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The concept of "Pelagic metapopulation" as exemplified by the case of Jack mackerel *Trachurus murphyi* in the South Pacific Ocean

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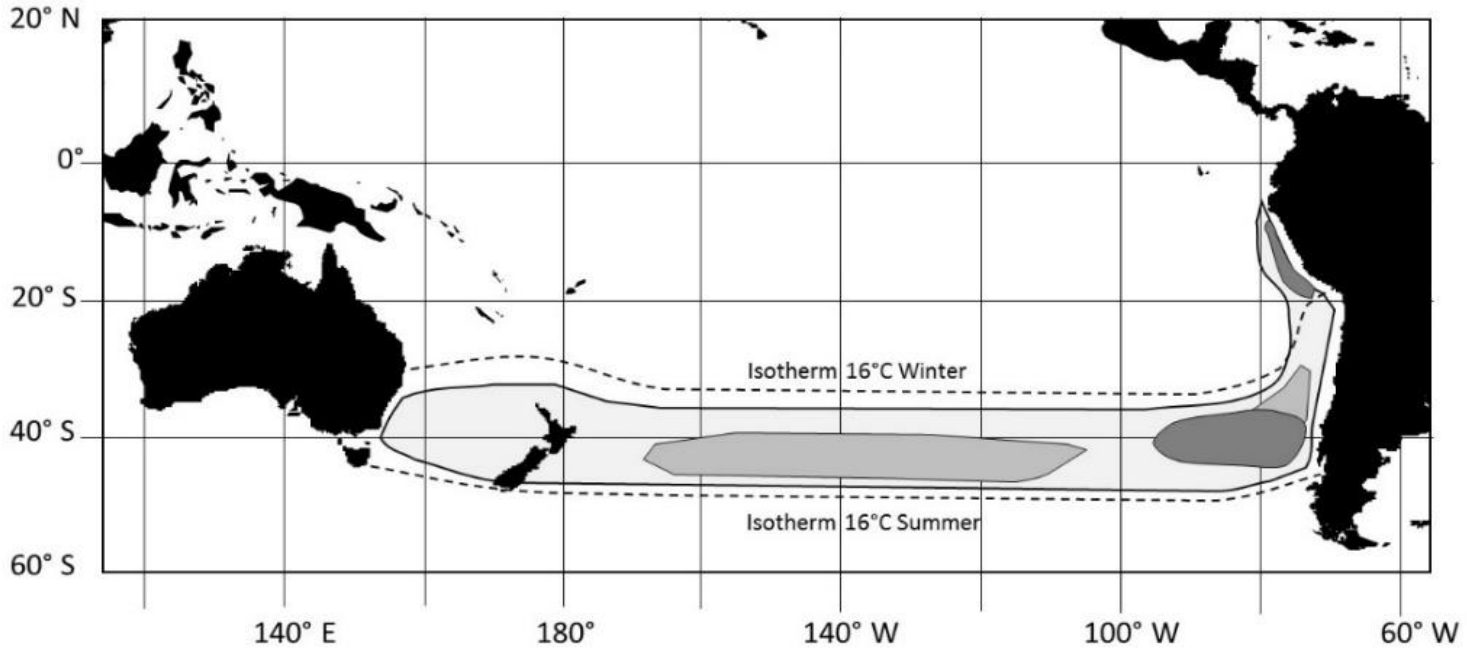


From a paper submitted to « Fish and Fisheries », September, 2016

What structure for the CJM population?

Characteristic (condition) nb	Observation / condition	Supporting	Contradicting	Incompatible with
1	No genetic evidence is found to differentiate fish caught in different regions ranging from Peru to Chile and onto the high seas	1, 5, 6		2, 3, 4
2	No clear segregation in otholith biogeochemistry was found for juveniles to distinguish between fish caught in Peruvian or Chilean waters.	1	2, 4	
3	There is a high degree of similarity in length distribution from Northern Chile and Southern Peru catches	1, 5		
4	Strong cohorts appear all over the Pacific	1, 5		
5	Only a continuous and permaner distribution of adult fish is show Chile			
6	A certain degree of segregation i otholiths biogeochemistry was f for adults to distinguish betwee caught off Peru and Chile			
7	Differences in growth and estim growth parameters are observe between fish caught off Peru an			
8	A difference in encountered nat mortality between fish off Peru Chile is observed			
9	Based on an analyses of the metazoa parasite fauna, a small difference between fish off Peru and the Chilean coast is observed	2, 4, 6	1	
10	A difference in age distribution in the catch taken off Peru and o seas is observed	2, 3, 4, 6	1	
11	A difference in estimated r productivity, obtained fro results, is observed betwe assessments separating th and Southern fisheries			
12	The existence of a 'few-fis between ~19-22° South is acoustic and catch geo-ref In addition, the predicted coastal habitat during part limits extensive mixing.			
13	A difference in encountere mortality between fish off			
	Chile is observed			
14	Spawning is observed in multiple patches / areas throughout the South Pacific and is not limited to spawning area	2, 3, 4, 6		
15	Analyses show that the 200 first captured off Chile, ma migrated under a strong La into Peruvian waters in the 2011			
16	Substantial connectivity be Chilean, Coastal and Peruvi			
17	The spatio-temporal SEAP parameterized for Jack ma that the distribution of adu juvenile fish is also orient perpendicular to the coast			
18	A recent eastward shift in area of the main catches in central area of the South P been observed with limite of Jack mackerel outside C jurisdictional areas.			
19	Observations of spawning from the Chilean coast up t			
20	At least two main spawning defined)			
21	Observations show local spawning activity inside New Zealand waters. Most catches correspond to large and old Jack mackerel	4, 6	1, 5	
22	Analyses of the trend in population units, based on assessment results separating Peruvian and other catches, do not show a close synchrony in development	6	1, 5	
23	No extensive connectivity between fish in Peruvian and Chilean waters or to the high seas except during strong El Niño when there is a flux from offshore to coast and south to north.	6	1, 5	
24	Jack mackerel is considered a highly migratory species with the ability to migrate between potential habitat patches	1, 5, 6		
25	The heterogeneous habitat owing to the Humboldt current system results in patchy suitable habitats	5		
26	No connectivity between coastal Chile and high-seas fish, no connectivity between Peru and high-seas fish	4	1, 6	
27	Habitat is only partly fragmented throughout the year. There is no fragmentation between habitat off Chile and onto the high seas		6	

THE SIX SCENARIOS LISTED BY SPRFMO (2008)

Scenario 1. Single discrete populations
Scenario 2. Two discrete populations (off Peru and Chile)
Scenario 3. Two discrete populations (coastal & high seas)
Scenario 4. Network of closed populations

(a)

Scenario 5. Superpopulation (= patchy population)
Scenario 6. Metapopulation

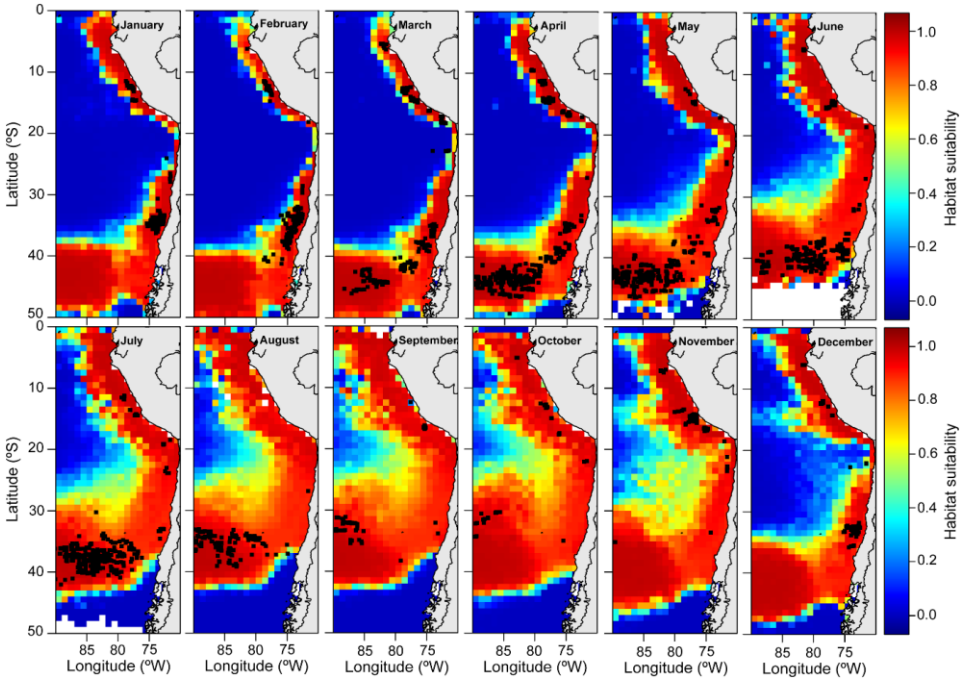
(b)

(a) no exchanges between sub-populations
(b) exchanges between sub-populations

Scenario 6 is the most likely (but 2 over 27 characteristics are still contradictory)

The next question: are metapopulations, as they are currently defined, relevant in the case of pelagic populations?

Jan.

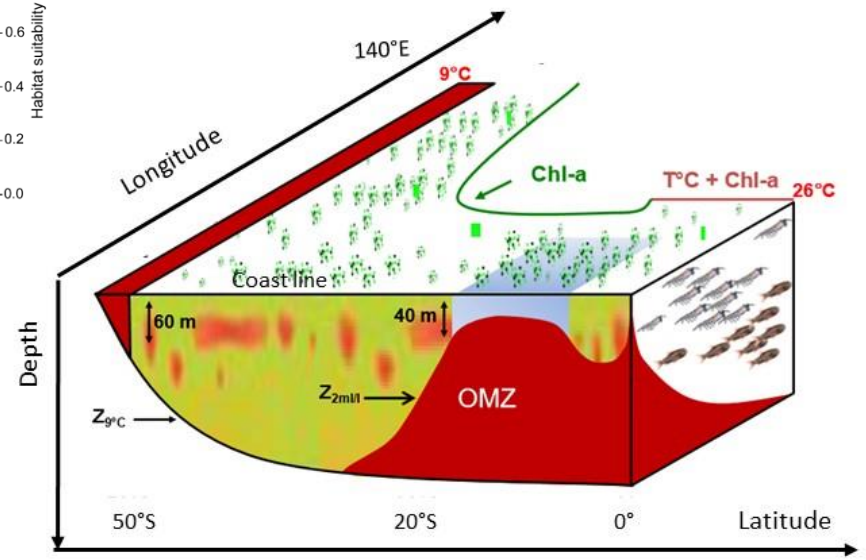


Dec.

Monthly mean distribution of the CJM habitat in the SE Pacific Ocean

Habitat is a key tool for studying and defining population structure

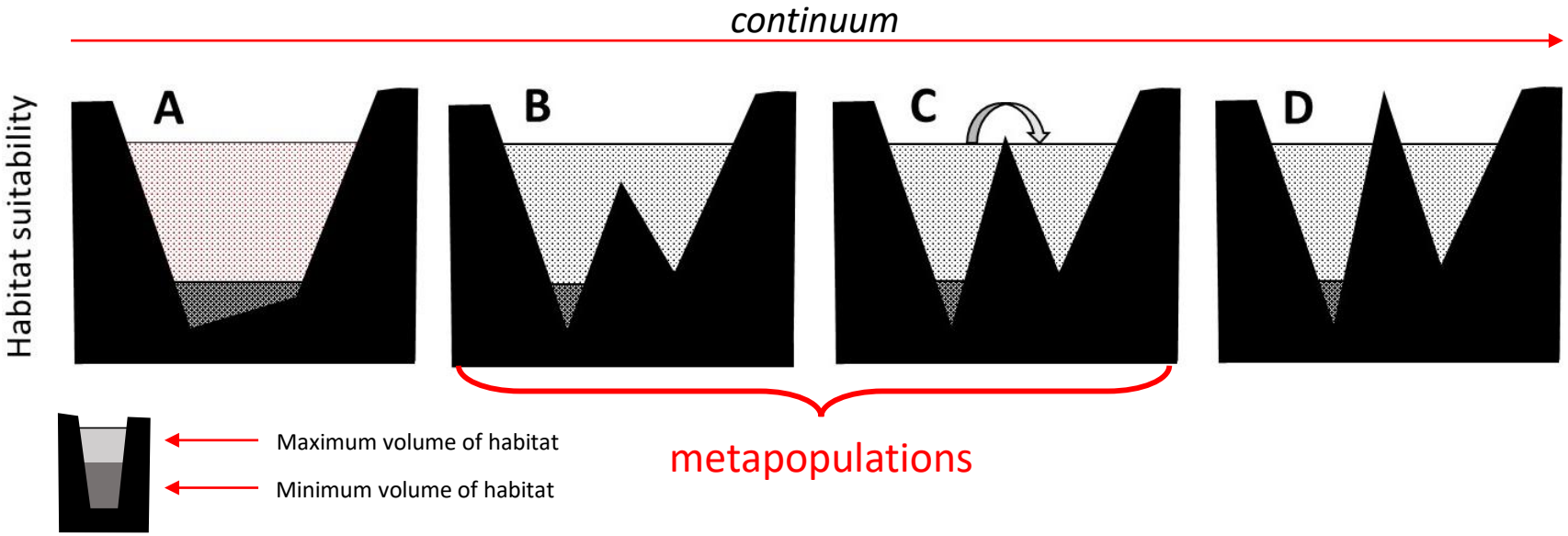
The CJM habitat described in the SE part of its distribution area



A 3D model of the CJM habitat

(Hintzen et al., 2015; Bertrand et al., 2016)

From single population to several discrete populations: Definition of the four main stages of population structures in a continuum as described using the Basin Model from McCall

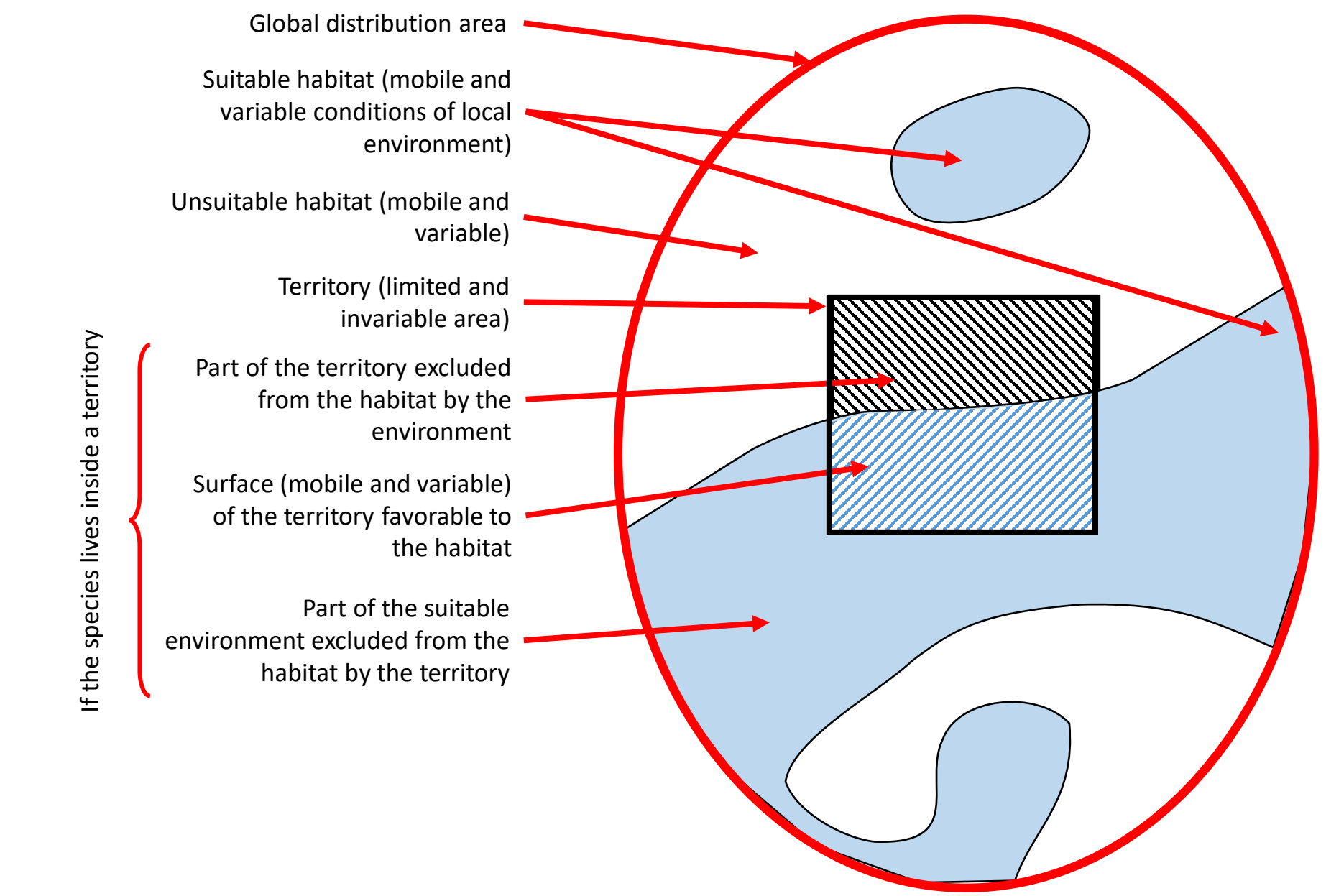


A. Single population (no discontinuity between the patches)
B. Populations connected by habitat overlappings; existence of a source
C. Populations connected by exchanges of individuals only; existence of a source
D. Multiple independent populations (populations never connected)

Only cases B and C represent metapopulations

Case B: Environment-Bounded Habitat metapopulation (EBH)
Case C: Territory-Bbounded Habitat metapopulation (TBH)

A few definitions for TBH and EBH



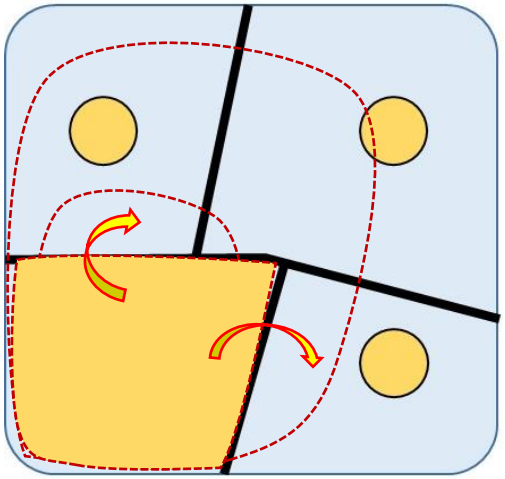
TBH metapopulations vs. EBH metapopulations : definitions

The "territory-bounded habitat" (TBH) metapopulation: environment changes within the territory induce changes on the surface of the suitable habitat up to the territory border. Exchanges between populations by passive transport of individuals or active behaviour.

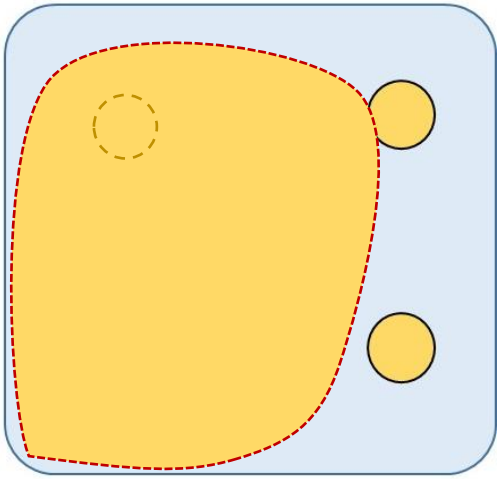
The "environment-bounded habitat" (EBH) metapopulation: the only limit of expansion is the area where favourable conditions of the local environment are found. Exchanges between local and global scales are achieved by large hydrological events, e.g. currents, eddies, etc. The suitable habitat may expand up to overlapping with other sub-population habitats

The effect of habitat type on population exchanges

Case C: Territory-bounded Habitat metapopulation



Case B: Environment-bounded Habitat metapopulation



Maximum distribution area

Territory limits

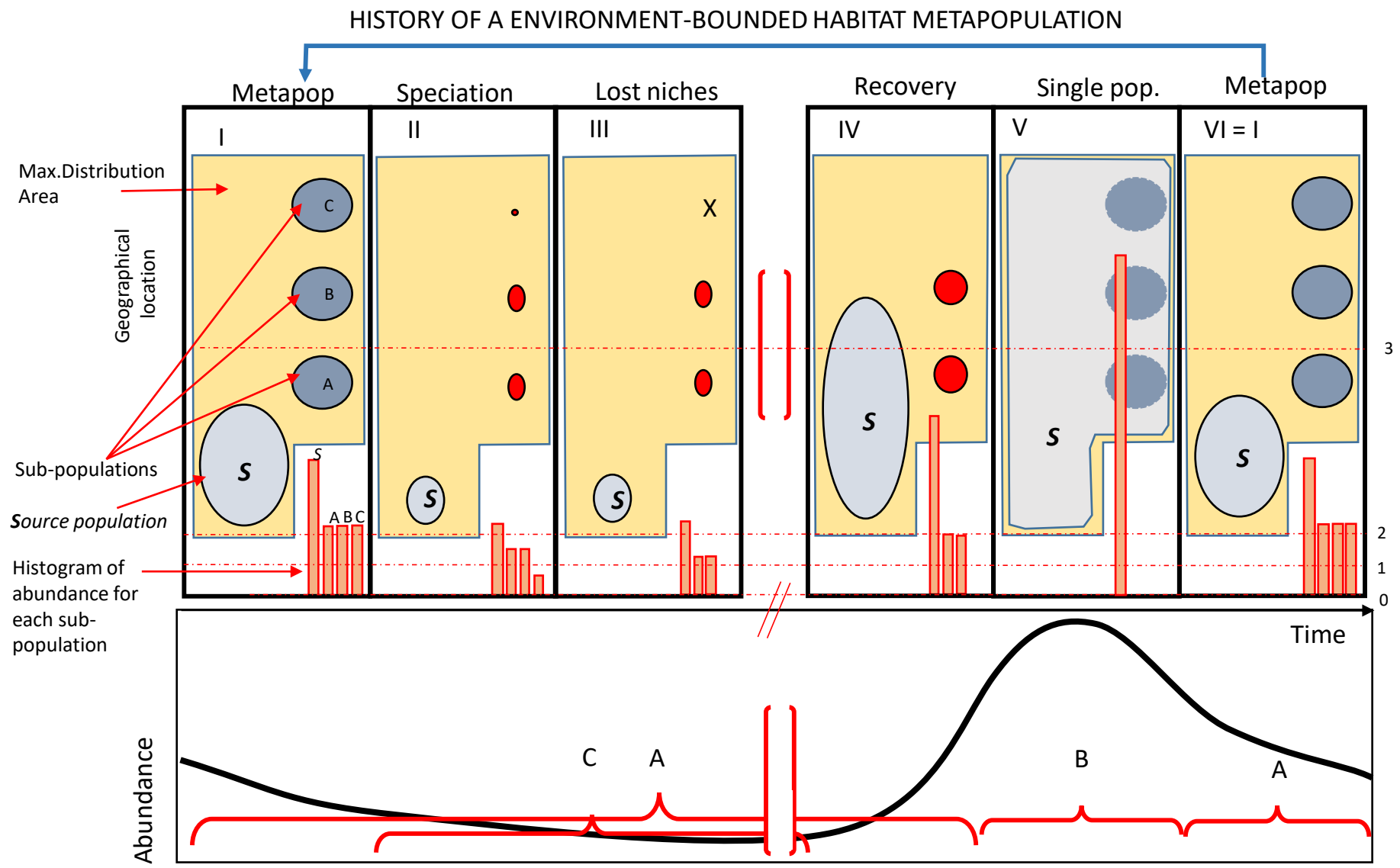
Source population (low distribution)

Other sub-population (low distribution)

a

b

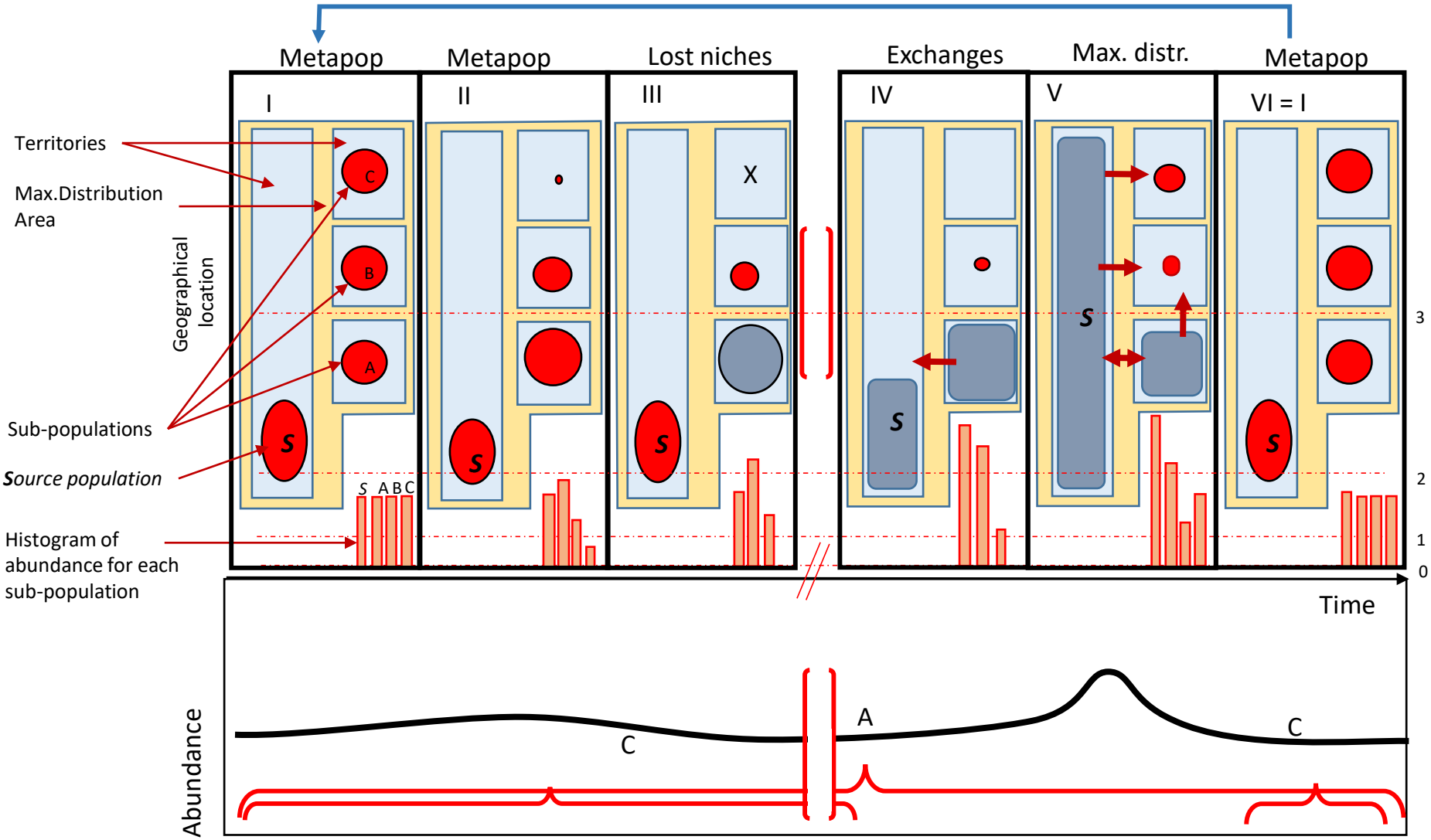
Local favourable environment occupied (a) or out of access (b)



Level 0: death of the species
Level 1: level of abundance below which sub-populations are unlikely to survive
Level 2: level of abundance above which speciation cannot occur
Level 3: all sub-population merged, no metapopulation during a while.

Phase A: metapopulation situation
Phase B: recovering of niches; single population
Phase C: speciation and loss of niches

HISTORY OF A TERRITORY-BOUNDED HABITAT METAPOPULATION



Level 0: death of the species
Level 1: level of abundance below which sub-populations are unlikely to survive
Level 2: level of abundance above which speciation cannot occur
Level 3: all sub-population merged, no metapopulation during a while.

Phase A: metapopulation situation
Phase B: single pop. (does not occur in TBH)
Phase C: speciation and loss of niches

The “pelagic fish metapopulation” : an EBH-metapopulation, where:

Three of the four necessary conditions for metapopulation existence (Hanski 1999) are fulfilled:

- discrete-breeding populations;
- risk of extinction for some or all populations;
- recolonization possible.
- On the contrary asynchrony in local dynamics does not permanently apply.

Other typical characteristics

- differences in scales between local and regional effects of the environment;
- existence of source-sink populations;
- autonomy of sub-populations and limited genetic exchanges.

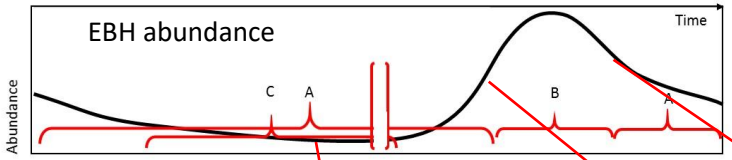
Exchange or colonisation

- conventional exchange of individuals by straying, learning and entrainment;
- habitat overlap.

Substantial changes in population abundance due to synchrony between sub-populations during periods of large abundances. Asynchrony is the rule during depleted periods.

We conclude that the Chilean Jack Mackerel is indeed a pelagic metapopulation.

CONCLUSION *(¡muy personal!)*
Abundance dynamics (and risks) in an exploited EBH metapopulation



"We make a distinction between a depleted and a collapsed population, where, in addition to biomass depletion, the latter includes damage to contingent structure or space-use pattern." Petitgas et al., 2010

If fishing effort remains high, overexploitation may occur during the depleted phases => collapse

risks of misunderstanding the meaning of biomass changes (where do we locate the "virgin biomass"?)

Metapopulation explosion

population depletion

Risk of confusion between depletion and collapse

High risk of collapse due to overfishing (inadapted fishing effort)

Mean statistical (depleted) paleoecological abundance

Depletion is not necessarily bad news for a population

Collapse? (overfishing)

HYPOTHETICAL scenario, assuming that the catch is a proxy of the overall abundance

Catch by fleet in kt

4000
3000
2000
1000

1970
1980
1990
2000
2010

Year