Tropical Water Quality Hub

National Environmental Science Programme

NESP 4.6: Recommendations to maintain functioning of the GBR



Kenny Wolfe, Peter Mumby

and the Reef Functions Working Group:

Ken Anthony, Russ Babcock, Line Bay, David Bourne, Tom Bridge, Damien Burrows, Guillermo Diaz-Pulido, Manuel Gonzalez-Rivero, Andrew Hoey, Mia Hoogenboom, Mark McCormick, Juan-Carlos Ortiz, Anthony Richardson, Jessica Stella, Angus Thompson, Sue-Ann Watson, Nicole Webster

MSEL Marine Spatial Ecology Lab

The University Of Queensland AUSTRALIA

Griffith UNIVERSITY

ARC Centre of Excellence Coral Reef Studies

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Australian Government Great Barrier Reef Marine Park Authority

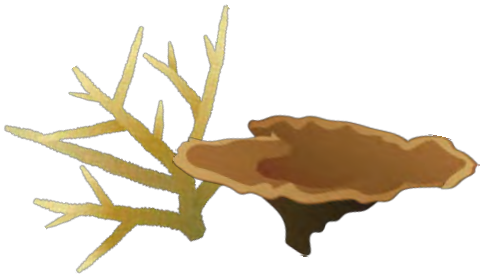
2018 International Year of the Reef

Rationale – NESP 4.6:

Historical notion to protect **biodiversity**

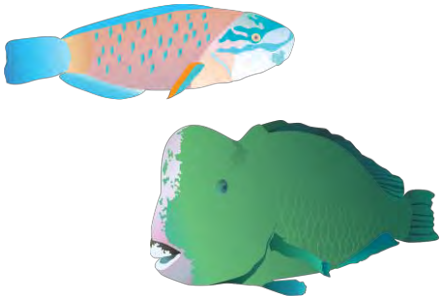
A subset of species may be critical to maintaining and/or facilitating ecosystem functioning

Acropora spp.
↑ Reef framework
↑ Recovery

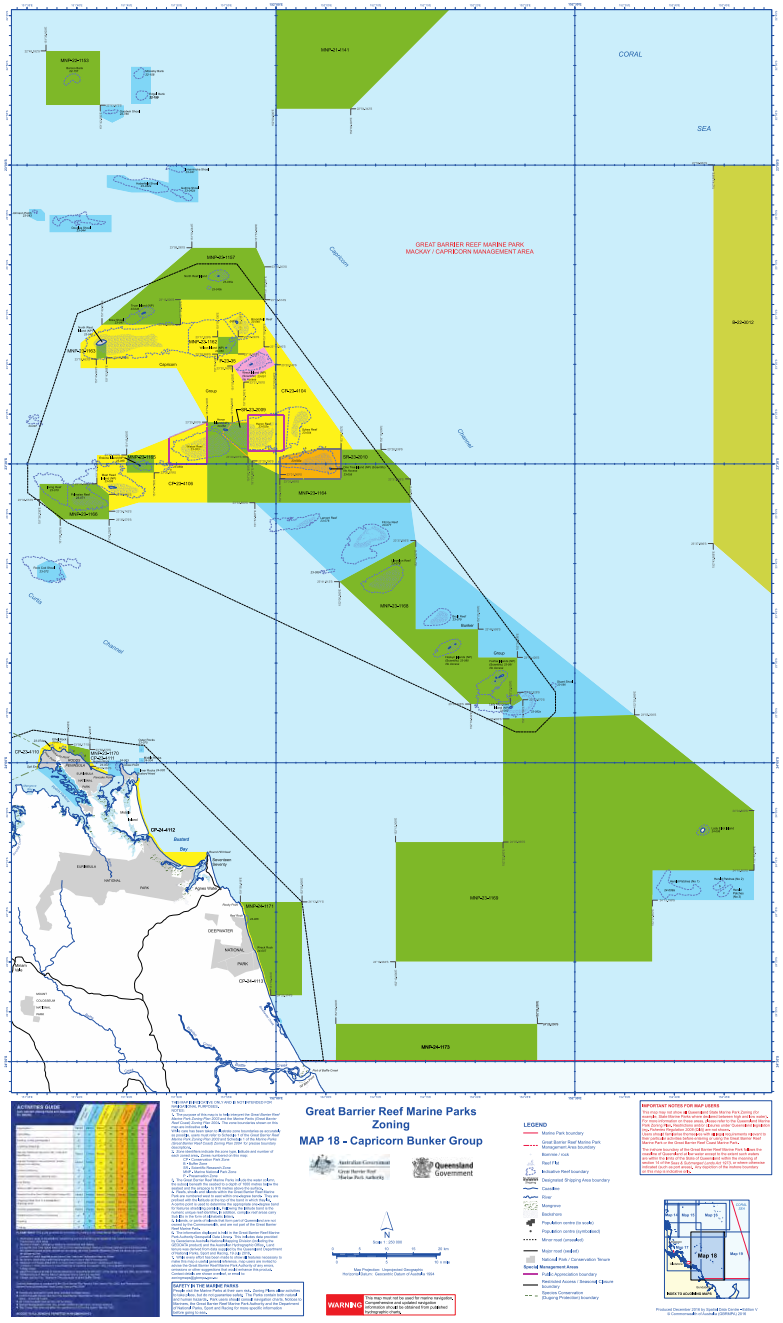


(Ortiz et al. 2018)

Parrotfishes
↑ Herbivory
↑ Coral growth



(Hoey & Bellwood 2008; Mumby et al. 2013)



Rationale – NESP 4.6:

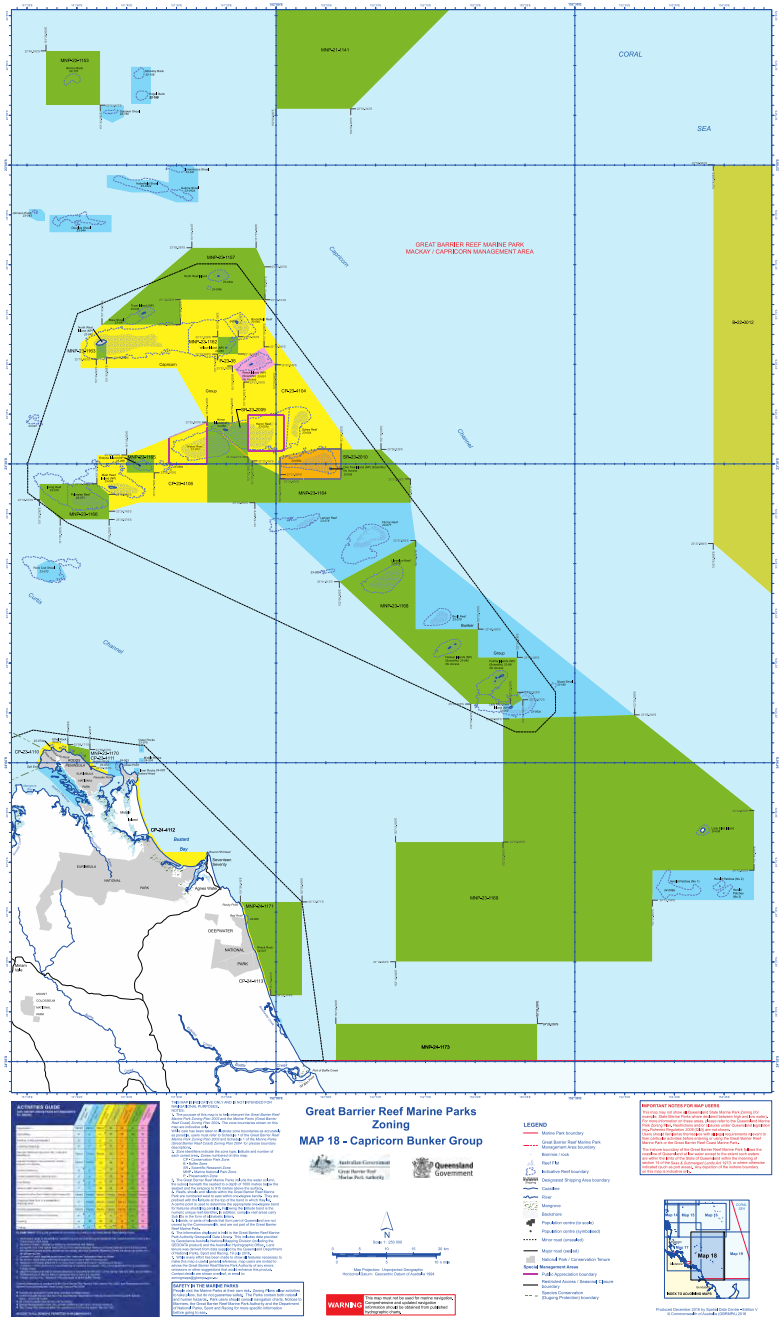
Historical notion to protect **biodiversity**

A subset of species may be critical to maintaining and/or facilitating ecosystem functioning

Aims:

- What species/groups are the most **functionally important** on the GBR?

- To make recommendations to supplement current measures of broader-scale habitat protection (marine park areas):
  - Are they **vulnerable**?
  - Are they **manageable**?



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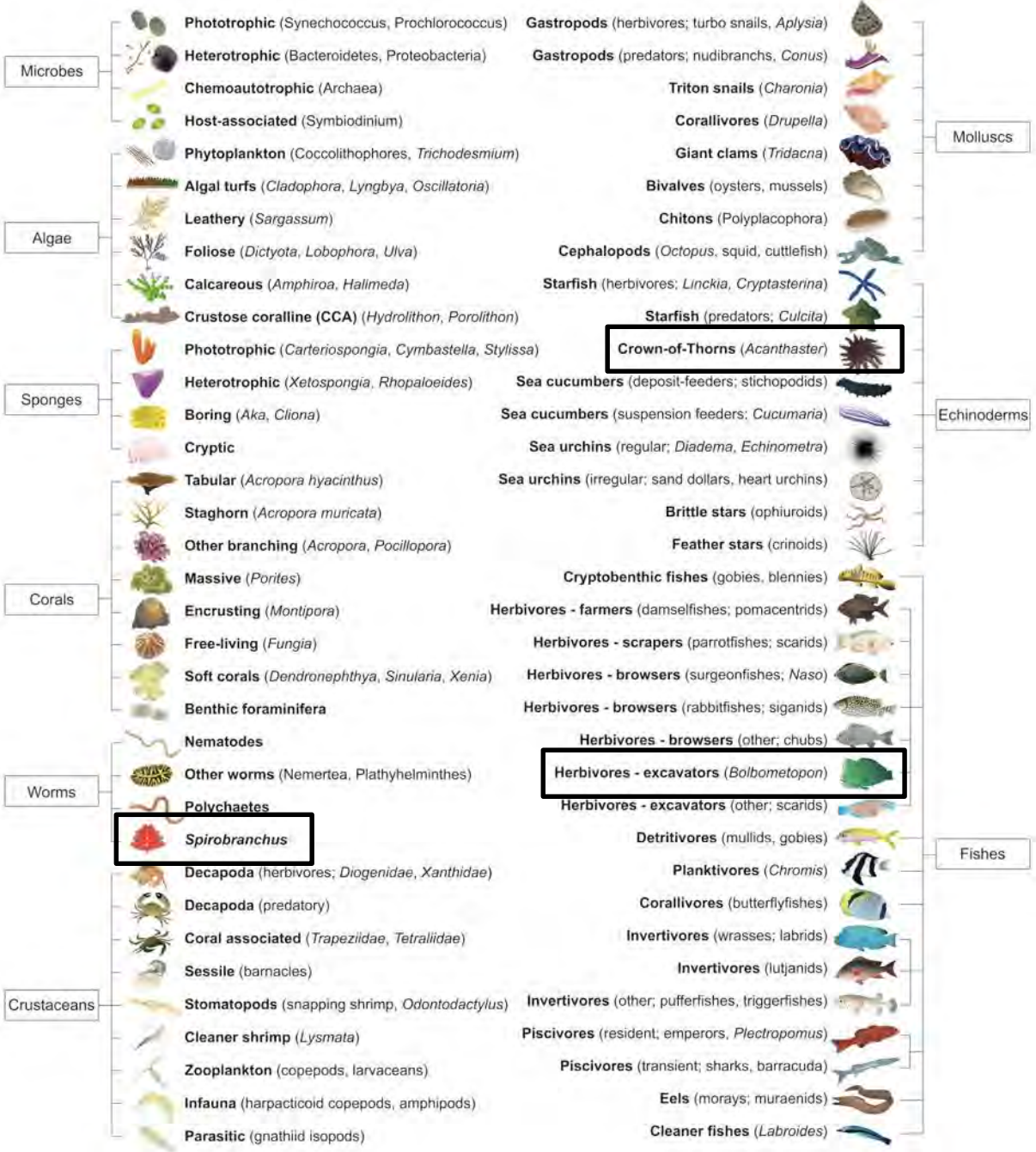
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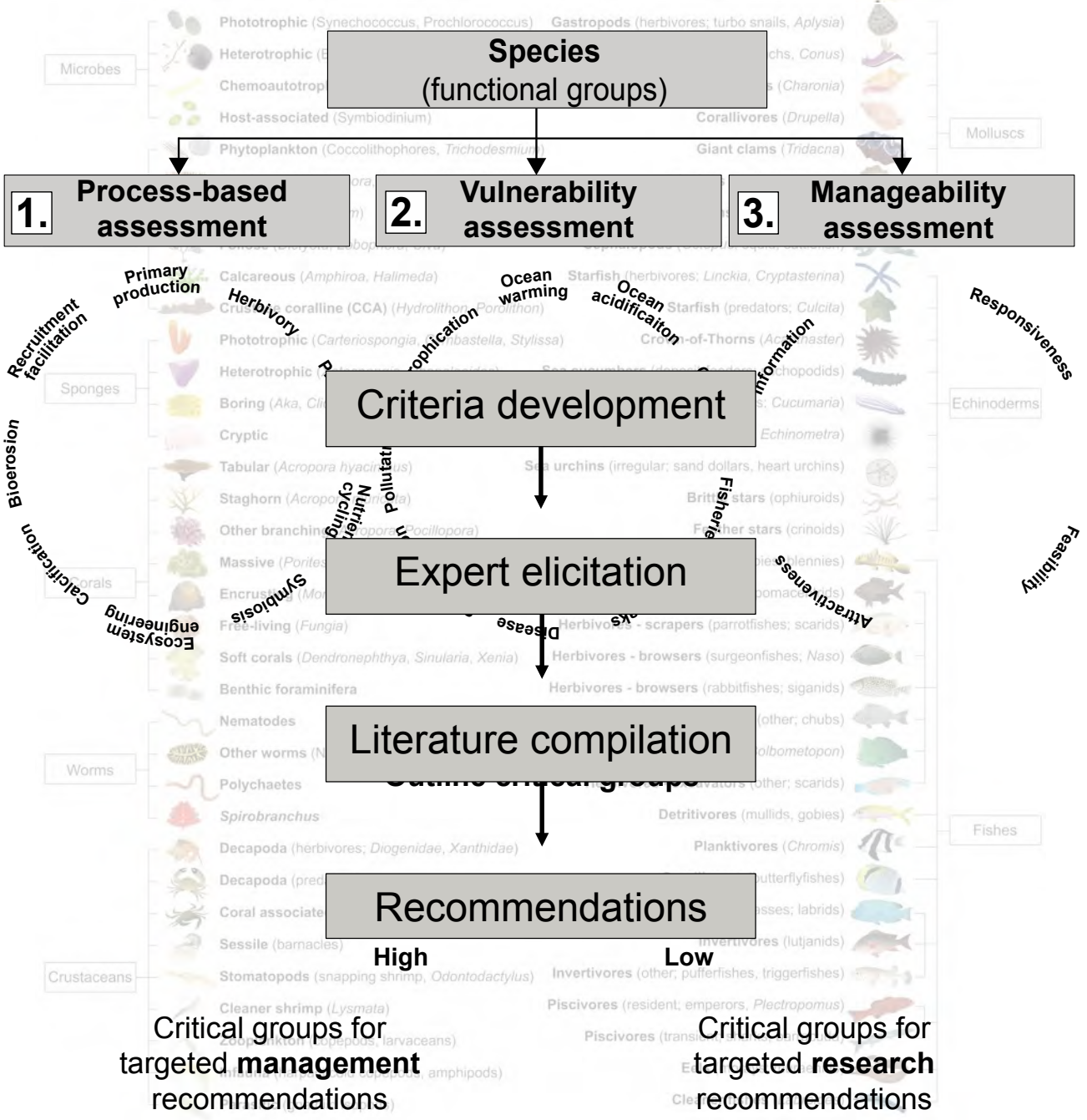
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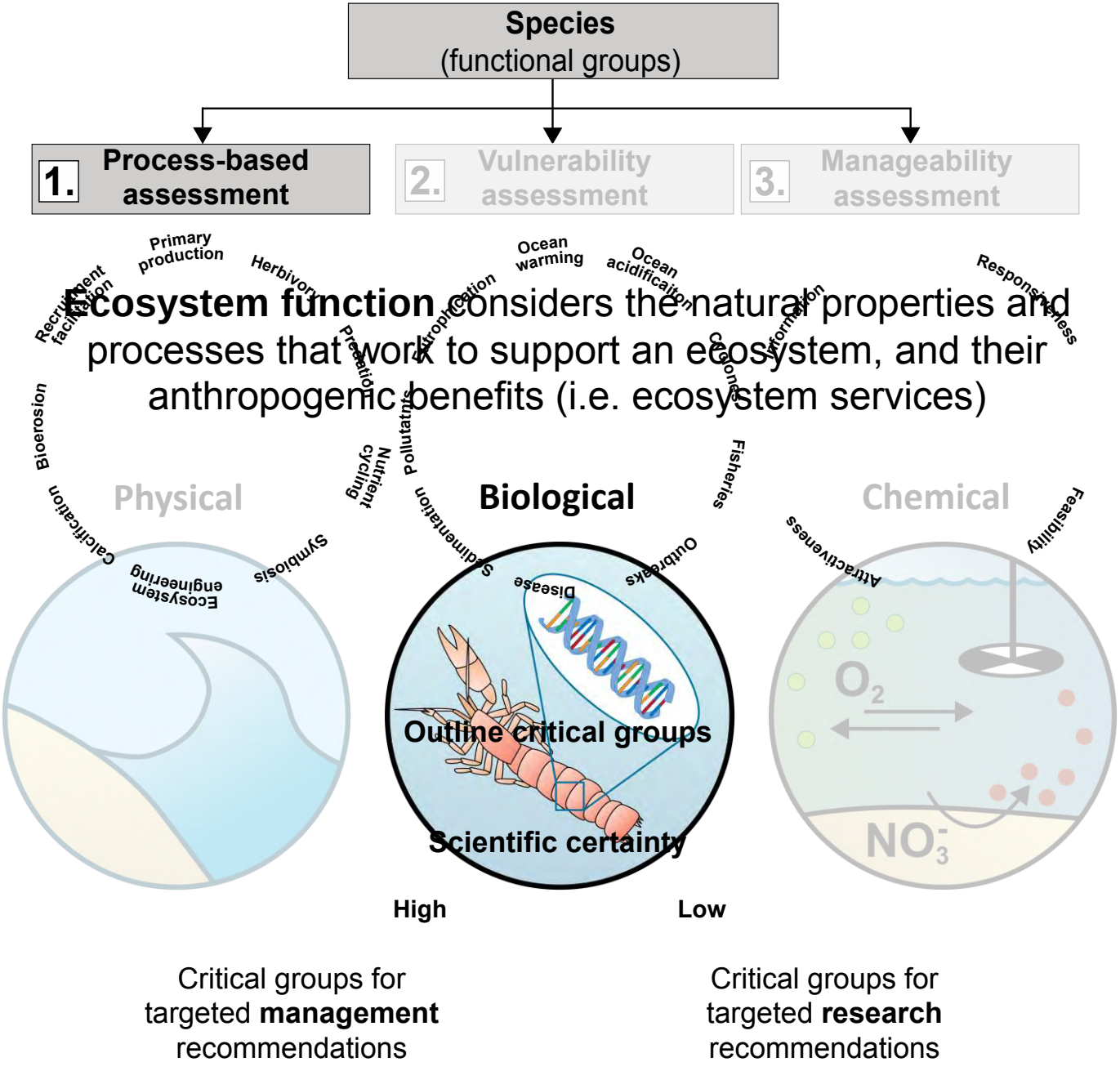
Australian Government Great Barrier Reef Marine Park Authority

2018 International Year of the Reef




Microbes
Phototrophic (Synechococcus, Prochlorococcus)
Heterotrophic (Bacteroidetes, Proteobacteria)
Chemoautotrophic (Archaea)
Host-associated (Symbiodinium)
Algae
Phytoplankton (Coccolithophores, Trichodesmium)
Algal turfs (Cladophora, Lyngbya, Oscillatoria)
Leathery (Sargassum)
Foliose (Dictyota, Lobophora, Ulva)
Calcareous (Amphiroa, Halimeda)
Crustose coralline (CCA) (Hydrolithon, Porolithon)
Sponges
Phototrophic (Carteriospongia, Cymbastella, Stylissa)
Heterotrophic (Xetospongia, Rhopaloeides)
Boring (Aka, Cliona)
Cryptic
Corals
Tabular (Acropora hyacinthus)
Staghorn (Acropora muricata)
Other branching (Acropora, Pocillopora)
Massive (Porites)
Encrusting (Montipora)
Free-living (Fungia)
Soft corals (Dendronephthya, Sinularia, Xenia)
Benthic foraminifera
Worms
Nematodes
Other worms (Nemertea, Plathyhelminthes)
Polychaetes
Spirobranchus
Crustaceans
Decapoda (herbivores; Diogenidae, Xanthidae)
Decapoda (predatory)
Coral associated (Trapeziidae, Tetraliidae)
Sessile (barnacles)
Stomatopods (snapping shrimp, Odontodactylus)
Cleaner shrimp (Lysmata)
Zooplankton (copepods, larvaceans)
Infauna (harpacticoid copepods, amphipods)
Parasitic (gnathiid isopods)
Molluscs
Gastropods (herbivores; turbo snails, Aplysia)
Gastropods (predators; nudibranchs, Conus)
Triton snails (Charonia)
Corallivores (Drupella)
Giant clams (Tridacna)
Bivalves (oysters, mussels)
Chitons (Polyplacophora)
Cephalopods (Octopus, squid, cuttlefish)
Echinoderms
Starfish (herbivores; Linckia, Cryptasterina)
Starfish (predators; Culcita)
Crown-of-Thorns (Acanthaster)
Sea cucumbers (deposit-feeders; stichopodids)
Sea cucumbers (suspension feeders; Cucumaria)
Sea urchins (regular; Diadema, Echinometra)
Sea urchins (irregular; sand dollars, heart urchins)
Brittle stars (ophiuroids)
Feather stars (crinoids)
Fishes
Cryptobenthic fishes (gobies, blennies)
Herbivores - farmers (damselfishes; pomacentrids)
Herbivores - scrapers (parrotfishes; scarids)
Herbivores - browsers (surgeonfishes; Naso)
Herbivores - browsers (rabbitfishes; siganids)
Herbivores - browsers (other; chubs)
Herbivores - excavators (Bolbometopon)
Herbivores - excavators (other; scarids)
Detritivores (mullids, gobies)
Planktivores (Chromis)
Corallivores (butterflyfishes)
Invertivores (wrasses; labrids)
Invertivores (lutjanids)
Invertivores (other; pufferfishes, triggerfishes)
Piscivores (resident; emperors, Plectropomus)
Piscivores (transient; sharks, barracuda)
Eels (morays; muraenids)
Cleaner fishes (Labroides)


Species
(functional groups)
1. Process-based assessment
2. Vulnerability assessment
3. Manageability assessment
Criteria development
Expert elicitation
Literature compilation
Recommendations
High
Low
Primary production
Herbivory
Recruitment facilitation
Bioerosion
Calcification
Ecosystem engineering
Symbiosis
Nutrient cycling
Pollutation
Disease
Ocean warming
Ocean acidificaiton
Responsiveness
Feasibility
Attractiveness
Fisheries
Microbes
Sponges
Corals
Worms
Crustaceans
Molluscs
Echinoderms
Fishes
Phototrophic (Synechococcus, Prochlorococcus)
Heterotrophic
Chemoautotroph
Host-associated (Symbiodinium)
Phytoplankton (Coccolithophores, Trichodesmium)
Calcareous (Amphiroa, Halimeda)
Crustose coralline (CCA) (Hydrolithon, Porolithon)
Phototrophic (Carteriospongia, Cliona, Pseudoceratina, Stylissa)
Heterotrophic
Boring (Aka, Cliona)
Cryptic
Tabular (Acropora hyacinthus)
Staghorn (Acropora)
Other branching (Acropora, Pocillopora)
Massive (Porites)
Encrusting (Montipora)
Free-living (Fungia)
Soft corals (Dendronephthya, Sinularia, Xenia)
Benthic foraminifera
Nematodes
Other worms
Polychaetes
Spirobranchus
Decapoda (herbivores; Diogenidae, Xanthidae)
Decapoda (pred
Coral associate
Sessile (barnacles)
Stomatopods (snapping shrimp, Odontodactylus)
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Invertivores (other; pufferfishes, triggerfishes)
Piscivores (resident; emperors, Plectropomus)
Piscivores (transi
Critical groups for targeted management recommendations
Critical groups for targeted research recommendations



(de Groot et al. 2002; Jax 2005; Srivastava and Vellend 2005)

Species
(functional groups)

1. Process-based assessment

2. Vulnerability assessment

3. Manageability assessment

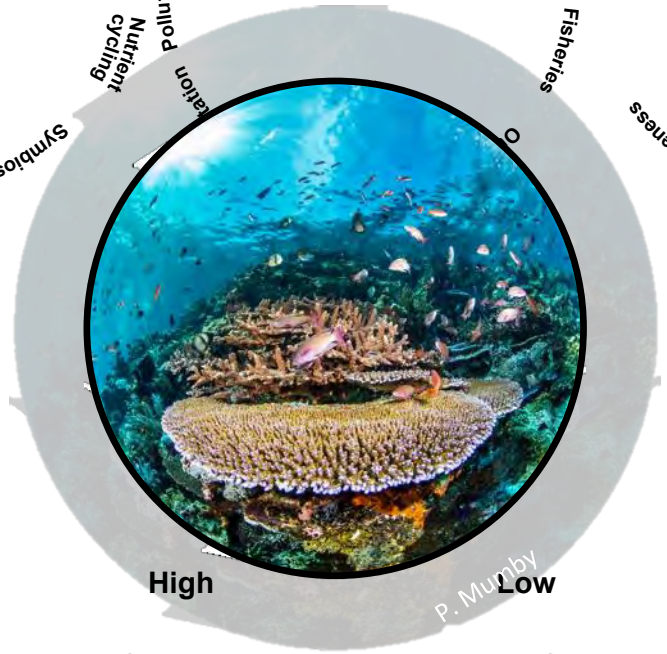
Ecosystem function considers the natural properties and processes that work to support an ecosystem, and their anthropogenic benefits (i.e. ecosystem services)

Production functions e.g. Fisheries

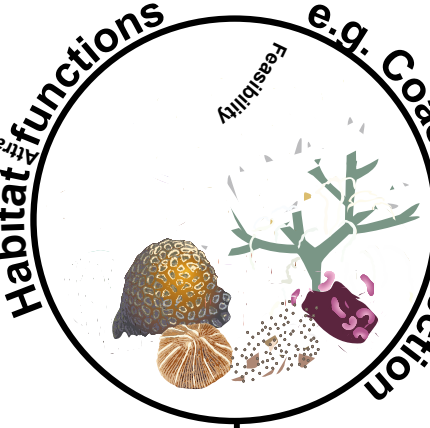


Photosynthesis
Herbivory
Predation
Nutrient cycling
Symbiosis

Critical groups for targeted **management** recommendations



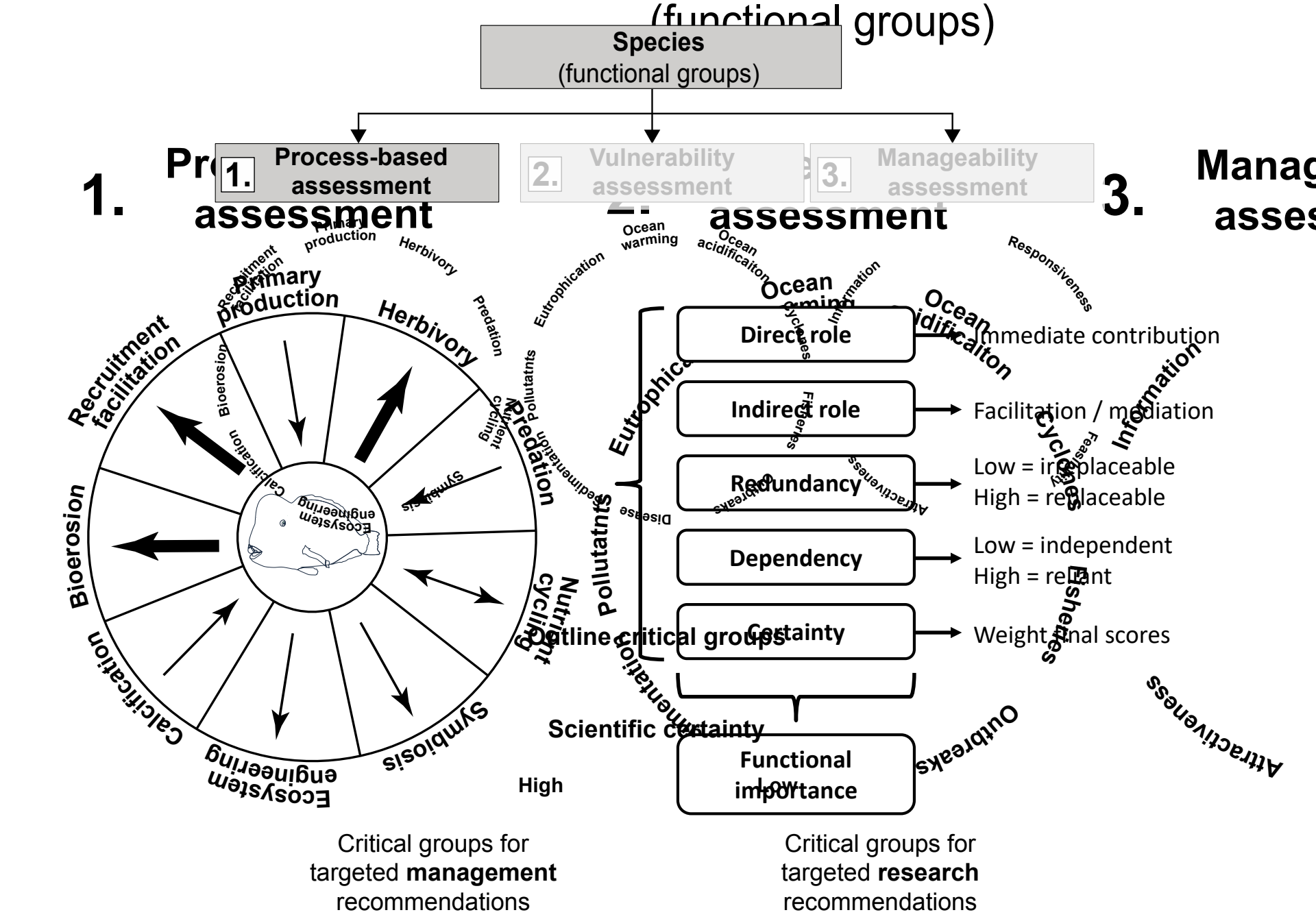
Habitat functions e.g. Coastal protection

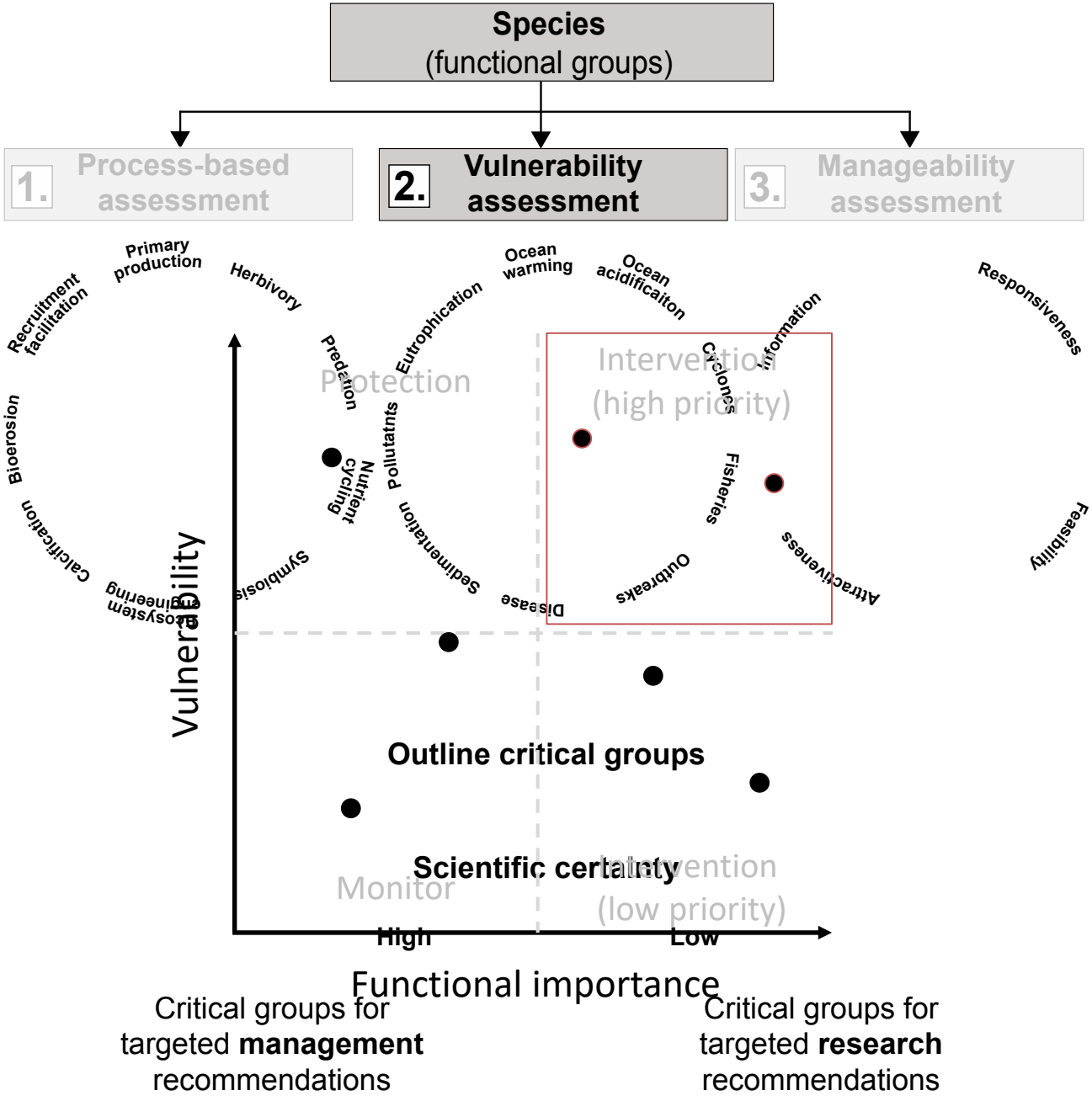


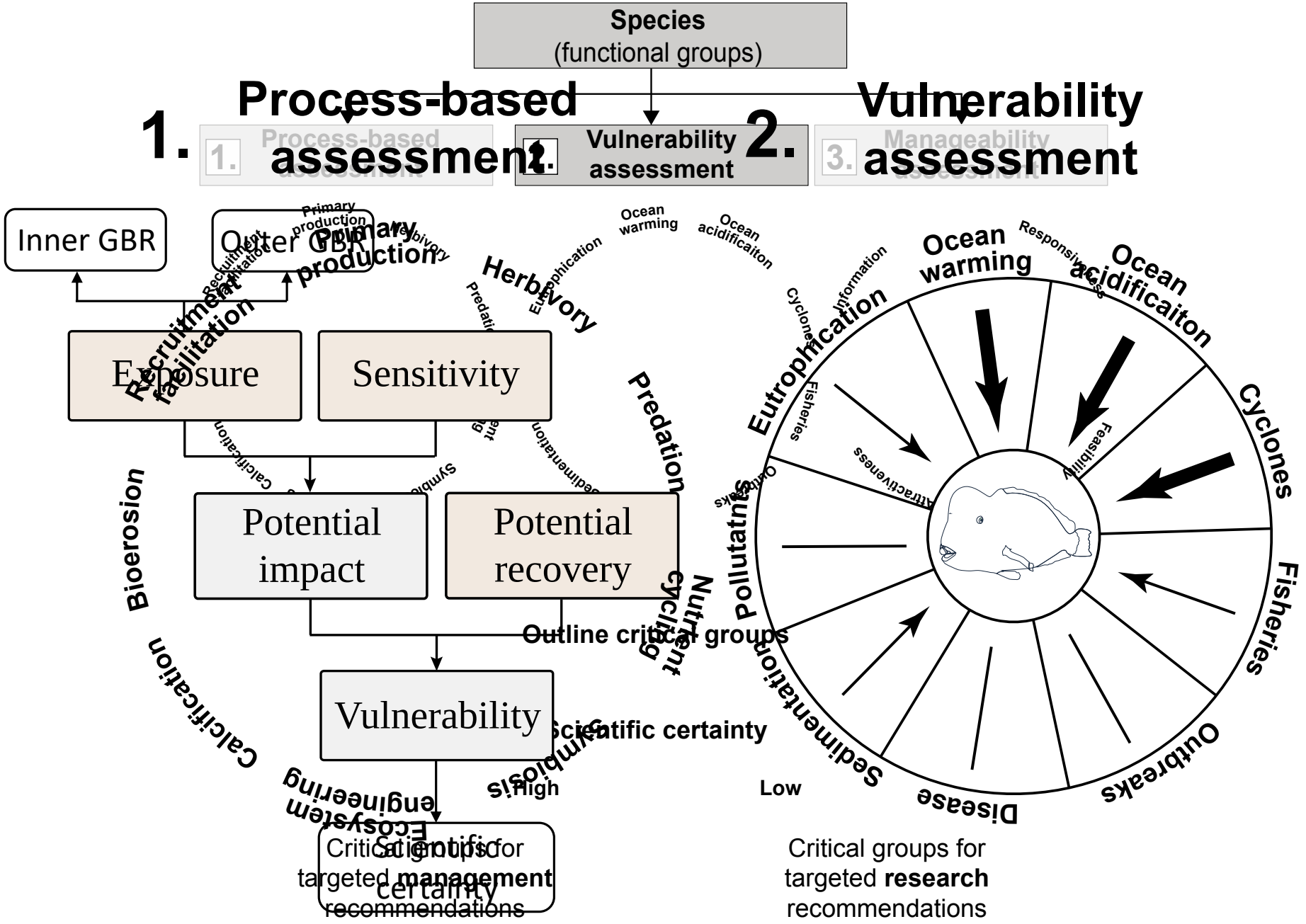
Calcification
Bioerosion
Ecosystem engineering
Recruitment facilitation

Critical groups for targeted **research** recommendations

(de Groot et al. 2002; Harborne et al. 2016)


(functional groups)
Species
(functional groups)
1. Process-based assessment
2. Vulnerability assessment
3. Manageability assessment
1.
assessment
2.
assessment
3.
Manag
asses
Primary production
Herbivory
Predation
Nutrient cycling
Symbiosis
Ecosystem engineering
Calcification
Bioerosion
Recruitment facilitation
Eutrophication
Ocean warming
Ocean acidification
Pollutatnts
Disease
Cycles
Fleshiness
Outbreaks
Attractiveness
Information
Responsiveness
Direct role
Indirect role
Redundancy
Dependency
Certainty
Functional importance
Immediate contribution
Facilitation / mediation
Low = irreplaceable
High = replaceable
Low = independent
High = relant
Weight final scores
Outline critical groups
Scientific certainty
High
Low
Critical groups for targeted management recommendations
Critical groups for targeted research recommendations

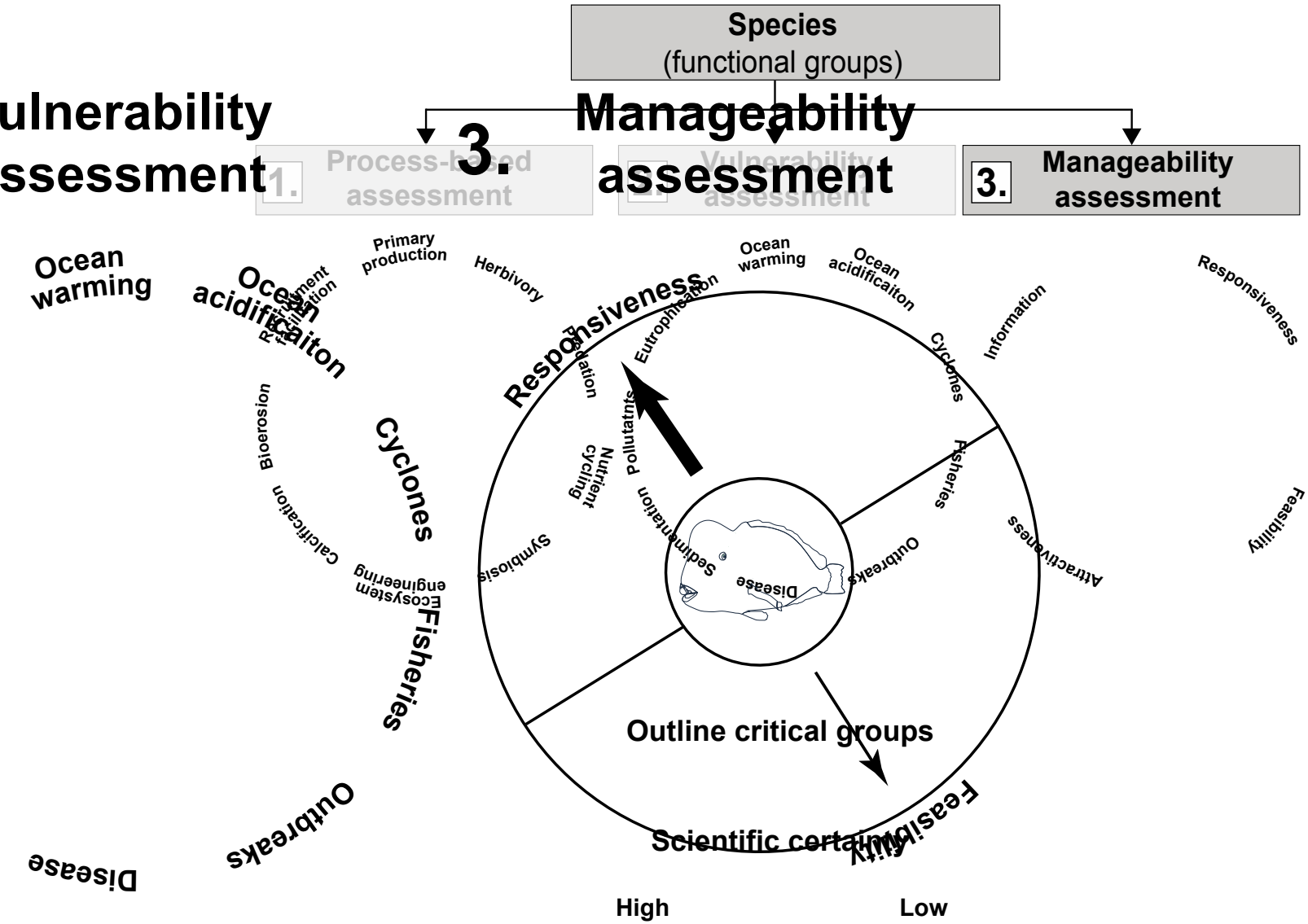

Species
(functional groups)
1. Process-based assessment
2. Vulnerability assessment
3. Manageability assessment
Primary production
Herbivory
Ocean warming
Ocean acidificaiton
Recruitment facilitation
Eutrophication
Information
Responsiveness
Predation
Protection
Intervention
(high priority)
Cyclones
Bioerosion
Nutrient cycling
Pollutatnts
Fisheries
Feasibility
Calcification
Sedimentation
Symbiosis
Disease
Outbreaks
Attractiveness
Ecosystem engineering
Vulnerability
Outline critical groups
Scientific certainty
Monitor
Intervention
(low priority)
High
Low
Functional importance
Critical groups for targeted management recommendations
Critical groups for targeted research recommendations


Species
(functional groups)
1. Process-based assessment
2. Vulnerability assessment
3. Manageability assessment
Inner GBR
Outer GBR
Primary production
Herbivory
Recruitment facilitation
Predation
Eutrophication
Ocean warming
Ocean acidificaiton
Cyclones
Fisheries
Pollutatnes
Disease
Outbreaks
Sedimentation
Bioerosion
Calcification
Ecosystem engineering
Symbiosis
Nutrient cycling
Exposure
Sensitivity
Potential impact
Potential recovery
Vulnerability
Scientific certainty
High
Low
Outline critical groups
Critical groups for targeted management recommendations
Critical groups for targeted research recommendations

(IPCC 2007)

ulnerability
ssessment

3. Manageability assessment



Manageable: (top 66-percentile) top candidates

Unmanageable: (bottom 33-percentile) innovative approaches

Critical groups for targeted **management** recommendations

Critical groups for targeted **research** recommendations

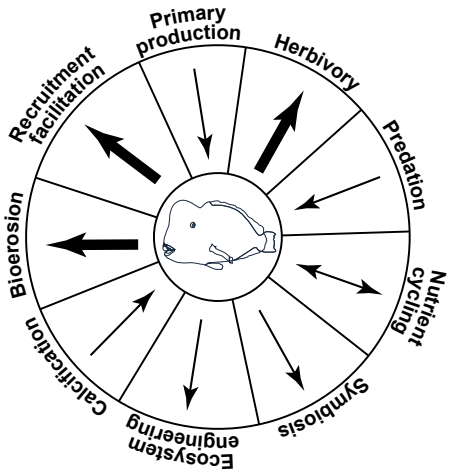
e critical groups

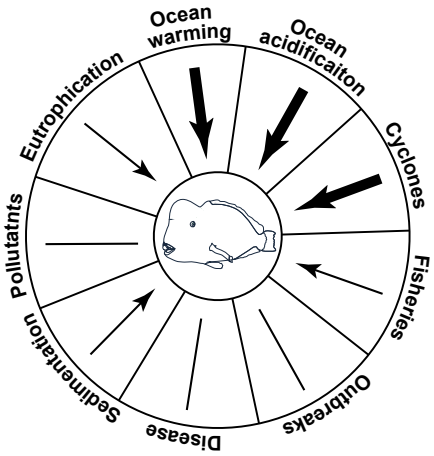
Species
(functional groups)

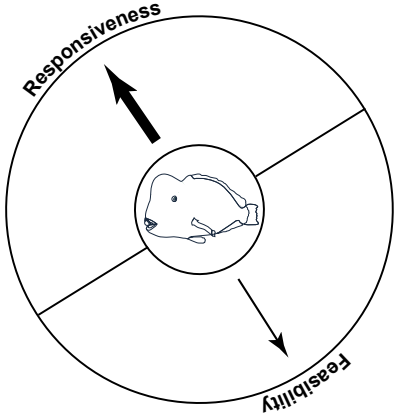
1. **Process-based assessment**

2. **Vulnerability assessment**

3. **Manageability assessment**





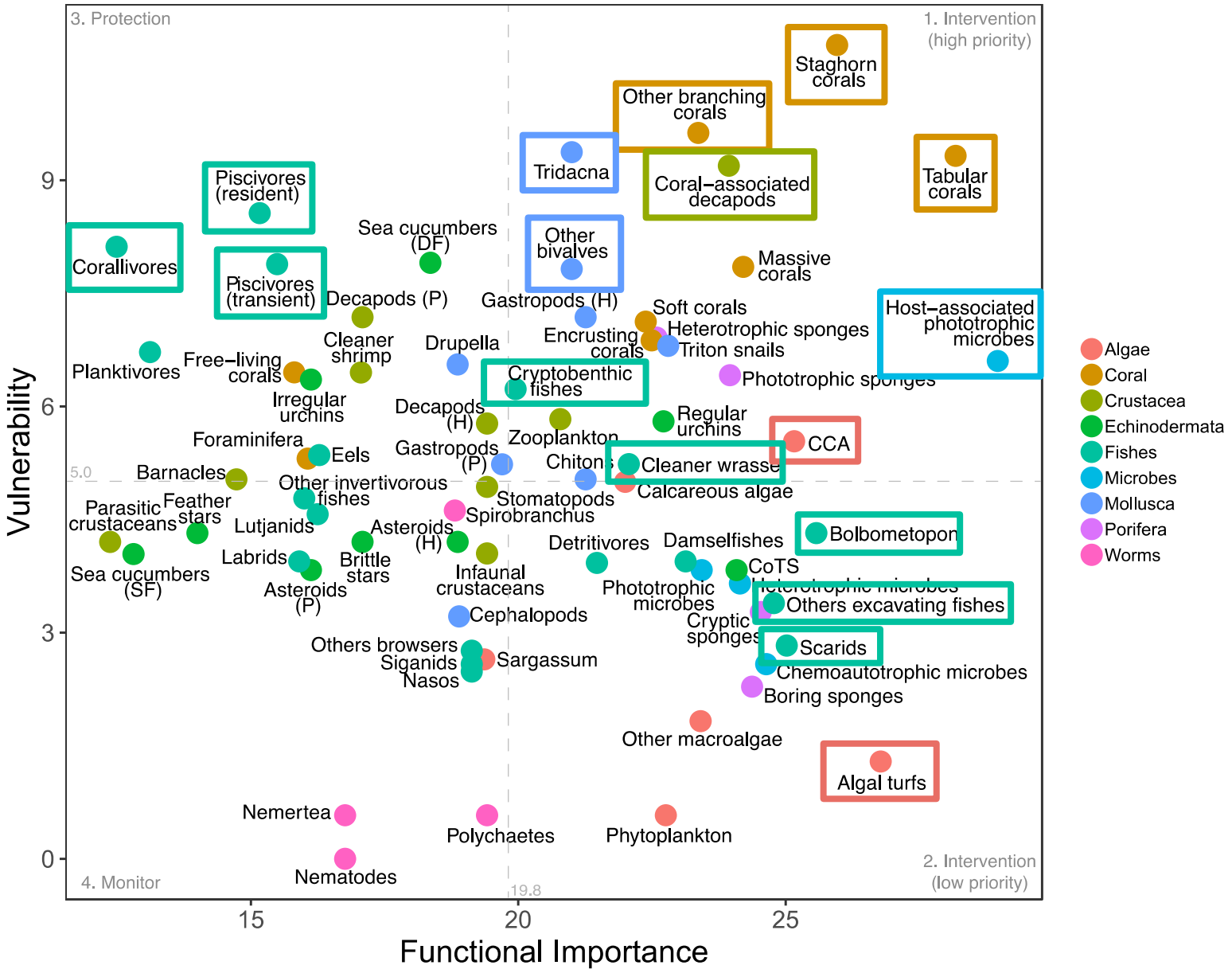


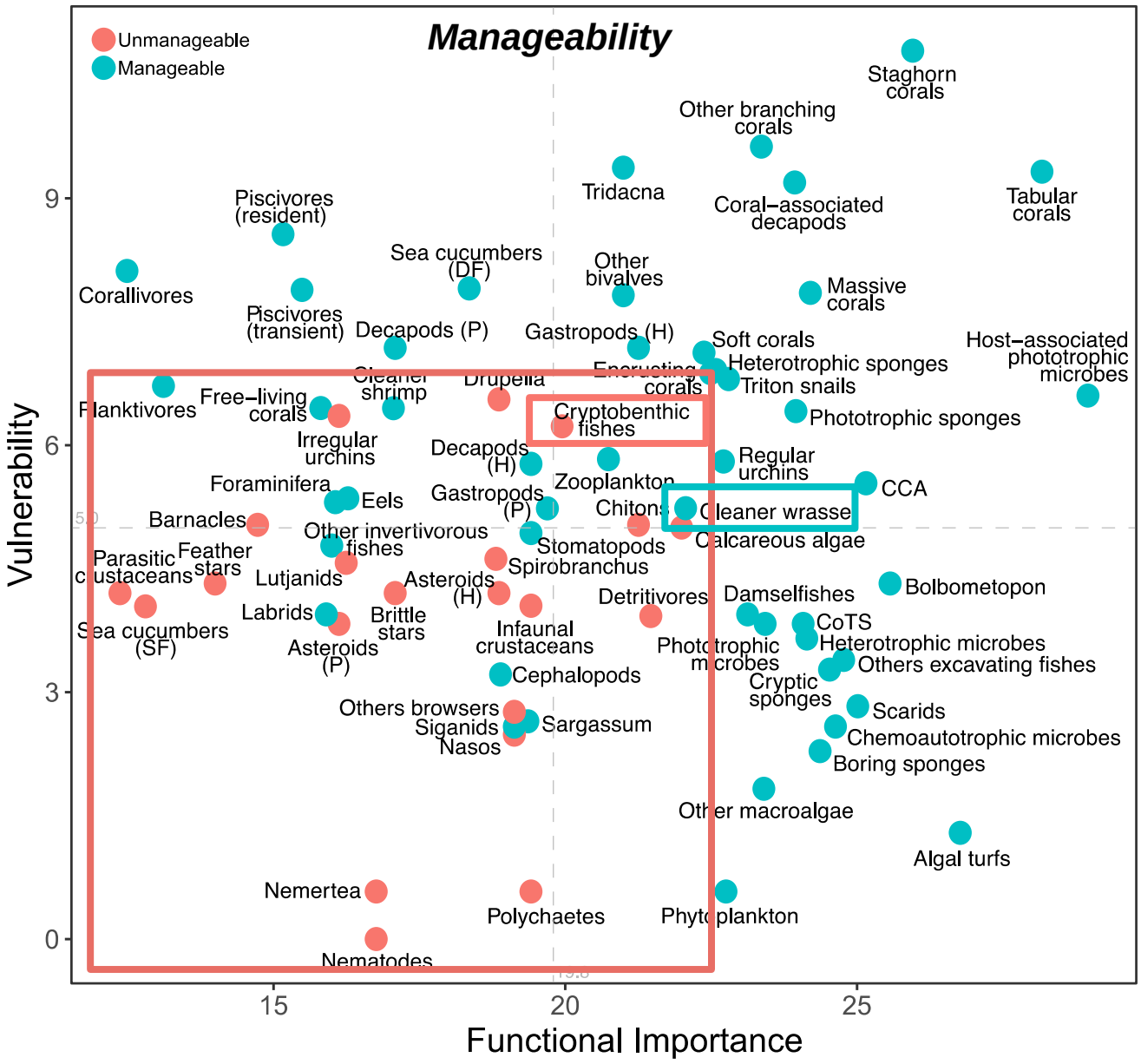
Outline critical groups

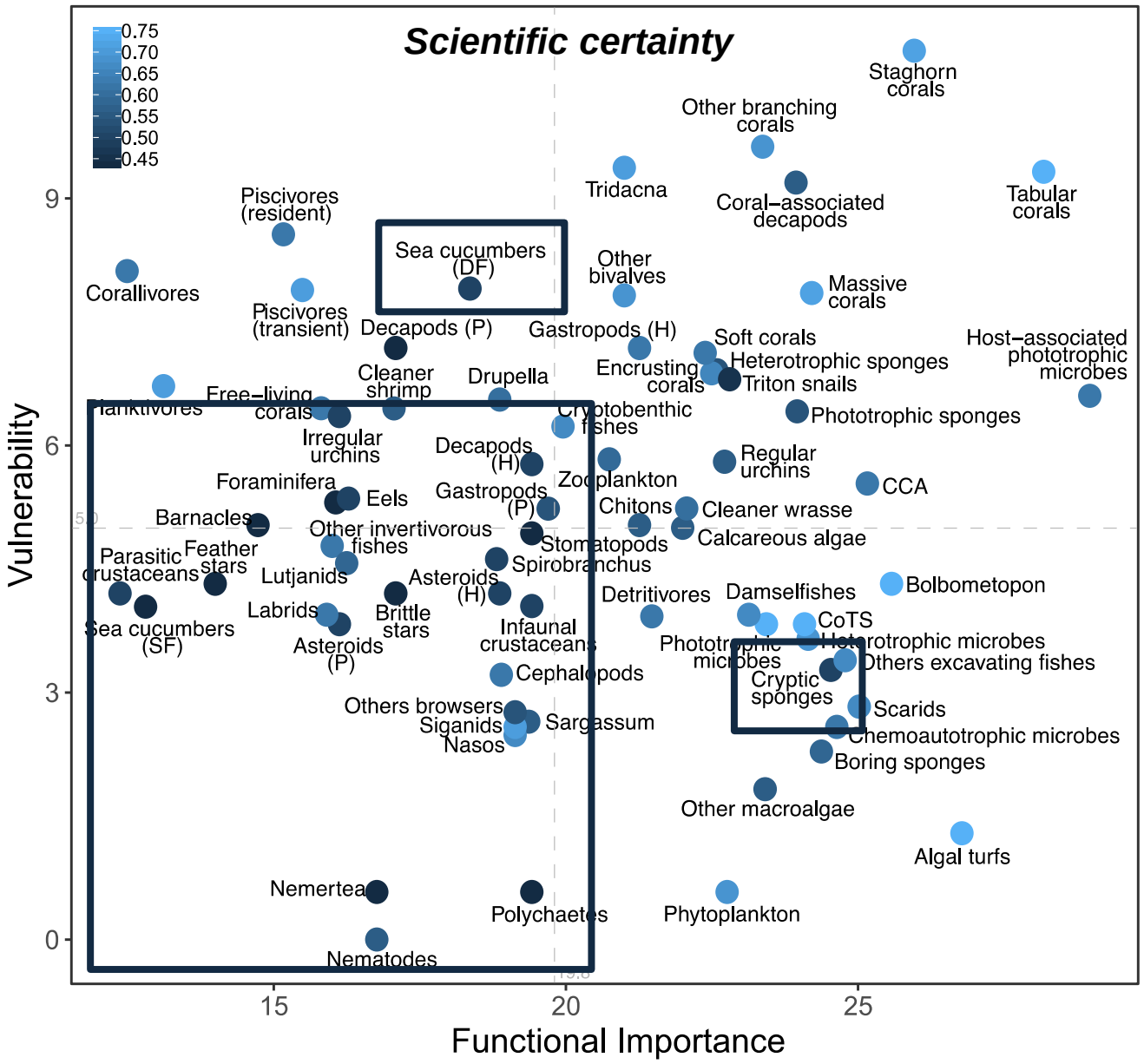
Scientific certainty

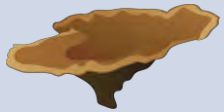
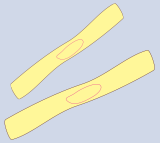
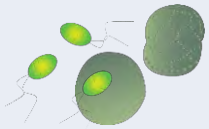
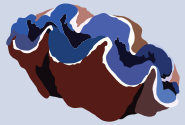
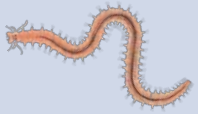
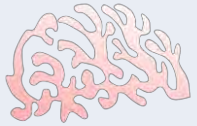
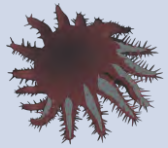
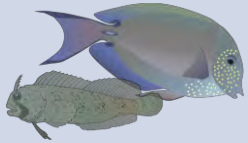
High — Critical groups for targeted **management** recommendations

Low — Critical groups for targeted **research** recommendations


3. Protection
1. Intervention
(high priority)
4. Monitor
2. Intervention
(low priority)
5.0
19.8
Vulnerability
Functional Importance
0
3
6
9
15
20
25
Staghorn corals
Other branching corals
Tridacna
Coral–associated decapods
Tabular corals
Piscivores (resident)
Sea cucumbers (DF)
Other bivalves
Massive corals
Corallivores
Piscivores (transient)
Decapods (P)
Gastropods (H)
Soft corals
Host–associated phototrophic microbes
Cleaner shrimp
Drupella
Encrusting corals
Heterotrophic sponges
Triton snails
Planktivores
Free–living corals
Cryptobenthic fishes
Phototrophic sponges
Irregular urchins
Decapods (H)
Regular urchins
Foraminifera
Eels
Gastropods (P)
Zooplankton
CCA
Barnacles
Chiton
Cleaner wrasse
Other invertivorous fishes
Calcareous algae
Stomatopods
Parasitic crustaceans
Feather stars
Spirobranchus
Lutjanids
Asteroids (H)
Detritivores
Damselfishes
Bolbometopon
Labrids
Brittle stars
CoTS
Sea cucumbers (SF)
Infaunal crustaceans
Phototrophic microbes
Asteroids (P)
Others excavating fishes
Cephalopods
Cryptic sponges
Others browsers
Scarids
Siganids
Sargassum
Chemoautotrophic microbes
Nasos
Boring sponges
Other macroalgae
Algal turfs
Nemertea
Polychaetes
Phytoplankton
Nematodes
Algae
Coral
Crustacea
Echinodermata
Fishes
Microbes
Mollusca
Porifera
Worms


Manageability
Unmanageable
Manageable
Vulnerability
Functional Importance
0
3
6
9
15
20
25
Staghorn corals
Other branching corals
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Cleaner shrimp
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Irregular urchins
Decapods (H)
Regular urchins
Foraminifera
Eels
Gastropods (P)
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Barnacles
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Other invertivorous fishes
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Bolbometopon
Labrids
Brittle stars
Infaunal crustaceans
CoTS
Sea cucumbers (SF)
Asteroids (P)
Phototrophic microbes
Heterotrophic microbes
Others excavating fishes
Cephalopods
Cryptic sponges
Others browsers
Scarids
Siganids
Sargassum
Chemoautotrophic microbes
Nasos
Boring sponges
Other macroalgae
Algal turfs
Nemertea
Polychaetes
Phytoplankton
Nematodes


Scientific certainty
0.75
0.70
0.65
0.60
0.55
0.50
0.45
Vulnerability
Functional Importance
0
3
6
9
15
20
25
Staghorn corals
Other branching corals
Tridacna
Coral–associated decapods
Tabular corals
Piscivores (resident)
Sea cucumbers (DF)
Other bivalves
Massive corals
Corallivores
Piscivores (transient)
Decapods (P)
Gastropods (H)
Soft corals
Host–associated phototrophic microbes
Cleaner shrimp
Drupella
Encrusting corals
Heterotrophic sponges
Triton snails
Free–living corals
Cryptobenthic fishes
Phototrophic sponges
Irregular urchins
Decapods (H)
Regular urchins
Foraminifera
Eels
Gastropods (P)
Zooplankton
CCA
Barnacles
Other invertivorous fishes
Chitons
Cleaner wrasse
Calcareous algae
Parasitic crustaceans
Feather stars
Stomatopods
Spirobranchus
Lutjanids
Asteroids (H)
Detritivores
Damselfishes
Bolbometopon
Labrids
Brittle stars
CoTS
Sea cucumbers (SF)
Infaunal crustaceans
Heterotrophic microbes
Asteroids (P)
Phototrophic microbes
Others excavating fishes
Cephalopods
Cryptic sponges
Others browsers
Scarids
Siganids
Sargassum
Chemoautotrophic microbes
Nasos
Boring sponges
Other macroalgae
Algal turfs
Nemertea
Polychaetes
Phytoplankton
Nematodes

The Winners	The Surprises	Uncertainty
Branching & tabular corals 	Chemoautotrophic microbes 	Eels and octopuses (cryptic predators) 
Microbial communities 	Cleaner wrasse 	Deposit-feeding sea cucumbers 
Crustose coralline algae (CCA) 	Bivalves 	Marine worms 
Algal turfs (EAM) 	Coral-associated crabs 	Cryptic sponges 
CoTS (triton snails) 	Detritivorous fishes 	Crustaceans 

Gaps in knowledge

1. **Invertivory** on the GBR: a poorly understood link in the trophic chain
   (Jessica Stella)

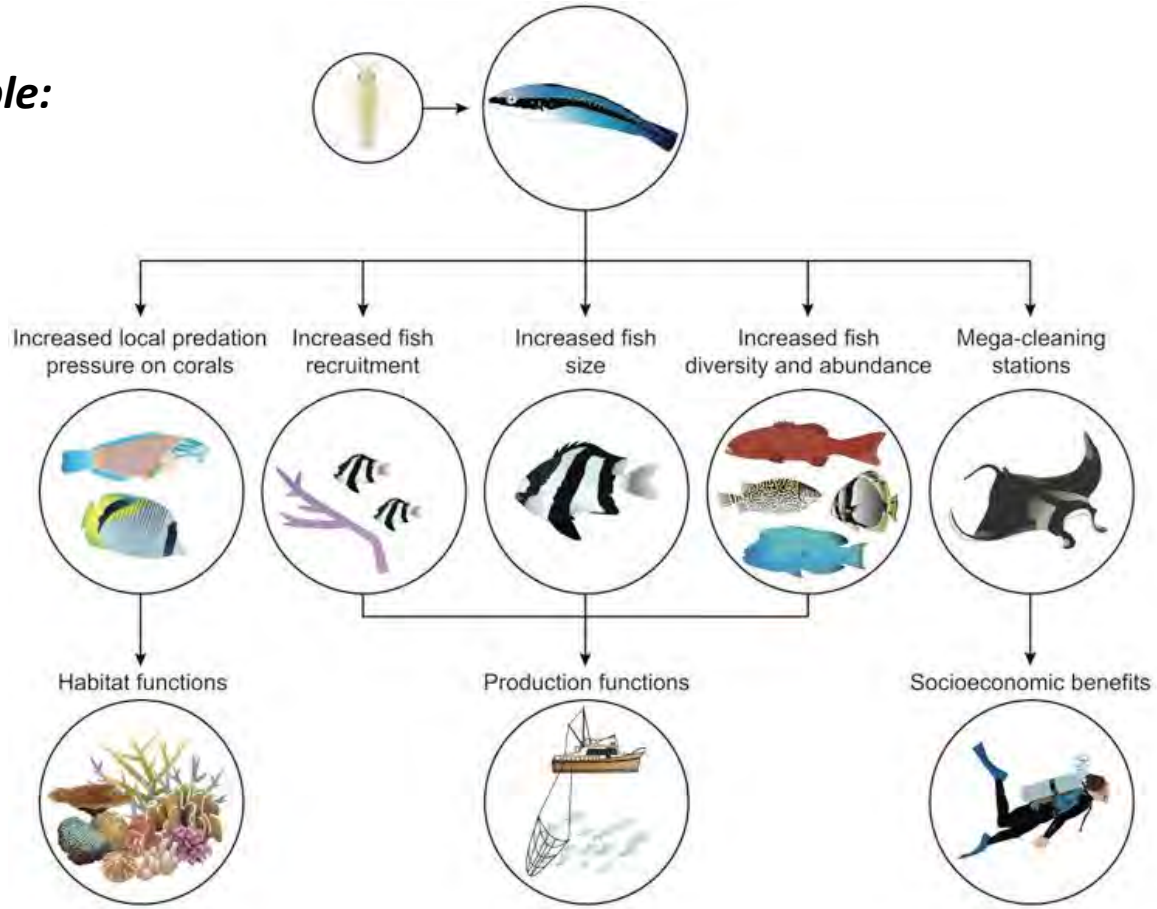
2. Calculating the **carbonate budget** for the GBR: coral cover and coralline growth
   (Guillermo Diaz-Pulido)

3. **Microbial communities** on the GBR: links to water quality parameters that indicate healthy reef systems
   (Nicole Webster, David Bourne)

4. Spatial patterns and functional impacts of **recreational spearfishing** on the GBR
   (Peter Mumby)

5. **Juvenile CoTS** "in waiting": the missing link in population and connectivity models
   (Maria Byrne)

Output example:



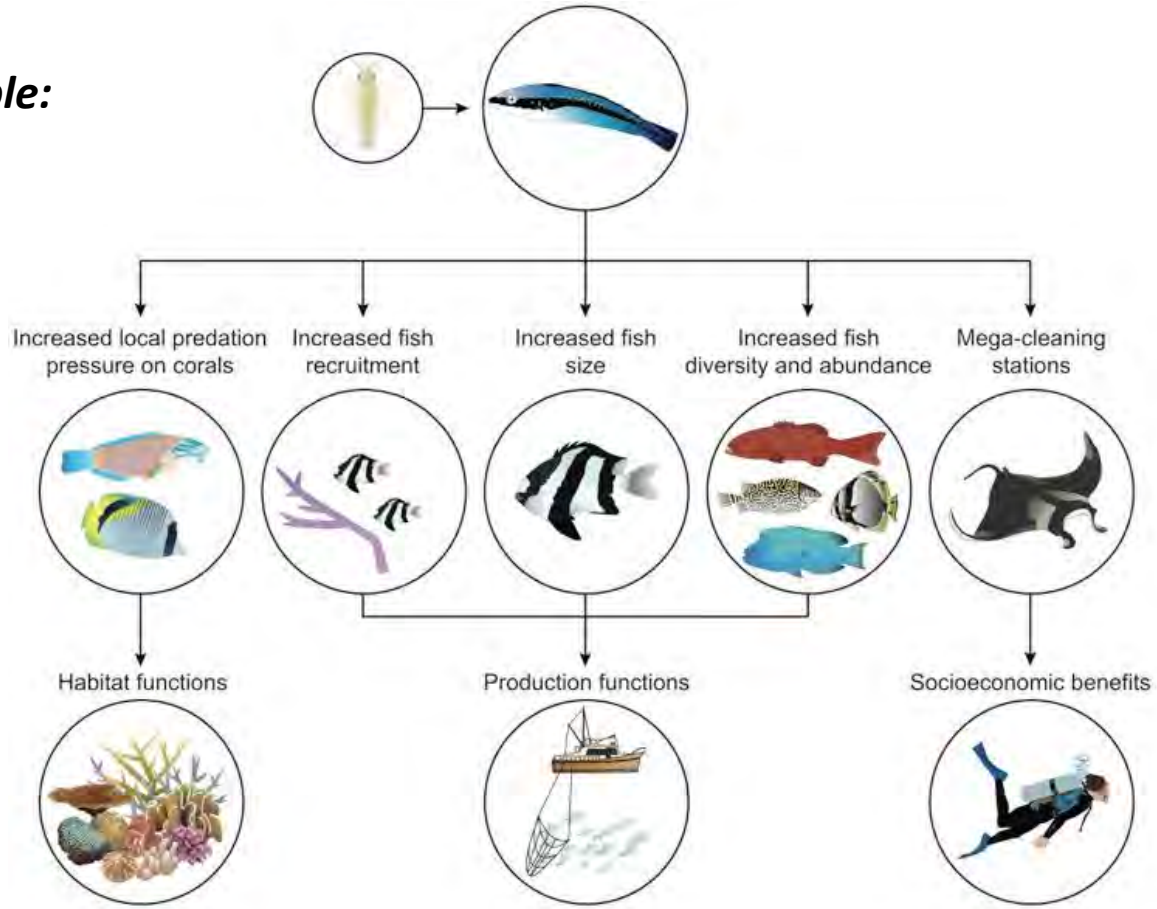
Management recommendations:

(1) Local-scale assessments might assign some high priority to **cleaners and cleaning stations as key features**, as outlined in the GBRMPA Blueprint for Resilience for herbivores and plating corals (GBRMPA 2017, 2018a).

(2) Optimise **involvement by tourist operators and citizen science groups** (e.g. Eye on the Reef) in reporting cleaning stations, and monitoring community dynamics.

(3) Identify "**mega stations**" (e.g. Lady Elliott Island) for integration into ecosystem monitoring and **tourism initiatives**.

Output example:

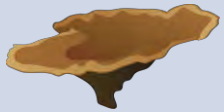
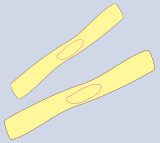
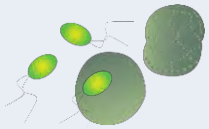
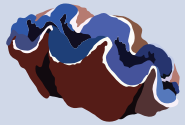
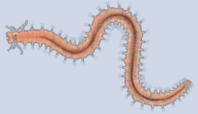
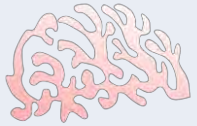
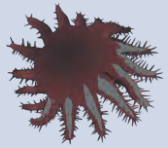
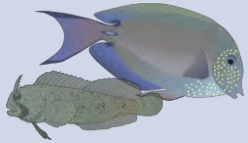


Science recommendations:

(1) Characterise how cleaners influence **reef resilience and health** beyond fish-fish interactions (i.e. coral growth, reef recovery).

(2) Understand how **environmental stressors** (e.g. bleaching) impact cleaners and their interactions.

(3) Quantify to what extent a **loss of cleaners** may affect reef functioning.

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National Environmental Science Programme

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Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/)

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