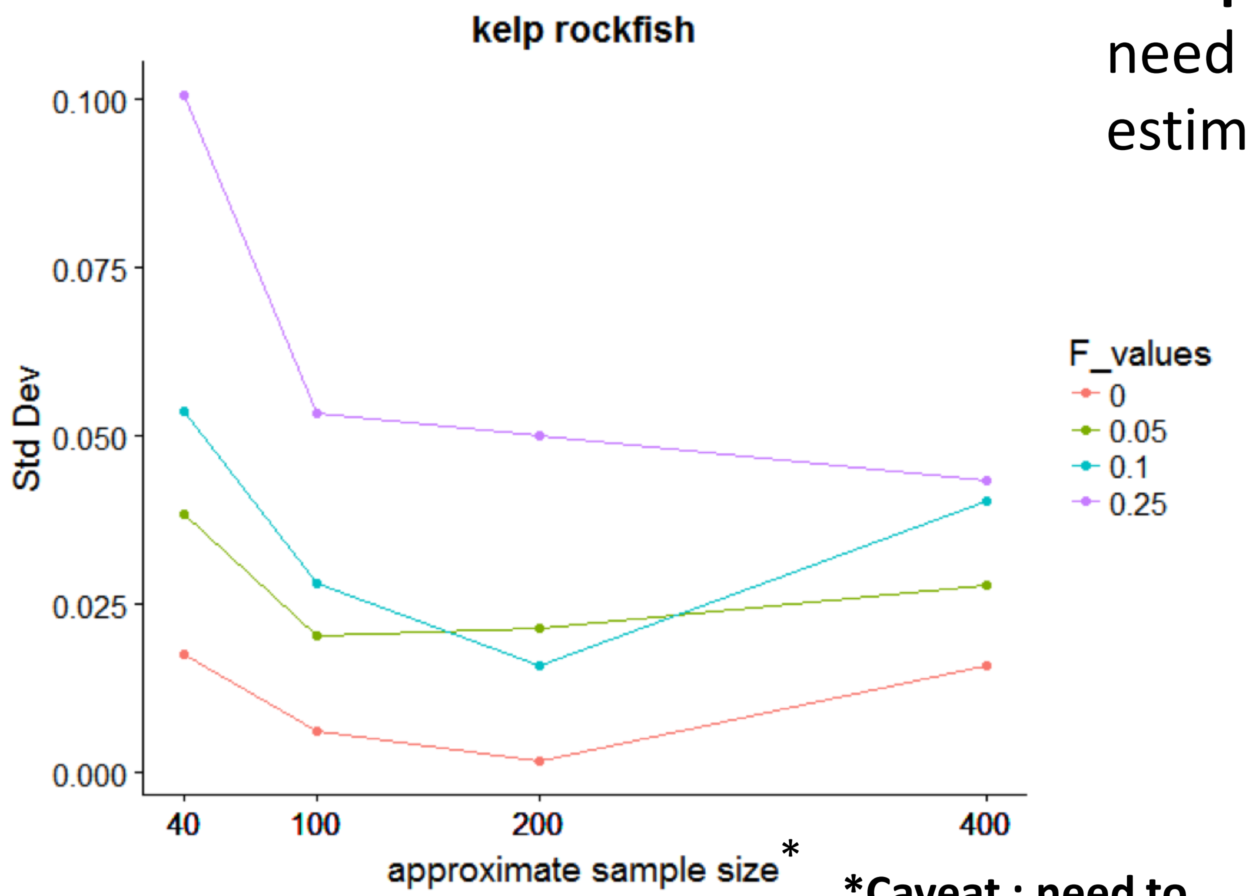
Data
Rich



median F = ~0.58

F

Higher sample sizes lead to greater precision of F estimate

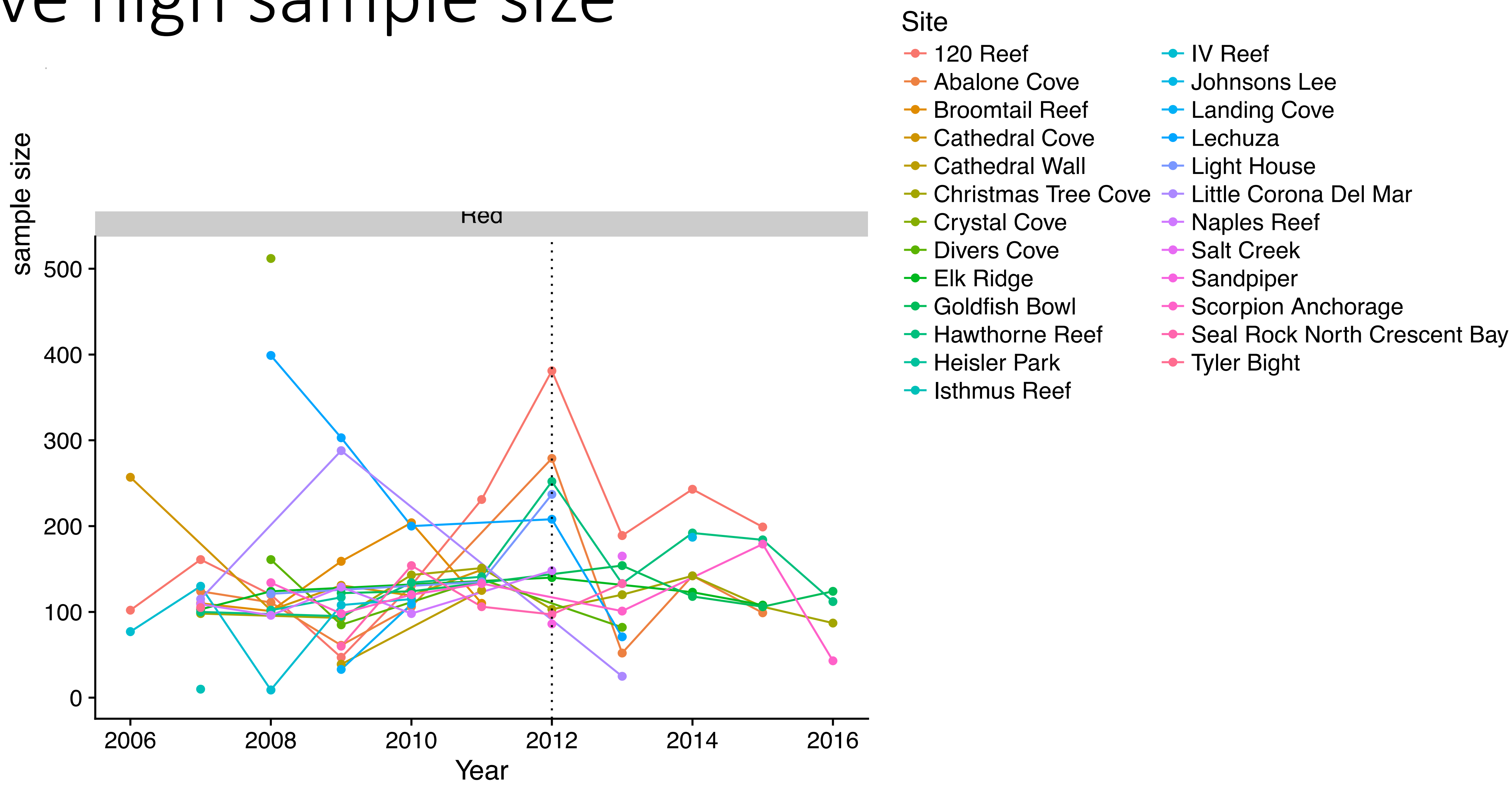


Sample size*: May need 100's to estimate F

***Caveat : need to transform this to be sample size**

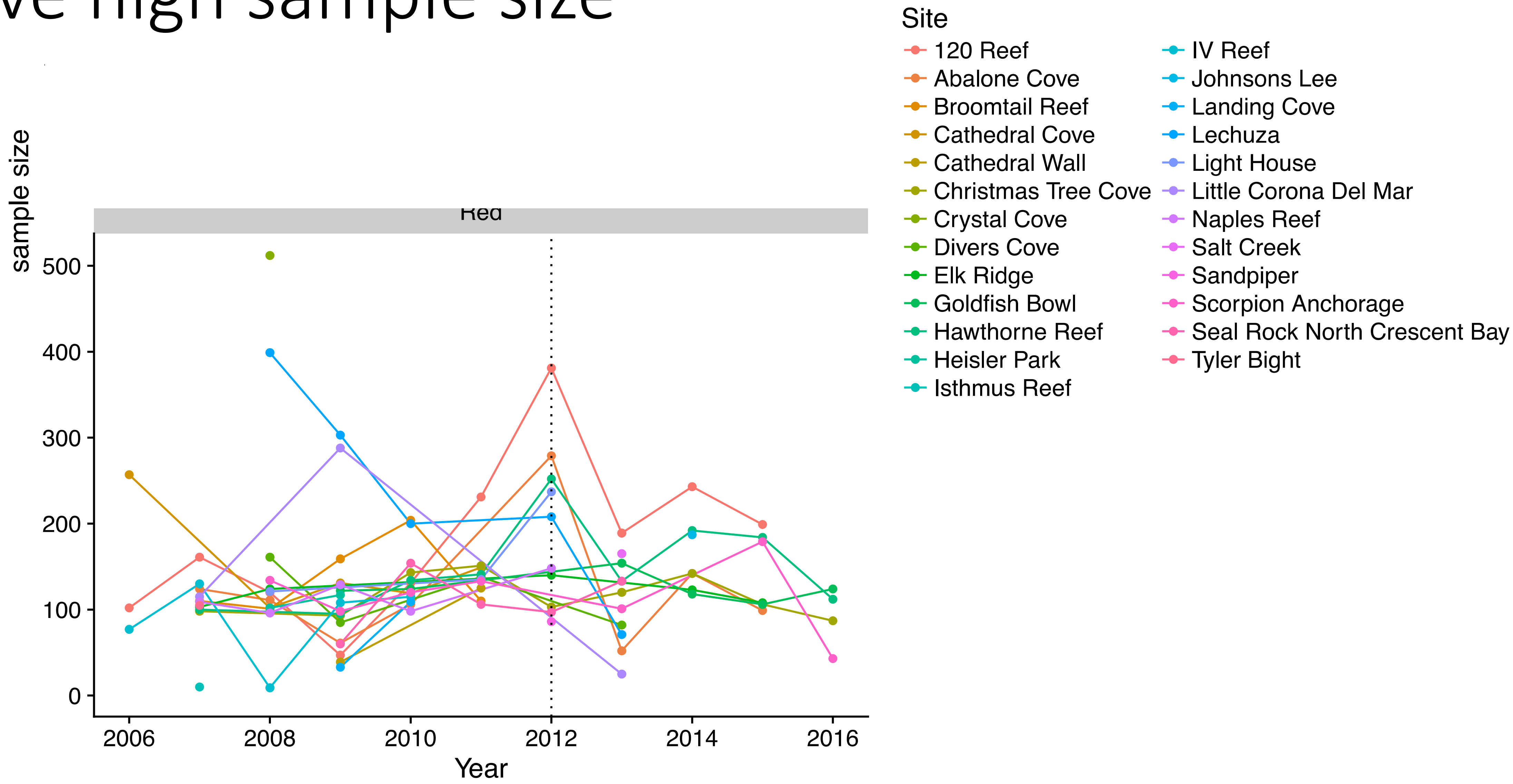
Reef Check data: South Coast red urchins have high sample size

Data Rich



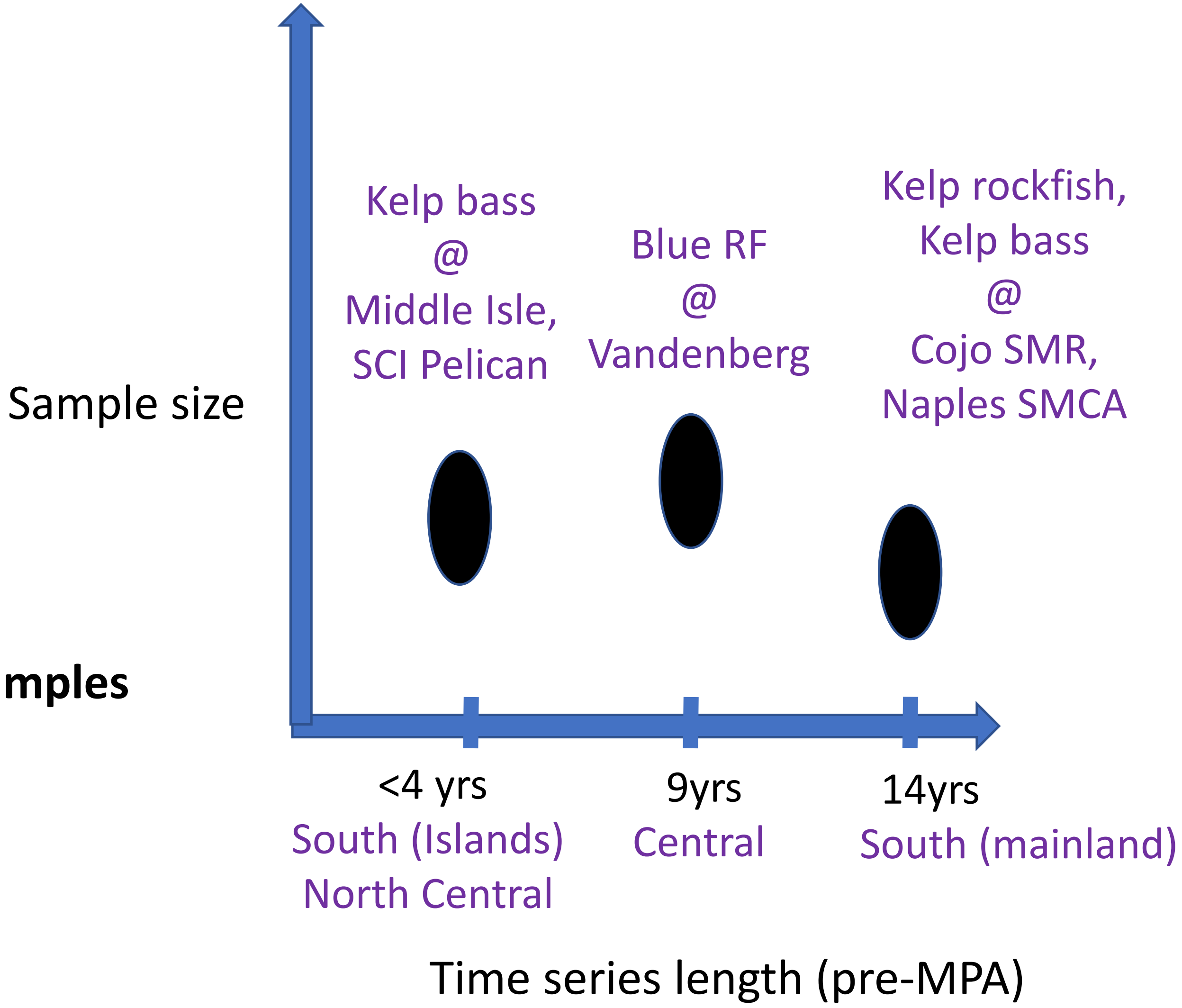
Reef Check data: South Coast red urchins have high sample size

Data Rich



Exploring sample size, time series length, and sampling frequency can inform Action Plan

Data
Rich



i.e., will longer time series compensate for lower sample sizes for reliable F estimate?
If so is F relatively high?

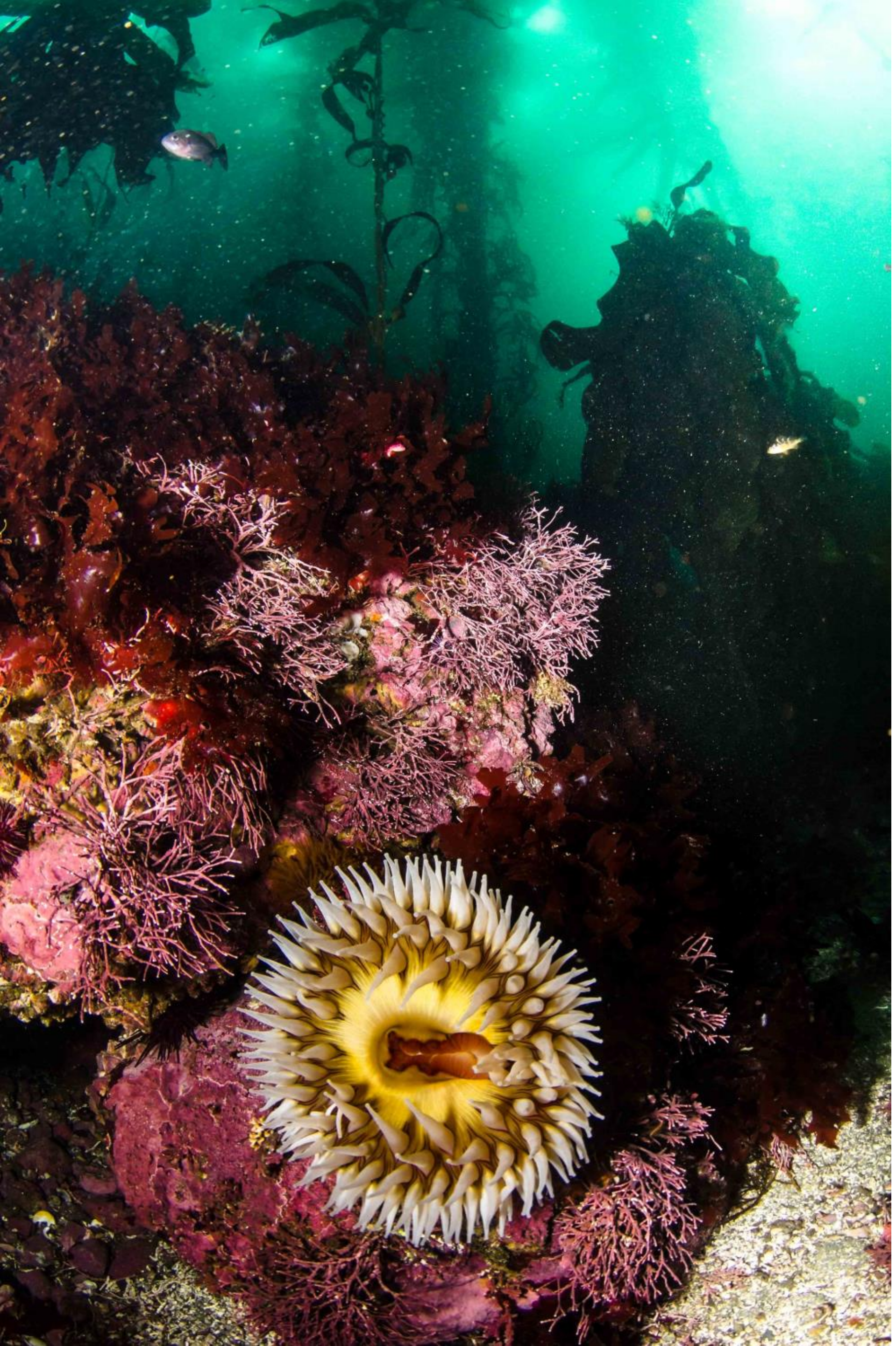
3rd axis:
Frequency of samples

Ex: 1/2yrs but 2x sampling effort

Data moderate: Estimate fine-scale historical fishing effort

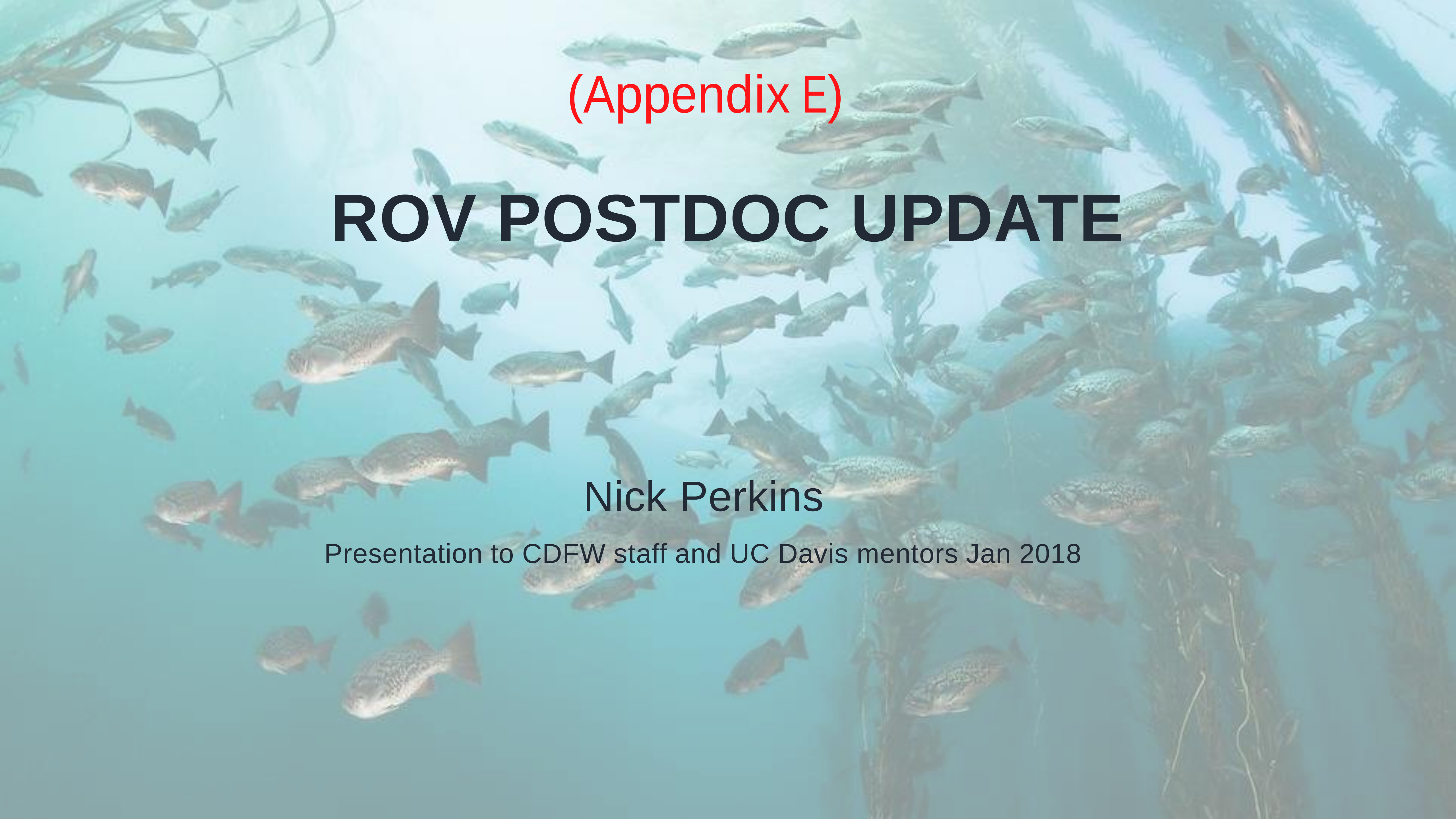
- Fishing effort may be proportional to Fishing mortality
- Focus on important recreational species not ideal for SSIPM, e.g.:
  - Lingcod
  - Cabezon
  - CA Scorpionfish
  - Kelp bass

  } Particularly important in the Southern region
- Determine historical fishing effort within MPAs
  - Olivia Rhoades (OST/SCCWRP) has mapped relative fishing effort, following Paulo Serpa's approach
- Can compare relative effort among ports within region for private/rental and party boat modes
  - Standardize by the number of samples (interviews)
  - This can help us select monitoring sites with high historical fishing for each region



Thanks for listening!

Questions or Suggestions??



(Appendix E)

ROV POSTDOC UPDATE

Nick Perkins

Presentation to CDFW staff and UC Davis mentors Jan 2018

COMPONENTS OF PROJECT

1. Methods for analyzing ROV transect data
   - Model based approaches
   - Spatial point process models

2. Survey and sampling design with a ROV

3. Eco-regionalization using ROV and SCUBA data

1. METHODS FOR ANALYZING ROV TRANSECT DATA

- Model-based approaches:
  - Able to incorporate habitat and bathymetry covariates
  - Improved estimates across areas

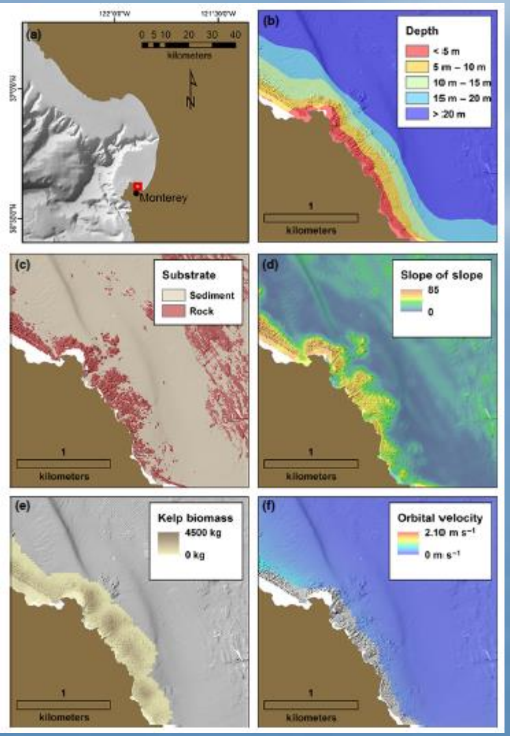


Table 3 Comparison of species abundance estimates generated by three methods for extrapolating species density within the Point Sur MPA: uniform extrapolation treating all rocks as equal, non-spatial habitat-based extrapolation and the abundances predicted from the spatially explicit species distribution models

Species	Common name	Uniform extrapolated abundance	Geomorphic-based extrapolated abundance	SDM-based extrapolated abundance
Embiotoca jacksoni	Black Perch	9149	2897	4890
Embiotoca lateralis	Striped Perch	59,065	23,014	22,655
Sebastes serranoides	Olive Rockfish	157,071	46,466	19,895
Sebastes atrovirens	Kelp Rockfish	38,133	13,313	9198
Sebastes carnatus	Gopher Rockfish	69,650	19,072	14,621
Sebastes chrysomelas	Black & Yellow Rockfish	20,977	11,315	10,817
Sebastes melanops	Black Rockfish	161,165	12,844	8666

Figure and table from Young and Carr (2015)

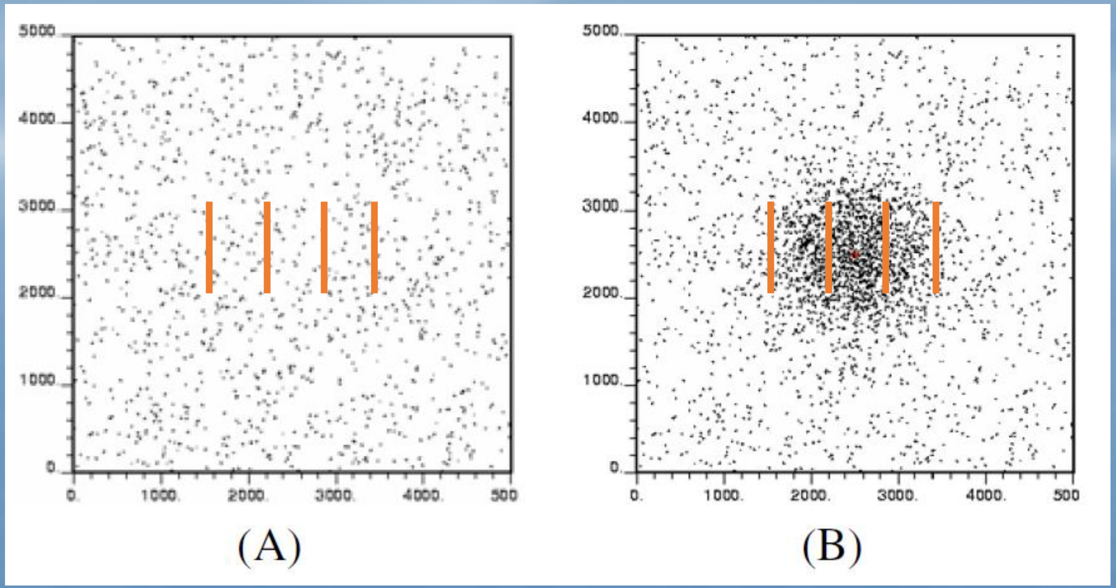
SPATIAL AUTOCORRELATION

- Model parameter estimates assume that samples are independent

- Often acknowledged, but rarely explored

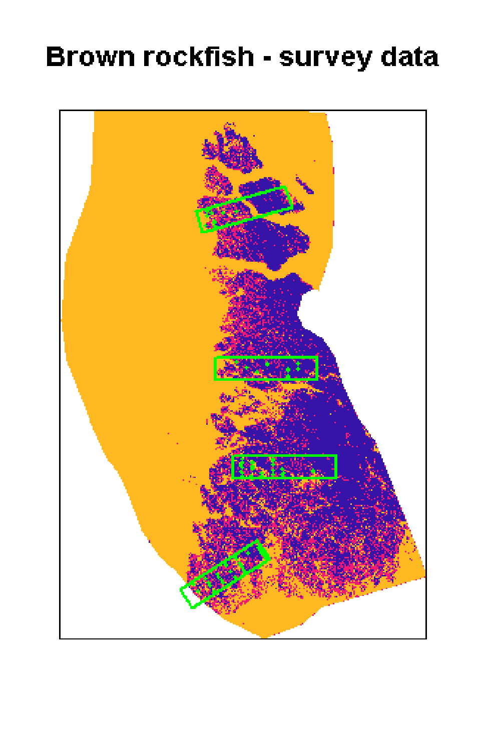
- Not taking into account spatial autocorrelation leads to biased results e.g. parameter estimates ~25% different (Dormann et al. 2007)

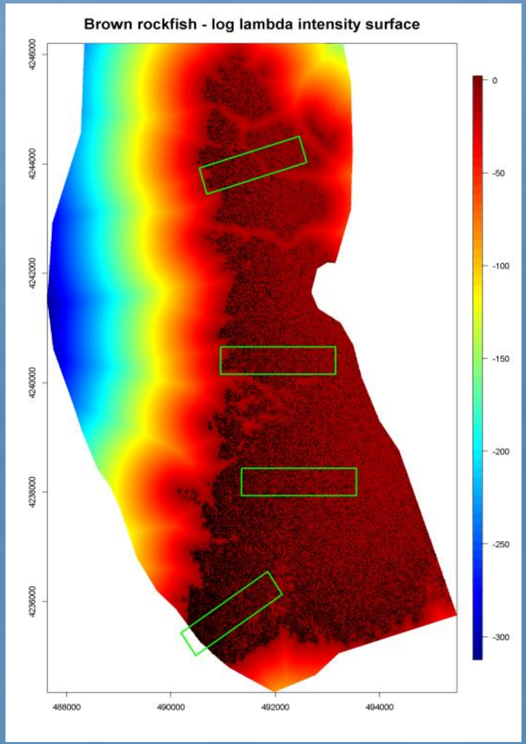
    ➡ Biased estimates of abundance

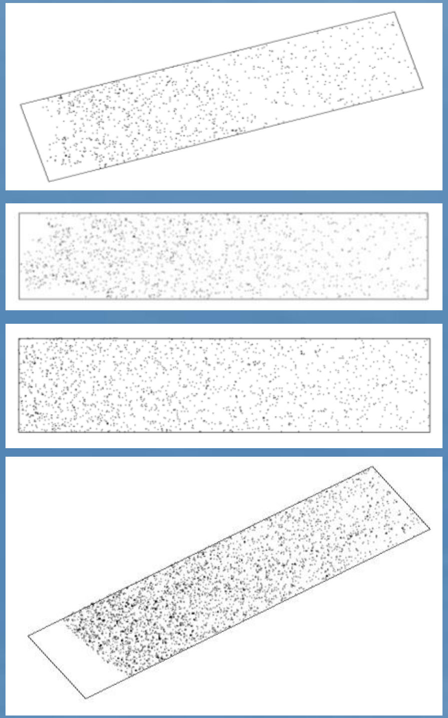


SPATIAL POINT PROCESS MODELS

- Spatial model where occurrence of individuals (e.g. fish) are modeled as points across a landscape, taking into account the spatial structuring
- Models the intensity (i.e. the number) of fish expected to occur in an area given the weighting of all other covariates
- Allows prediction of the total number of fish (i.e. abundance) across an area and where they are likely to occur





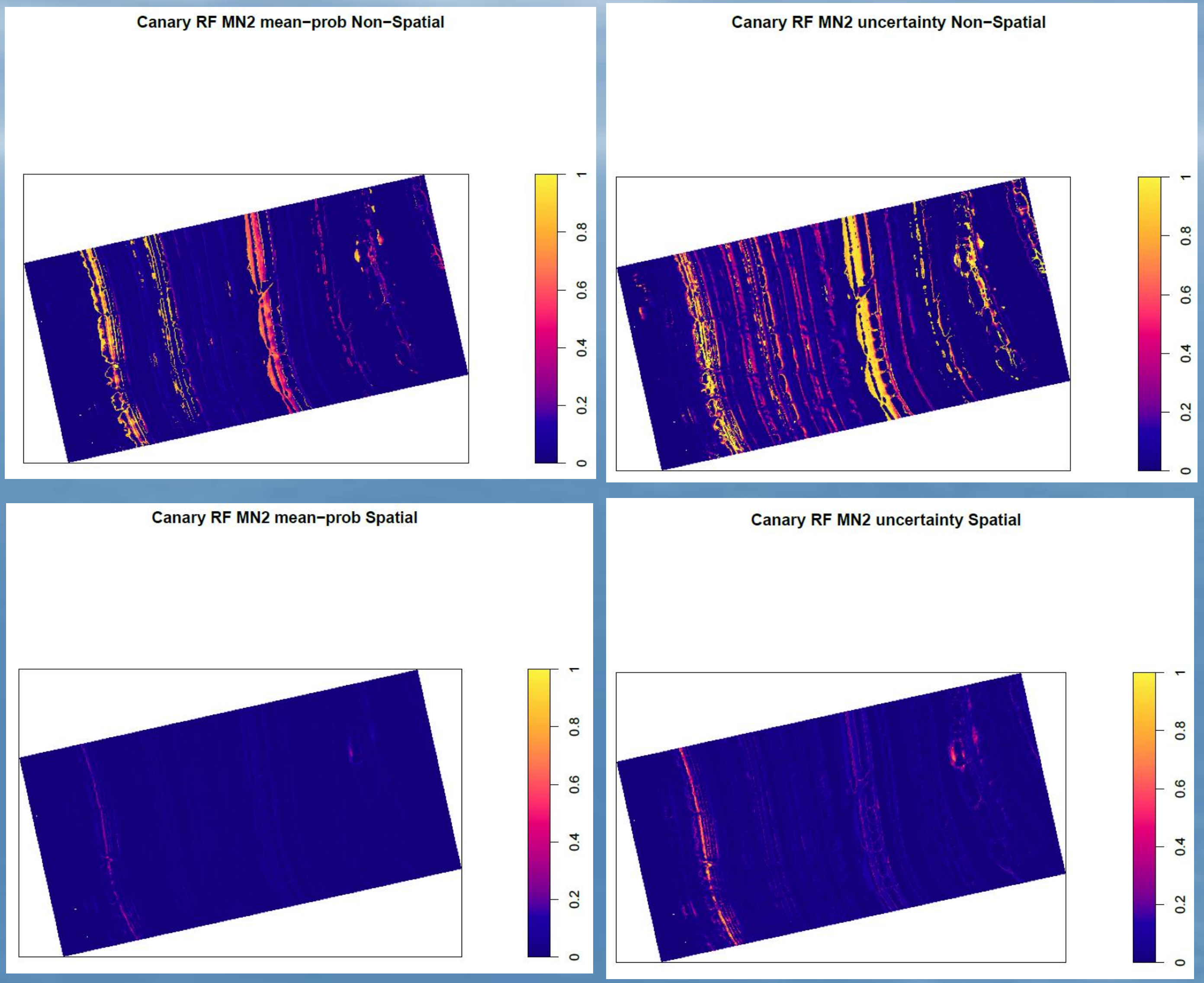


MODELING APPROACH

- Exploration of important bathymetry derived covariates using multiple sites within a region:
  - Depth
  - Habitat and distance to hard substrate
  - Bathymetric Profile Index (BPI) – different scales
  - VRM and other measures of rugosity
  - Slope and curvature
  - Aspect

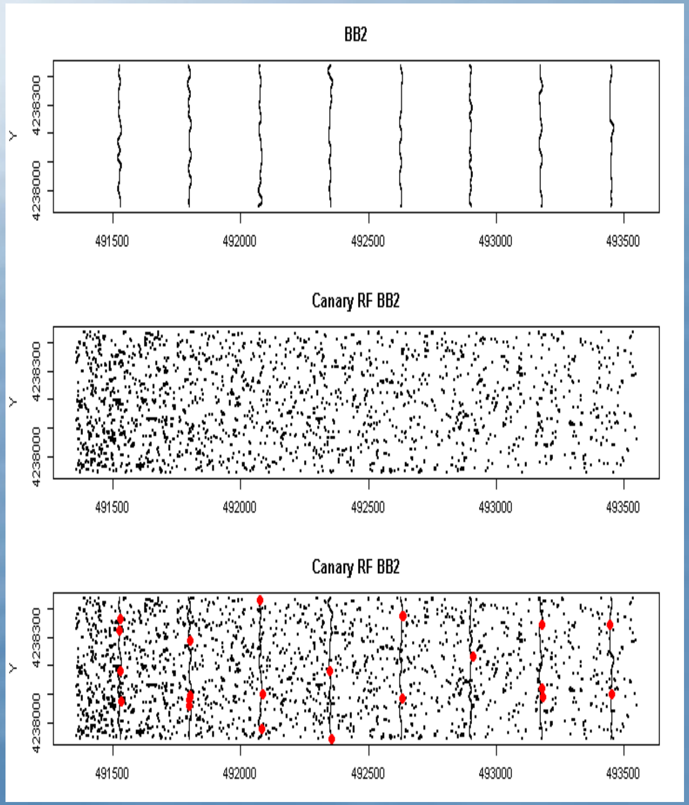
- Modeling of spatial effects at the individual site level

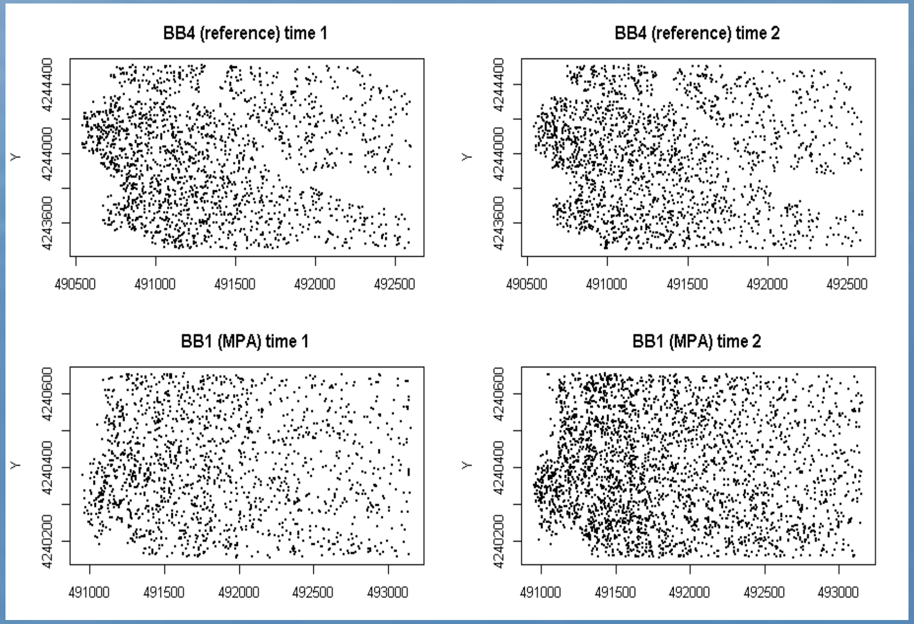
- Comparison of non-spatial and spatial models

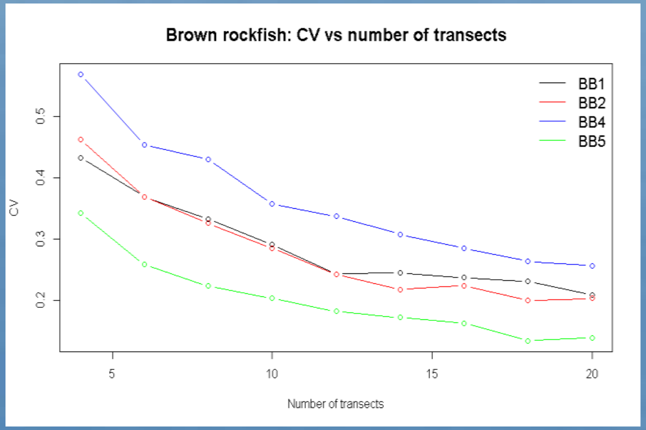


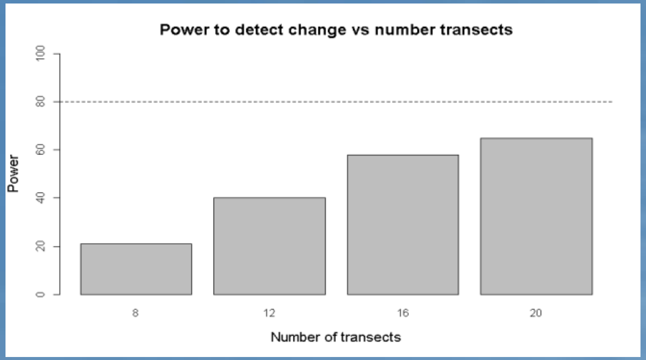
2. SURVEY AND SAMPLING DESIGN WITH A ROV

- Building on the previous work, using model parameter estimates, we can simulate fish distributions across sites/regions
- Test different designs and sampling effort
- Simulate changing abundance and/or size distributions







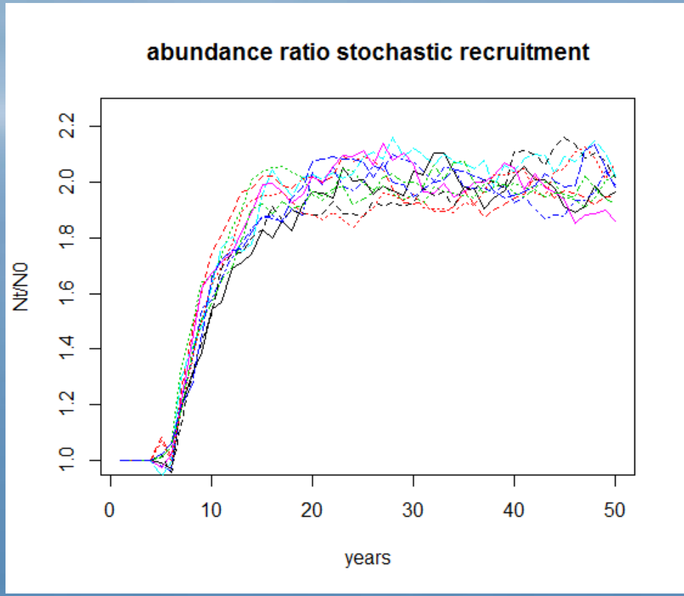


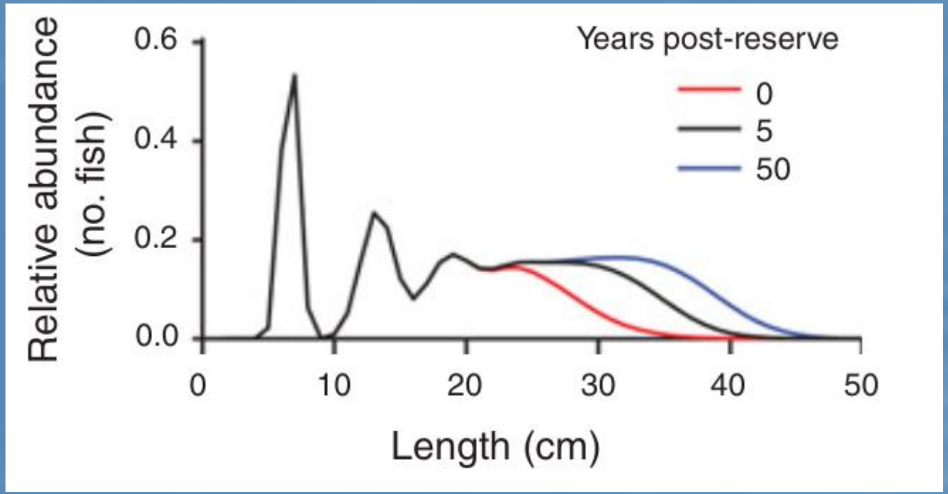
SIMULATION: TIME-SERIES AND POWER TO DETECT CHANGE

- Based on work by the other postdocs we can simulate a time-series of data of expected recovery inside a MPA – abundance and size structure

- Test power to detect change

- Need to decide on:
  - Species to model
  - Sites
  - Designs



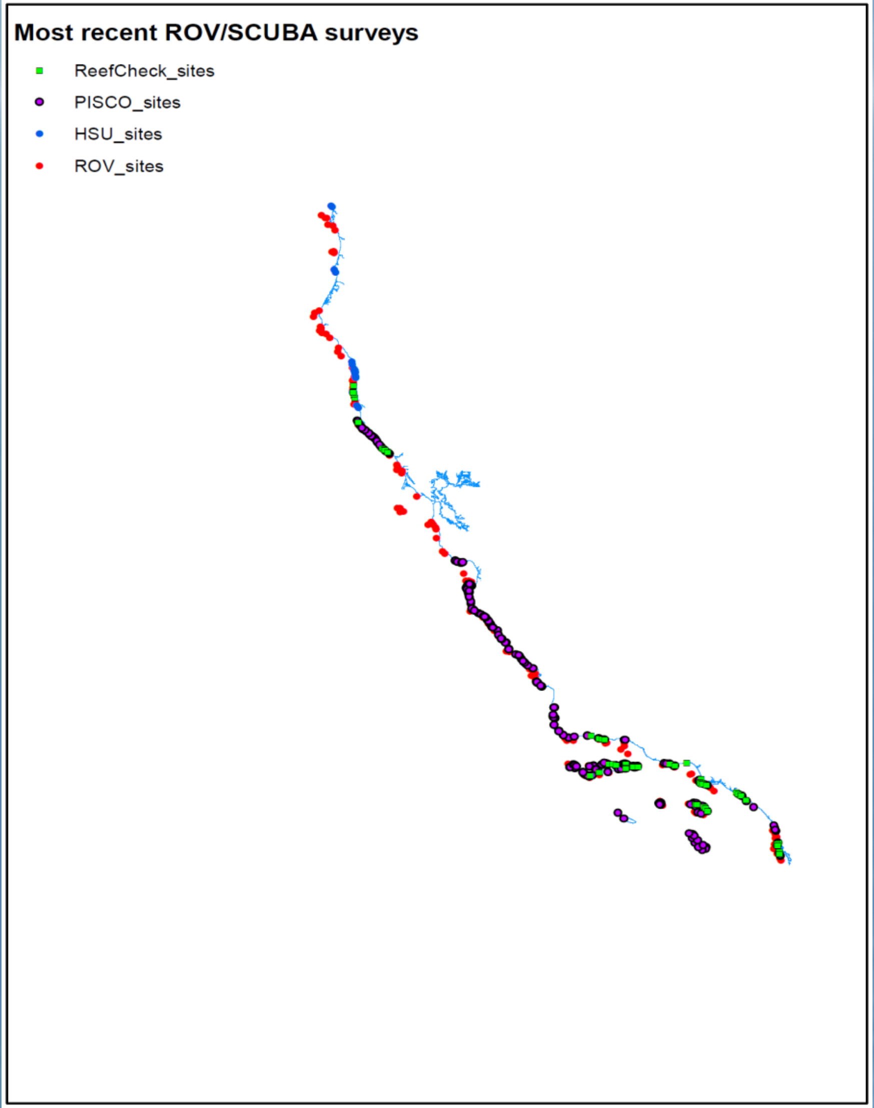


Figures taken from presentations by Katie Kaplan and Will White

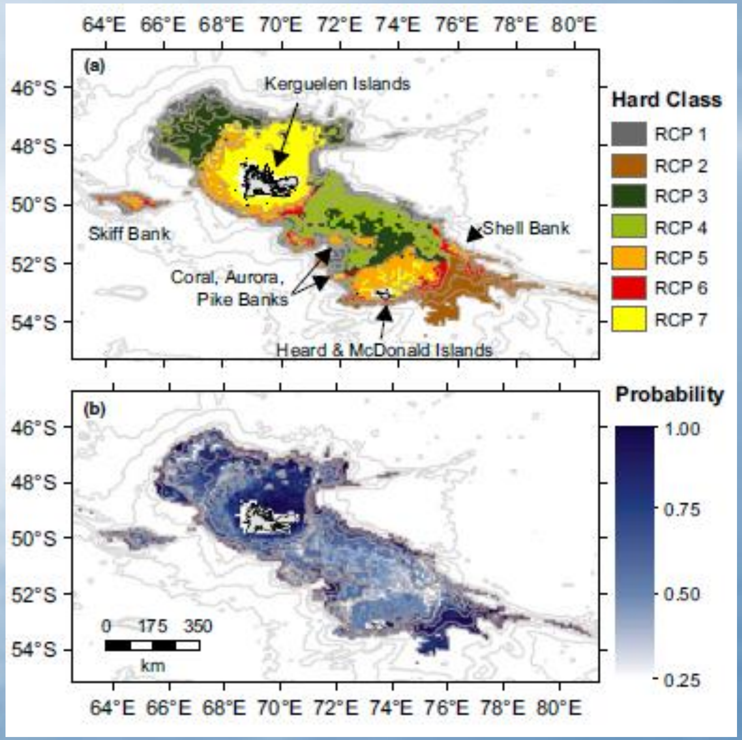
3. ECO-REGIONALIZATION OF SUBTIDAL COMMUNITIES

- Combine:
  - ROV and SCUBA data sets
  - Oceanographic variables: SST and indices, fronts, Chl a, SSH
  - Habitat – 1 km cells

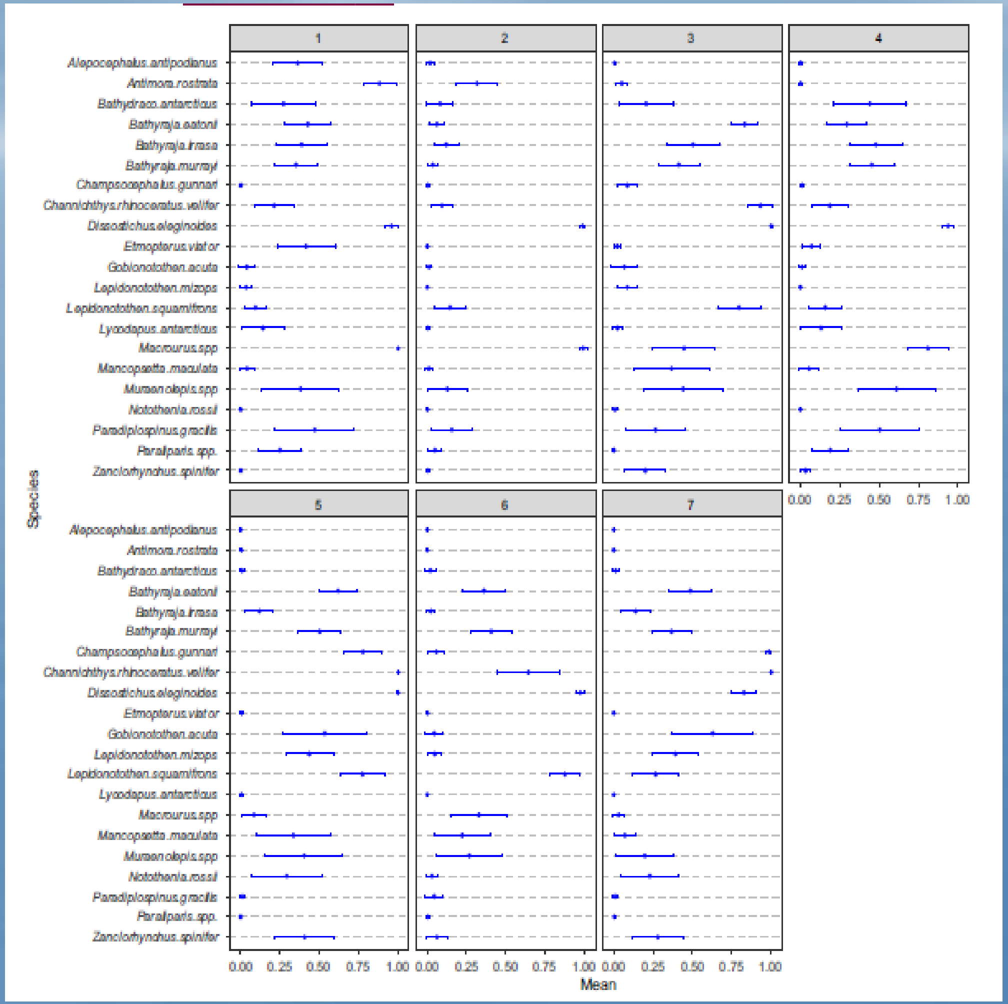
- “Regions of Common Profile” (RCP) model:
  - Allows sampling effects to be incorporated
  - Data driven map of eco-regions across the state
  - Places MPA and reference sites in broader context
  - May aid in site selection: representative sites and/or replication within eco-regions



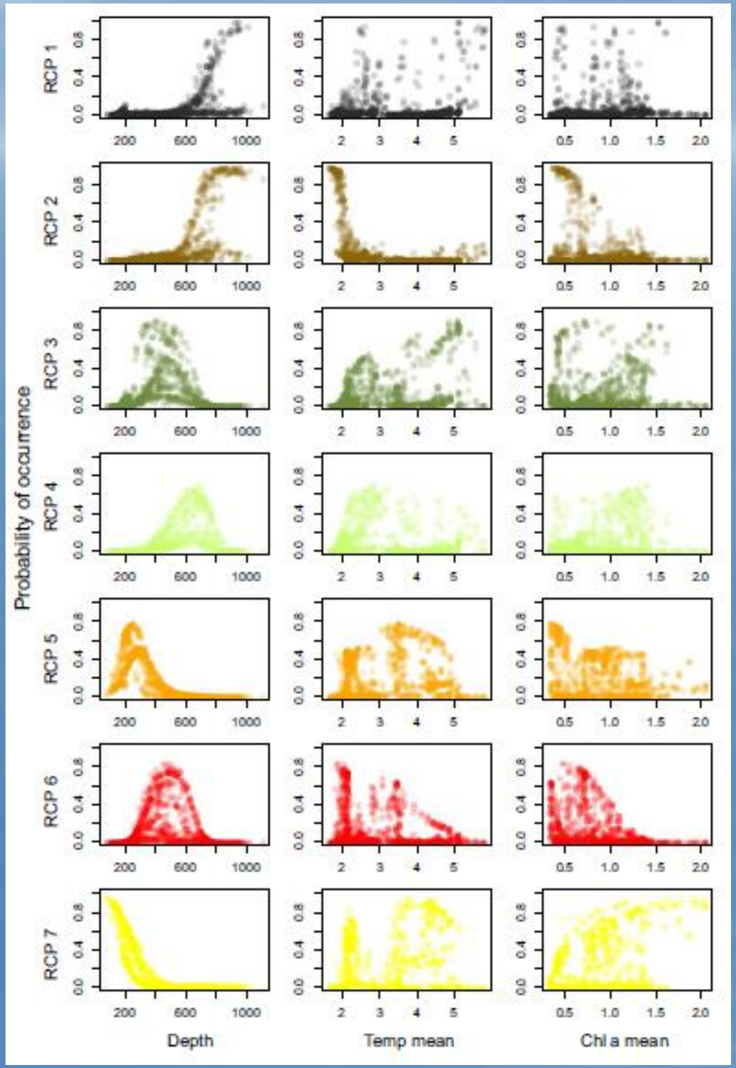
RCP MODEL: EXAMPLE OUTPUT



Mapped groupings and uncertainties



Species contributions to groups



Environmental drivers for groups

Figures taken from Hill et al. (2017)

ECO-REGIONS AND MONITORING

- We may expect regions with similar assemblages and environmental conditions to have similar responses

- Models that take eco-regions into account have been shown to have higher power to detect MPA effects

- Potential to link community changes over time to changing environmental/oceanographic conditions

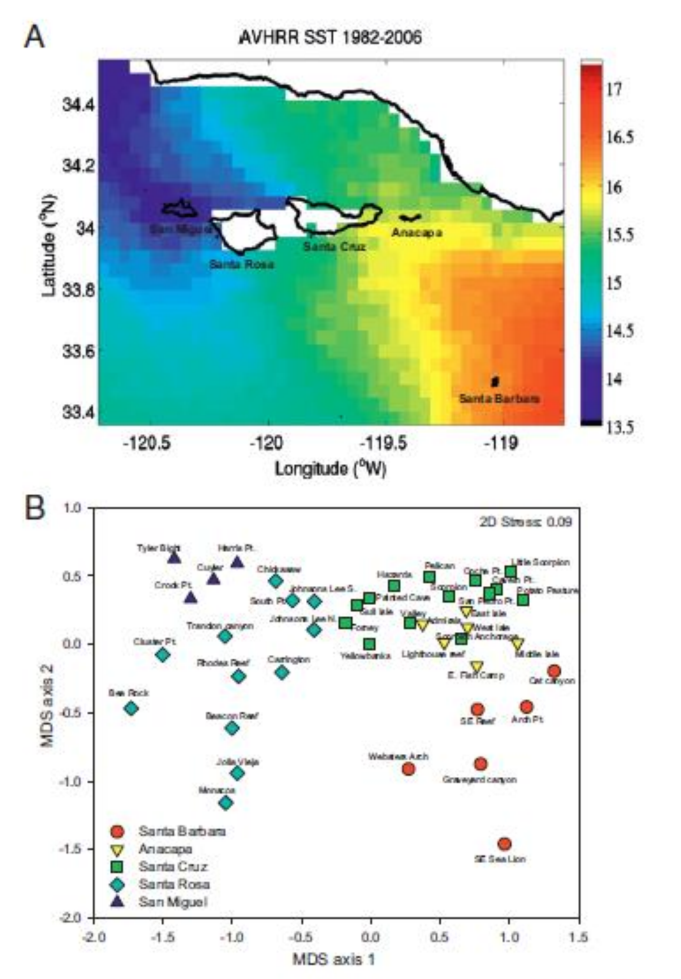


Fig. 2. (*A*) Map of the Channel Islands showing long-term (1982–2006) average SST recorded by Advanced Very High Resolution Radiometer satellite. The sharp gradient in SST between the western and eastern islands is apparent. (*B*) Nonmetric MDS analysis depicting similarities in fish community structure among survey sites. Most sites group at the island scale, suggesting similarities among fish communities at this scale. MDS axis 1 is positively correlated with average SST at each site ($r = 0.88$; $P < 0.0001$).

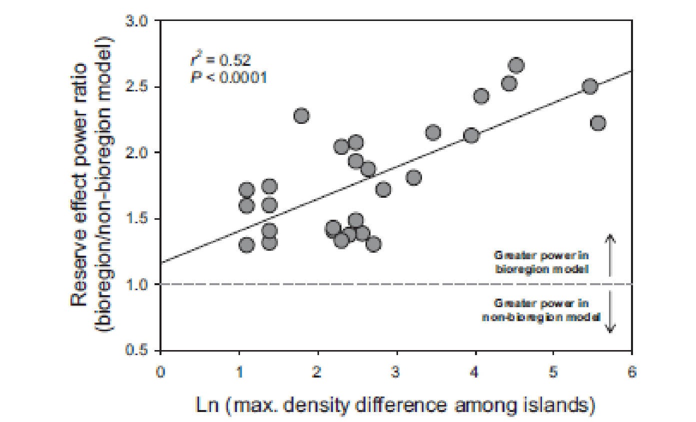


Fig. 3. Relationship between the reserve effect power ratio (power in bioregion model/power in nonbioregion model) and the maximum difference in a species' density across the Channel Islands (values from Table S3). In all cases, the power to detect reserve effects is improved by controlling for biogeography (i.e., all points occur above the dashed line, indicating improved power in the bioregion model). Statistical power increases most for species that exhibit strong biogeographic differences in abundance.

Figures taken from Hamilton et al. (2010)

ECO-REGIONS AND SITE SELECTION

- Understanding broad distributional patterns and their drivers can aid in:
  - Choosing sites so that there is replication within regions (may not always be feasible given budget and logistical constraints)
  - Making sure that regions that have distinct species assemblages are included in long-term monitoring plans (MLPA obligations)
  - Ensuring that reference sites are truly comparable in terms of communities and environmental drivers that are likely to influence them over time
  - Linking to connectivity matrices: do eco-regions regions = regions with ROMs connectivity?