DYNAMIC OCEAN MANAGEMENT INCREASES THE EFFICIENCY AND EFFICACY OF FISHERIES MANAGEMENT

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NEREUS PREDICTING THE FUTURE OCEAN ネレウス 未来の海を考える

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Can dynamic management be more efficient than static?

Dynamic ocean management increases the efficiency and efficacy of fisheries management

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In response to the inherent dynamic nature of the oceans and continuing difficulty in managing ecosystem impacts of fisheries, interest in the concept of dynamic ocean management, or real-time management of ocean resources, has accelerated in the last several years. However, scientists have yet to quantitatively assess the efficiency of dynamic management over static management. Of particular interest is how scale influences effectiveness, both in terms of how it reflects underlying ecological processes and how this relates to potential efficiency gains. Here, we address the empirical evidence gap and further the ecological theory underpinning dynamic management. We illustrate, through the simulation of closures across a range of spatiotemporal scales, that dynamic ocean management can address previously intractable problems at scales associated with coactive and social patterns (e.g., competition, predation, niche partitioning, parasitism, and social aggregations). Furthermore, it can significantly improve the efficiency of management: as the resolution of the closures used increases (i.e., as the closures become more targeted), the percentage of target catch forgone or displaced decreases, the reduction ratio (bycatch/catch) increases, and the total time-area required to achieve the desired bycatch reduction decreases. In the scenario examined, coarser scale management measures (annual time-area closures and monthly full-fishery closures) would displace up to four to five times the target catch and require 100–200 times more square kilometer-days of closure than dynamic measures (grid-based closures and move-on rules). To achieve similar reductions in juvenile bycatch, the fishery would forgo or displace between USD 15–52 million in landings using a static approach over a dynamic management approach.

dynamic ocean management | real-time management | ecosystem-based fisheries management | spatiotemporal | bycatch

Although traditional fisheries management has focused on assessing the health of individual fish stocks, there has been a strong trend over the past two decades toward the incorporation of ecosystem components into fisheries management (1, 2). Ecosystem-based fisheries management (EBFM) seeks to meet multiple, potentially conflicting goals across ecological, economic, and social objectives (3, 4). Meeting these goals is made more complex in marine ecosystems due to the inherent dynamic nature of the oceans. In response to continuing difficulty in managing the ecosystem impacts of fisheries in a highly dynamic environment, including bycatch (i.e., the accidental interaction of fishing gear with nontarget species), interest in the concept of dynamic ocean management (DOM) has accelerated (5–10). Maxwell et al. (8) define dynamic management as "management that changes in space and time in response to the shifting nature of the ocean and its users based on the integration of new biological, oceanographic, social and/or economic data in near real-time" (8). Dynamic management reflects advancement in our ability to manage ocean resources across finer spatial and temporal scales as a result of technological improvements that have paved the way for higher-resolution collection of both fisheries and environmental data (e.g., electronic logbooks, vessel monitoring systems, smartphone technology, remote sensing, and animal tracking) (9). The existing literature has focused on the presumed capacity of dynamic management to increase management efficiency across both ecological and economic objectives (7, 8), and in codifying the different approaches to dynamic management across fisheries and other applications (7, 10). However, little to no empirical research exists to quantify the implied benefits of dynamic management or compare the efficiency of the various spatiotemporal management measures. Additionally, and critically, the benefits of dynamic management hinge on the premise that it is capable of managing resources at scales more aligned with resources and resource users, yet we lack a quantitative assessment of how scale influences the effectiveness of dynamic management—both in terms of how it reflects underlying ecological processes, and how this relates to the efficiency of dynamic management approaches.

Scale in Fisheries Management

Frameworks for dynamic management (e.g., ref. 6) have defined it in contrast to traditional static spatiotemporal management of fisheries (i.e., coordination of fisheries in space and/or time) including monthly or seasonal closures of specific areas (often known as "time–area closures"), and seasonal full-fishery closures. Alternatively, dynamic management operates at smaller scales of space and time, and depends on contemporaneous conditions. Work on dynamic management has focused on three types of measures: grid-based hot-spot closures, real-time closures based on move-on rules, and oceanographic closures. Grid-based closures involve the overlaying of a grid on an area of interest and closing individual grid cells where bycatch has exceeded a threshold level (e.g., refs. 11 and 12); they have been implemented on a daily or weekly basis with cell sizes as small as

Significance

Food security and the economic well-being of millions of people depend on sustainable fisheries, which require innovative approaches to management that can balance ecological, economic, and social objectives. We offer empirical evidence that dynamic ocean management, or real-time ocean management, can increase the efficacy and efficiency of fisheries management over static approaches by better aligning human and ecological scales of use. Furthermore, we show that dynamic management can address critical ecological patterns previously considered to be largely intractable in fisheries management (e.g., competition, niche partitioning, predation, parasitism, or social aggregations) at appropriate scales. The evidence and theory offered supports the use of dynamic ocean management in a range of scenarios to improve the ecological, economic, and social sustainability of fisheries.

Author contributions: D.C.D., A.M.B., and P.N.H. designed research; D.C.D. performed research; D.C.D., S.M.M., A.M.B., and P.N.H. analyzed data; and D.C.D., S.M.M., A.M.B., and P.N.H. wrote the paper.

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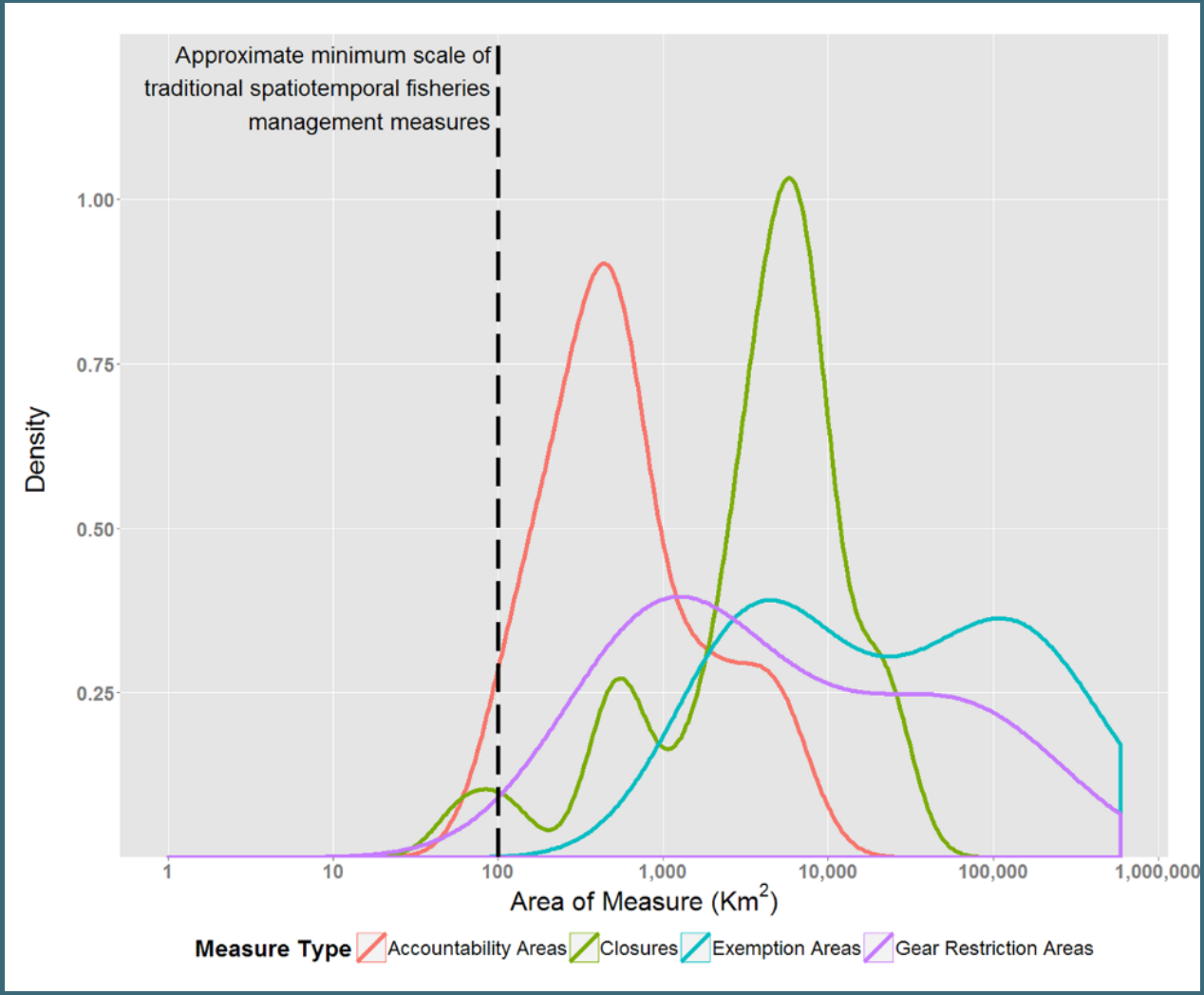
Dunn et al. 2016, *PNAS*

What scales we are managing at?



Distribution of the size of management measures in the Northeast Multispecies (Groundfish) Fishery

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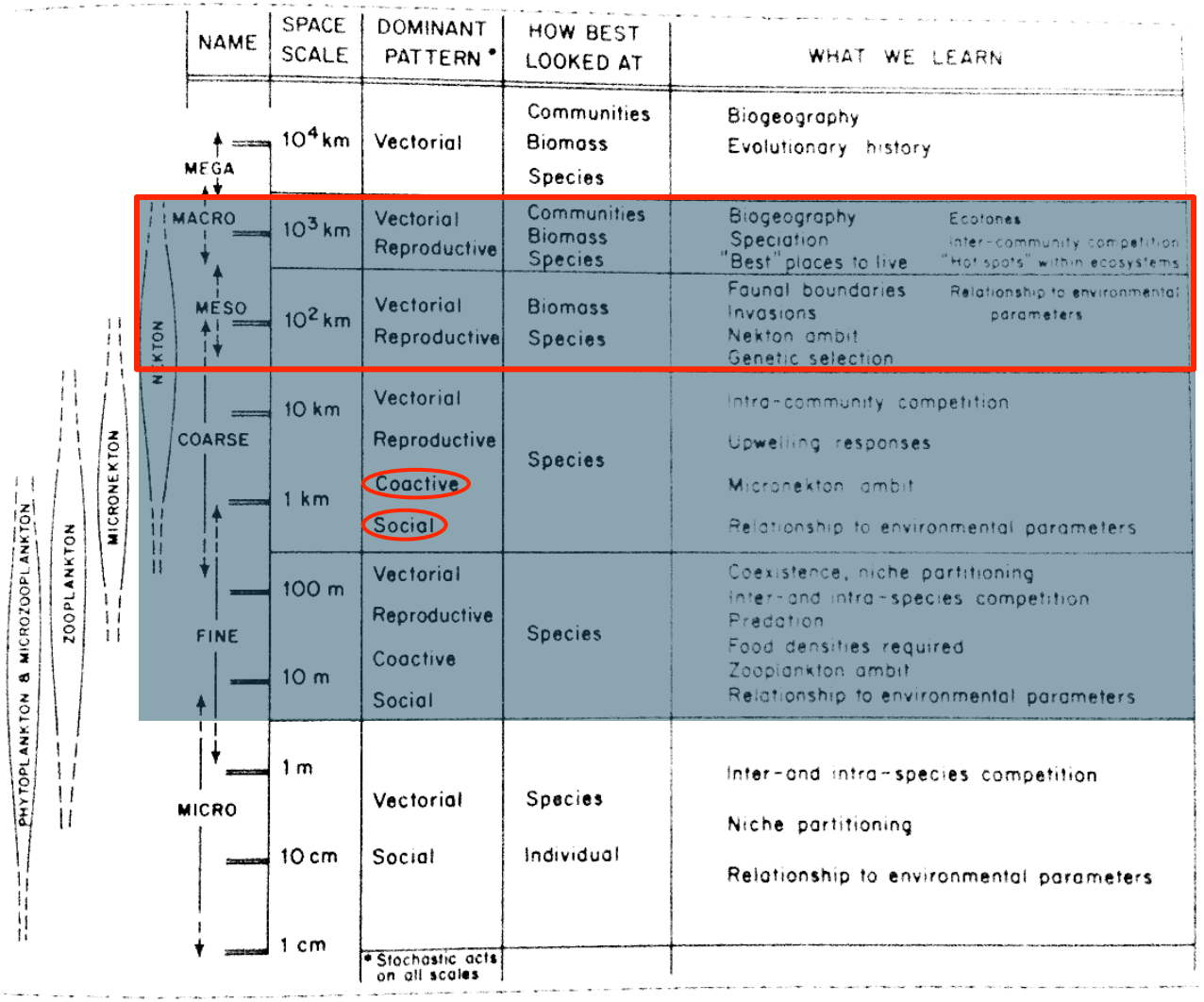
DOMINANT PATTERNS DIFFER ACROSS SCALES



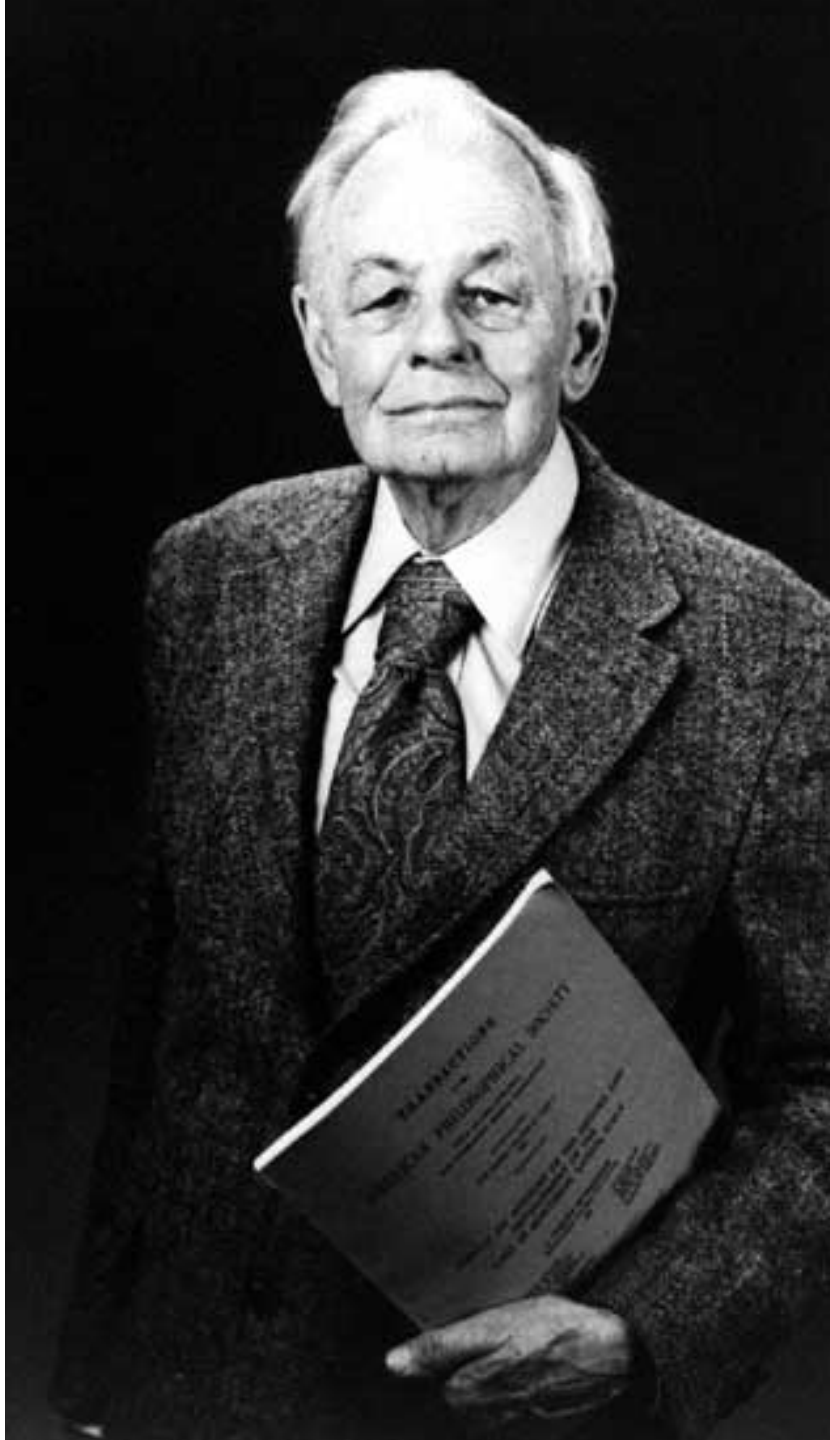
NAME	SPACE SCALE	DOMINANT PATTERN *	HOW BEST LOOKED AT	WHAT WE LEARN
MEGA	10^4 km	Vectorial	Communities Biomass Species	Biogeography Evolutionary history
MACRO	10^3 km	Vectorial Reproductive	Communities Biomass Species	Biogeography Speciation "Best" places to live Ecotones Inter-community competition "Hot spots" within ecosystems
MESO	10^2 km	Vectorial Reproductive	Biomass Species	Faunal boundaries Invasions Nekton ambit Genetic selection Relationship to environmental parameters
COARSE	10 km 1 km	Vectorial Reproductive Coactive Social	Species	Intra-community competition Upwelling responses Micronekton ambit Relationship to environmental parameters
FINE	100 m 10 m	Vectorial Reproductive Coactive Social	Species	Coexistence, niche partitioning Inter- and intra-species competition Predation Food densities required Zooplankton ambit Relationship to environmental parameters
MICRO	1 m 10 cm 1 cm	Vectorial Social	Species Individual	Inter- and intra-species competition Niche partitioning Relationship to environmental parameters

* Stochastic acts on all scales

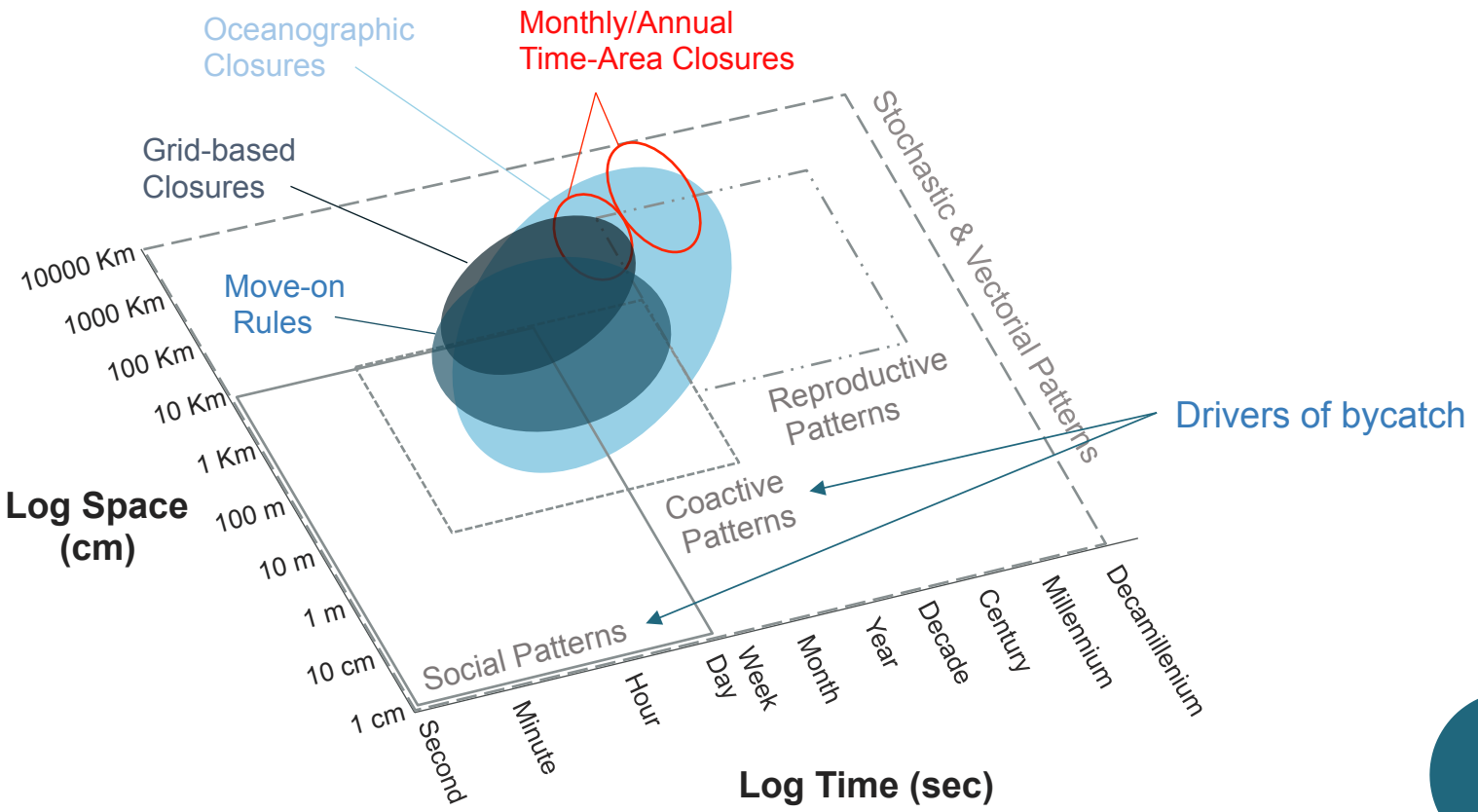
Haury, McGowan & Wiebe 1978

Hutchinson 1953: *The concept of pattern in ecology*

- Coactive Patterns
  - Arise from interactions between species
    - Competition
    - Niche partitioning
    - Predation
    - Parasitism
- Social Patterns
  - "determined by signalling of various kinds, leading either to spacing or aggregation"



What Ecological Processes can fisheries management address?



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Management Strategy Evaluation

Management Measures	
Seasonal Closure ✓	2600 km² full fishery closure; No algorithm needed
Fixed Area Closure ✓	100km² permanent closure; Marxan
Time/Area Closure ✓	100km² monthly closure; Marxan
Event-triggered Closure ✓	50km² daily or weekly grid-based closures, and 20km² move-on rules
Oceanographic Closure ✗	

Management Strategy Evaluation

Scenario: Reduce juvenile Atlantic cod bycatch by 60%

Catch = weight of adult Atlantic cod

Bycatch = weight of juvenile Atlantic cod

$$\frac{\text{Percent Bycatch Reduction} * \text{Bycatch Reduction to Catch Forgone Ratio}}{\text{Time-Area Required}}$$

Management Strategy Evaluation Results

Table 1. Results from the simulation of six different closures type spanning a range of spatial and temporal scales

Closure type	BLM or weight threshold, lb	Percent bycatch reduction	Percent target catch affected	Bycatch reduction efficiency	No. of closures	Area of closure; resolution, km^2	Days closed	Log $km^2 \cdot d$ of closure	Spatiotemporal efficiency, /1,000	SUM
Move-on rules	NA	62.17	8.57	7.25	48	19.63	1	2.97	0.2	4.64
Daily grid-based closures	10	61.66	17.39	3.55	30	50	1	3.18	0.3	4.13
Weekly grid-based closures	10	61.66	18.27	3.37	30	50	7	4.02	1.8	3.26
Monthly time–area closures	0.0001	60.01	18.77	3.20	5	100	30	4.18	2.6	3.08
Annual time–area closures	0.001	68.72	37.47	1.83	2	100	365	4.86	12.8	2.16
Monthly total closures	NA	68.54	43.28	1.58	4	2,600	30	5.49	54.8	1.46

More target catch affected

Less efficient bycatch reduction

Decreasing resolution

More space used

Less efficient

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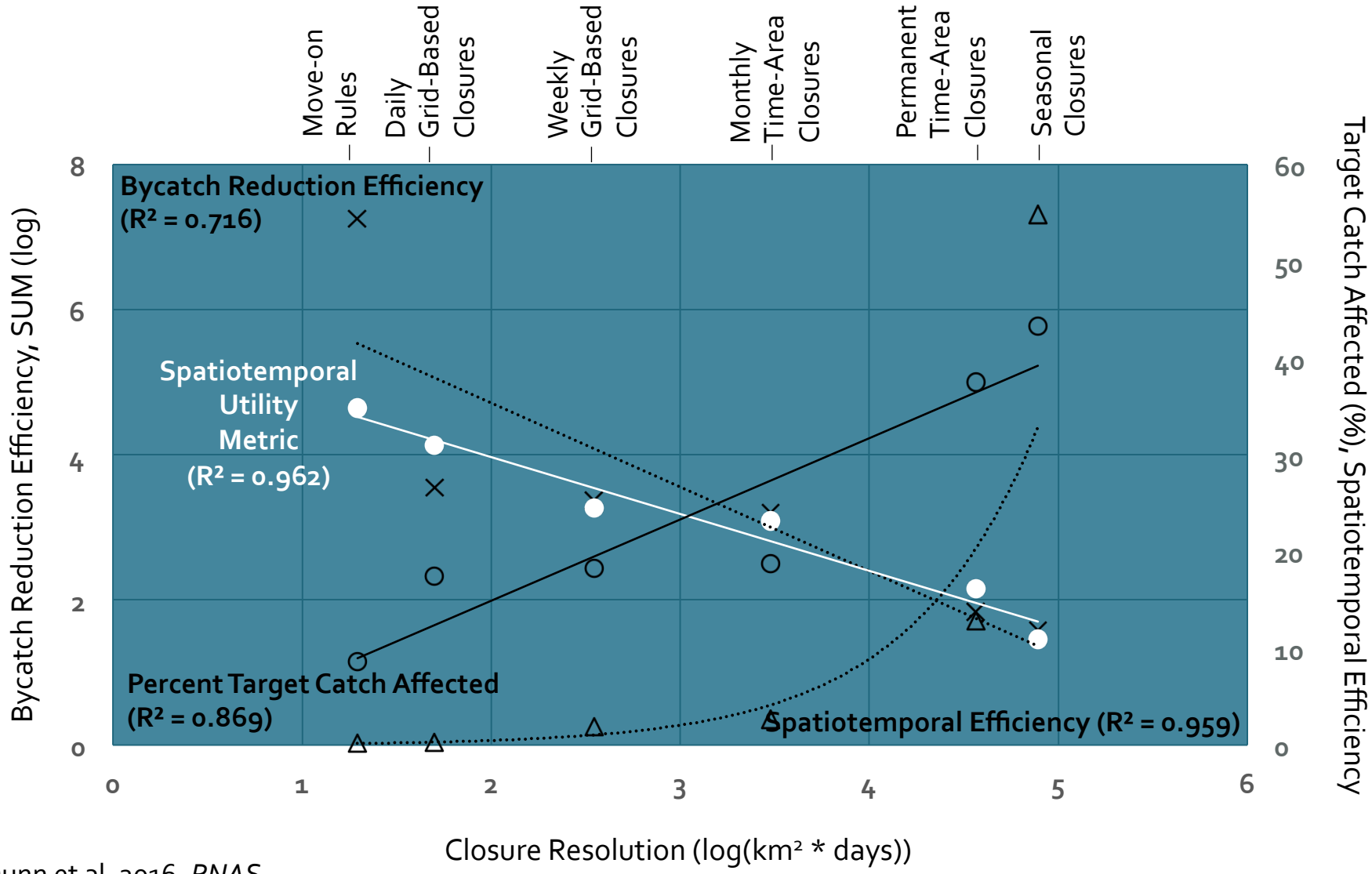
Management Strategy Evaluation Results



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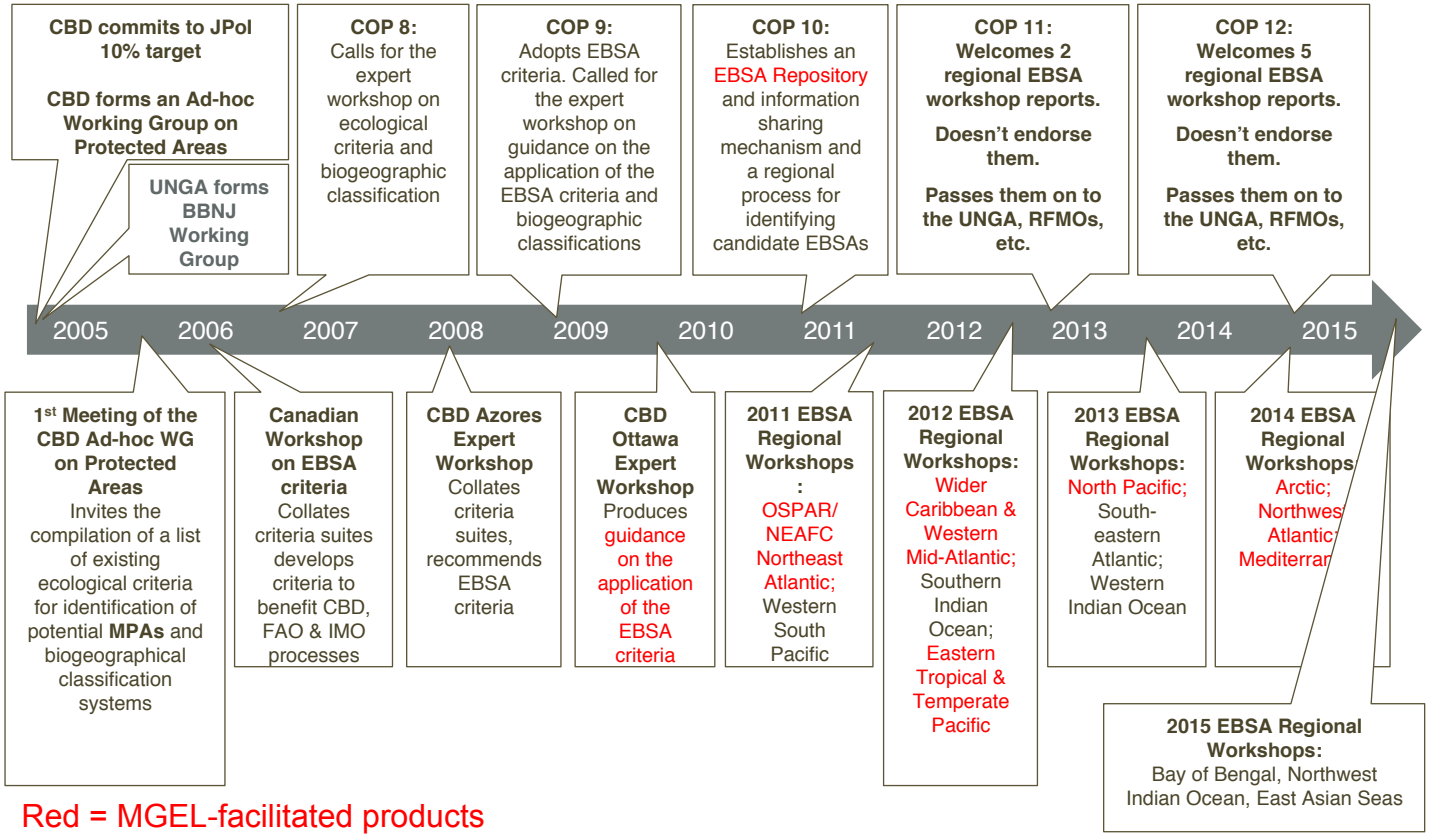
Take-home Messages

- Developed fisheries are generally managed on scales greater than 100km^2 and 1 month
- This results in mismatches in the space-time scales of management of fine scale coactive and social patterns… INCLUDING FISHERMEN-FISH INTERACTIONS
- Dynamic management seeks to better align the temporal and spatial scales of the resource, resource users, management, and markets.
- In our MSE evaluation dynamic management measures were orders of magnitude more efficient in time/area used and more effective in reducing bycatch of juveniles

BIODIVERSITY BEYOND NATIONAL JURISDICTION

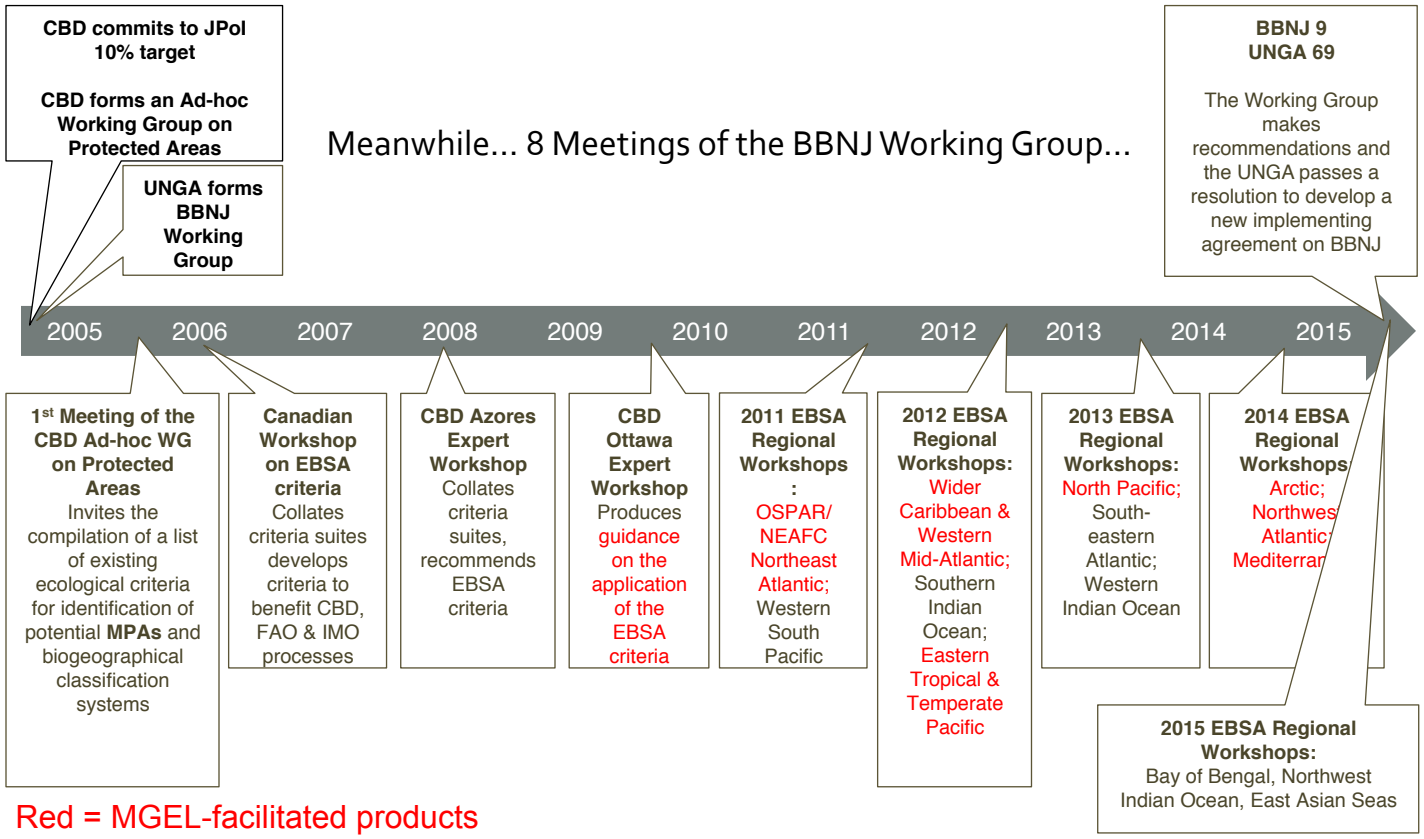
How can we inform negotiations of the PrepCom "package"?

10 years of EBSAs & BBNJ meetings



Red = MGEL-facilitated products

10 years of EBSAs & BBNJ meetings



Red = MGEL-facilitated products

A new International Legally Binding Instrument (ILBI) for Biodiversity Beyond National Jurisdiction

The Scope

- Geographic (what about areas over ECSs?)
- Material (should fisheries be excluded?)
- Functional (what are the functions of the ILBI?)
- Temporal (review period, nature of MPAs)

The "Package"

- Access & Benefit Sharing of Marine Genetic Resources
- Area-based management tools, including MPAs
- Environmental Impact Assessments (EIAs) and strategic environmental assessments (SEAs)
- Capacity building and marine technology transfer

Timeline

- Draft text for the ILBI by the end of 2017
- 2 meetings/year (March/April, August/September)

Next steps

IMCC4 Pre-Conference Focus Group

- Organizers: Daniel Dunn, Steve Fletcher, Telmo Morato
- July 28 – 29 (conference runs til August 5) St. John's, Newfoundland
- Nereus Participants:
  - William, Yoshi/Marjo, Steve, Pat, Gabriel, Richard, Guillermo
- **Will be presented during an IOC side-event**

Prep Com 2

- August 29 – September 9, New York City
- "JAPAN, supported by the RUSSIAN FEDERATION, CHINA, and ICELAND, reiterated the proposal to request RFMOs to deliver presentations at PrepCom 2."
- **Possible Nereus Side-Event?**

IMCC Pre-Conference Focus Group

Conserving the other 50% of the planet: status and opportunities in conservation of areas beyond national jurisdiction

DAY 1

Setting the stage: The history of the BBNJ process and the role of civil society
(Moderator: Kristina Gjerde)

- Progress towards a new treaty for the conservation and sustainable use of marine biodiversity in ABNJ – Susanna Fuller (Ecology Action Centre)
- Elements of the "package" being negotiated at the BBNJ PrepCom - TBD
- Comparing transparency in the management of fisheries with mining in ABNJ – Jeff Ardron (Commonwealth Secretariat)
- Species of cultural importance to Indigenous Peoples and local communities, and what they can contribute to the governance of marine biodiversity beyond national jurisdiction – Yoshitaka Ota (Nereus), Marjo Vierros (UN Univ.)

IMCC Pre-Conference Focus Group

DAY 1

Anthropogenic Impacts in ABNJ (Moderator: Lance Morgan)

- The deep ocean under climate change – Lisa Levin (Univ. of California, San Diego, DOSI)
- Climate change effects on ABNJ stocks – William Cheung (Univ. of British Columbia/Nereus)
- What are the environmental impacts of deep-sea mining and can they be reduced – Phil Weaver (Seascape Consultants, MIDAS, GOBI)
- A review of the impact of fisheries on open-ocean ecosystems – Guillermo Ortuño Crespo (Duke Univ./Nereus)
- *In absentia:* Deep-sea fisheries impacts – Derek Tittensor (Dalhousie University)

IMCC Pre-Conference Focus Group

DAY 1

Environmental Impact Assessments (Moderator: Telmo Morato)

- Existing practices and future opportunities for the use of EIAs in Areas Beyond National Jurisdiction - Steve Fletcher (UNEP-WCMC)
- Exploratory fisheries in ABNJ – Richard Caddell (NILOS/ Nereus)
- Emerging practice for environmental impact assessments for seabed mining [and other activities] beyond national jurisdiction - Kristina Gjerde (Wycliffe Management/MIDAS)

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DAY 1

Area-based management of ABNJ: Existing instruments

(Moderator: Steve Fletcher)

- Results and implications of the first intergovernmentally sanctioned effort to describe ecological or biologically important areas (EBSAs) and future directions – Pat Halpin (Duke Univ., GOBI, Nereus)
- The status of RFMO conservation measures – Matt Gianni (DSCC)
- The International Seabed Authority's Areas of Particular Environmental Interest and movement on a Mid-Atlantic Ridge Strategic Environmental Management Plan for deep sea mining – David Johnson (Seascape Consultants, GOBI, MIDAS)
- Role of a network of MPAs in areas beyond national jurisdiction – Daniel Dunn (Duke Univ., GOBI, Nereus)

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DAY 2

Data for EIAs and area-based management of ABNJ: Species
(Moderator: Sara Maxwell)

- Important Marine Mammal Areas in ABNJ – Michael Tetley (IUCN Joint SSC-WCPA Marine Mammal Protected Task Force)
- Global information systems to support environmental management of the ABNJ – (Pieter Provoost, OBIS/IOC)
- Global status of oceanic sharks & rays and priority areas for conservation beyond national jurisdiction –Fred Vanderperre (Univ. of the Azores)
- Important Bird Areas in ABNJ – Birdlife International

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DAY 2

Data for EIAs and area-based management of ABNJ: Biogeographies & Habitats

(Moderator: Lisa Levin)

- Global biogeography of brittlestars – Tim O'Hara (Museum Victoria)
- New global mesopelagic biogeographies – Gabriel Reygondeau (Nereus, Univ. of British Columbia)
- Predictive maps of cold-water corals – Marine Conservation Institute
- Myths and measures of seamount biodiversity – Telmo Morato (Univ. of the Azores)
- Life in the abyss: species diversity, biogeography and conservation – Tina Molodtsova (P.P. Shirshov Institute of Oceanology)
- *In absentia:* Celebrating and conserving the diversity of chemosynthetic ecosystems – Cindy Van Dover (Duke)

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DAY 2

Technology transfer & Capacity Building through monitoring & surveillance in ABNJ (Moderator: Pat Halpin)

- Technology Transfer and instrumenting the high seas – Torsten Thiele (Global Ocean Trust)
- Status of global monitoring of ocean health – Nic Bax (CSIRO)
- The role of the IOC in capacity development and technology transfer - Harriet Harden-Davies (Univ. of Wollongong, DOSI)
- The potential contribution of open science to capacity building and tech transfer - TBD

THANKS!


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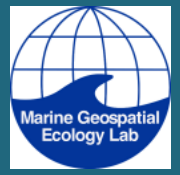
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