Seabed recovery on scallop grounds

Quantifying recovery rates and resilience of seabed habitats impacted by bottom fishing

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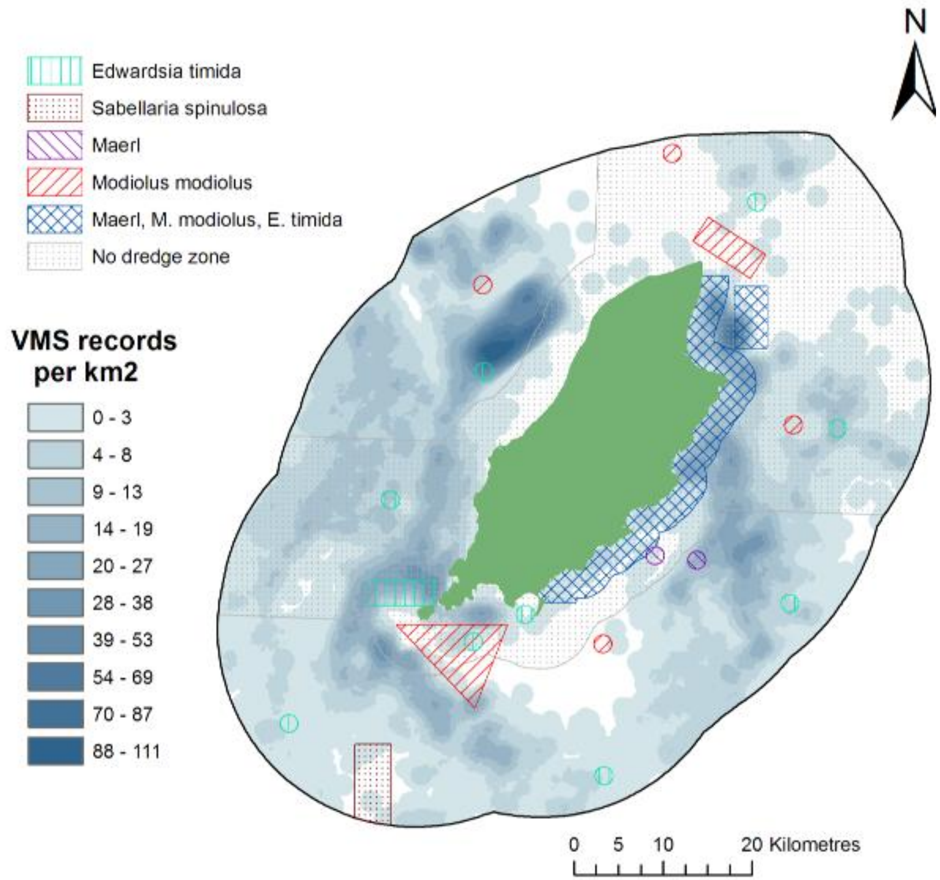
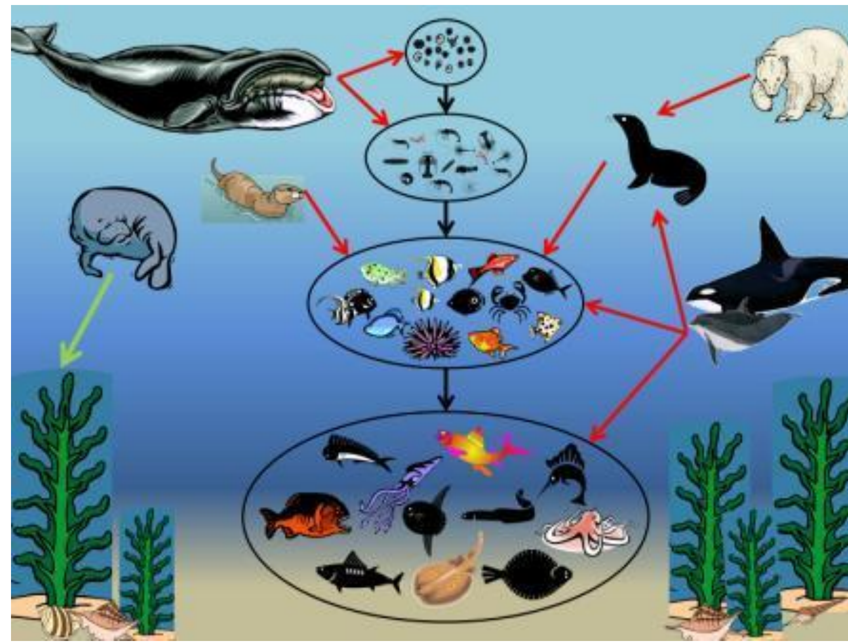
Scallop fishery



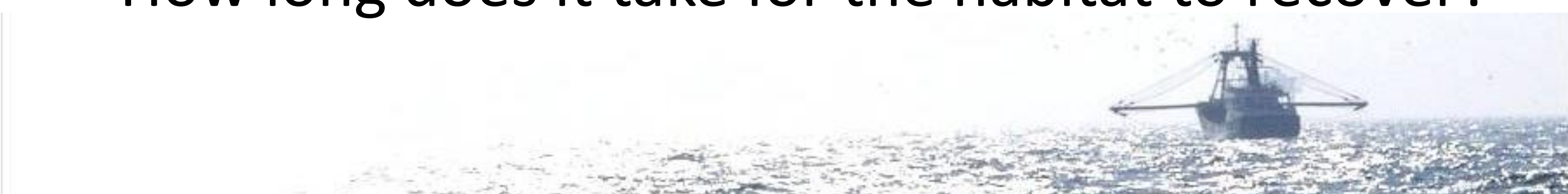
Ecosystem Approach to Fisheries – Habitat

- Can the seabed recover from dredging/trawling?

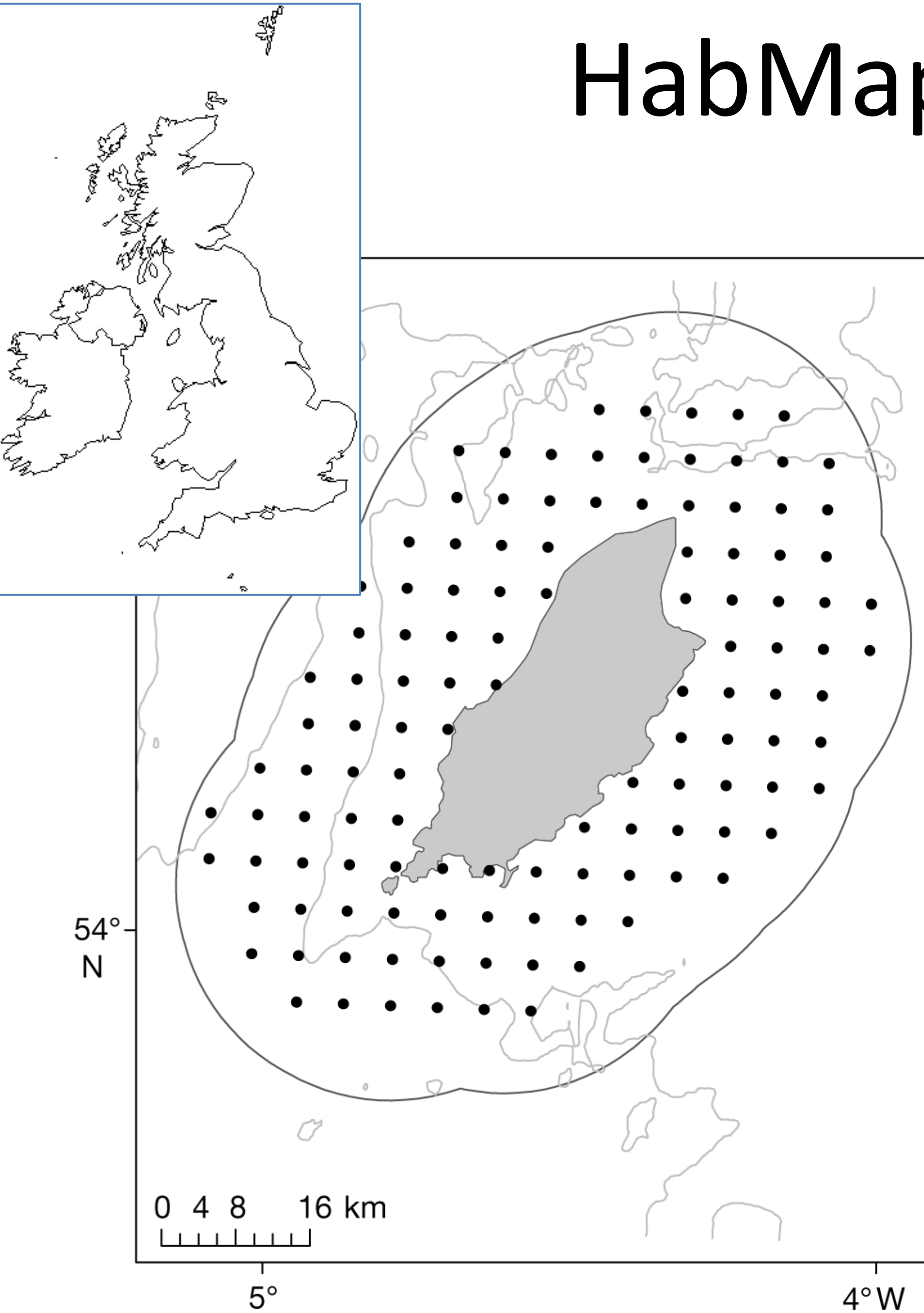


http://www.nefsc.noaa.gov/psb/NOEPS/NOEPSlessons.html#FW

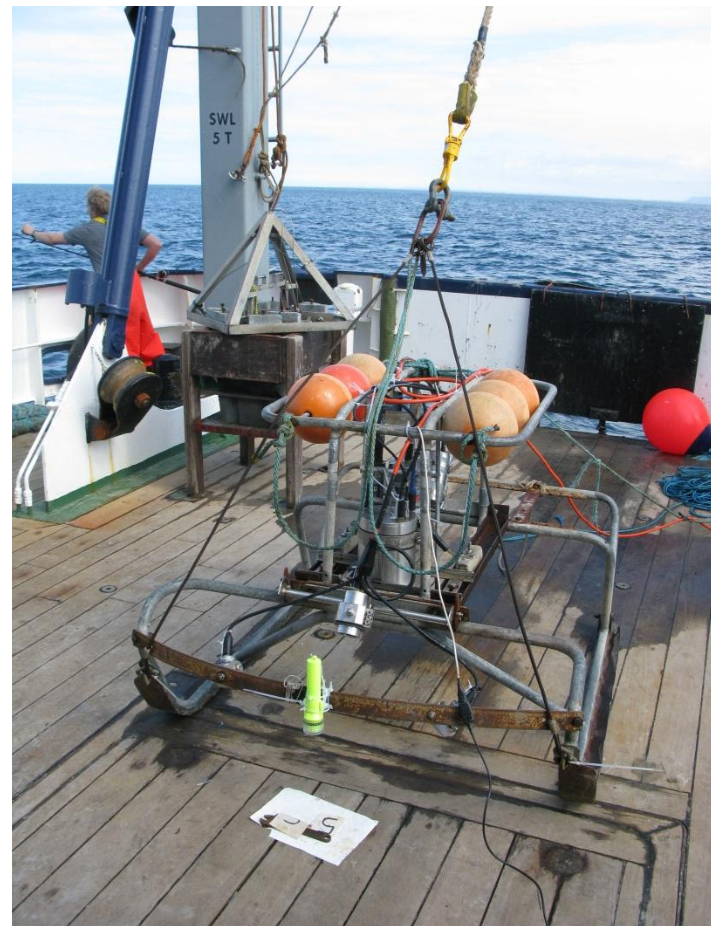
- Which non-target species are mostly affected?
- How long does it take for the habitat to recover?



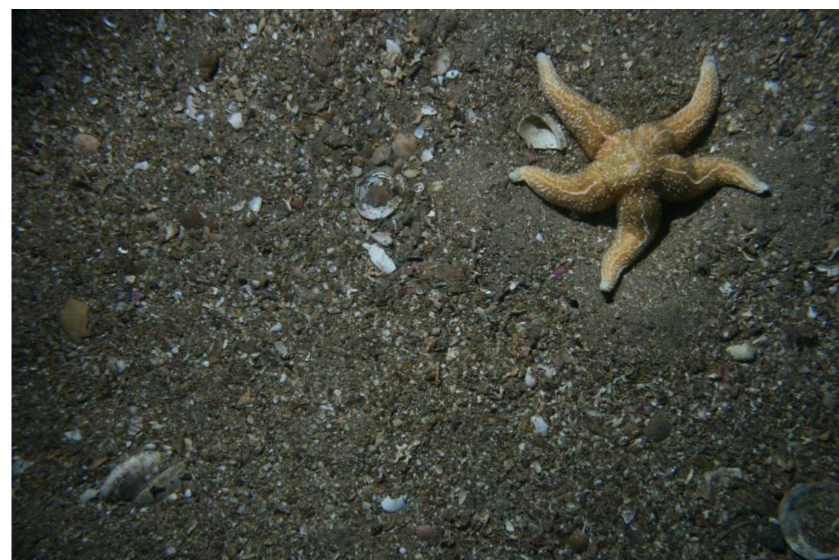
HabMap Survey



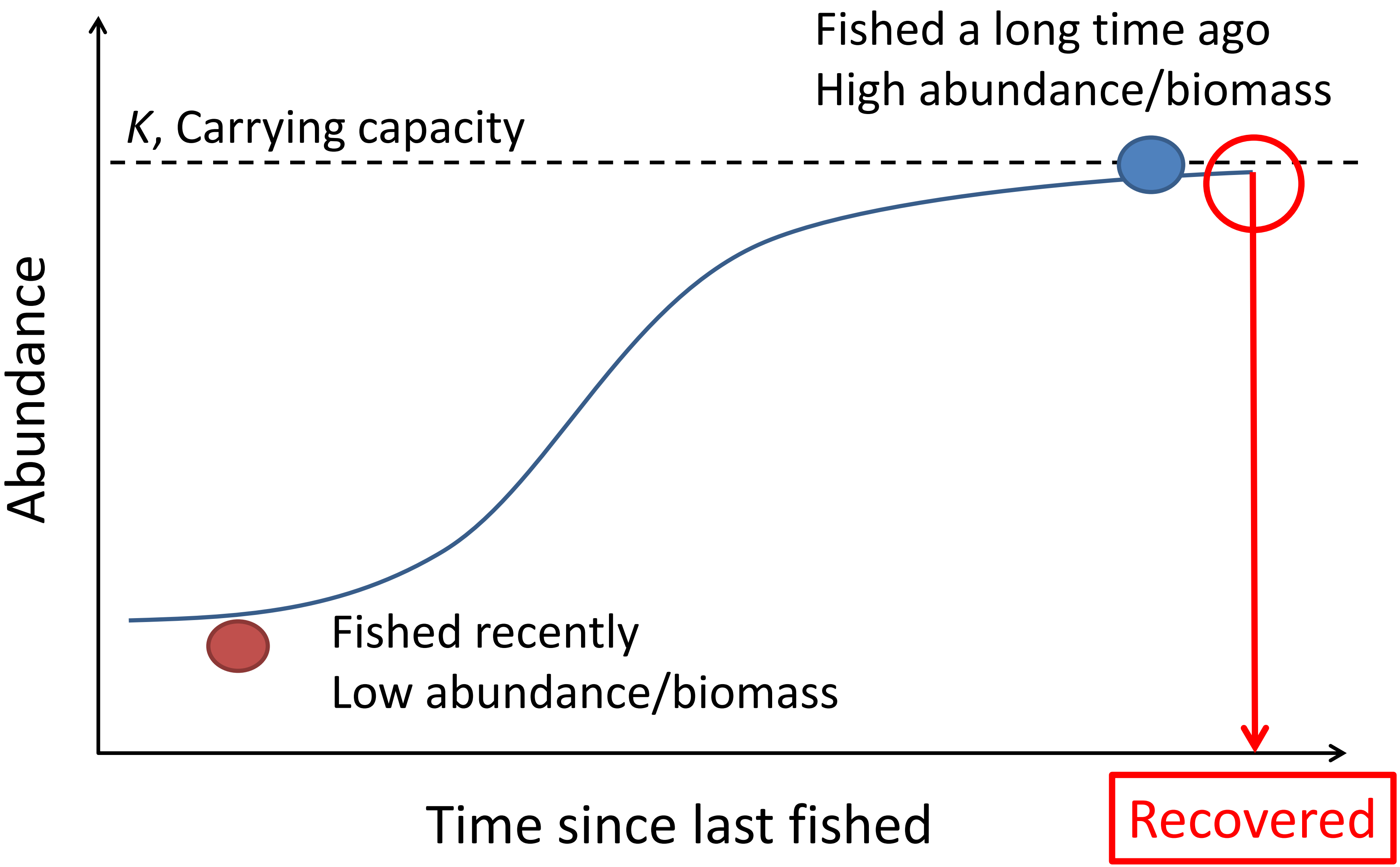
HabMap survey, Isle of Man – 2008 – Bangor University, Defa



HabMap Survey

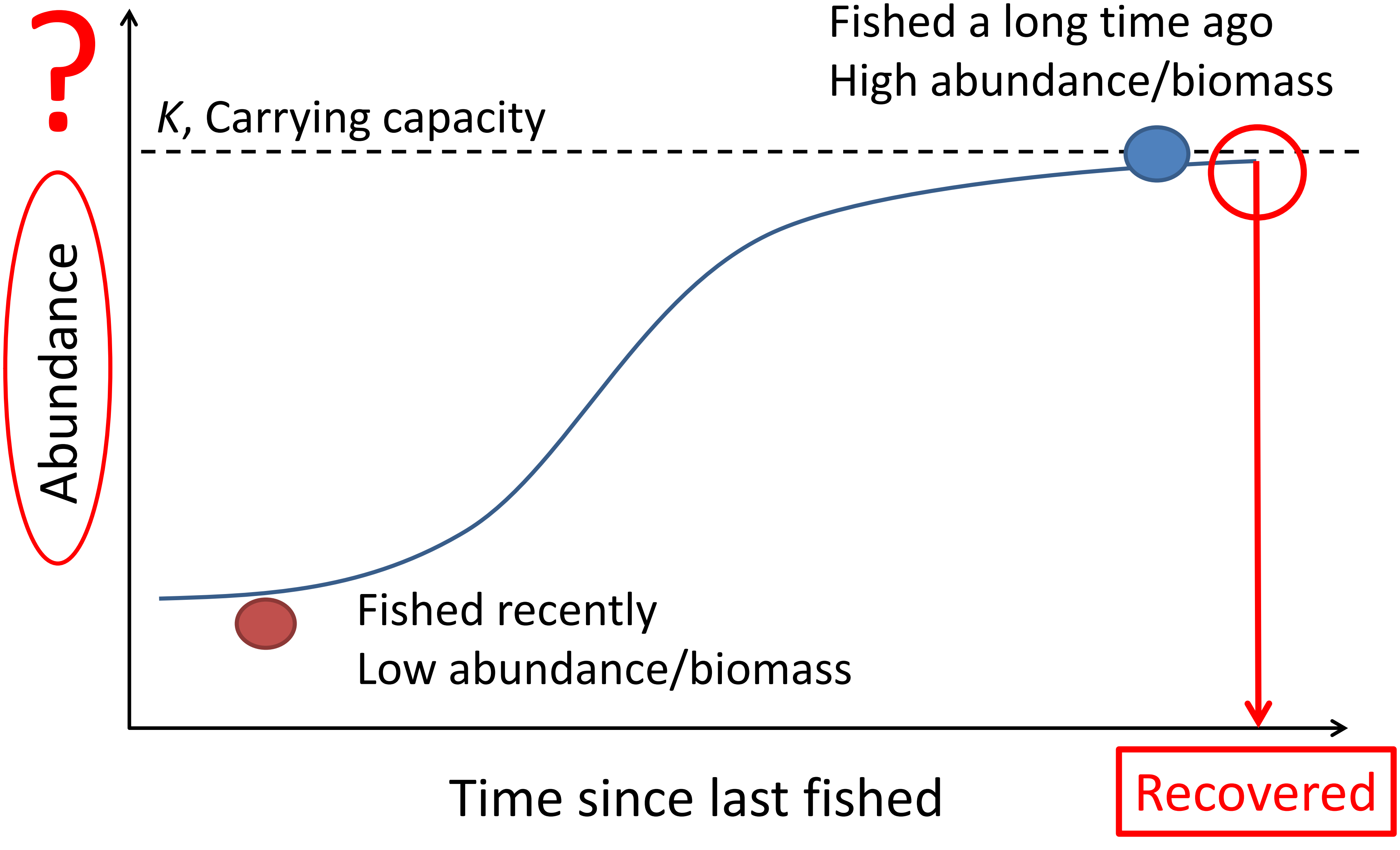


Theory



Fished a long time ago
High abundance/biomass
K, Carrying capacity
Abundance
Fished recently
Low abundance/biomass
Time since last fished
Recovered

Theory



?
Abundance
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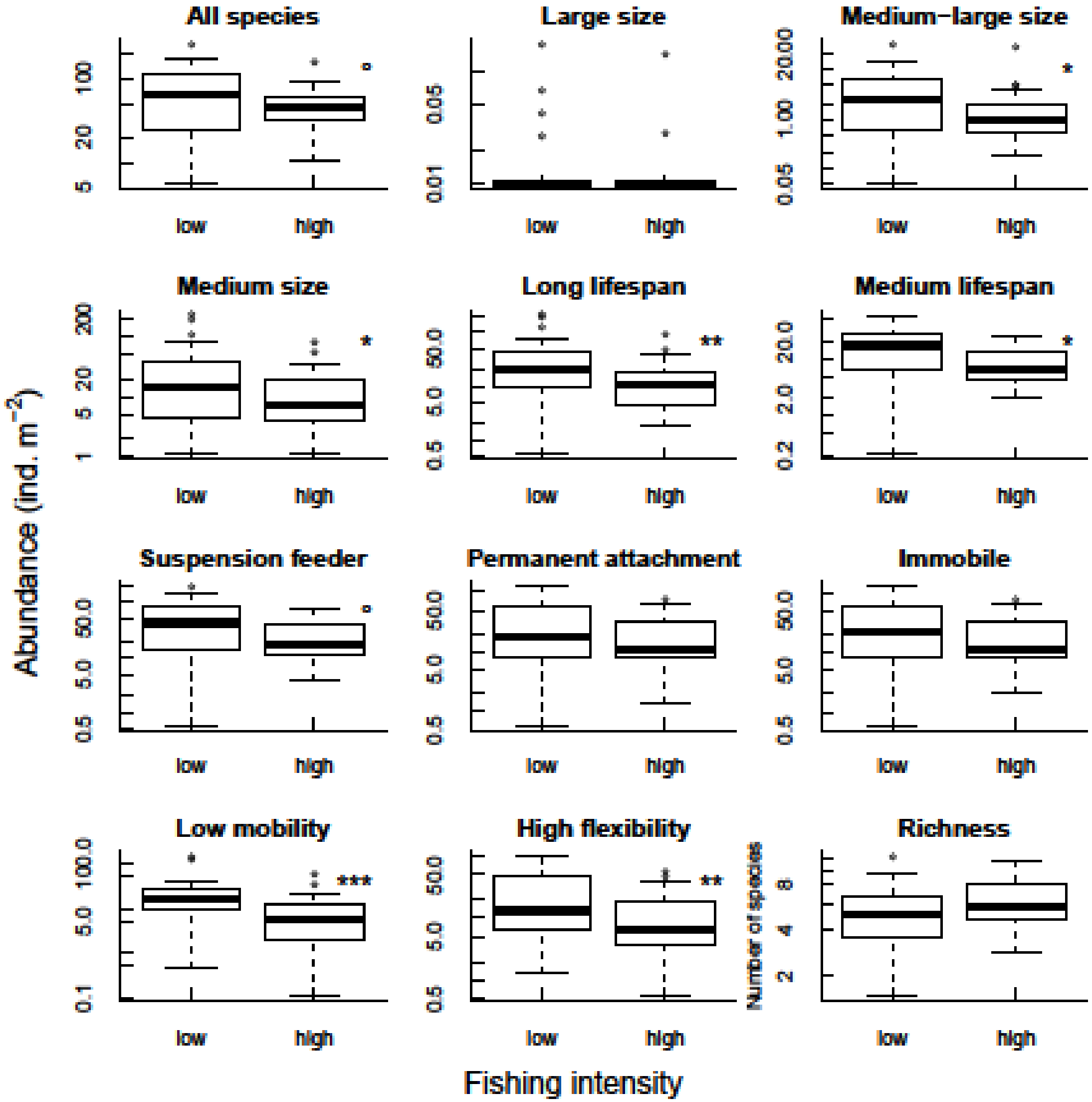
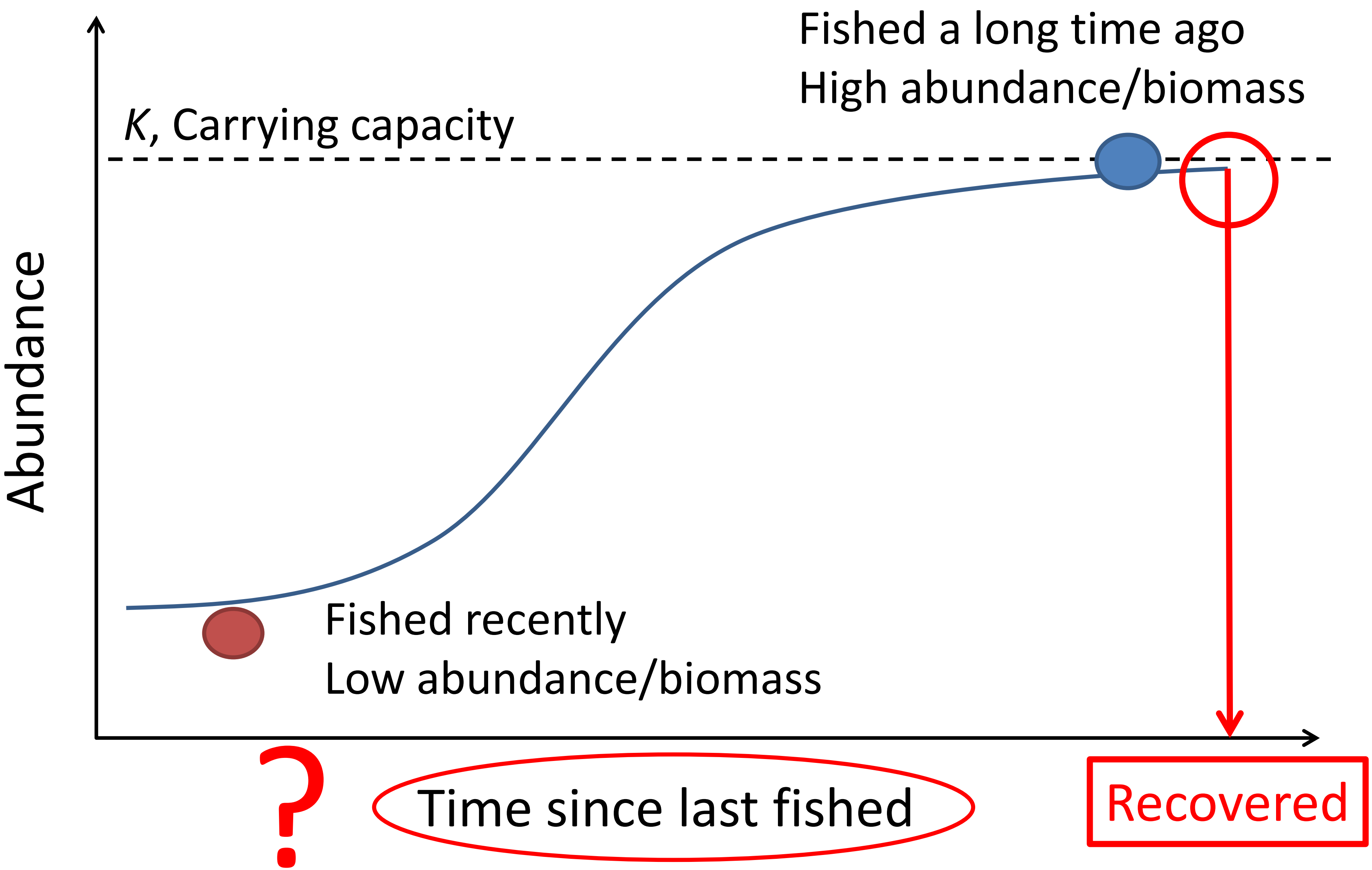
Defining sensitive traits in study area



<u>Sensitive traits to fishing:</u>

- Medium large size (21-50cm)
- Medium size (11-20cm)
- Long life span (>5yrs)
- Medium lifespan (3-5yrs)
- Suspension feeders
- Low mobility species
- High flexibility species

Theory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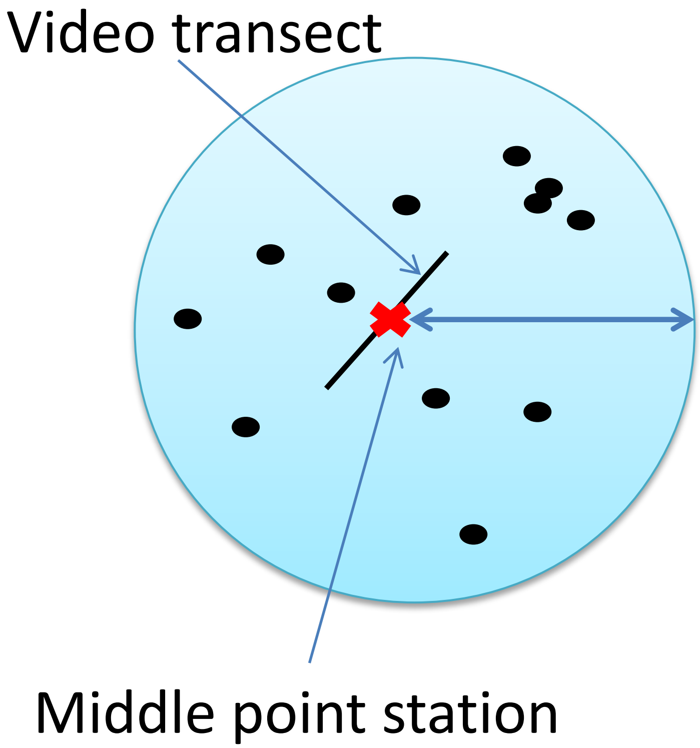
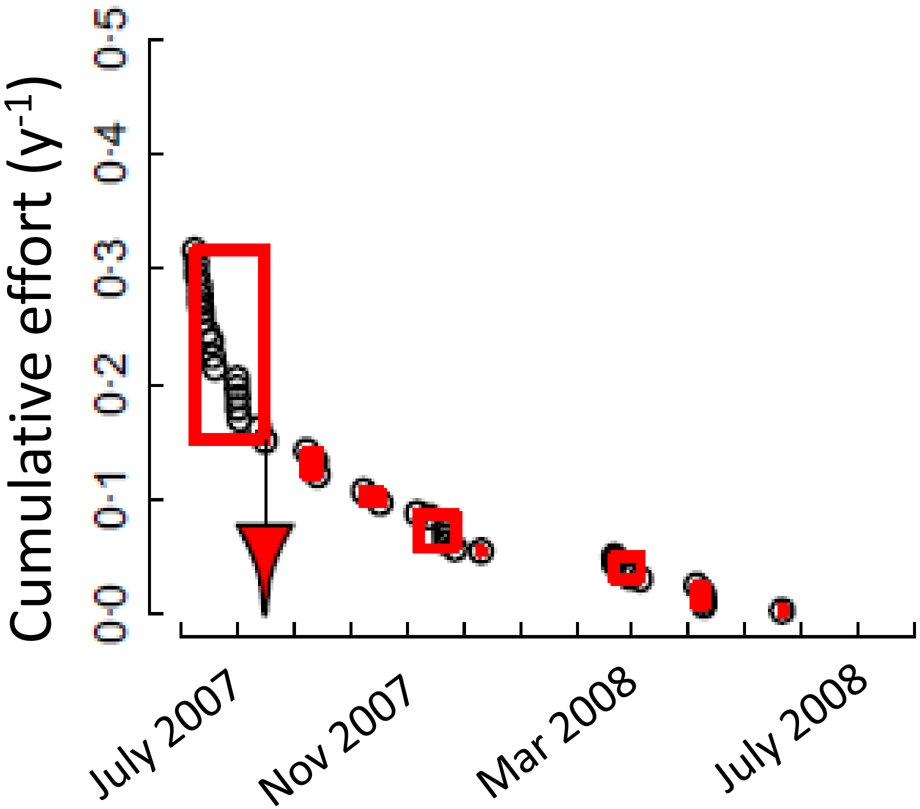
Finding last fishing event





Model

Recovery equation:

$$N = N_{t=0}/[N_{t=0}/K + e^{-rt}(1 - N_{t=0}/K)]$$

Parameters:

2 scenarios: *K* – Carrying capacity - Fixed or variable

Model selection:

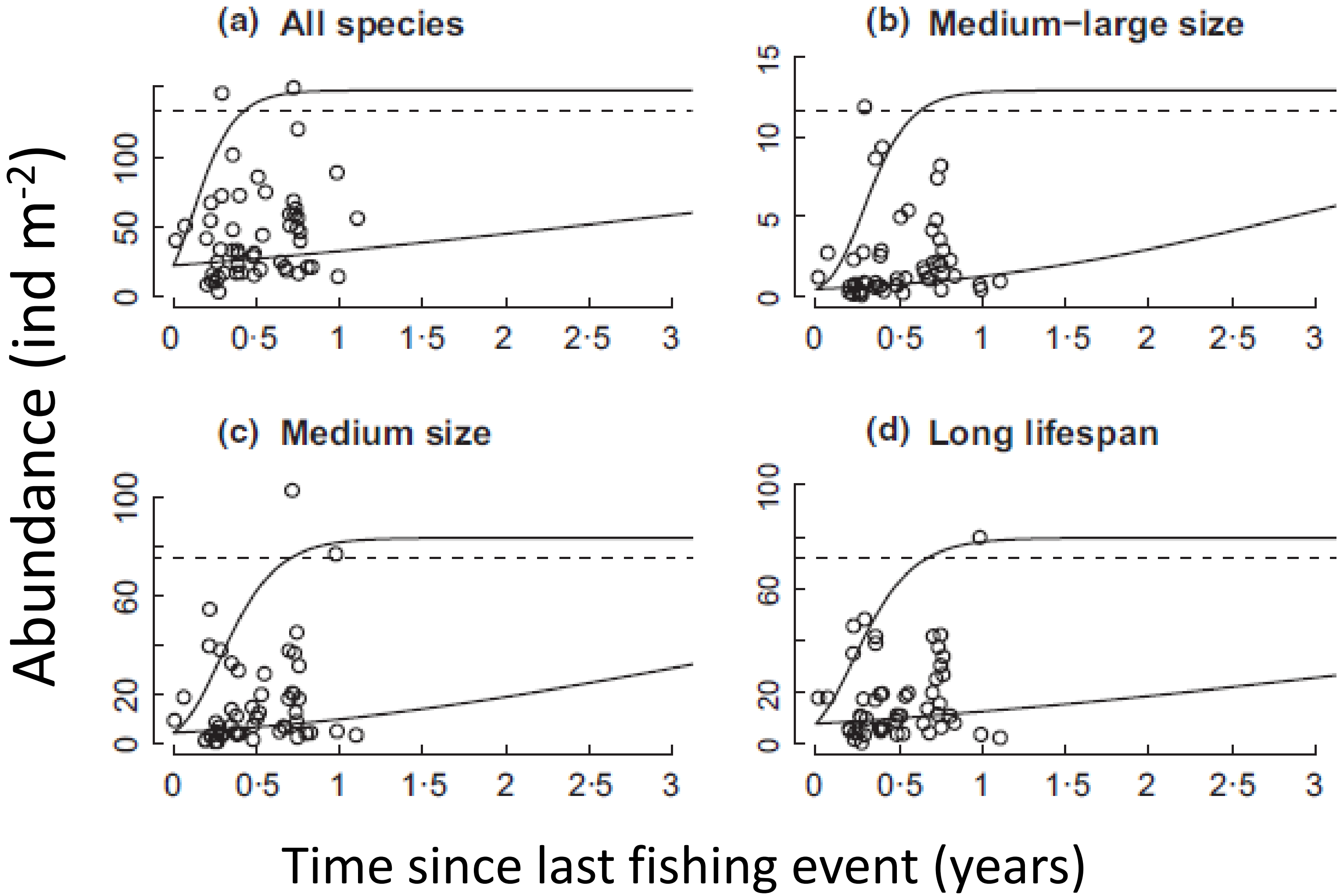
Nt=0 – Abundance at time 0

- intercept or random intercept (mixed effect model)
  - -> Fishing intensity
  - -> Substratum type

r – Growth parameter

- dependent on environmental covariate
  - -> *r = ax + b*, with x = tide, surrounding abundance or wave stress

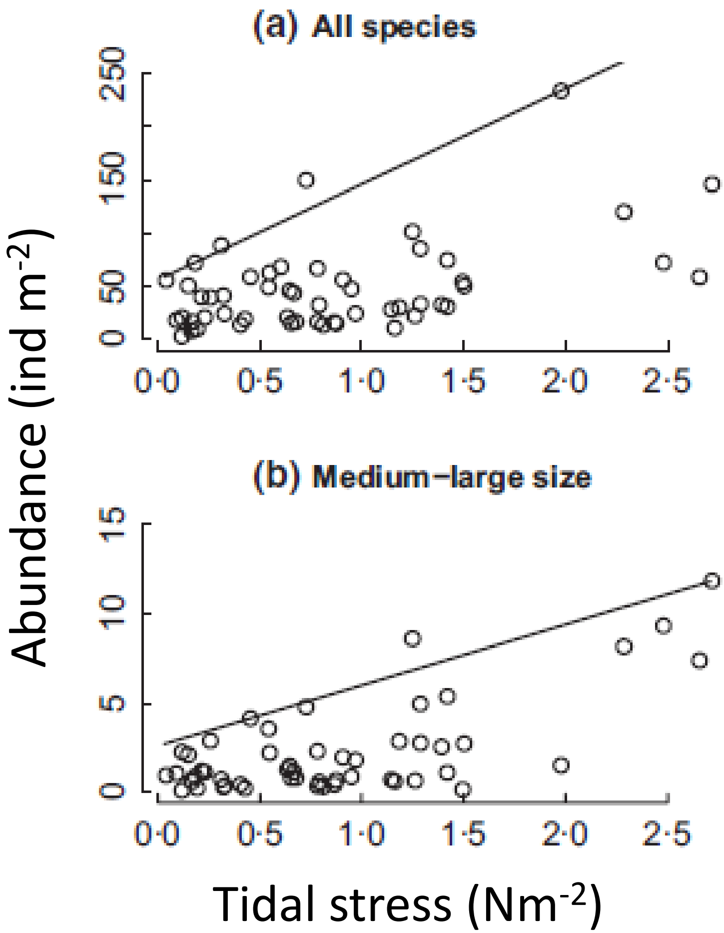
Results – Scenario 1 - FIXED *K*



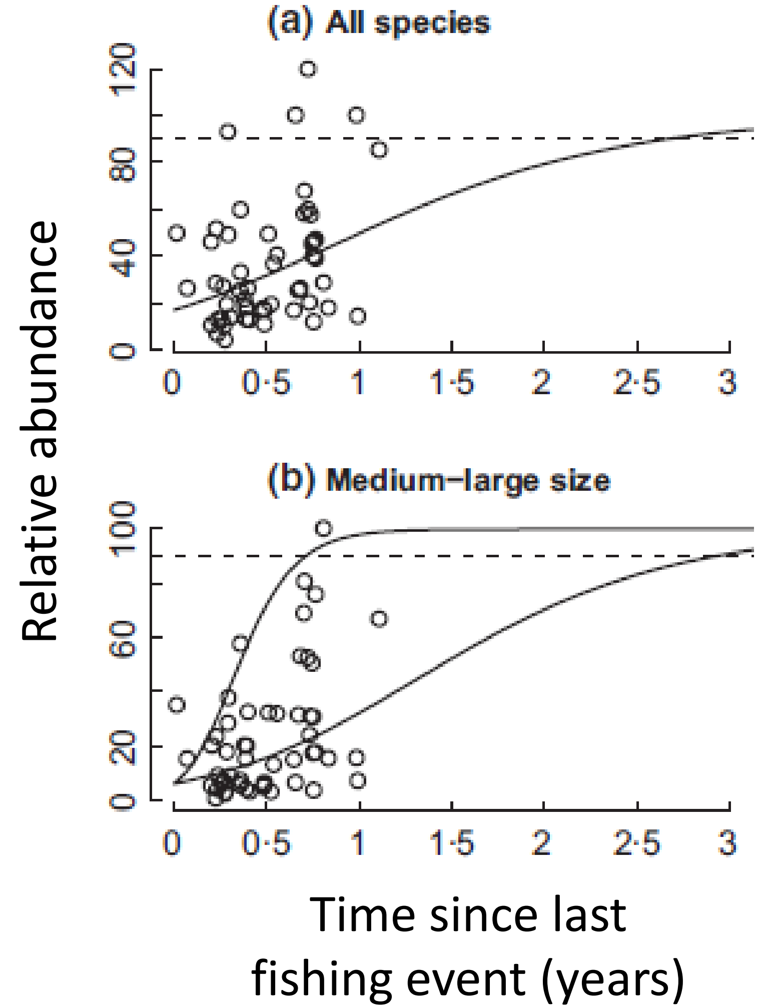
Here scale is 1km²

Results – Scenario 2 – VARIABLE *K*

1) Define K



2) Model recovery



Here scale is $1km^2$

Results – Parameters and recovery estimates

Response	Group	Scale (km^2)*	Model†	Covariate†‡	Random covariate†	$N_{t=0}$ (individuals m^{-2})¶	K¶	r ($\times 10^{-3}$) (day^{-1})‡	ΔAIC§	t_R (years)‡
Abundance (fixed K models)	All species	0·25	Mixed	Tidal velocity	Substratum	18·29 ± 2·24	147·63	0·97–29·37	14·15	0·3–9·1
		0·5	Nls	Tidal velocity		13·38	147·63	1·67–18·46	17·75	0·5–5·6
		1	Mixed	Tidal velocity	Substratum	22·02 ± 3·47	147·63	0·76–19·90	15·86	0·4–11·2
	Medium-large size *spp.*	0·25	Mixed	Tidal velocity	Fishing intensity	0·32 ± 0·02	12·90	1·5–45·43	18·38	0·3–7·8
		0·5	Mixed	Tidal velocity	Substratum	0·57 ± 0·3	12·90	1·76–16·65	21·66	0·6–6·2
		1	Mixed	Tidal velocity	Substratum	0·44 ± 0·03	12·90	1·69–17·88	14·24	0·6–6·6
	Medium size *spp.*	0·25	Nls	Tidal velocity		3·15	83·32	1·35–22·06	9·50	0·5–7·9
		0·5	Nls	Tidal velocity		2·55	83·32	2·24–13·97	14·94	0·8–4·9
		1	Mixed	Tidal velocity	Substratum	4·44 ± 1·25	83·32	1·23–14·46	12·84	0·7–8·2
	Long life span *spp.*	0·25	Mixed	Tidal velocity	Substratum	7·22 ± 2·13	79·51	0·66–35·35	8·59	0·3–>12
		0·5	Mixed	Tidal velocity	Substratum	7·14 ± 1·91	79·51	0·97–12·49	9·71	0·8–9·7
		1	Mixed	Tidal velocity	Substratum	7·84 ± 2·53	79·51	0·80–13·90	10·67	0·7–11·6
	Medium life span *spp.*	0·25	Mixed	Tidal velocity	Substratum	5 ± 0·47	41·64	0·57–59·84	18·08	0·2–>12
		0·5	Mixed	Tidal velocity	Substratum	4·76 ± 0·66	41·64	0·85–42·19	24·35	0·2–10·7
		1	Mixed	Tidal velocity	Substratum	5·19 ± 0·56	41·64	0·62–50·55	22·73	0·2–>12
	Suspension feeding *spp.*	0·25	Mixed	Tidal velocity	Fishing intensity	6·69 ± 0·75	100·80	1·82–23·01	12·20	0·4–5·4
		0·5	Nls	Tidal velocity		5·92	100·80	2·65–14·54	17·37	0·7–3·8
		1	Nls	Tidal velocity		8·05	100·80	1·88–15·40	12·80	0·6–5·1
	High body flexibility *spp.*	0·25	Mixed	Tidal velocity	Fishing intensity	3·63 ± 0·43	61·92	0·91–21·71	13·61	0·5–11
		0·5	Nls	Tidal velocity		2·48	61·92	2·00–18·13	22·65	0·6–5·3
		1	Mixed	Tidal velocity	Fishing intensity	4·27 ± 0·58	61·92	0·94–17·17	18·61	0·6–10·5
	Low mobility *spp.*	0·25	Nls	Tidal velocity		3·18	42·35	0·36–167·4	10·16	0·1–>12
		0·5	Mixed	Tidal velocity	Substratum	4·63 ± 0·93	42·35	0·07–639·97	9·77	0–>12
		1	Mixed	Tidal velocity	Substratum	4·61 ± 1·04	42·35	0·07–596·73	10·72	0–>12
Relative abundance (variable K models)	All species	0·25	Nls	None		14·79	100·00		5·21	2·5
		0·5	Nls	None		14·57	100·00		7·04	2·3
		1	Nls	None		16·98	100·00		5·33	2·7
	Medium-large size *spp.*	0·25	Nls	Abundance		7·55	100·00	2·67–4·00	3·13	2·7–4
		0·5	Nls	Wave		7·88	100·00	3·19–13·49	12·82	0·8–3·3
		1	Nls	Wave		6·18	100·00	3·77–15·52	17·73	0·7–2·9
	Medium life span *spp.*	ALL	Null model is better							
	High body flexibility *spp.*	0·25	Nls	None		10·39	100·00	2·76	12·82	3·6
		0·5	Nls	Wave		7·99	100·00	3·59–12·68	17·73	1–2·9
		1	Nls	Wave		8·35	100·00	3·31–14·37	12·82	0·9–3·1

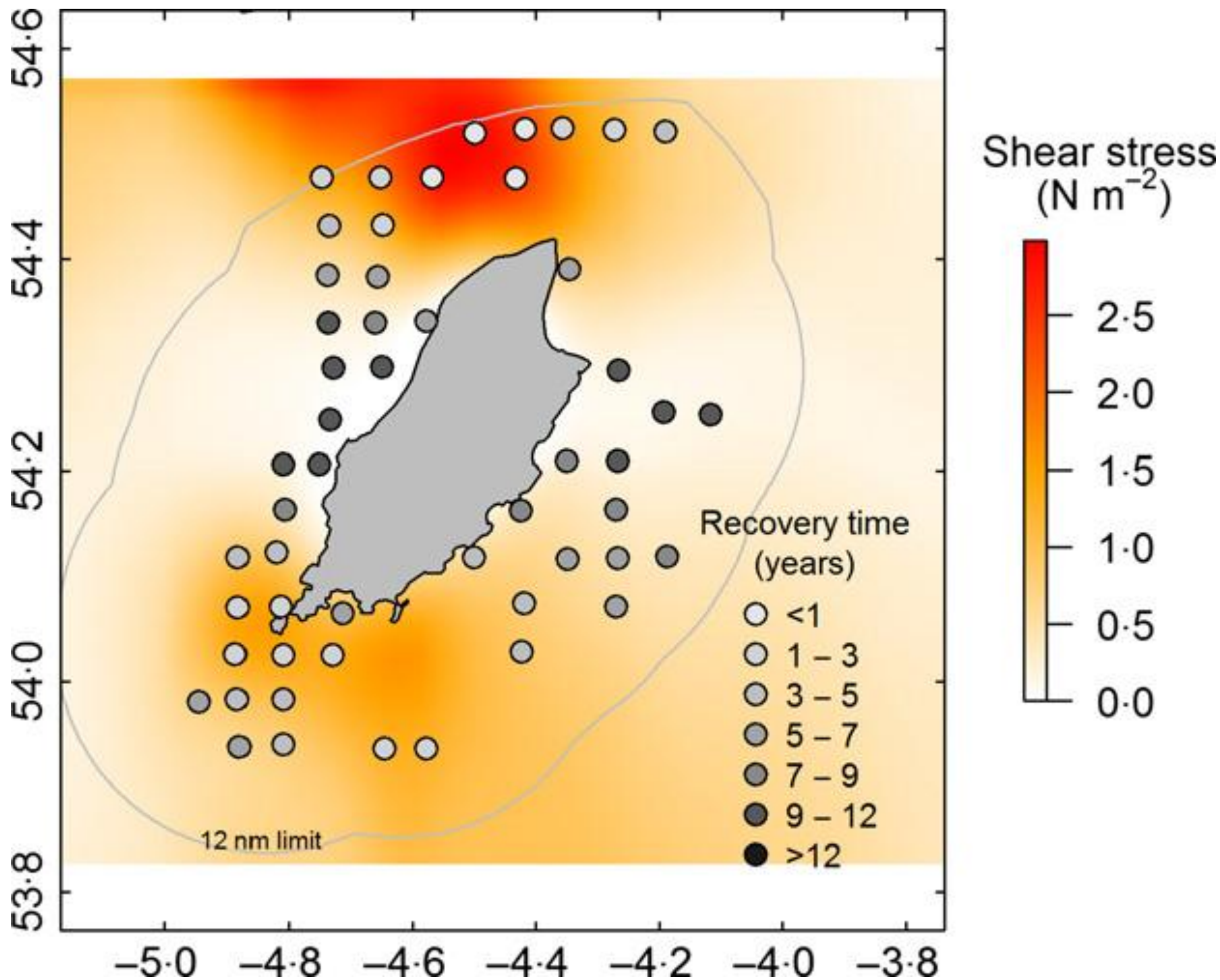
Zoom on results – Recovery estimates – Abundance (0.25km^2)

Species group	Recovery time
All species	0.3 – 9.1
Medium – large size species	0.6 – 6.2
Medium size species	0.5 – 7.9
Long life span species	0.3 - >12
Medium life span species	0.2 - >12
Suspension feeding species	0.4 – 5.4
High body flexibility species	0.5 - 11
Low mobility species	0.1 - >12

Zoom on results – Recovery estimates – Relative abundance (0.25km^2)

Species group	Recovery time	r covariate
All species	2.5 *(0.3 – 9.1)*	None
Medium – large size species	2.7 – 4 *(0.6 – 6.2)*	Local abundance
Medium life span species	NA	
High body flexibility species	3.6 *(0.5 – 11)*	None

Results –
Mapping out sensitivity for management



Ideas for management

- Do not close areas of high effort if it will be displaced to more sensitive areas
- If closing areas of low K and/or long recovery rates – maybe won't be successful
- If local abundance is important for recovery – close areas of potentially high abundance and/or quick recovery
- If rotational fishery is an option – fish in areas which recover quicker and close them for recovery as long as needed

- Best practice for scallop ground habitat management?
  - Forget about areas of low K/ long recovery rates
  - Permanently close several small areas of potentially high K
  - Rotate fishery in areas of fast recovery potential

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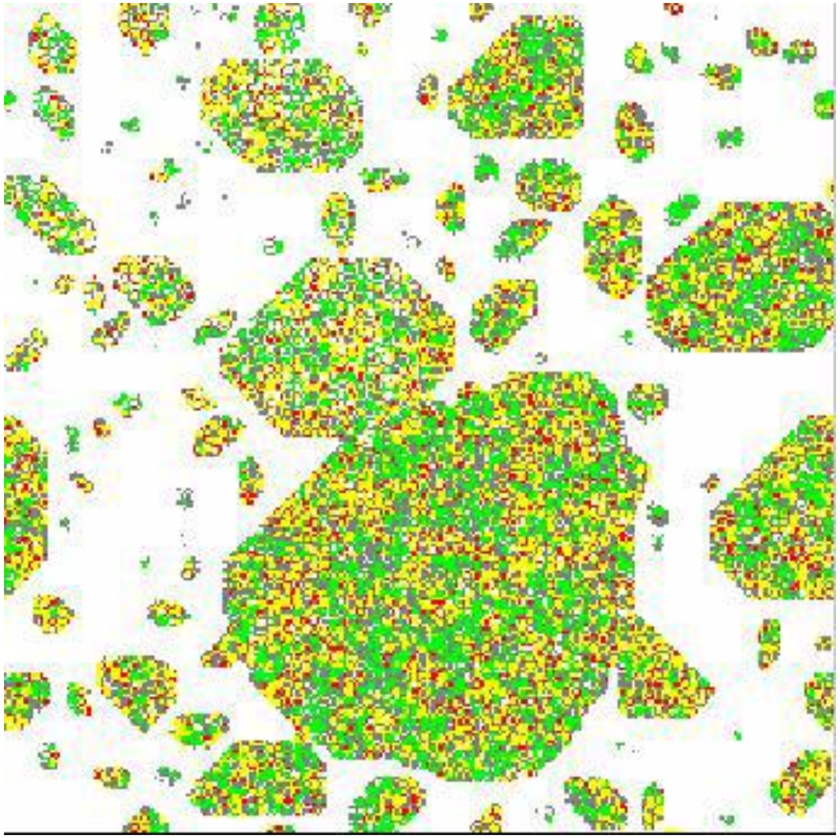
Testing management scenarios

- Depletion-recovery equations
- Spatially explicit models



Some conclusive remarks

- Importance fishing activity distribution

- Recovery rates for implementation of EAF

- Here, variation of recovery with tidal stress

- Limitations: unfished is not pristine + focus on abundance and not biomass


THANK YOU
FOR
YOUR ATTENTION