Monitoring Mediterranean monk seals, a population widely dispersed at low densities

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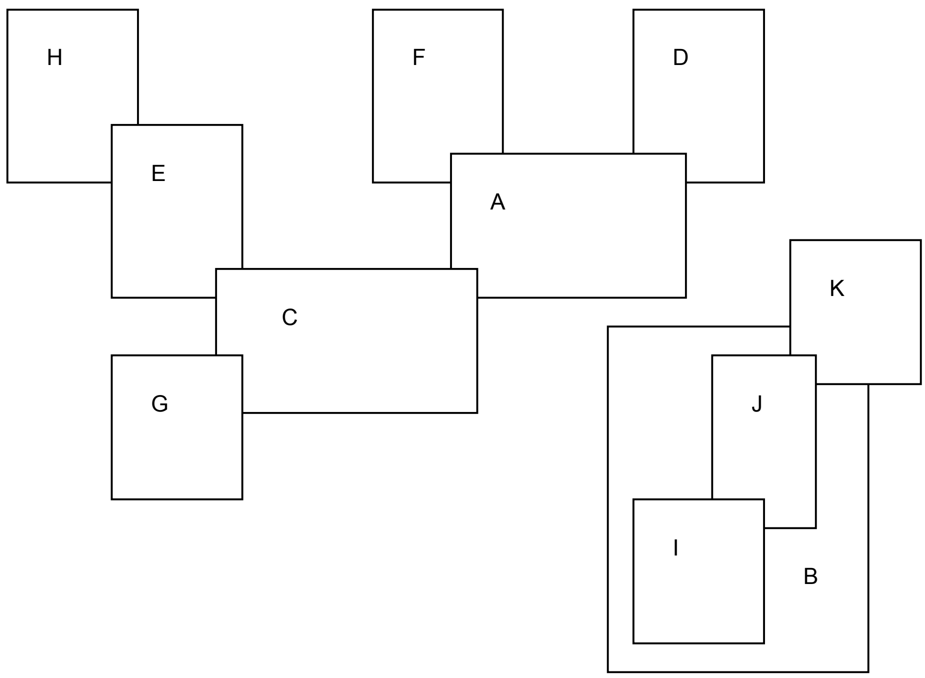
Surveying animals as sparsely distributed as Mediterranean monk seals is time consuming, expensive and may carry some risk of causing disturbance. It's vital, therefore, to extract as much information as possible from the results. In my talk I tried suggest two ways of maximising the information available from an existing survey.

To discover potential breeding and resting haul-outs along remote coastlines requires a slow and painstaking search. On the other hand, given GPS recording of detected haul-out locations the effort required to revisit sites is trivial. A relatively cheap way to capitalise on the survey results is to monitor signs of seal visits such as tracks or scat by repeated visits to selected sites. However, there is a risk that variation in the rate at which wave action erodes such signs, resulting from variation in weather or boat traffic, may be confounded with the rate at which signs are left by visiting seals. To control for the erosion rate, recorded signs should be cleared and an artificial sign left, such as a cross-shaped track in a sand or pebble beach or a small object placed on a rocky haul-out. On each subsequent visit the presence/absence of both artificial and real signs are noted. There is a potential to model the resulting data stochastically to estimate seal visit rate. Alternatively, by standardising the time interval between successive researcher visits, an index of seal visit rate is available by simply censoring those intervals over which the artificial signs were swept away by wave action.

Camera traps may permit individual identification of the photographed seals but unless the coverage is very intensive many seals may be identified only by markings visible from certain angles. As a result a given pair of images may show the same seal or two seals that are definitely different, or it may impossible say whether the images do or do not show different seals. It may therefore be impossible to say how many individuals the images show. However, it may still be valuable to calculate the minimum number of individuals, for example to assess whether a viable population remains over a given stretch of coastline.

The following diagram illustrates a scheme for calculating the minimum number.



The diagram shows prints arranged in piles on a table. Each pile is all the photos of a particular animal. The piles that are not overlapping (e.g. A and B) definitely show different seals. If the animals occurred in alphabetical order then after B no more images were obtained of seals that are definitely different from all previous seals. Yet there are obviously more than two seals represented, in fact by squinting at the diagram (i.e. using parallel processing) it is easy to see, with such a small set of images, that there are at least 6 different animals represented.

With more photos it becomes difficult to represent what we know via a diagram so we need an algorithm. In the case of the illustrated example we can summarise what we know in the following lower diagonal matrix:

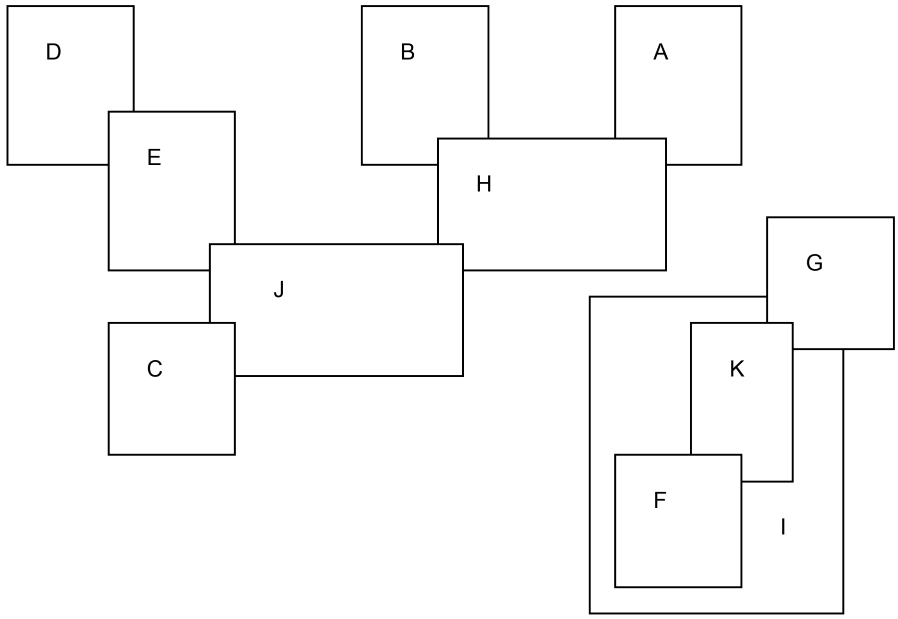
	A										
B	*d*	**B**									
C		*d*	**C**								
D		*d*	*d*	**D**							

E	*d*	*d*		*d*	**E**						
F		*d*	*d*	*d*	*d*	**F**					
G	*d*	*d*		*d*	*d*	*d*	**G**				
H	*d*	*d*	*d*	*d*		*d*	*d*	**H**			
I	*d*		*d*	*d*	*d*	*d*	*d*	*d*	**I**		
J	*d*		*d*	*d*	*d*	*d*	*d*	*d*		**J**	
K	*d*		*d*	*d*	*d*	*d*	*d*	*d*	*D*		**K**

Working down the matrix we can then list, for each animal, the animals it's definitely different from that are definitely different from each other:

This animal	**distinct from these mutually distinct animals**	**number of animals**
A	B,E,G	**4**
B	A,E,G	**4**
C	B,D,F,H	**5**
D	B,C,F,H	**5**
E	A,B,G	**4**
F	B,C,D,H	**5**
G	A,B,E	**4**
H	A,B,G	**4**
I	A,E,G,K	**5**
J	A,E,G	**4**
K	A,E,G,I	**5**

Considering the piles in that order we got only 5 animals. We get a larger minimum number of animals by picking the piles in order from least to most overlaps instead of considering the animals in the order in which they happened to be photographed. Re-labelling the piles:



rearranges the rows in the matrix to put all the Ds near the top:

	A										
B	d	B									
C	d	d	C								
D	d	d	d	D							
E	d	d	d		E						
F	d	d	d	d	d	F					
G	d	d	d	d	d	d	G				
H			d	d	e	d	d	H			
I	d	d	d	d	d			d	I		
J	d	d		d		d	d		d	J	
K	d	d	d	d	d			d		d	K

and leads to the result that there are at least 6 animals:

This animal	distinct from these mutually distinct animals	number of animals
A	B,C,D,F,G	6
B	A,C,D,F,G	6
C	A,B,D,F,G	6

D	A,B,C,F,G	**6**
E	A,B,C,F,G	**6**
F	A,B,C,D,G	**6**
G	A,B,C,D,F	**6**
H	C,D,F,G	**5**
I	A,B,C,D	**5**
J	A,B,D,F,G	**6**
K	A,B,C,D	**5**