Persistence of prey 'hot spots' in southeast Alaska

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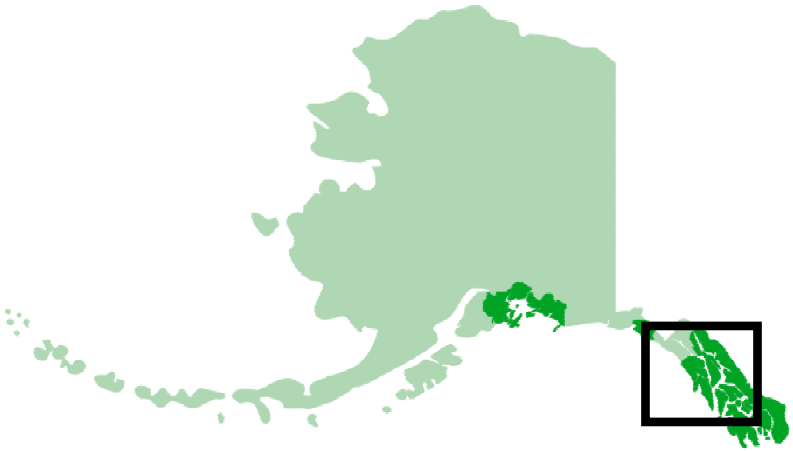
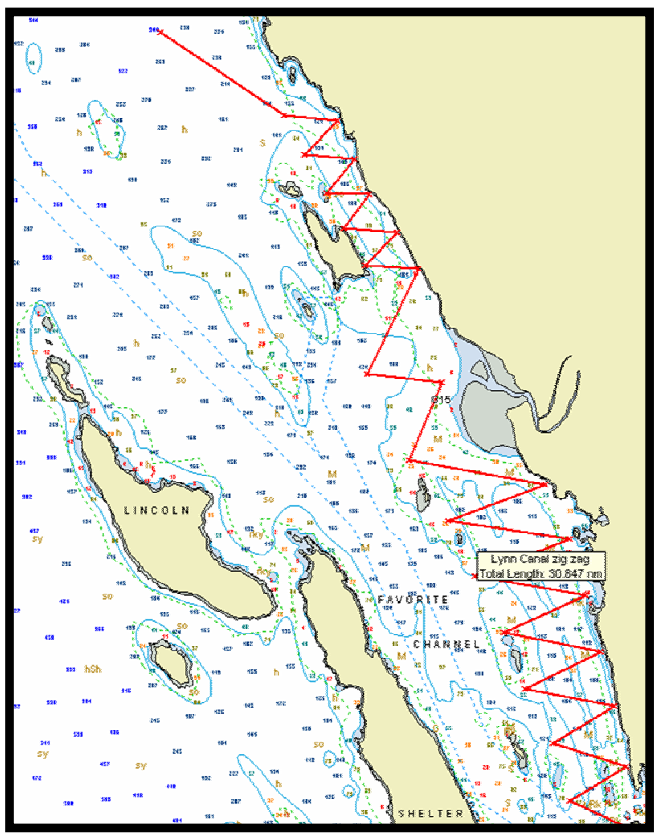
Questions:

1. Are there high aggregations of pelagic fish prey in space and time?
2. Do these 'hot spots' persist through time?
3. What is the response of predators to these aggregations?



~40 km study area



Methods:

1. **Hydroacoustic surveys for pelagic prey conducted June 2001-May 2004**

2. **Periodic midwater trawls to sample prey energy and confirm echo sound**

3. **Concurrent observations of top predators including Steller sea lions and humpback whales**

4. **Transformed data from estimates of biomass to energy densities integrated across the water column**

5. **Blocked data into tenths of a latitudinal minute such that each 'block' constituted approximately 1.83 km)**

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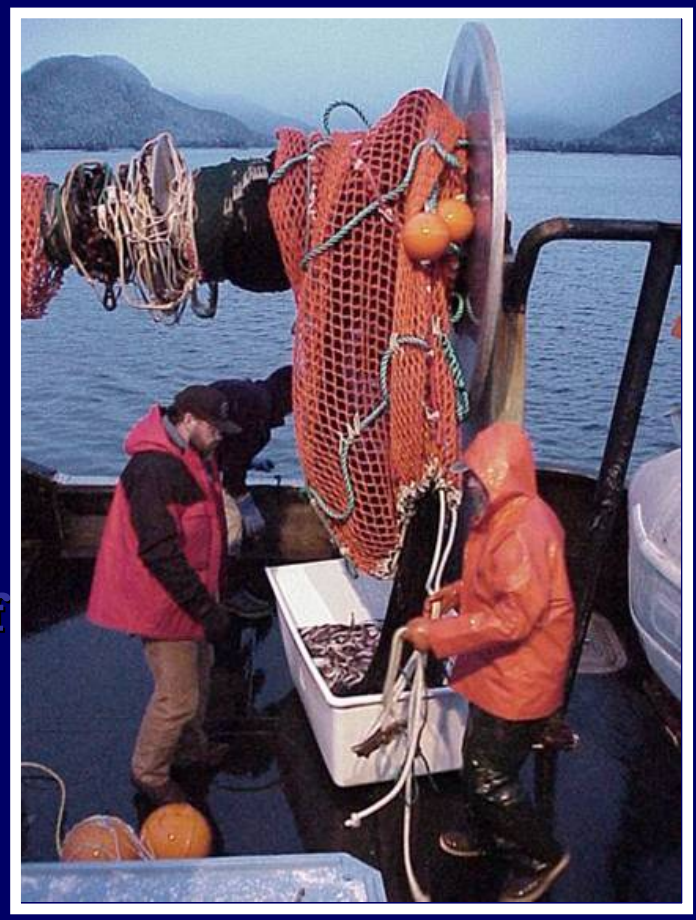

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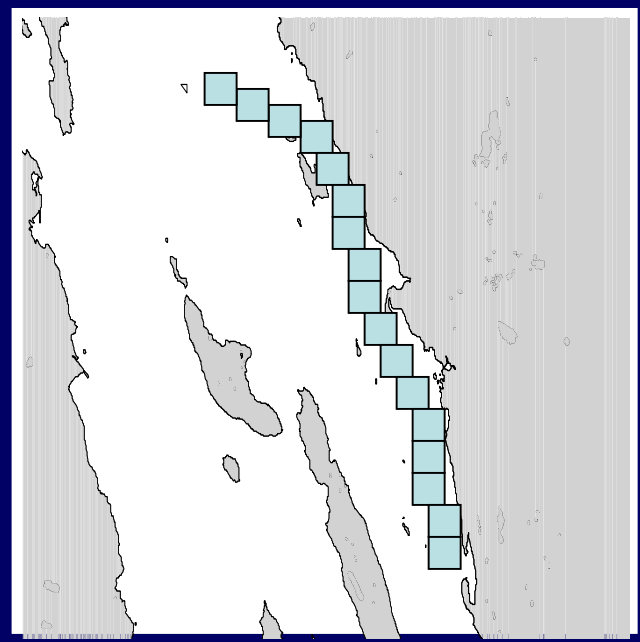

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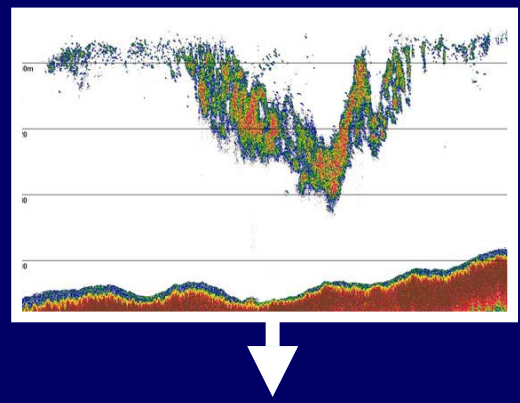
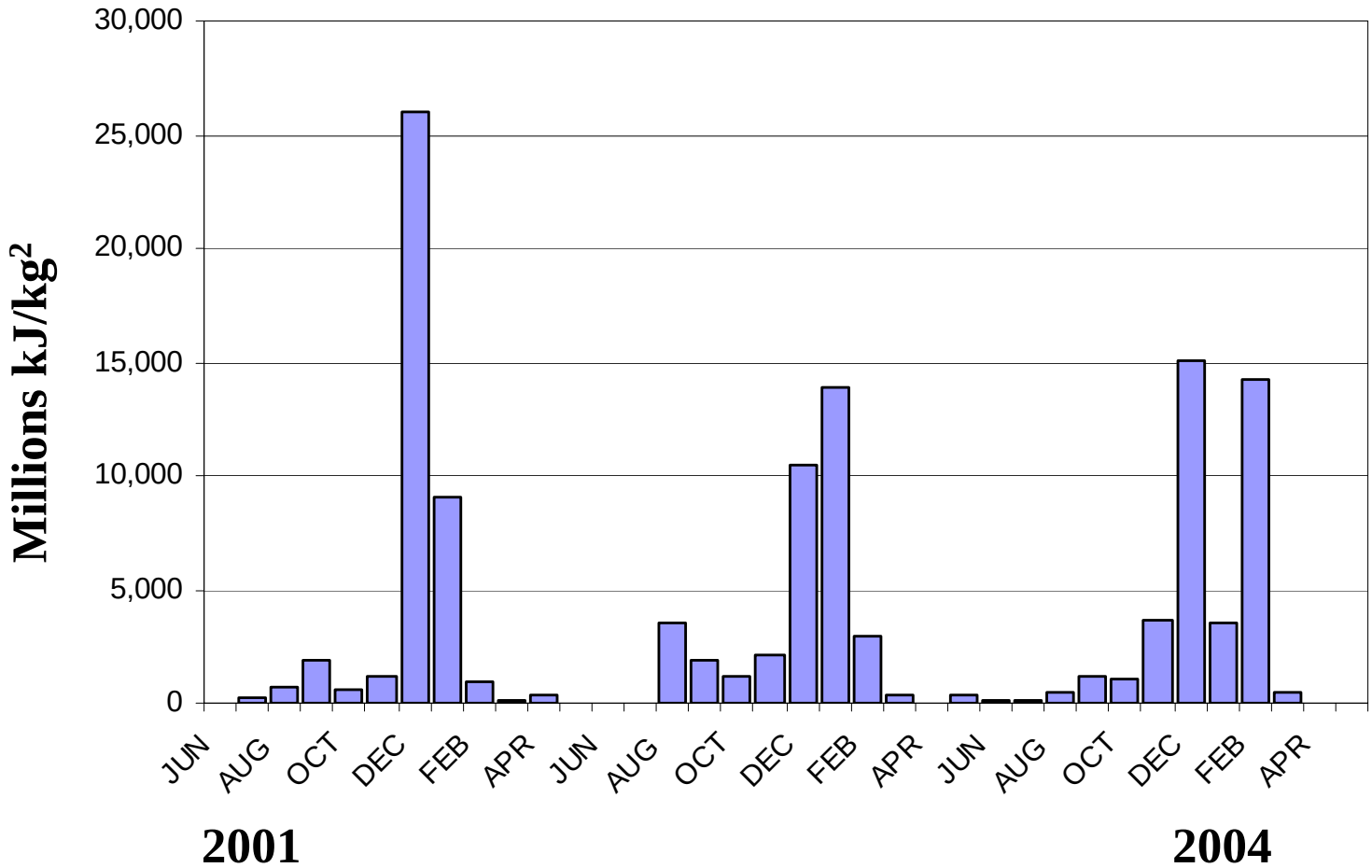


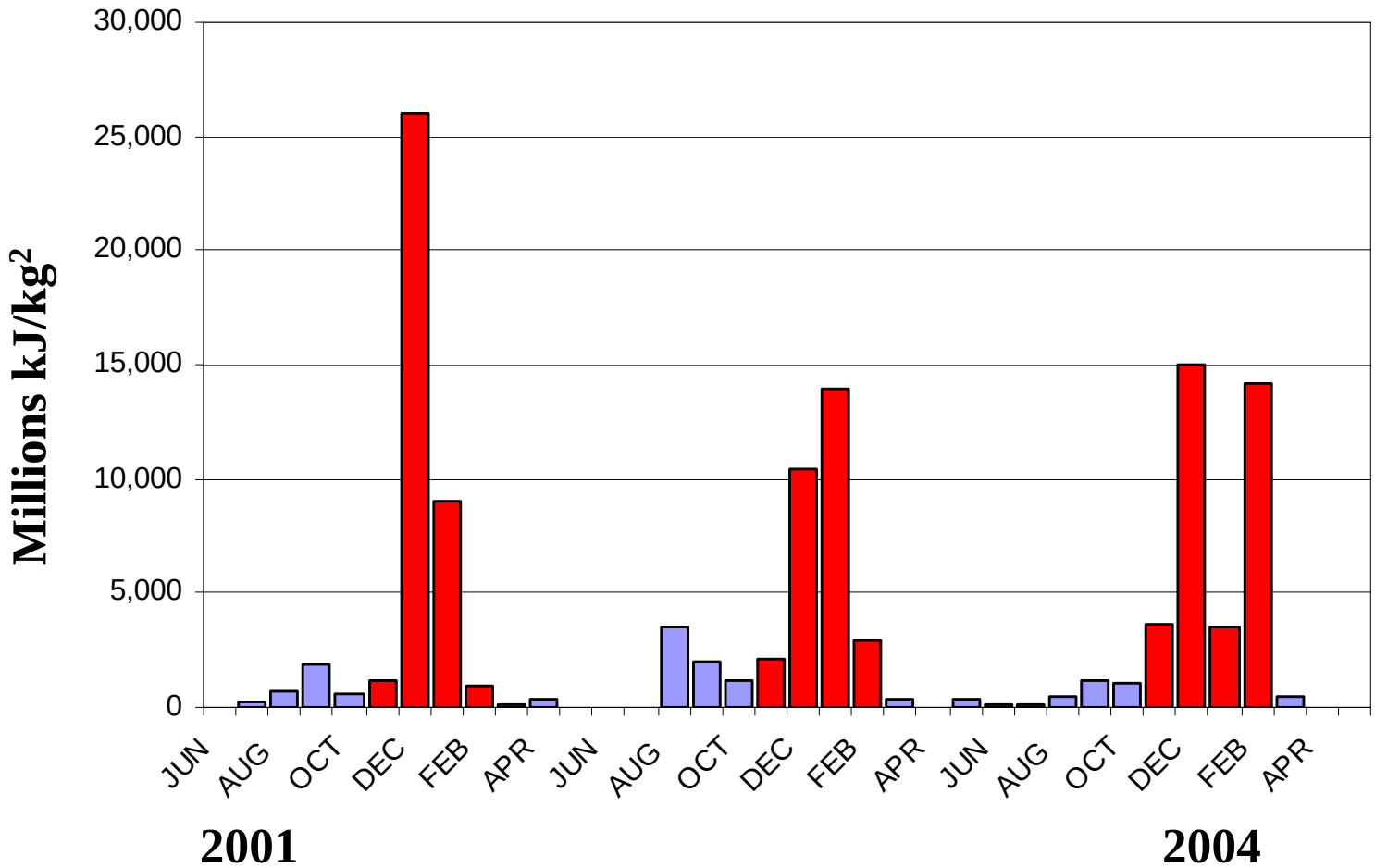
$kJ \times 10^6/km^2$

Results:

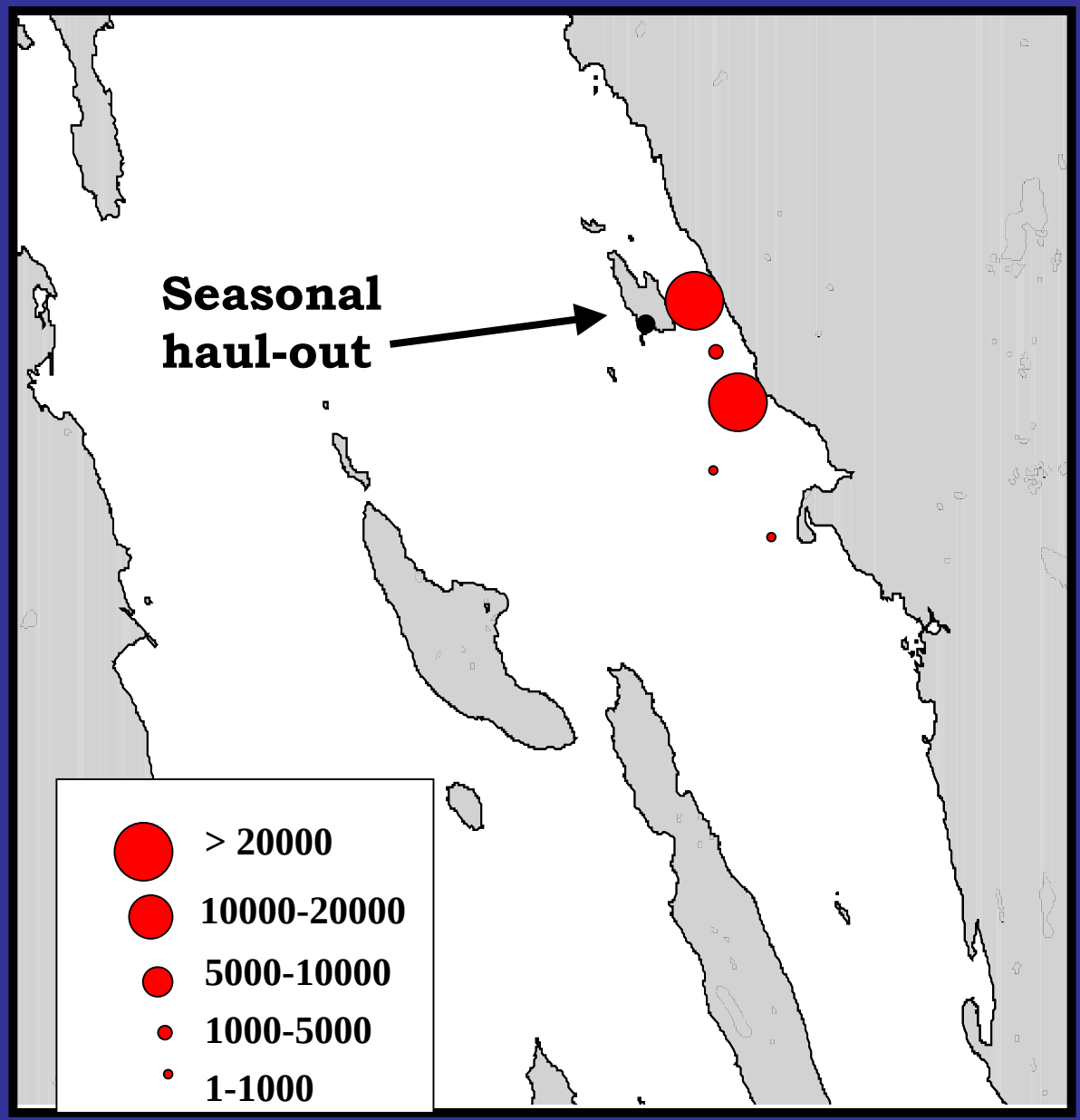
On average prey energy density is not equal across months



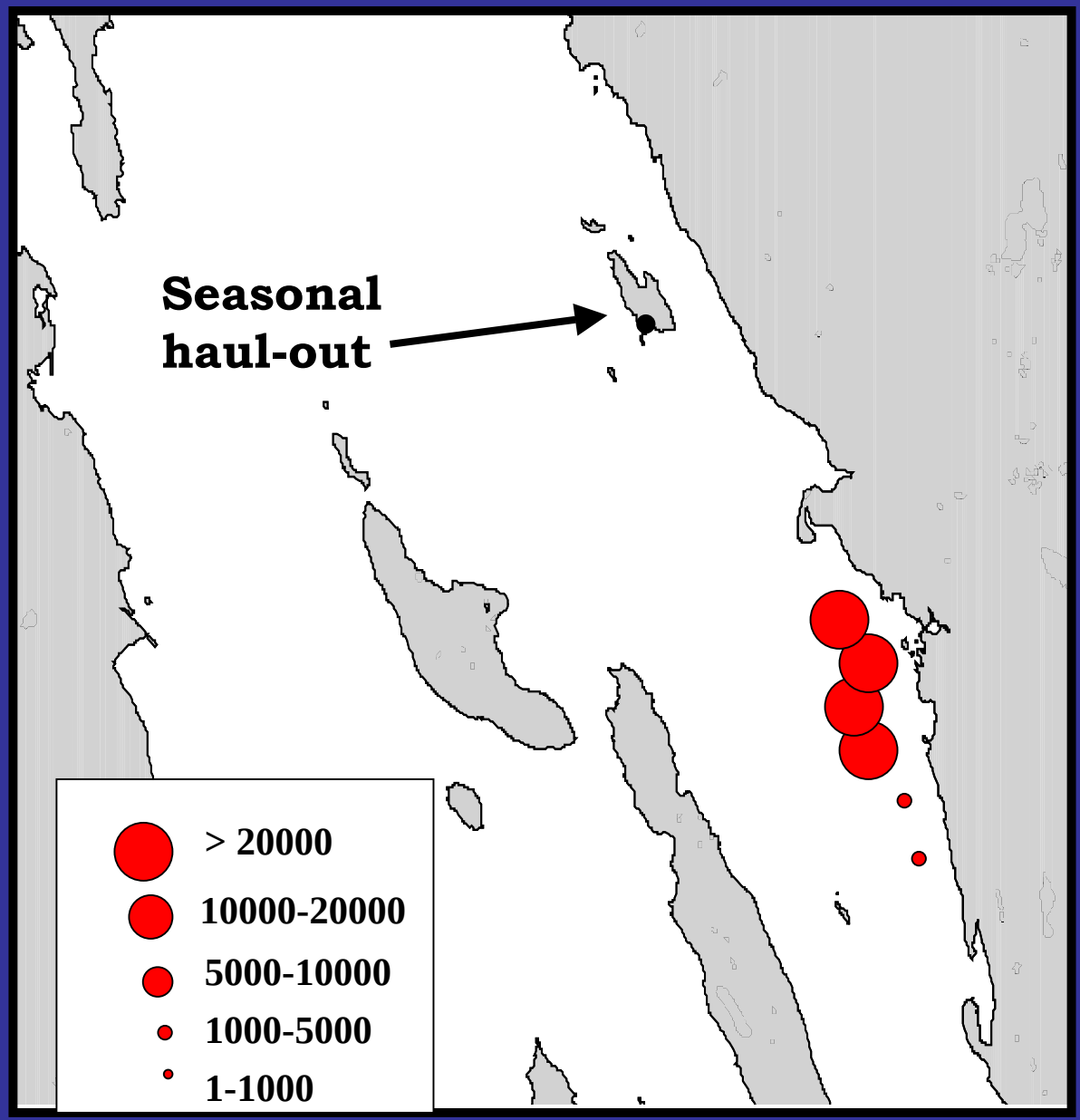
Cold winter months (Nov-Feb) are hot



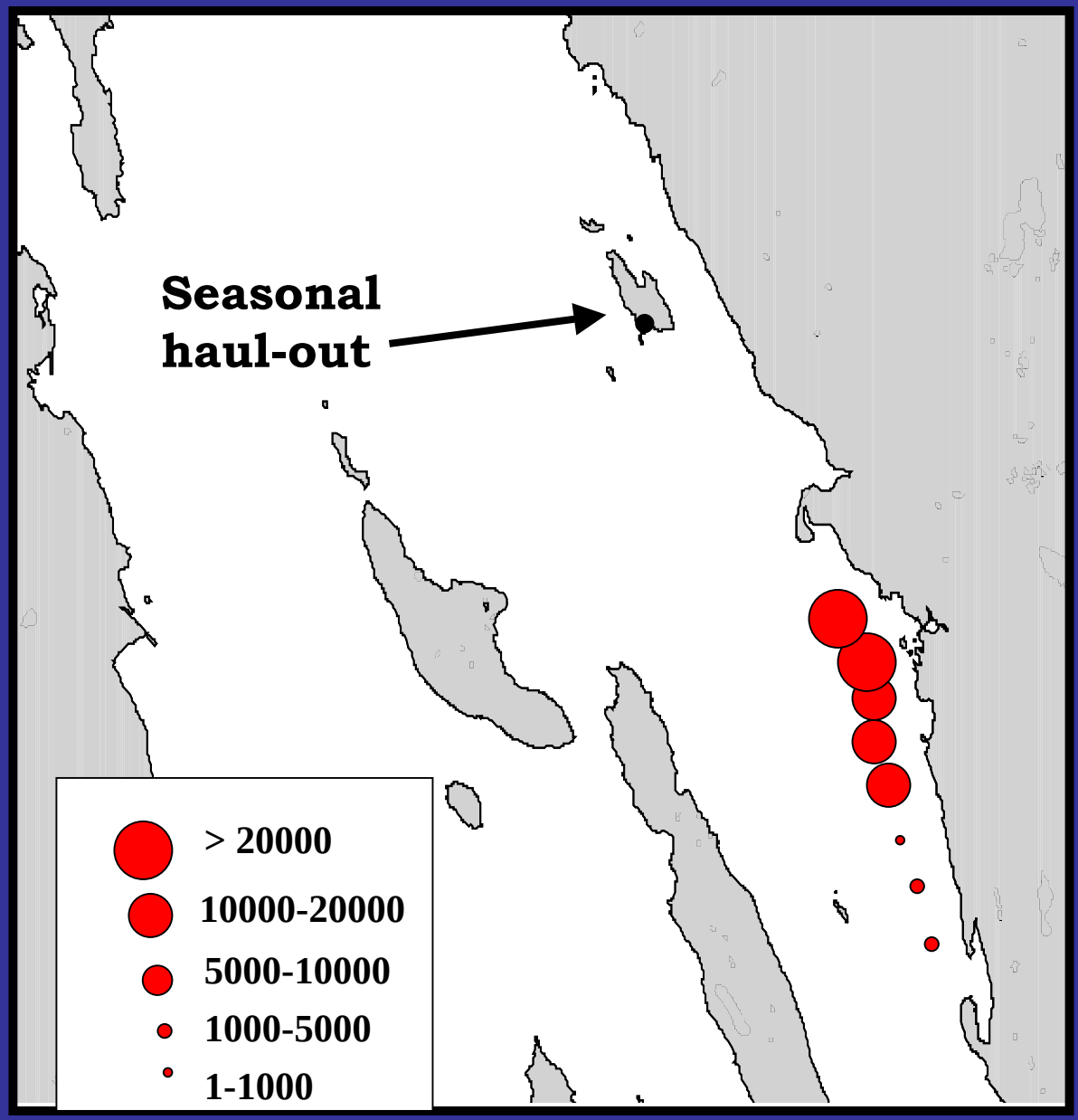
Distribution of pelagic prey energy November 2003



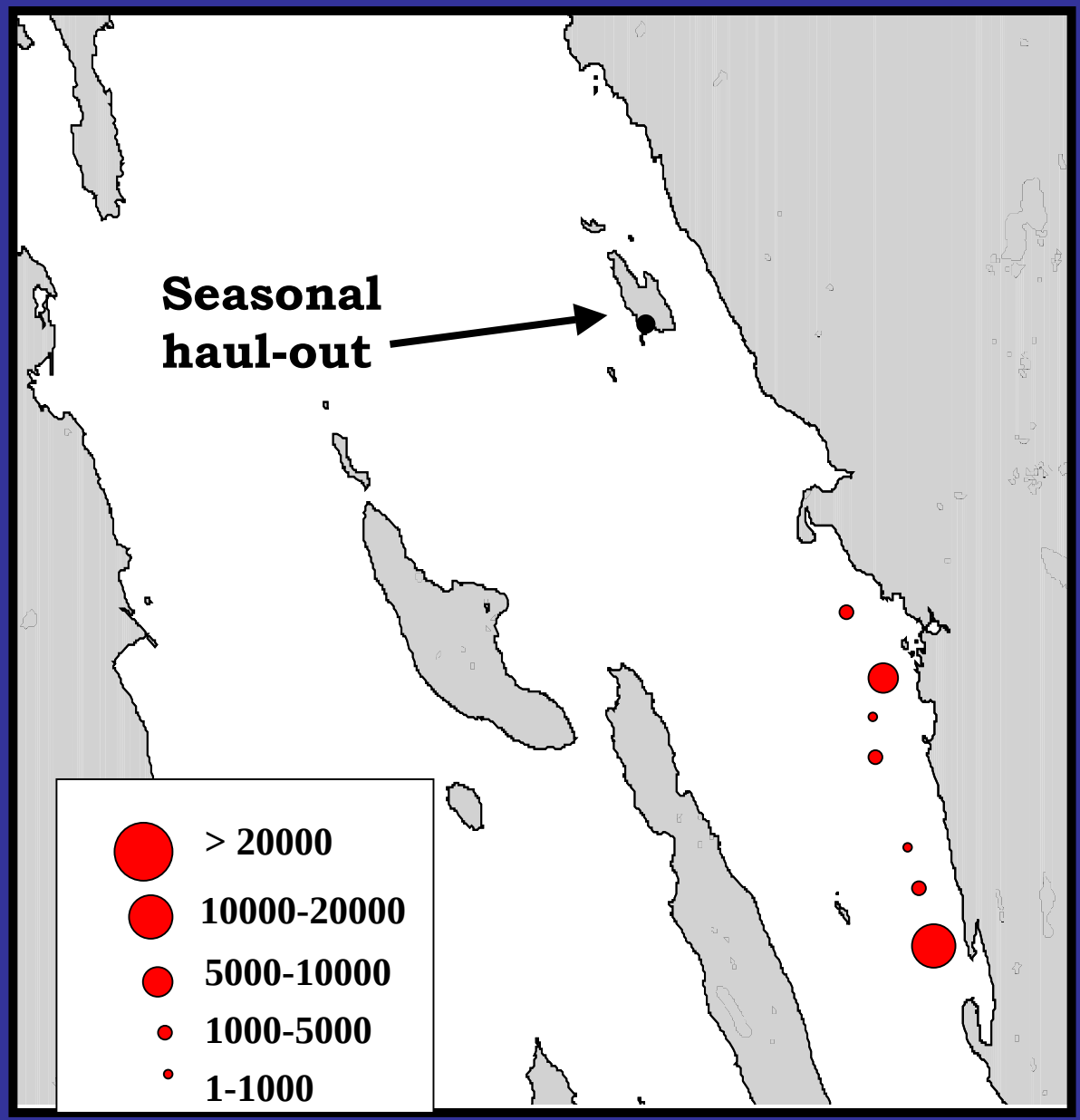
Distribution of pelagic prey energy December 2003



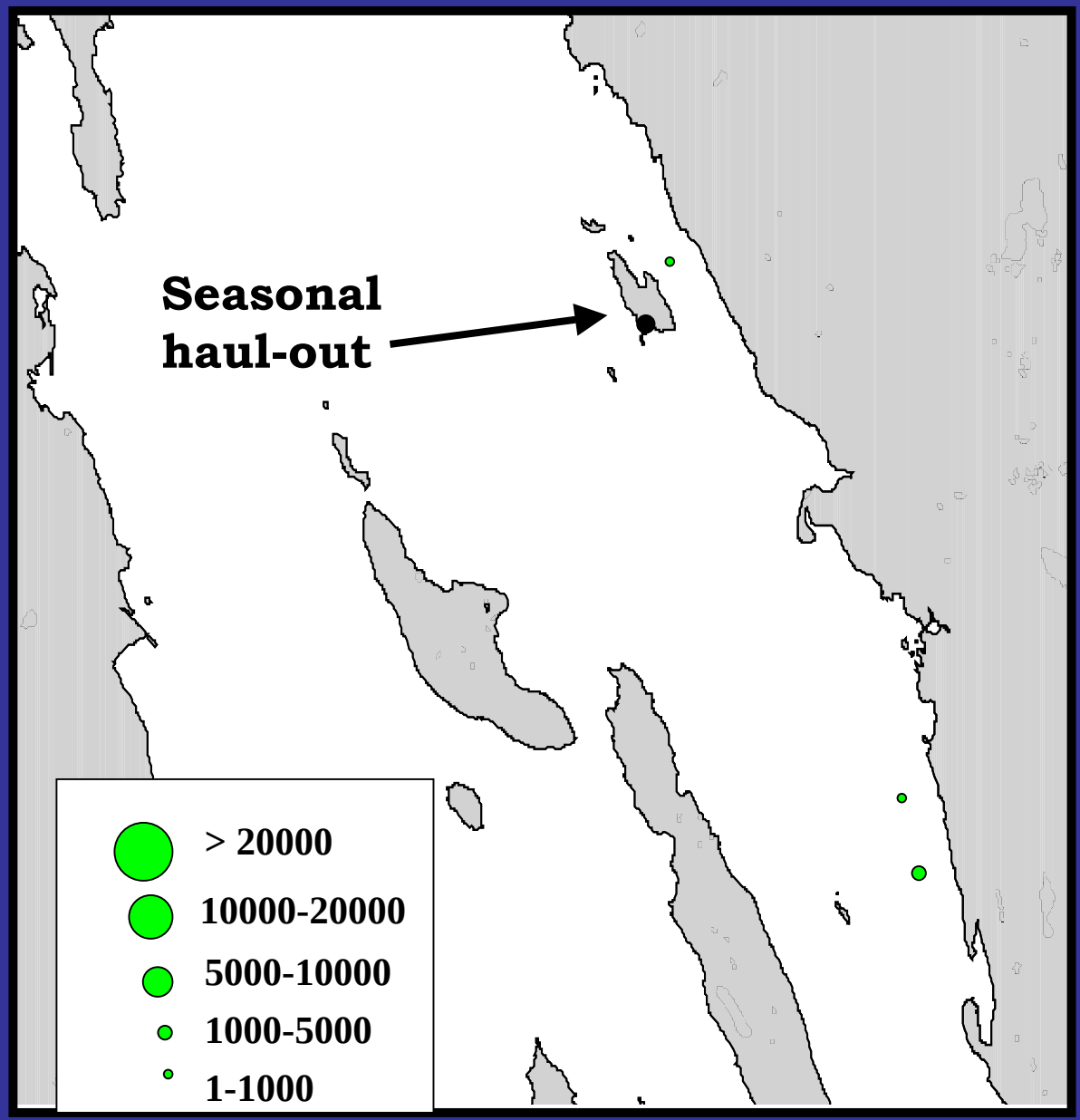
Distribution of pelagic prey energy January 2004



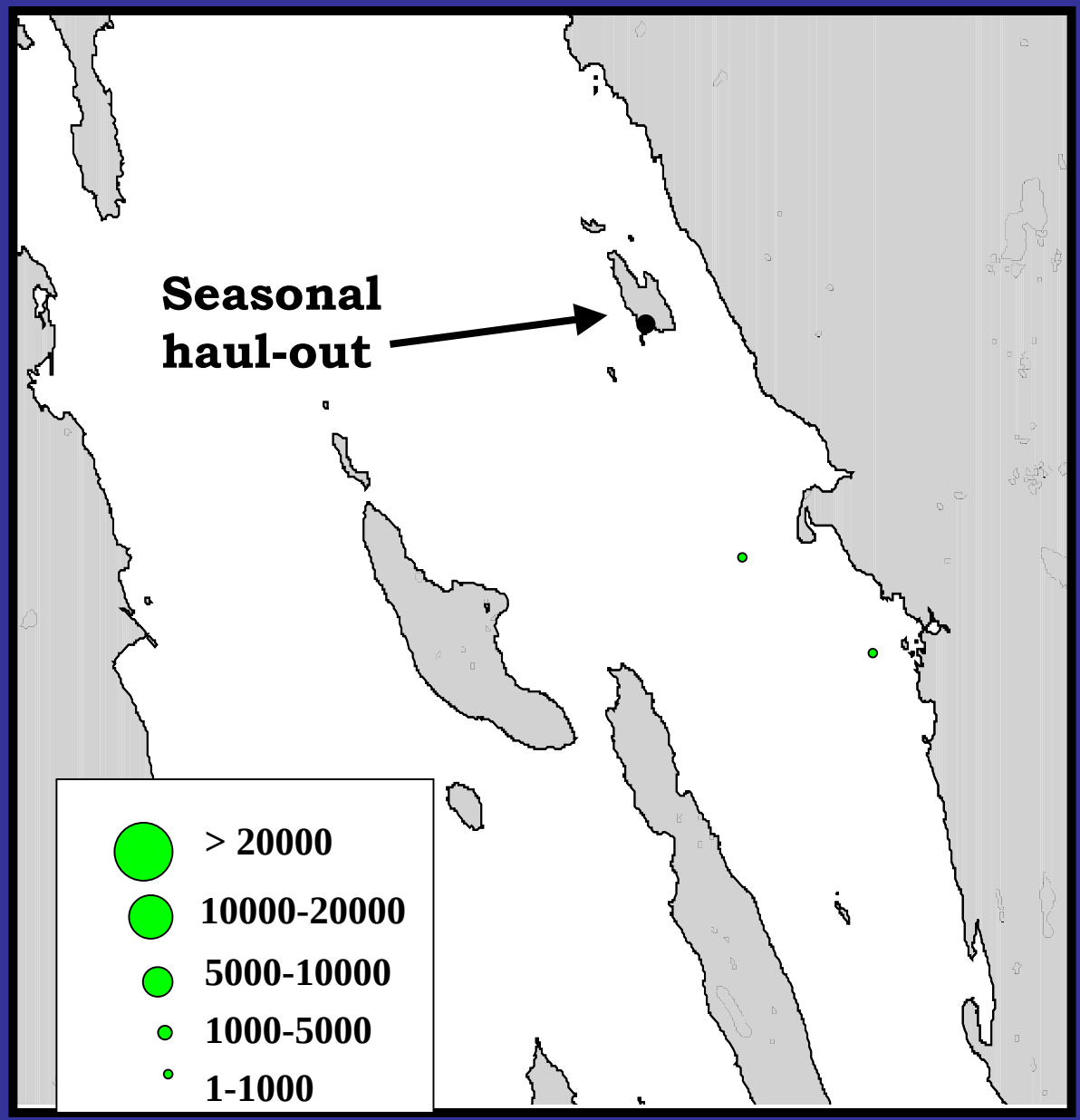
Distribution of pelagic prey energy February 2004



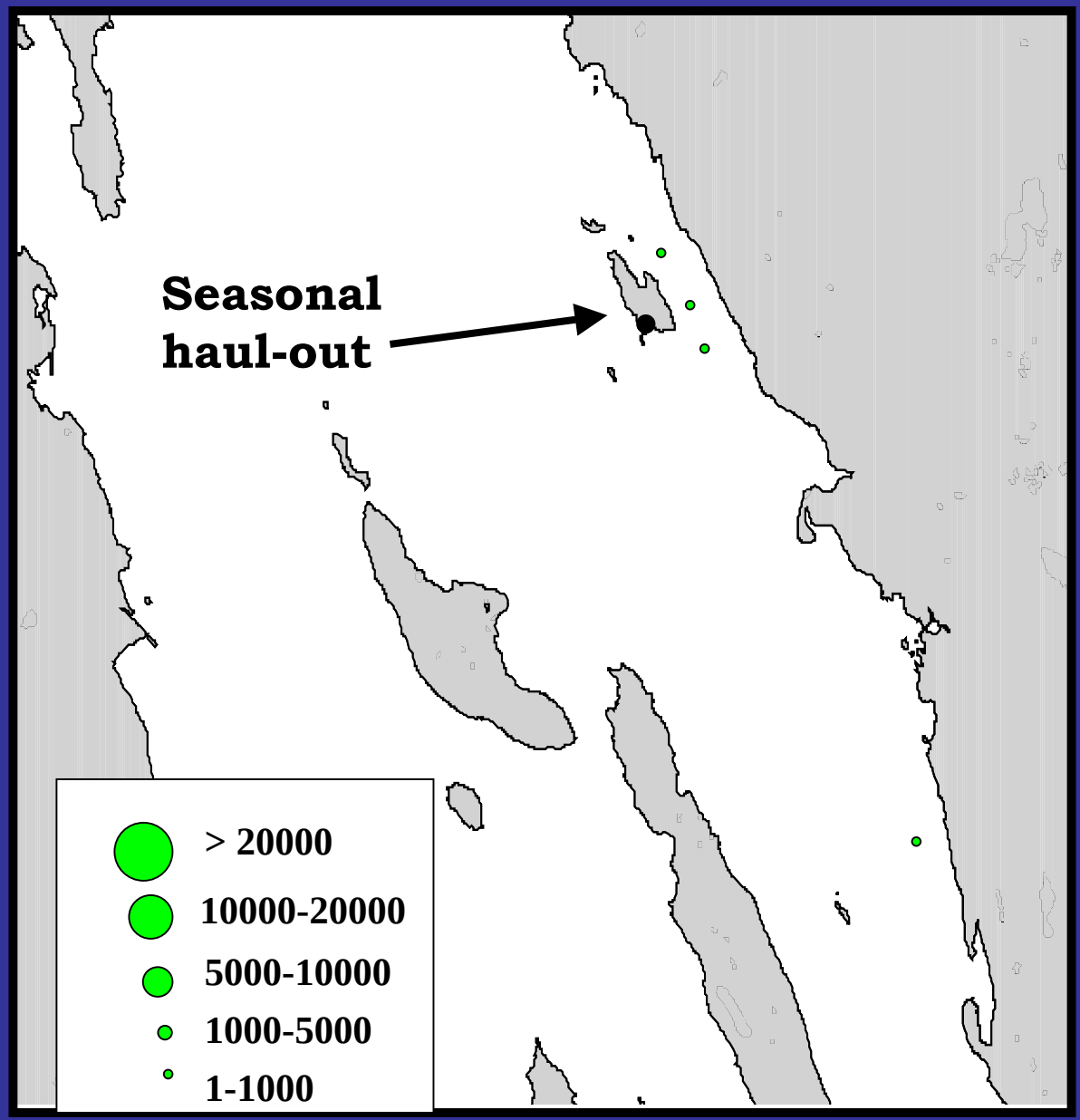
Distribution of pelagic prey energy March 2004



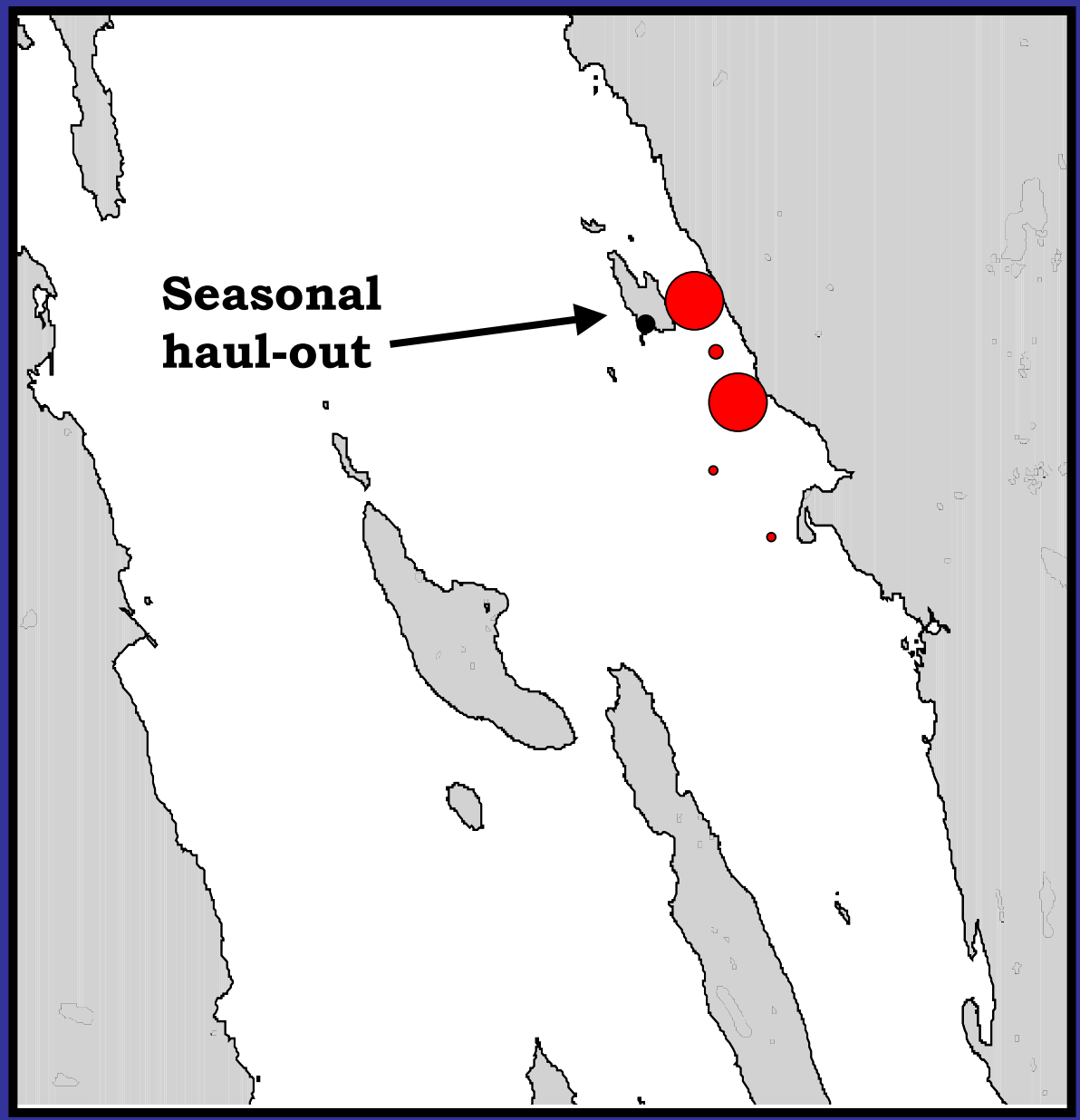
Distribution of pelagic prey energy April 2004



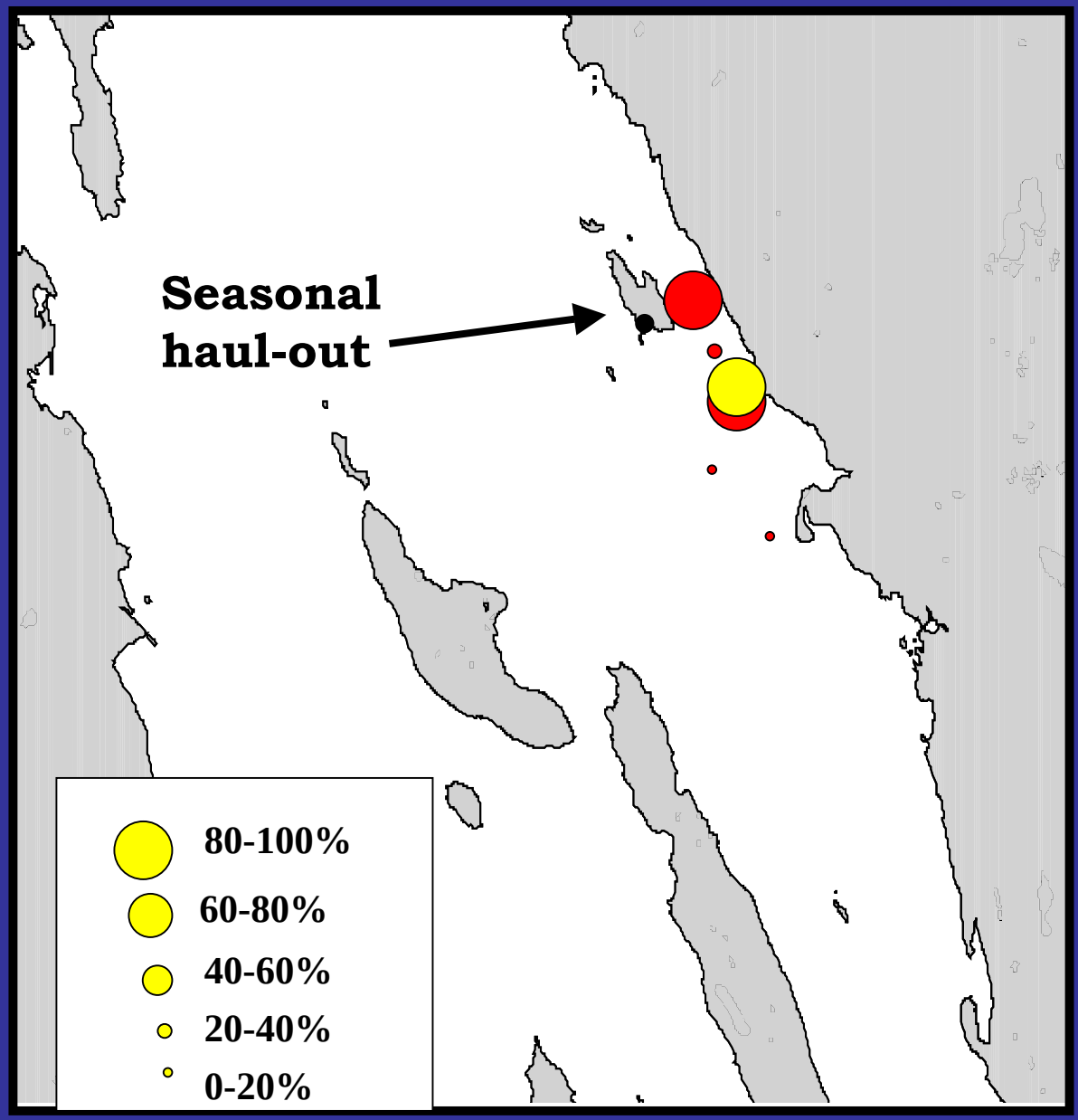
Distribution of pelagic prey energy May 2004



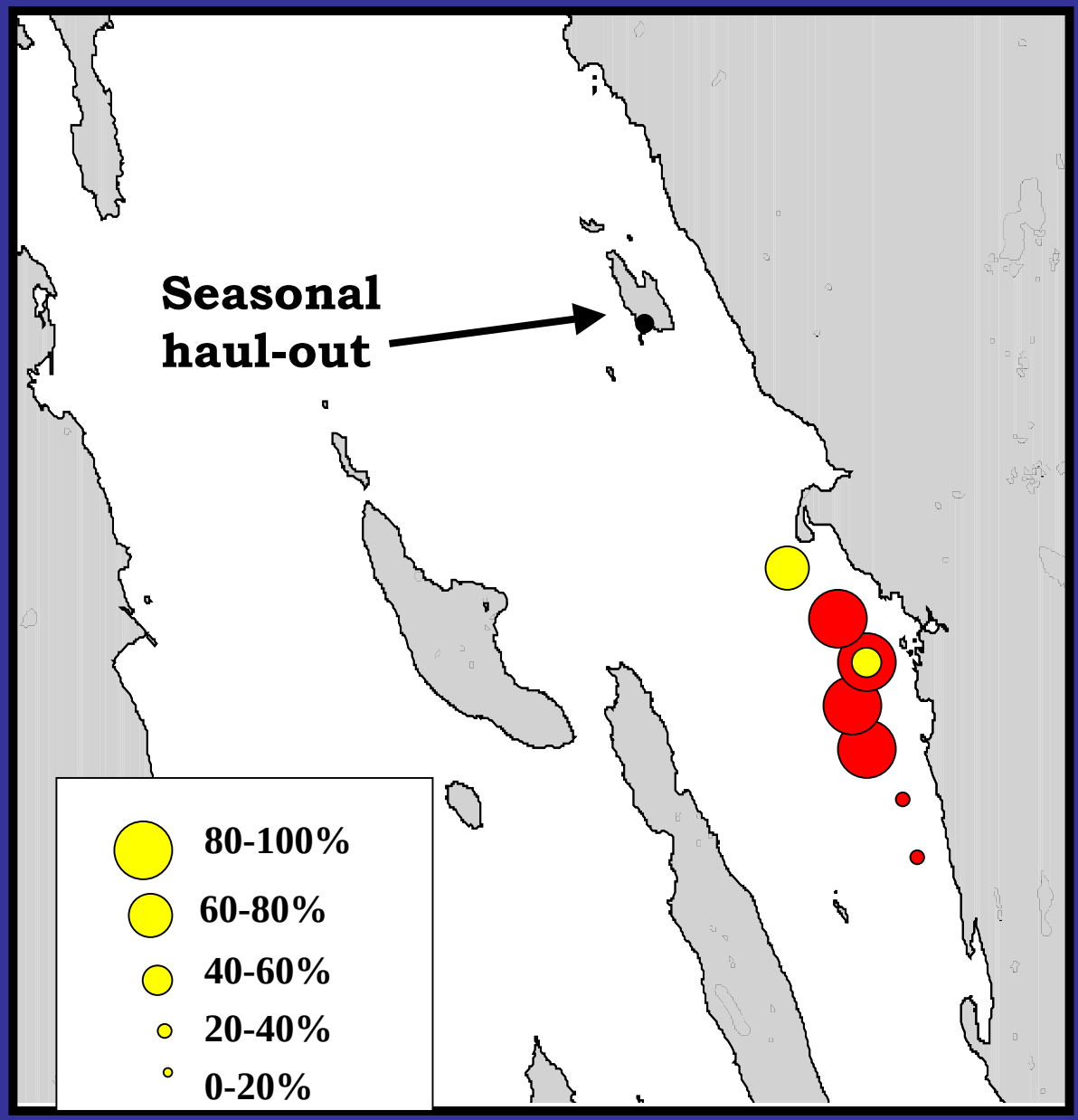
Distribution of pelagic prey energy November 2003



Proportion of observed Steller sea lions November 2003



Proportion of observed Steller sea lions December 2003



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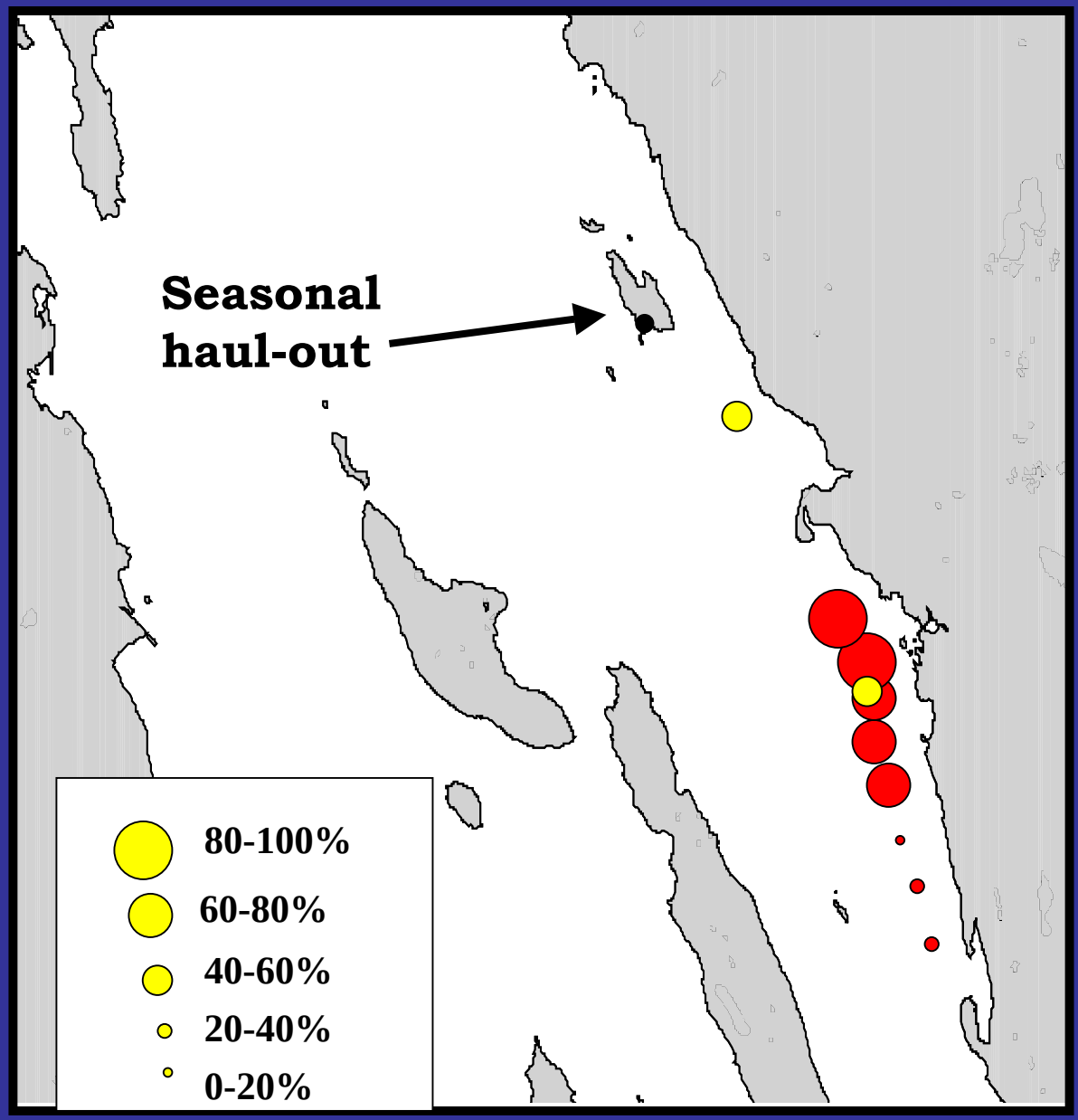
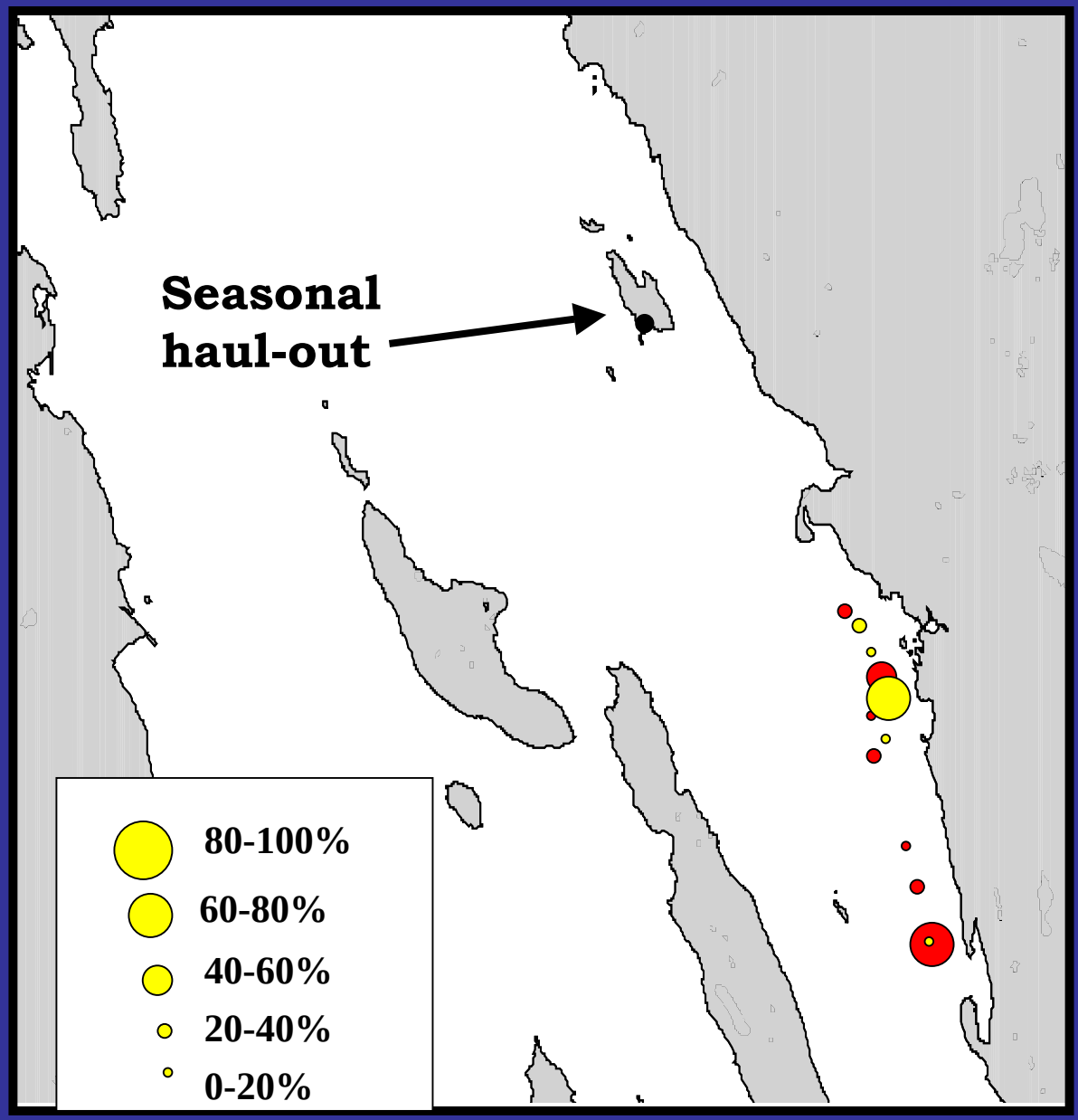
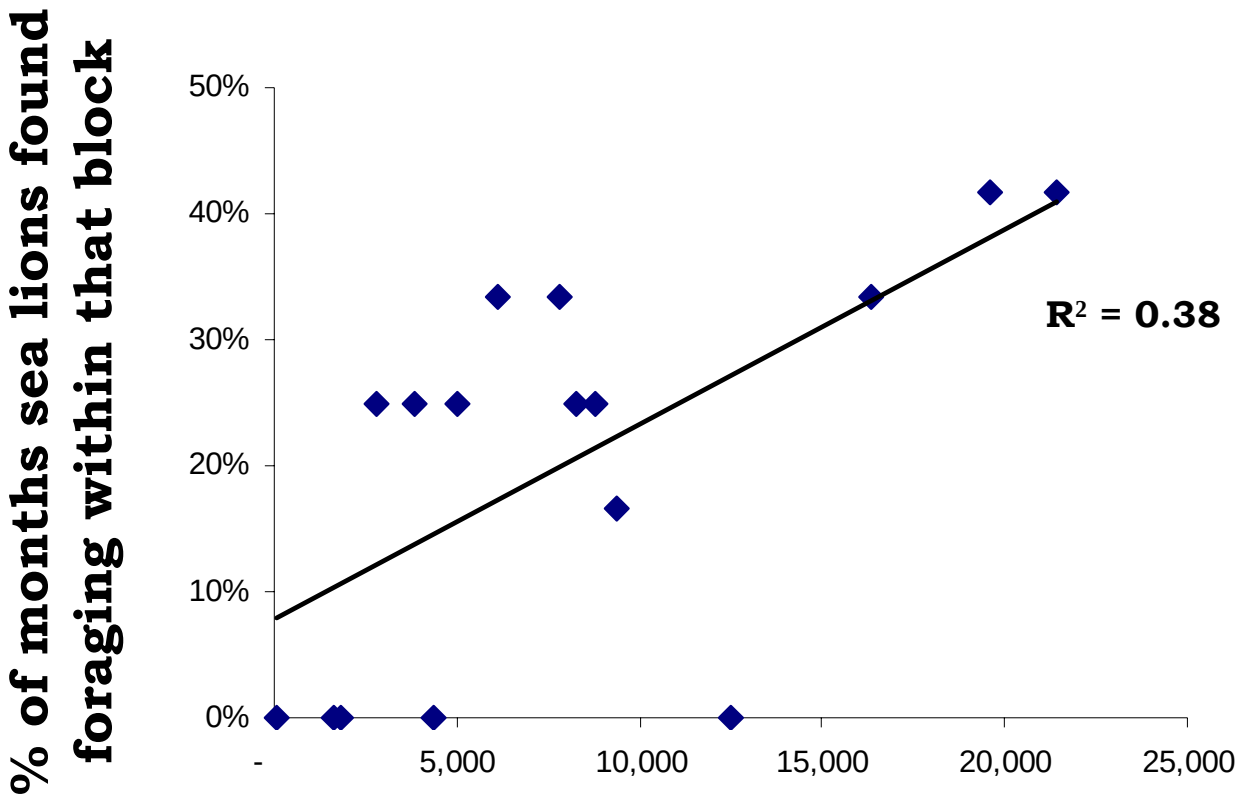


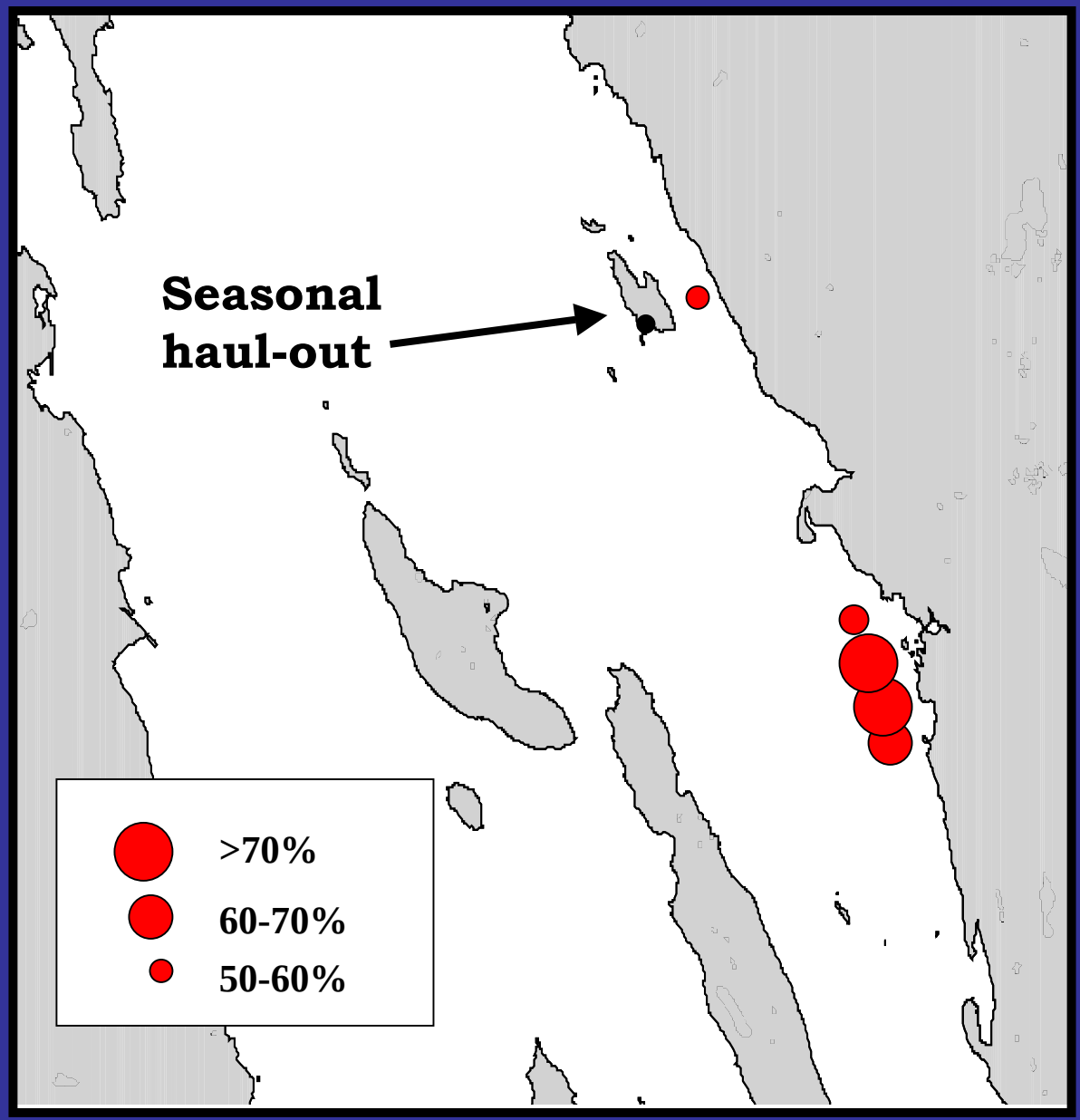
Proportion of observed Steller sea lions February 2004



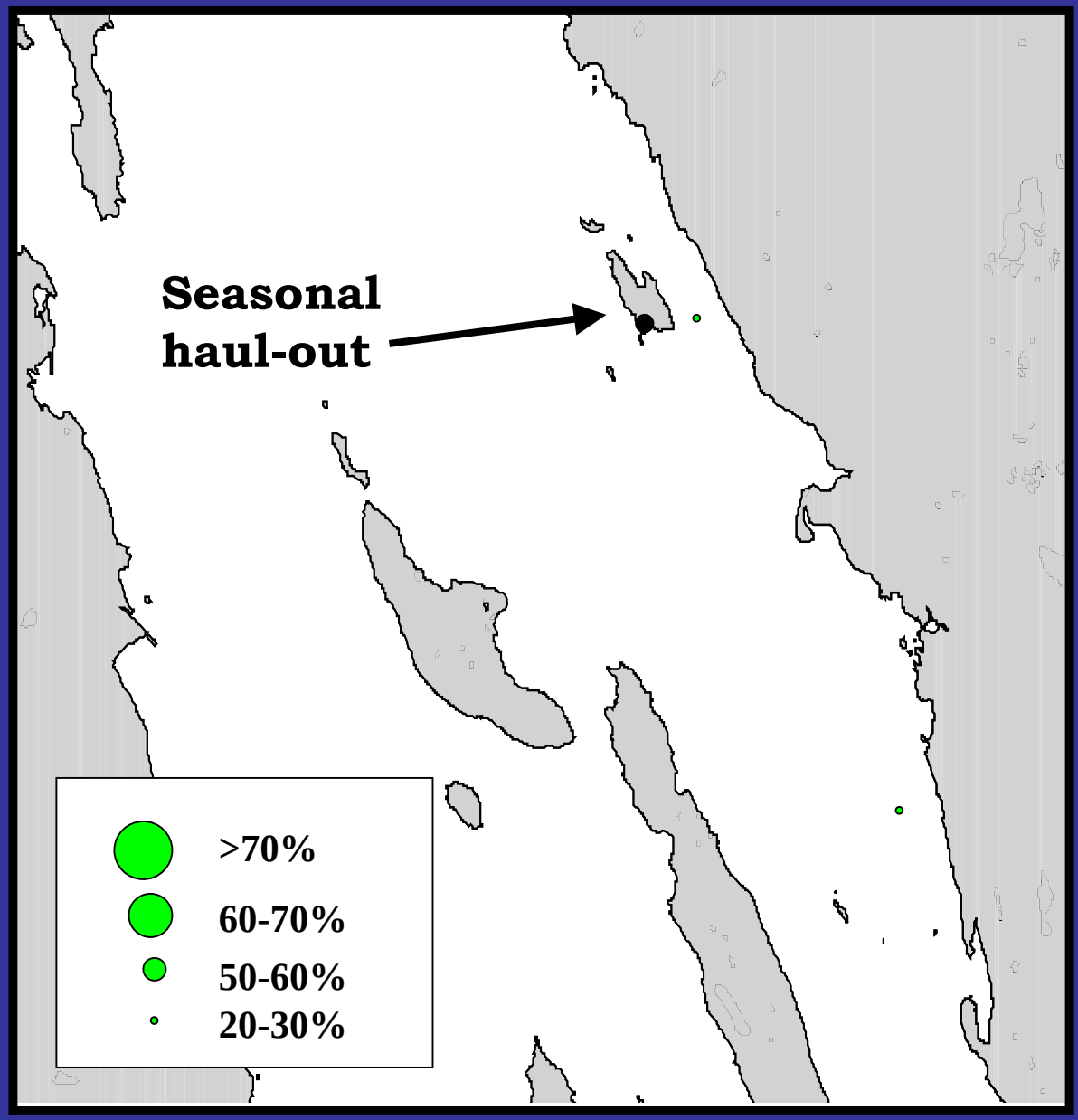
Strong relationship between the average energy density of each block (winter) and the distribution of Steller sea lions



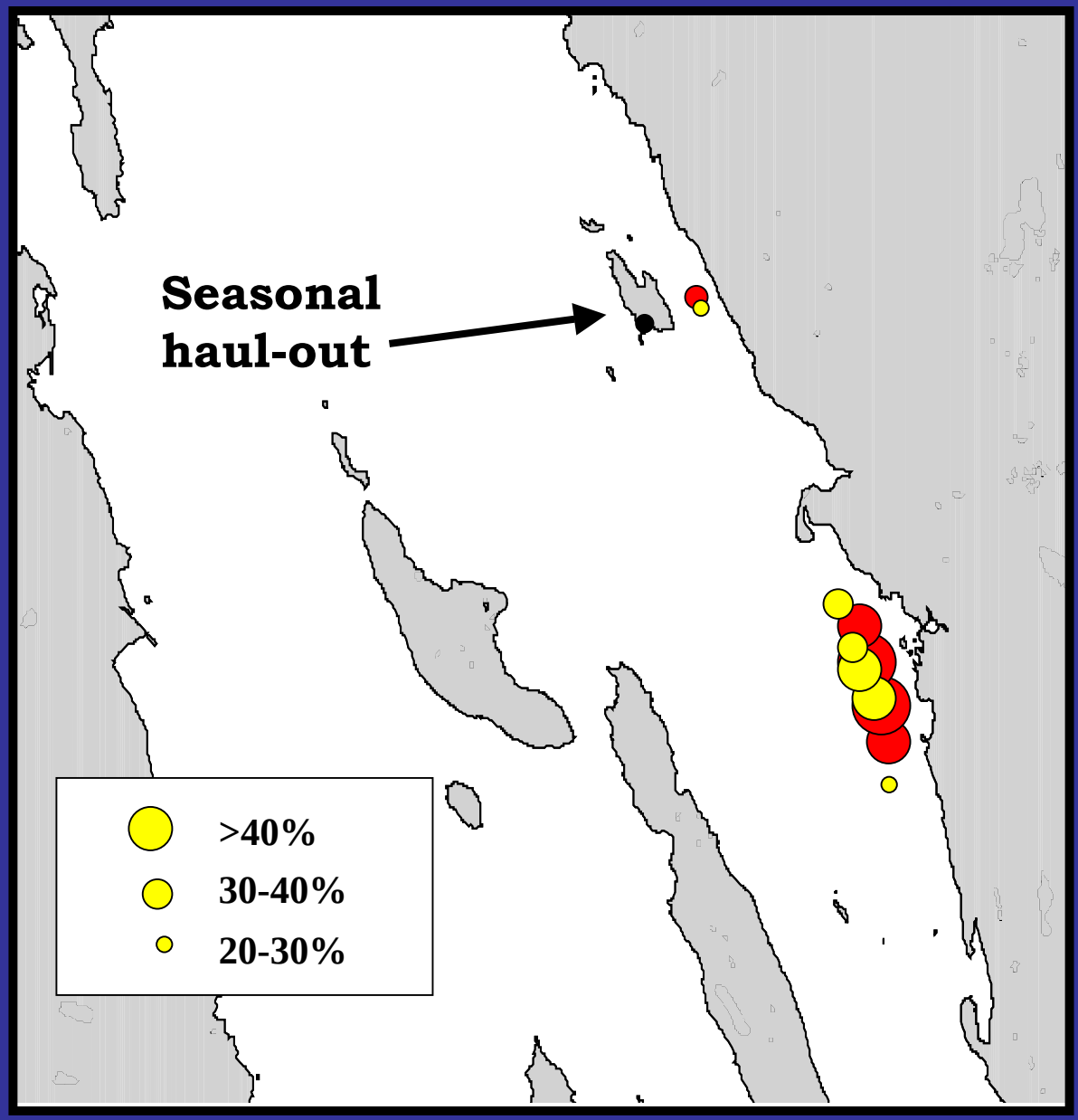
Hot spot persistence: the probability of encountering a hot spot across all winter months



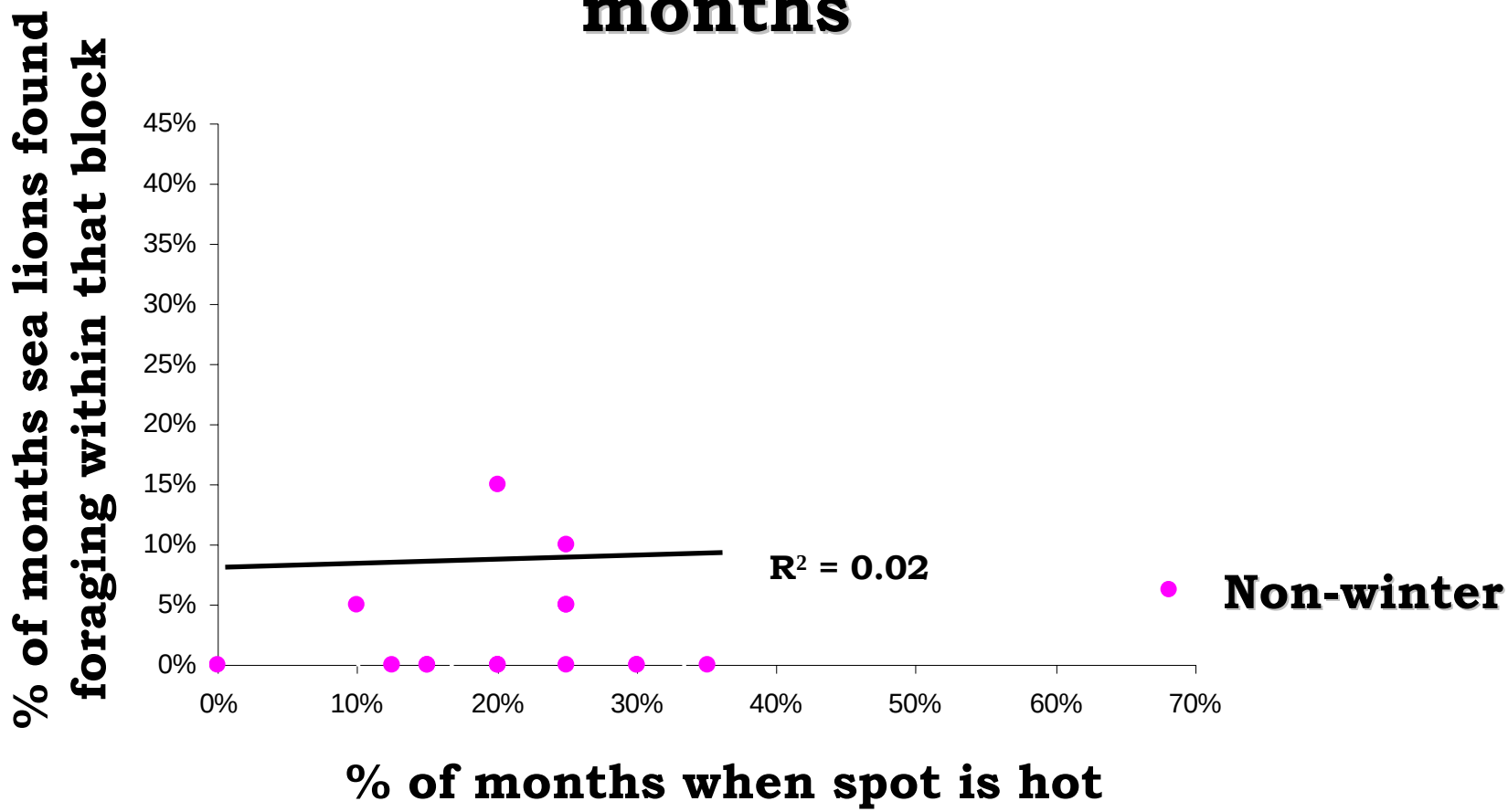
Hot spots do not persist during the non-winter months



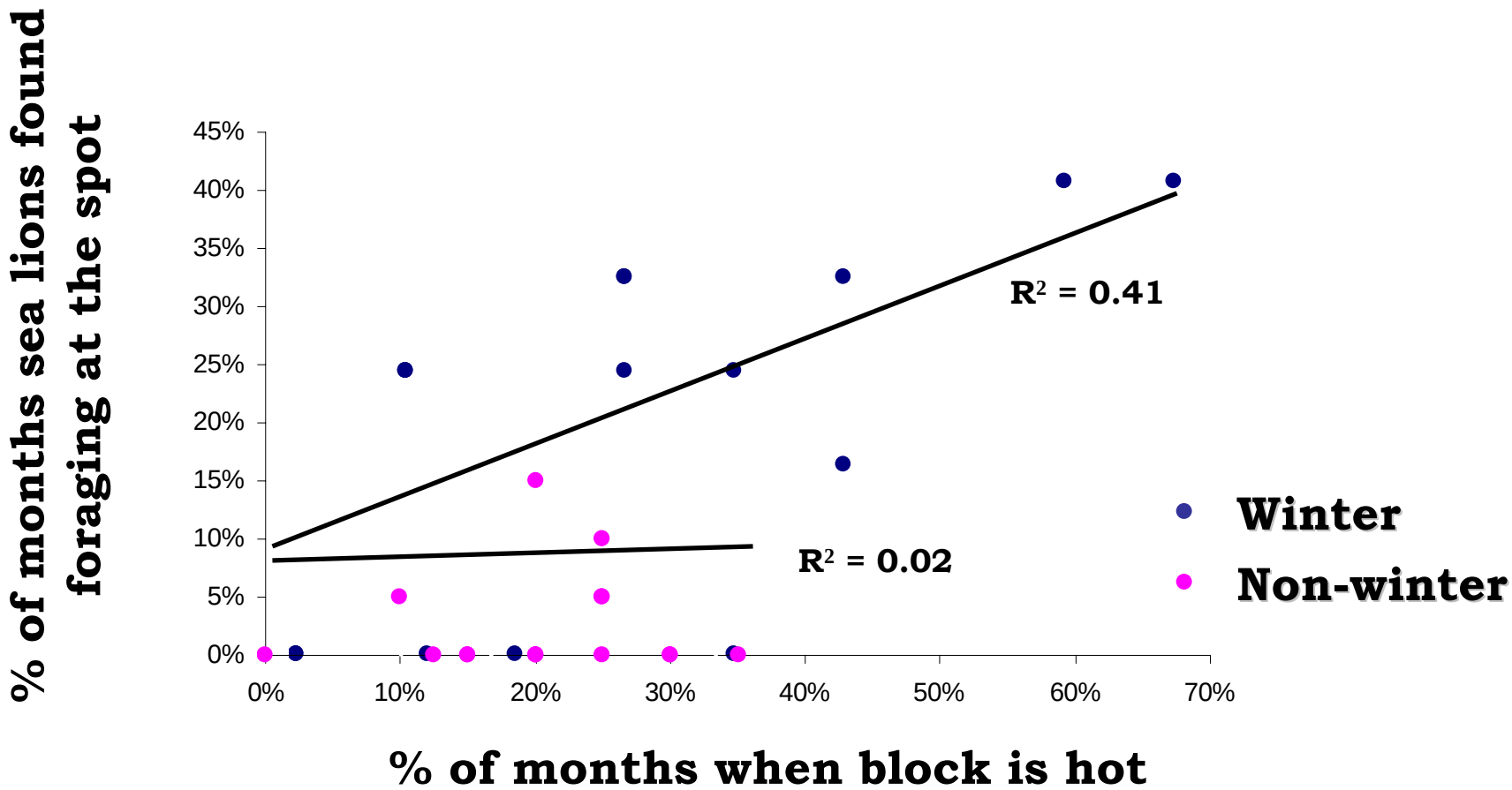
Proportion of winter surveys when sea lions seen foraging



No relationship between hot spot location and foraging sea lions during the non-winter months



Sea lions consistently utilized the prey hot spots during the winter (Nov-Feb)



1. Are prey aggregated in time and space?

- Overwintering herring schools result in high prey aggregations Nov-Feb and occur in consistent locations.

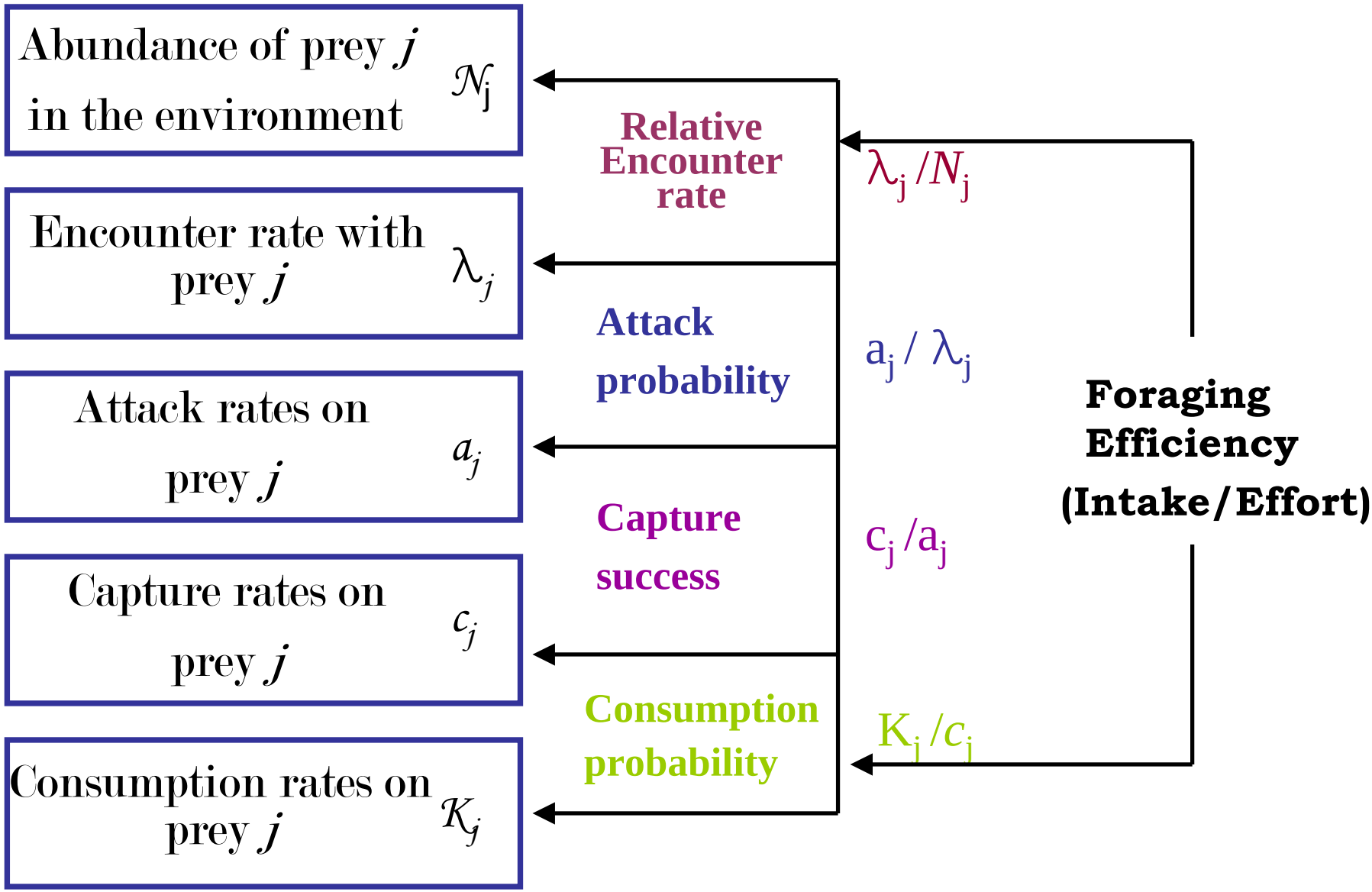
2. Do these prey 'hot spots' persist?

- Some hot spot areas persisted through time; the probability of encountering a high concentration of prey exceeded 70% for some areas

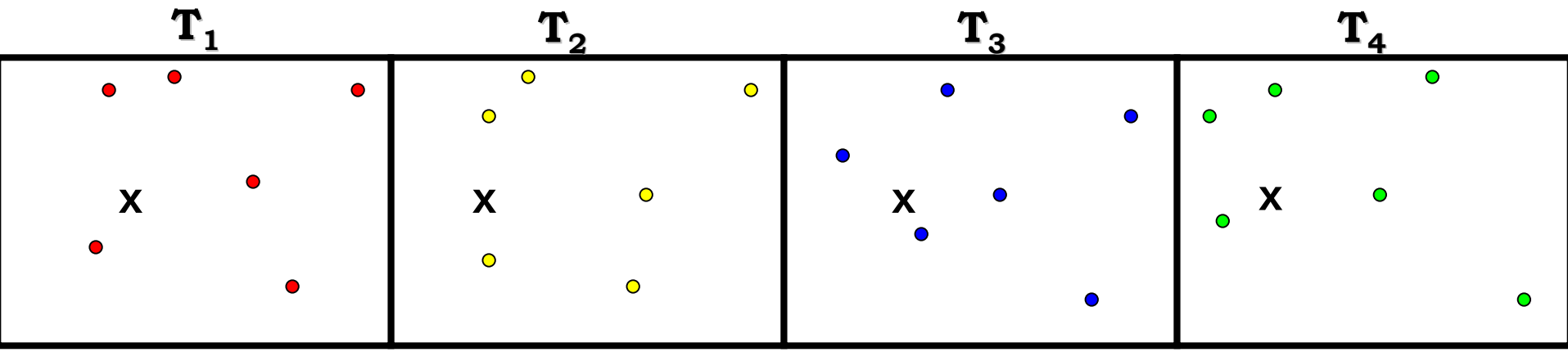
3. Do predators respond to this persistence?

- Strong relationship (during the winter) between sea lion distribution and distribution of prey. However, it appears that sea lions response is greatest in areas with highest prey persistence rather than highest prey density

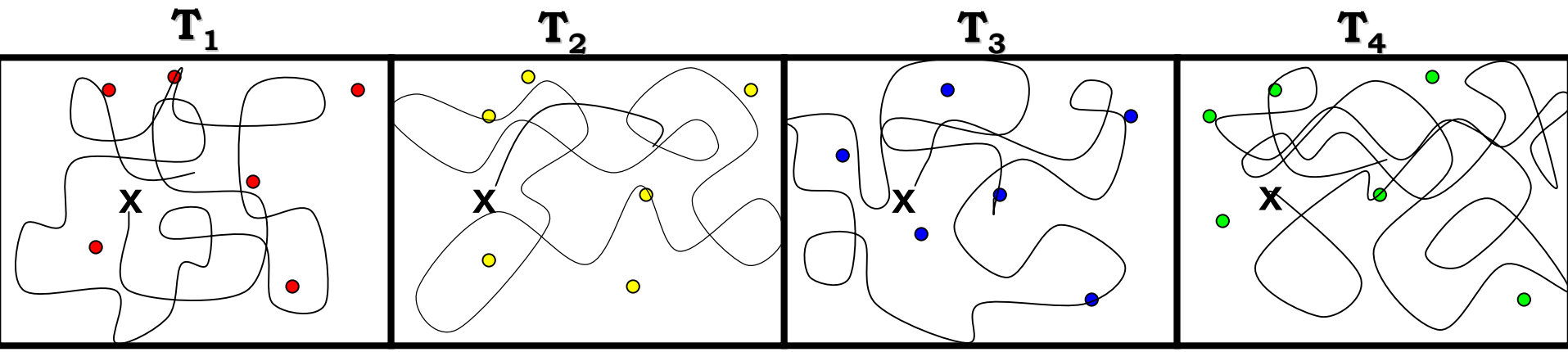
So what?


Abundance of prey *j* in the environment
$\mathcal{N}_j$
Encounter rate with prey *j*
λ_j
Attack rates on prey *j*
a_j
Capture rates on prey *j*
c_j
Consumption rates on prey *j*
$\mathcal{K}_j$
Relative Encounter rate
Attack probability
Capture success
Consumption probability
λ_j / N_j
a_j / λ_j
c_j / a_j
K_j / c_j
Foraging Efficiency (Intake/Effort)

High density, low persistence of prey patches



High density, low persistence of prey patches



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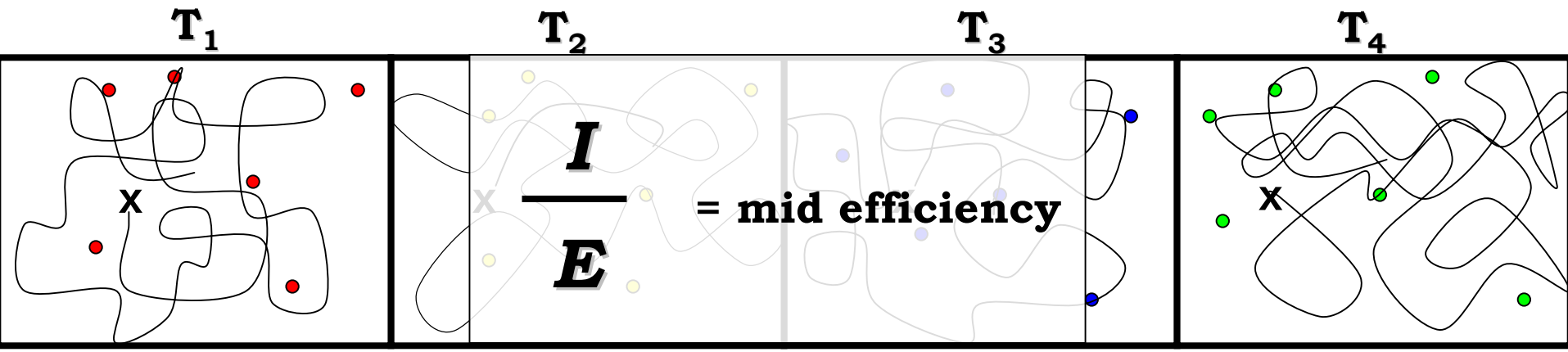
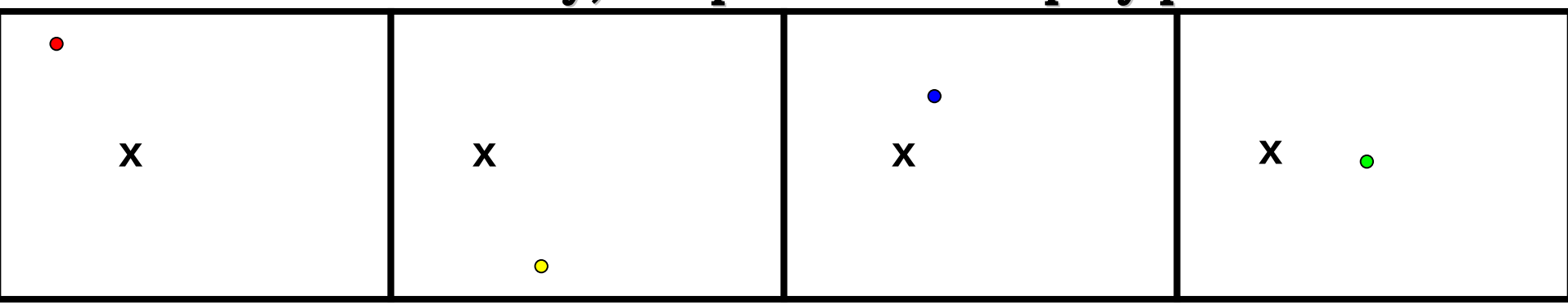


High density, low persistence of prey patches

Low density, low persistence of prey patches



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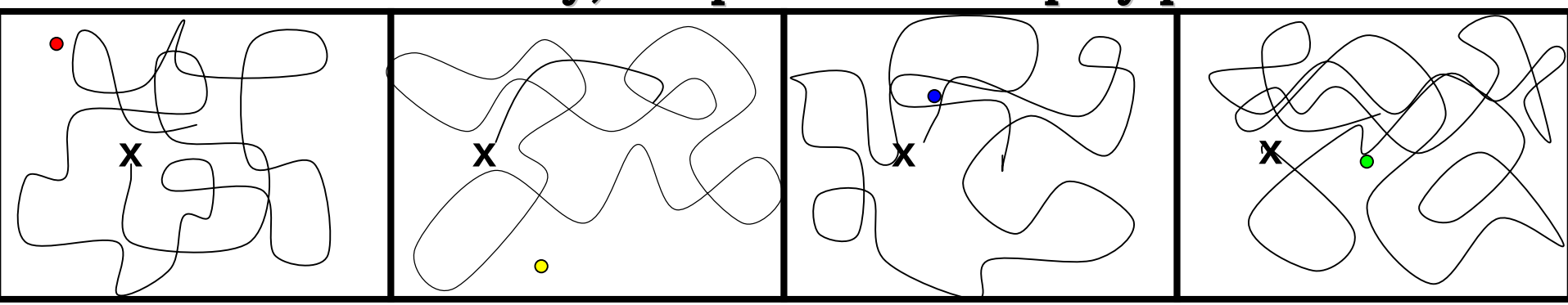

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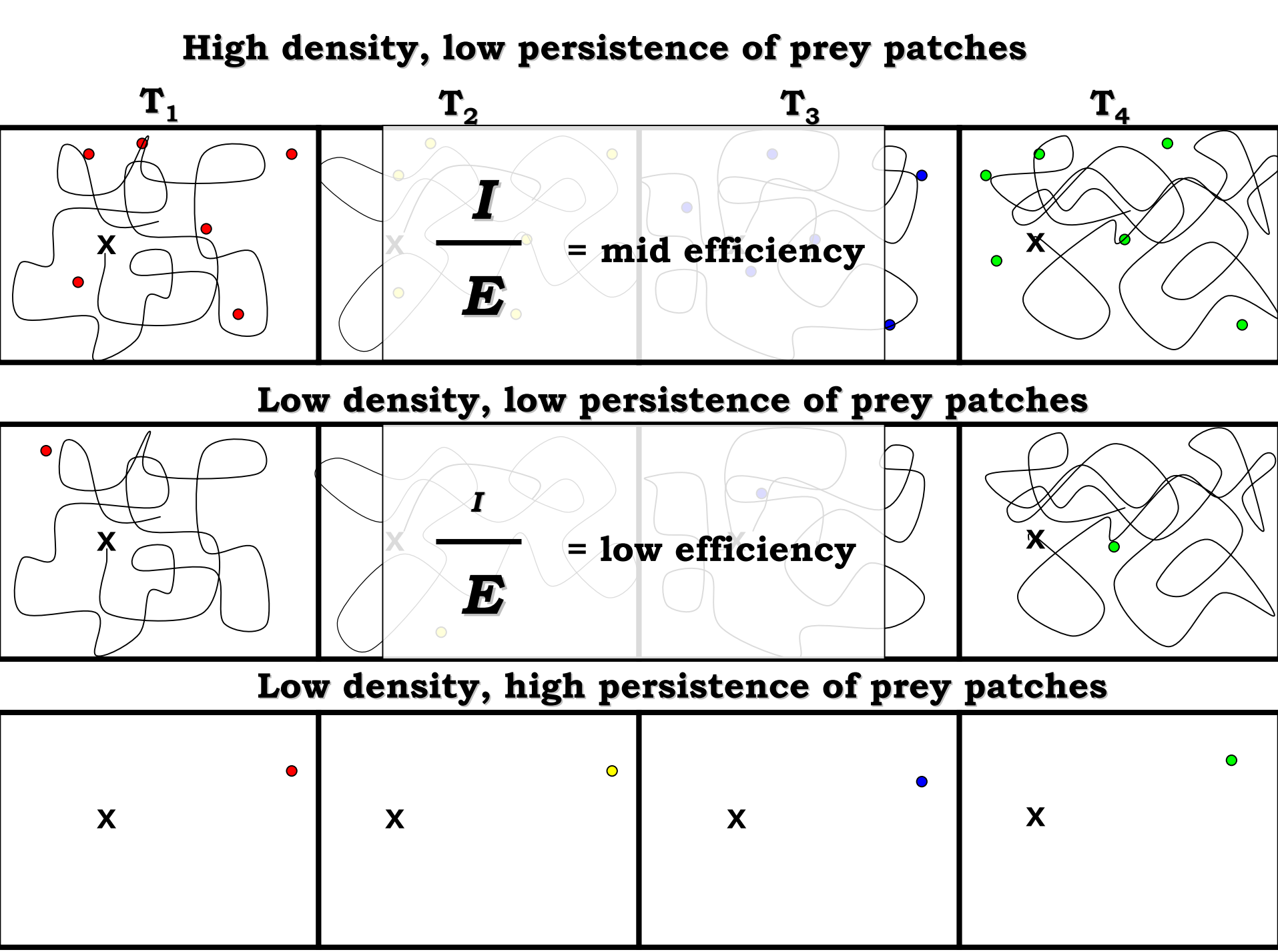
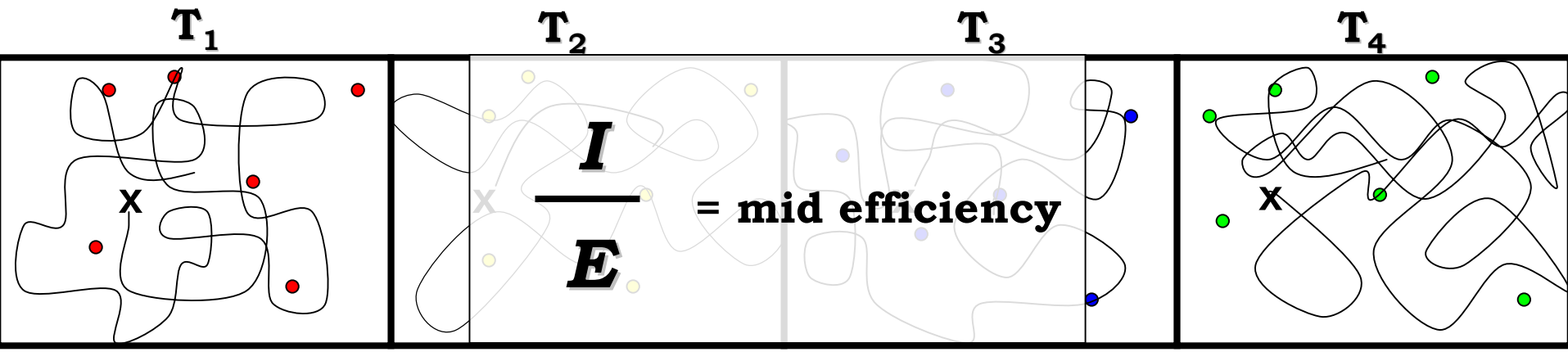
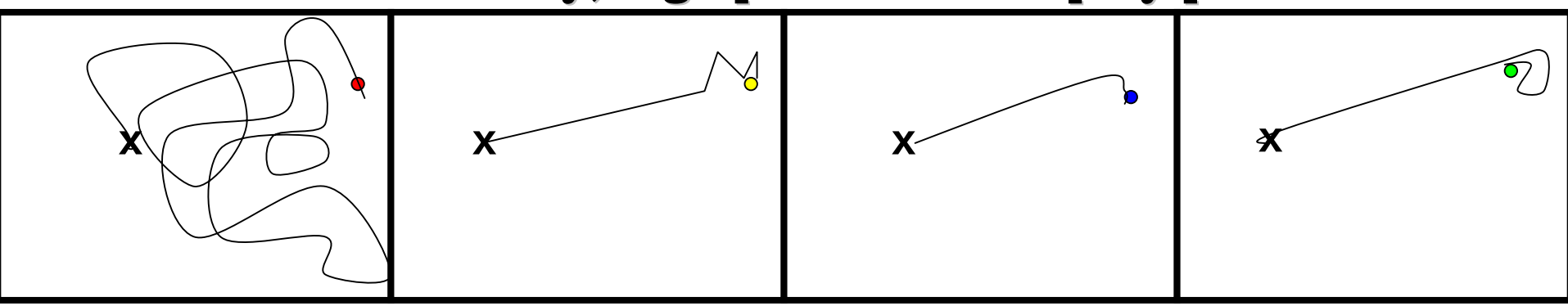

High density, low persistence of prey patches
T1
T2
T3
T4
X
I/E = mid efficiency
Low density, low persistence of prey patches
I/E = low efficiency
Low density, high persistence of prey patches

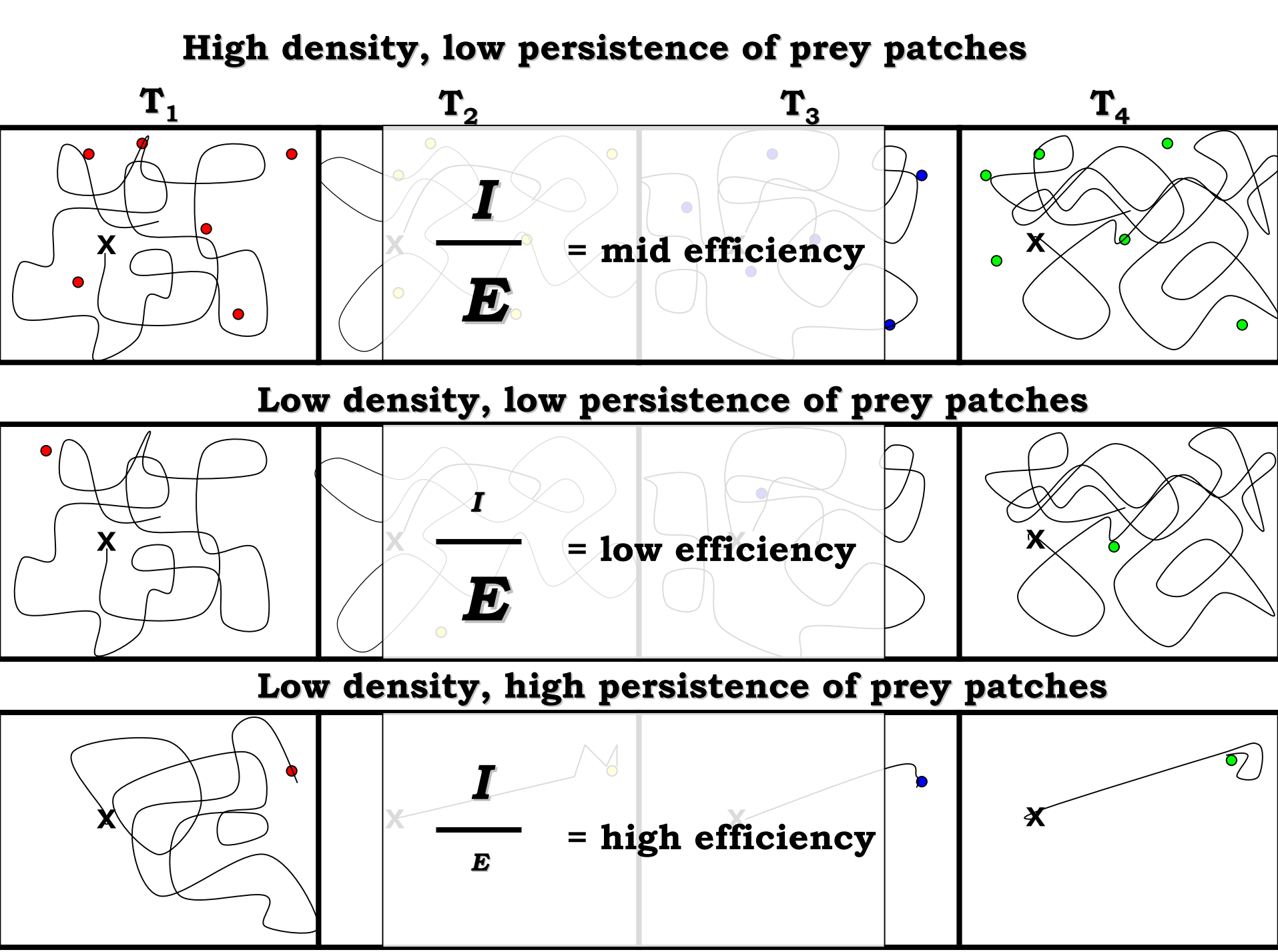
High density, low persistence of prey patches



Low density, low persistence of prey patches

Low density, high persistence of prey patches




High density, low persistence of prey patches
T1
T2
T3
T4
I / E = mid efficiency
Low density, low persistence of prey patches
I / E = low efficiency
Low density, high persistence of prey patches
I / E = high efficiency

Density may not be the only characteristic of prey aggregations that are important to predators; persistence may be just as important, particularly for those that do not have the ability to search large areas efficiently.


Johnson