Moving parts of the food web: detecting and predicting climate-induced migratory changes to structure, function, resilience and production of marine ecosystems

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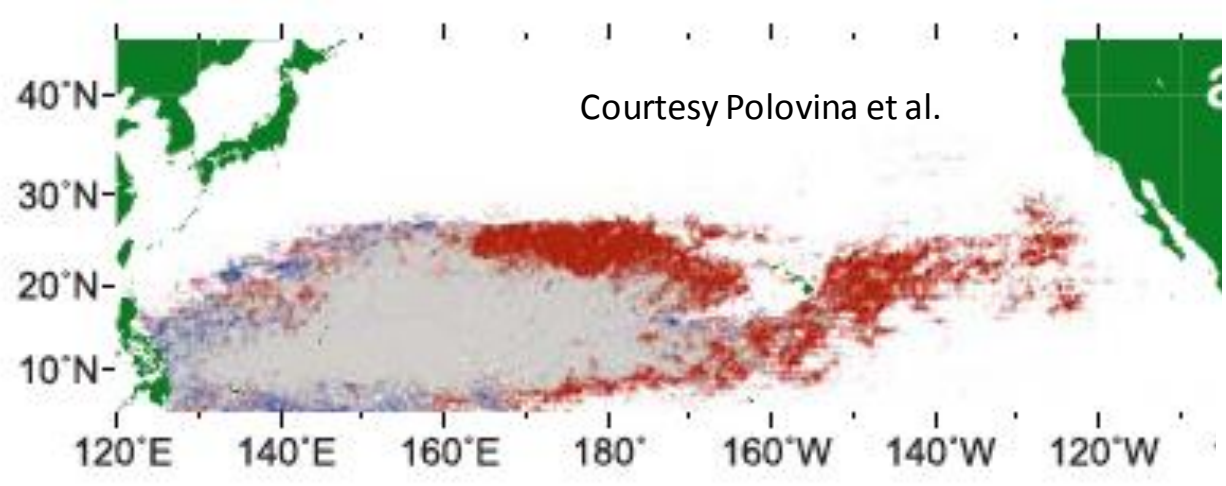
NOAA Fisheries

S9: Impact of Climate Change on Ecosystem Carrying Capacity Via Food-web Spatial Relocations
MAR 2015

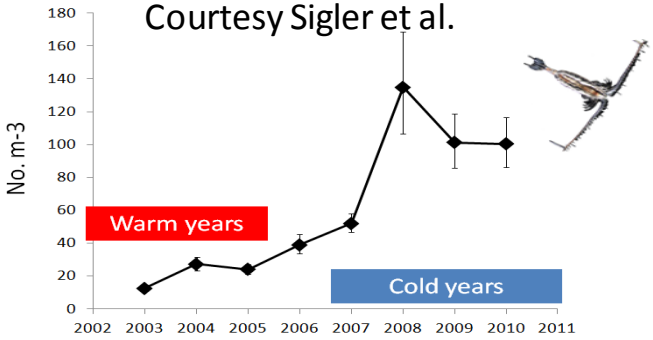
Climate Change is Already Impacting Marine Food Webs

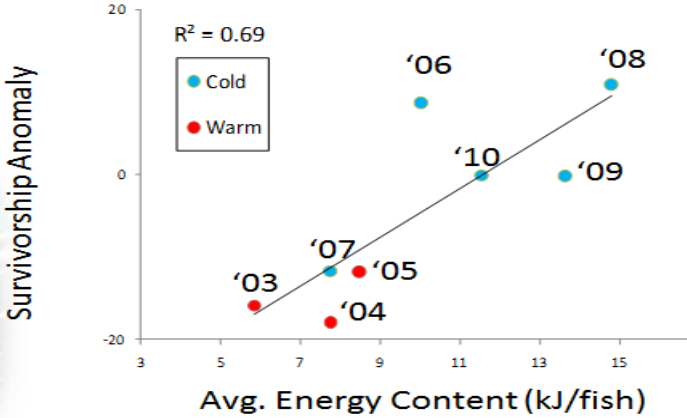


Courtesy Polovina et al.

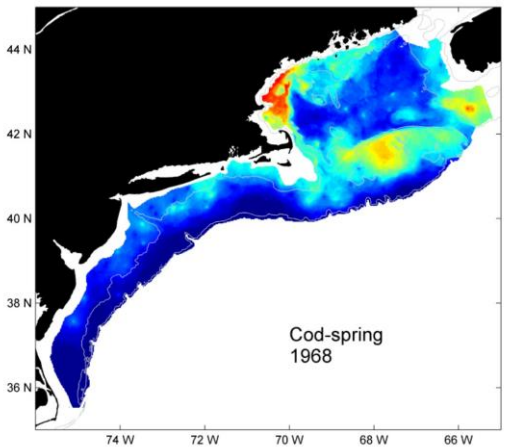
1998/1999 Only	1998/1999 and 2005/2006	2005/2006 Only

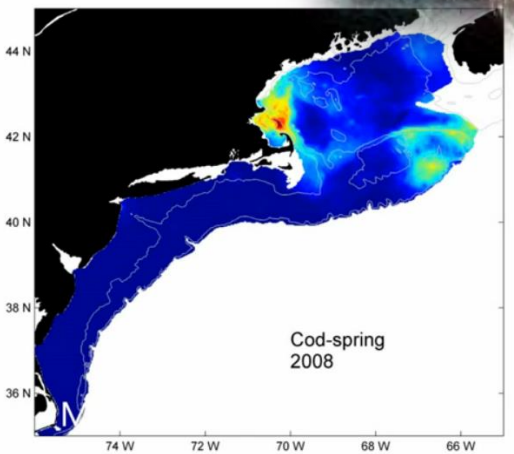
Courtesy Sigler et al.

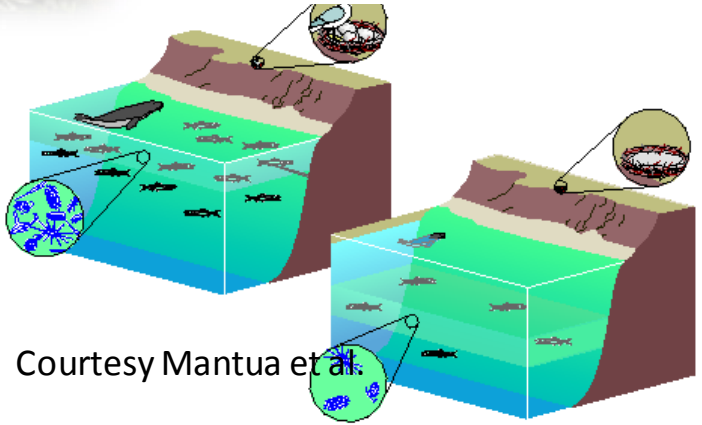




Courtesy Nye, Richardson, Fogarty et al.

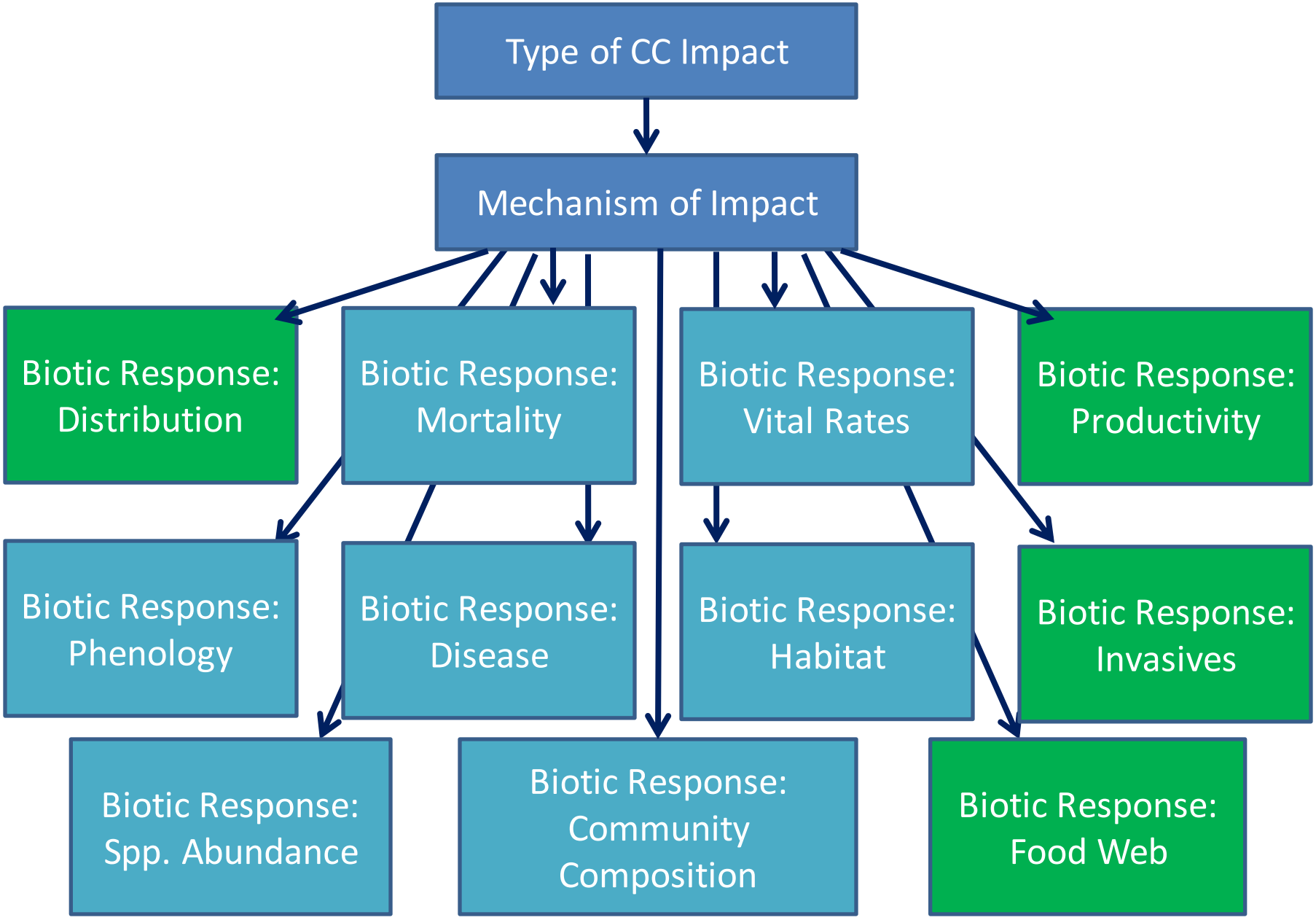




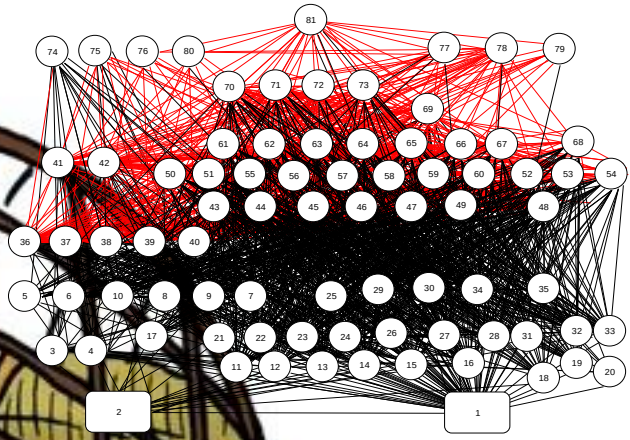


Courtesy Mantua et al.

Biological Responses



The Hut Hypotheses



I. Adding

A. Roof

B. Base

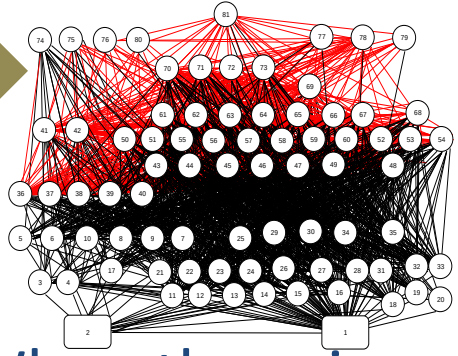
C. Inside

II. Removing

A. Roof

B. Base

C. Inside



The Hut Hypotheses
I.A. Adding to the Roof

When there is an invasive, or resurgence of N or B or size, for upper TL spp

- H.I.A.1- this initiates a trophic cascade, with some parts of the food web thriving
- H.I.A.2- this exhibits general top-down effects and limits production of mid or lower TL
- H.I.A.3- this increases competition and limits production of other upper TL spp
- H.I.A.4- this makes the food web “top-heavy” and collapses the upper TL groups, releasing mid TL to dominance
- H.I.A.Alt- no or minimal response

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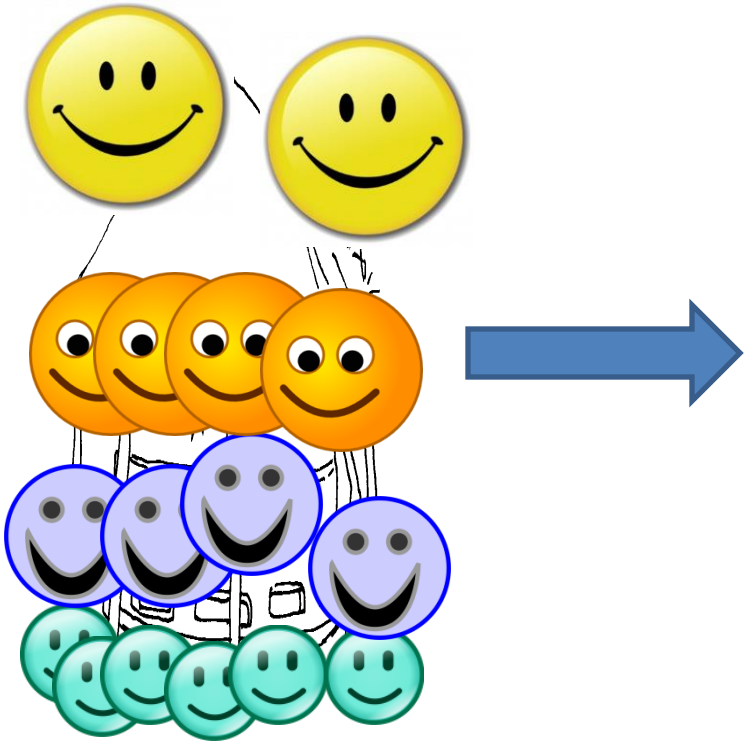

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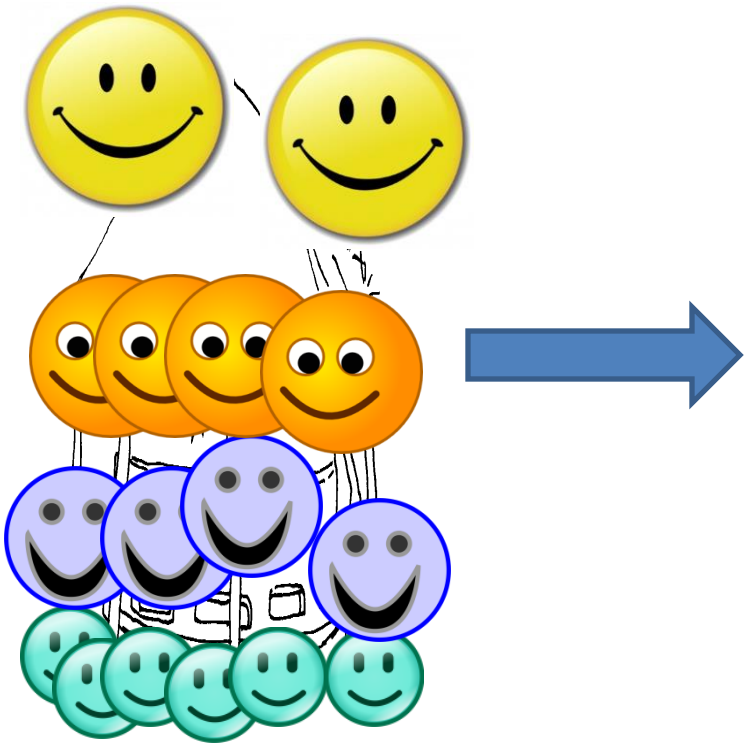

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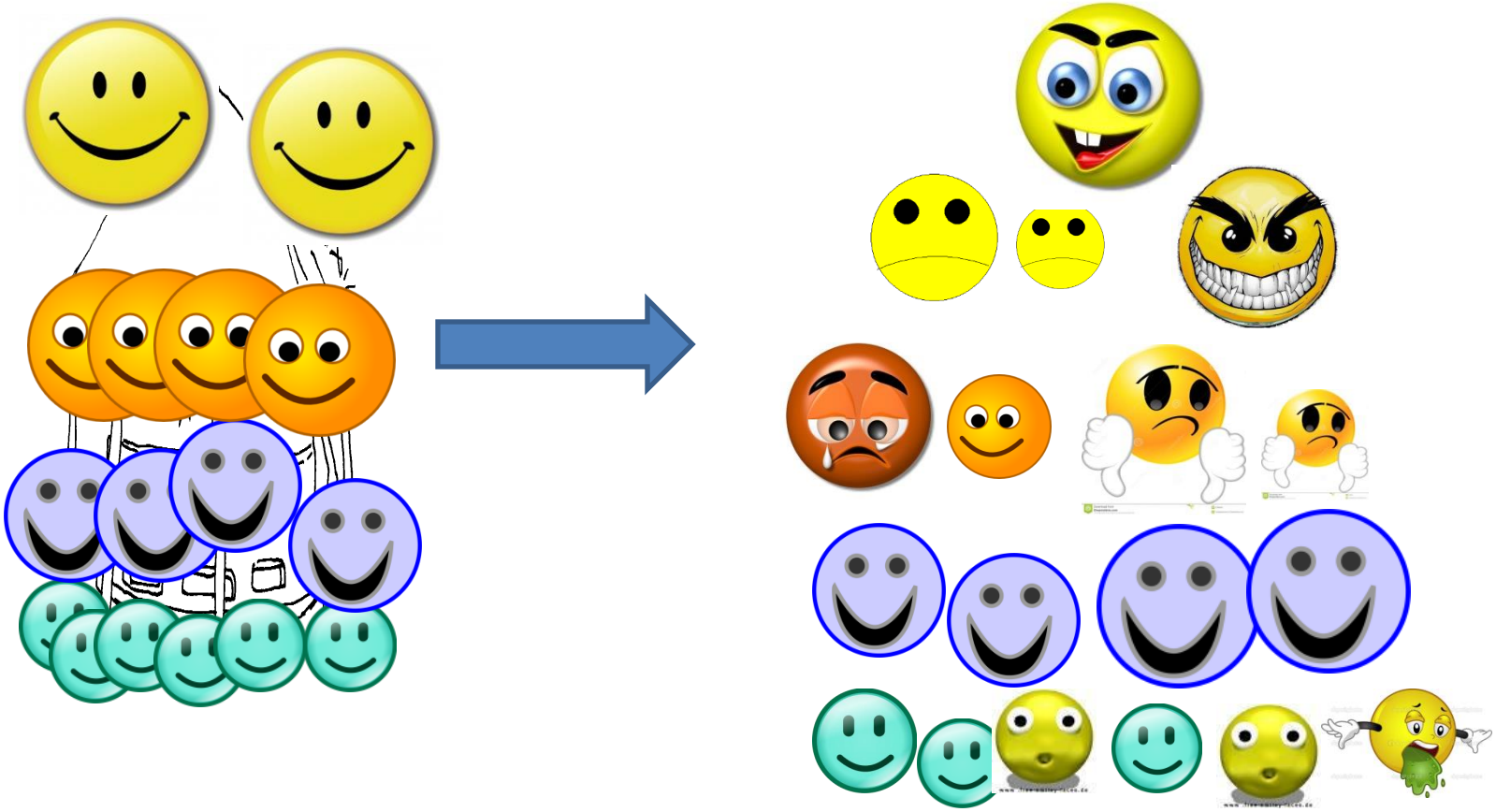
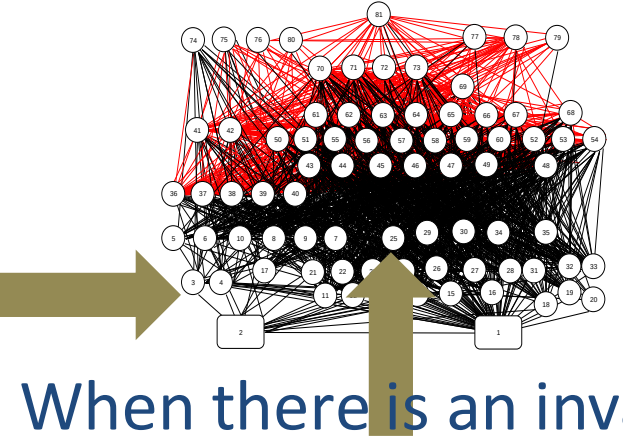


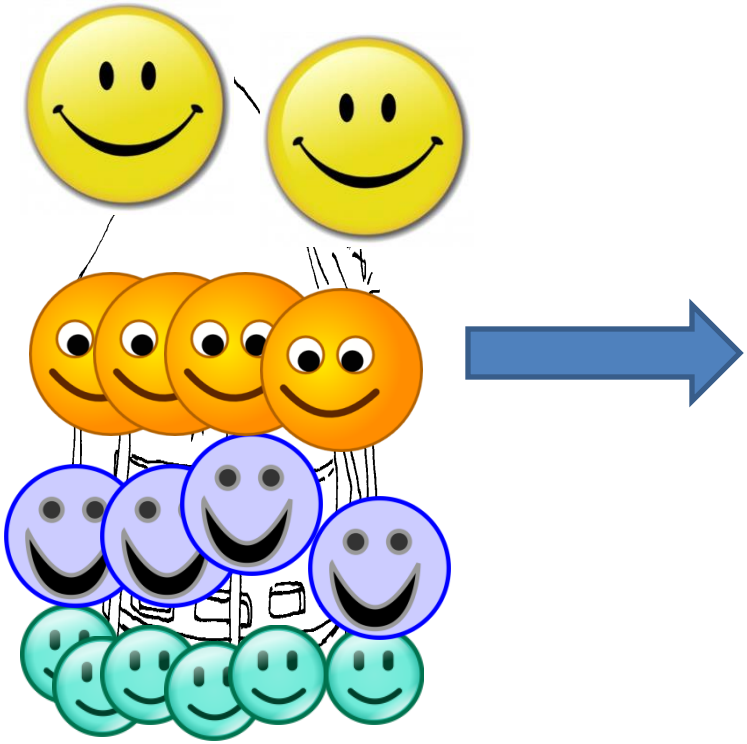


The Hut Hypotheses
I.B. Adding to the Base

When there is an invasive or an increase in production for basal (especially PP) lower TL spp

- H.I.B.1- this exhibits bottom-up effects and generally increases production at all TL
- H.I.B.2- this increases production in only some parts of the food web, but a net overall increase
- H.I.B.3- this displaces existing lower TL spp, is unpalatable to 2nd consumers, collapsing the food web or creating new energy pathways
- H.I.B.4- this increases competition and limits production of other lower TL spp
- H.I.B.Alt- no or minimal response

The Hut Hypotheses
I.B. Adding to the Base



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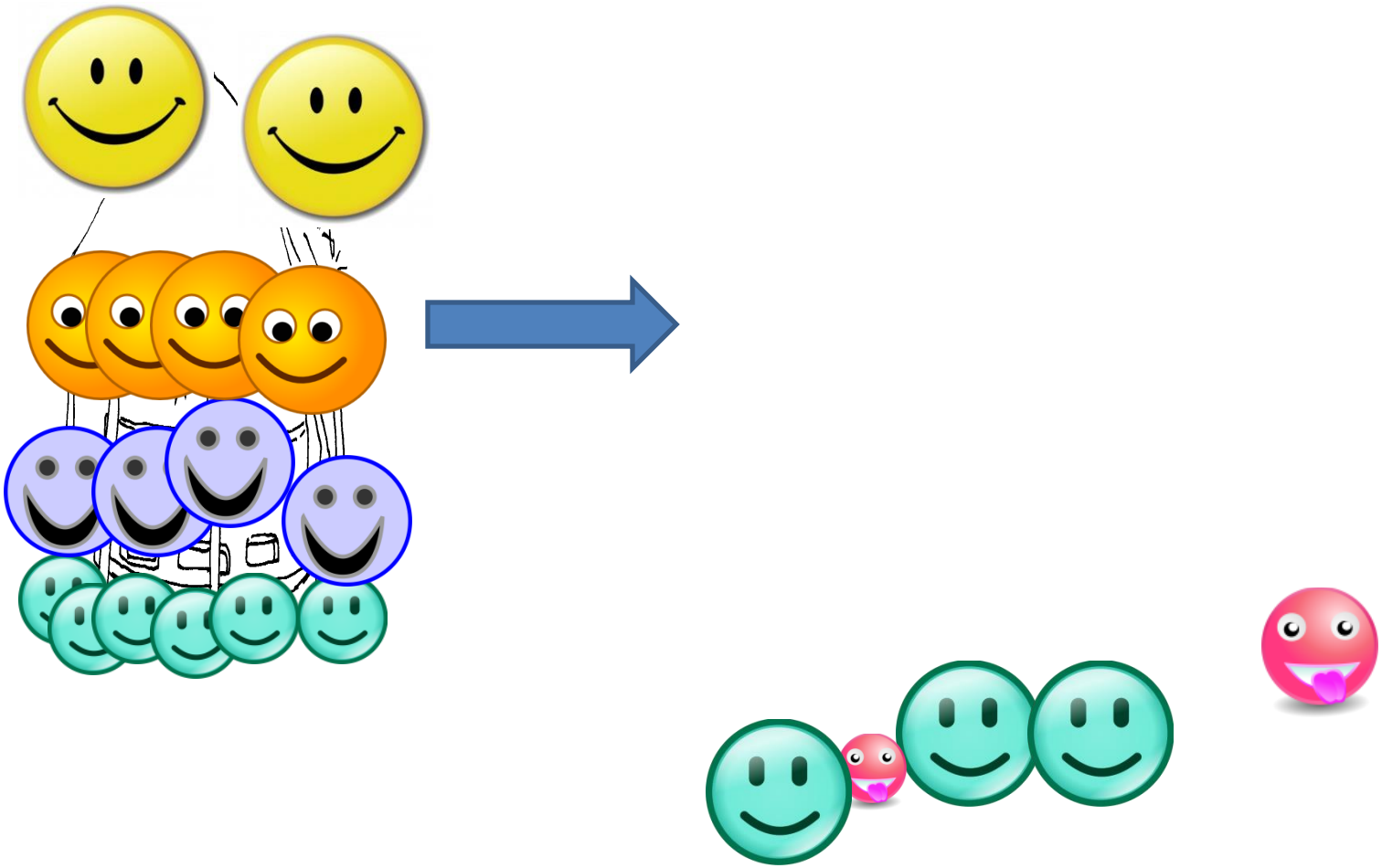

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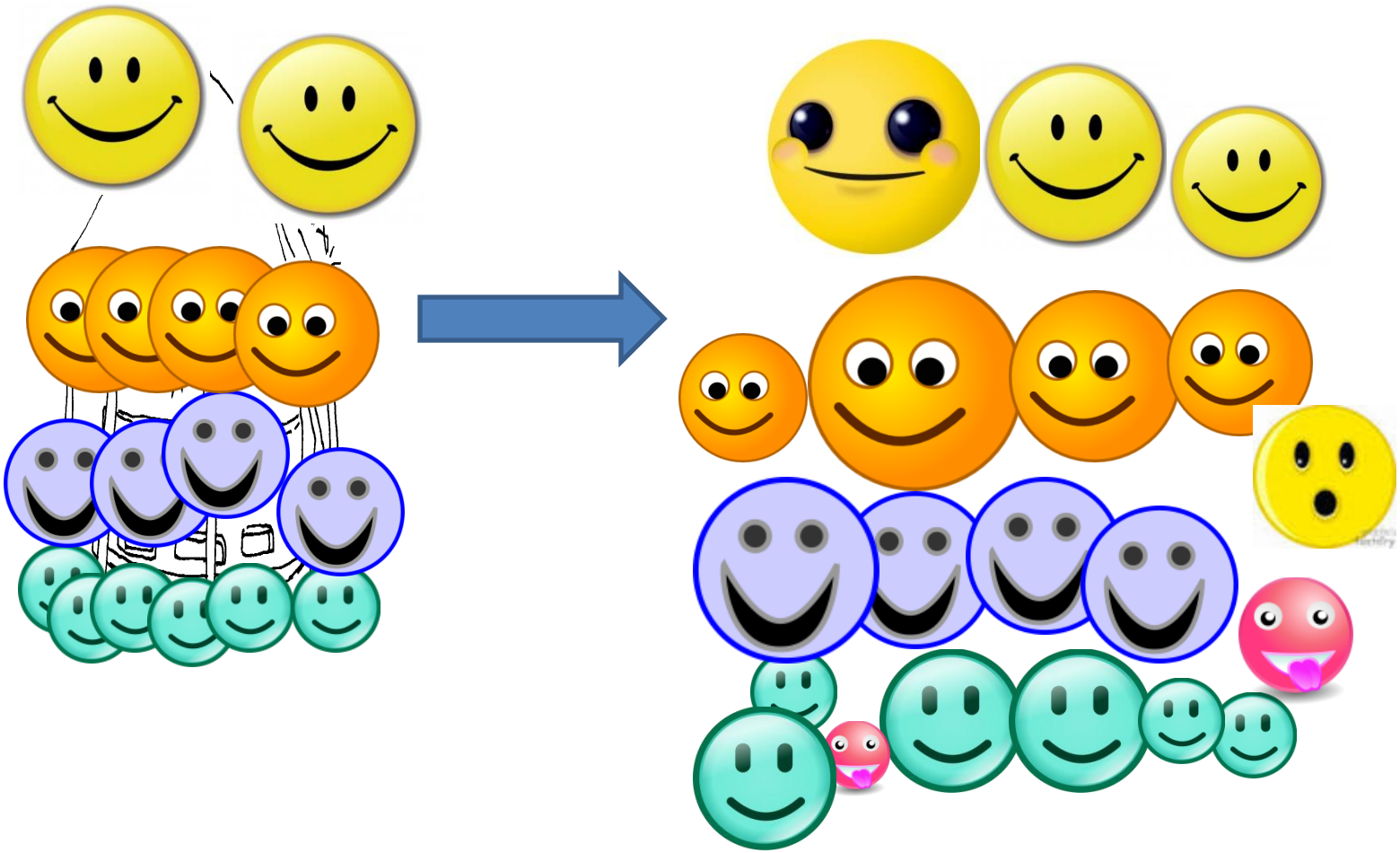
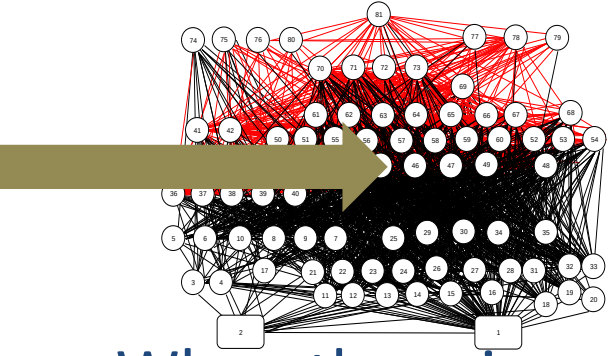


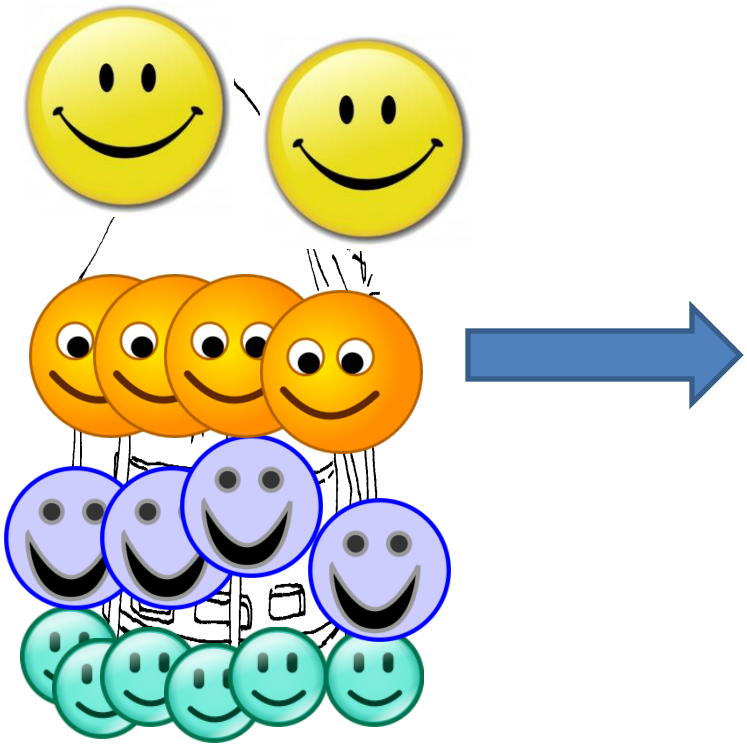


The Hut Hypotheses
I.C. Adding to the Inside

When there is an invasive, or resurgence of N or B or size, for mid TL spp

- H.I.C.1- this increases competition and limits production of other mid TL spp
- H.I.C.2- this is unpalatable to existing predators, limiting upper TL production
- H.I.C.3- new energy pathways are formed and this spp becomes dominant
- H.I.C.4- new energy pathways are formed, and other mid TL spp become important
- H.I.C.Alt- no or minimal response

The Hut Hypotheses
I.C. Adding to the Inside



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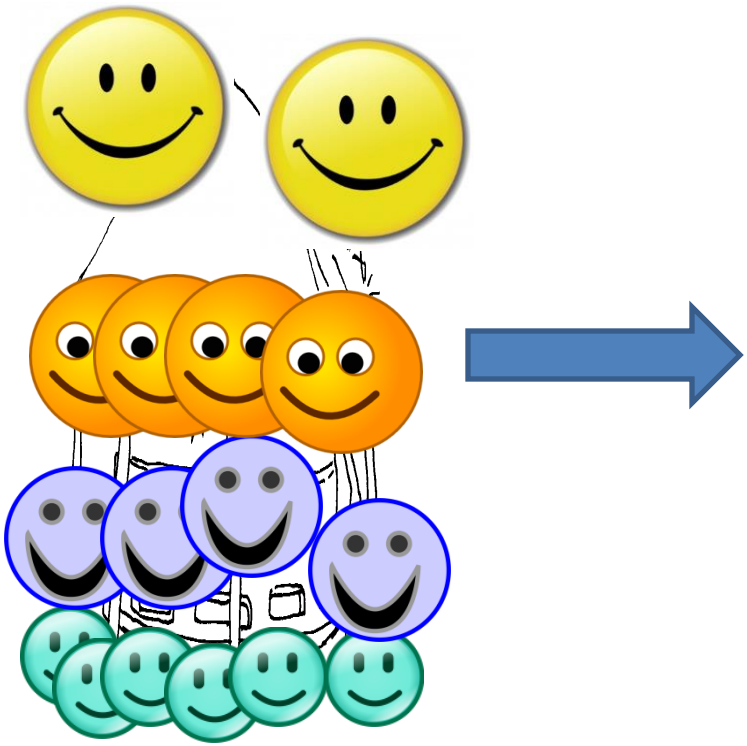

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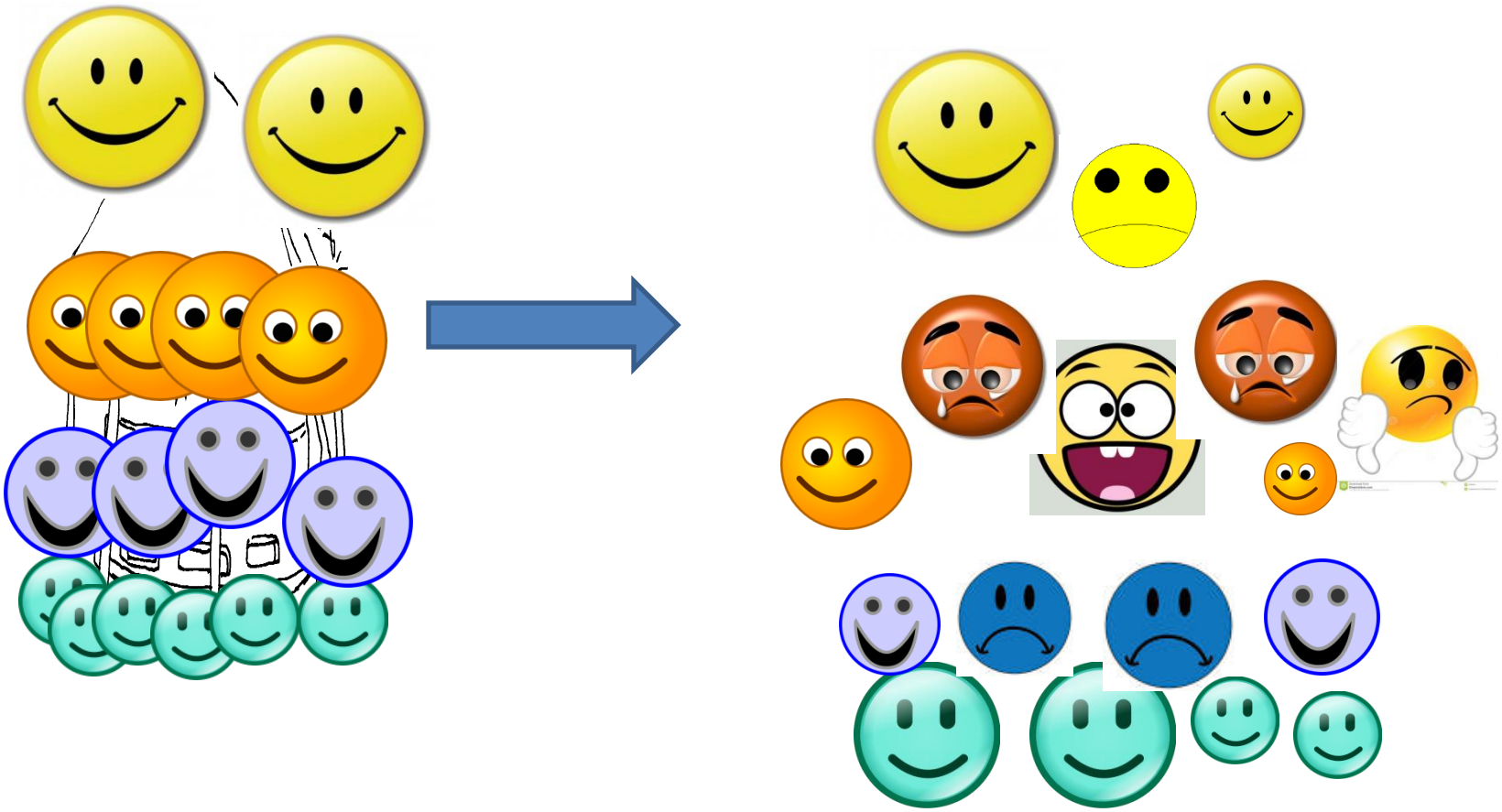
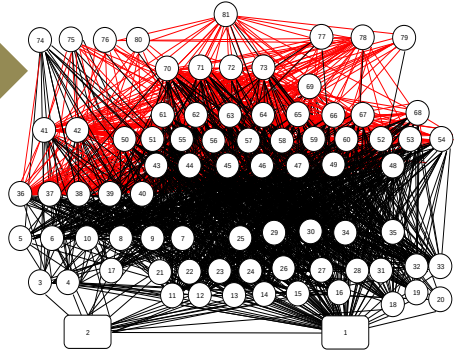




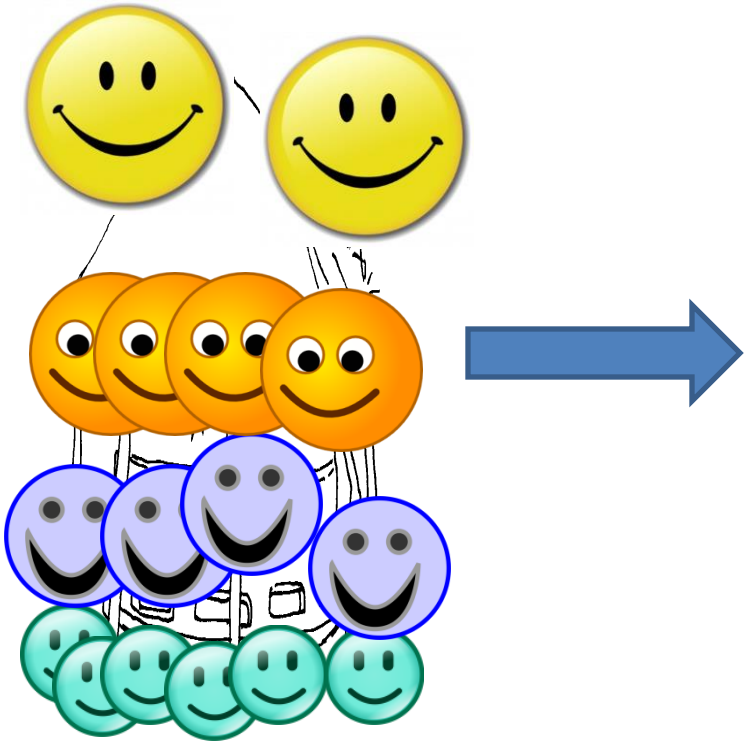
The Hut Hypotheses

II.A. Removing from the Roof

When there is a removal, or decline of N or B or size, for upper TL spp

- H.II.A.1- this reverses a trophic cascade, with some parts of the food web thriving
- H.II.A.2- this relaxes predation pressure, and production of mid TL increases
- H.II.A.3- this decreases competition and increases production of other upper TL spp
- H.II.A.Alt- no or minimal response

The Hut Hypotheses
II.A. Removing from the Roof



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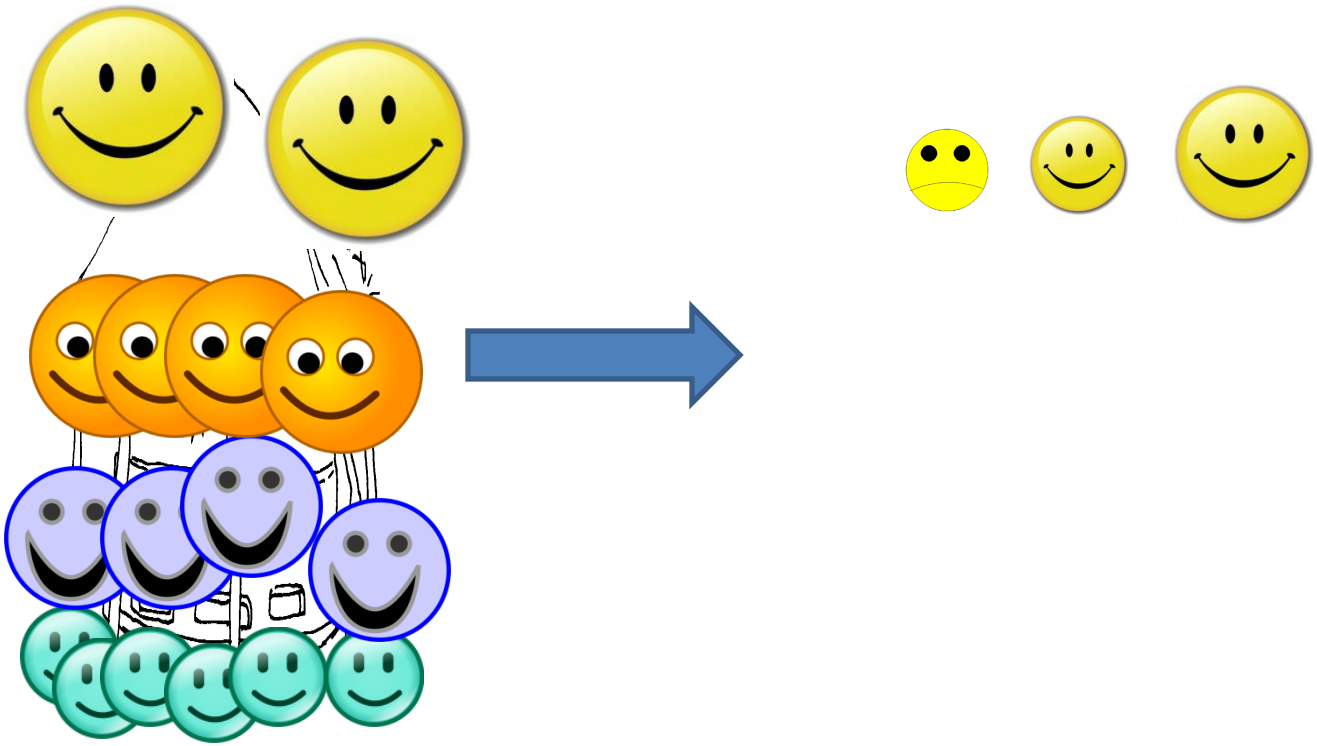

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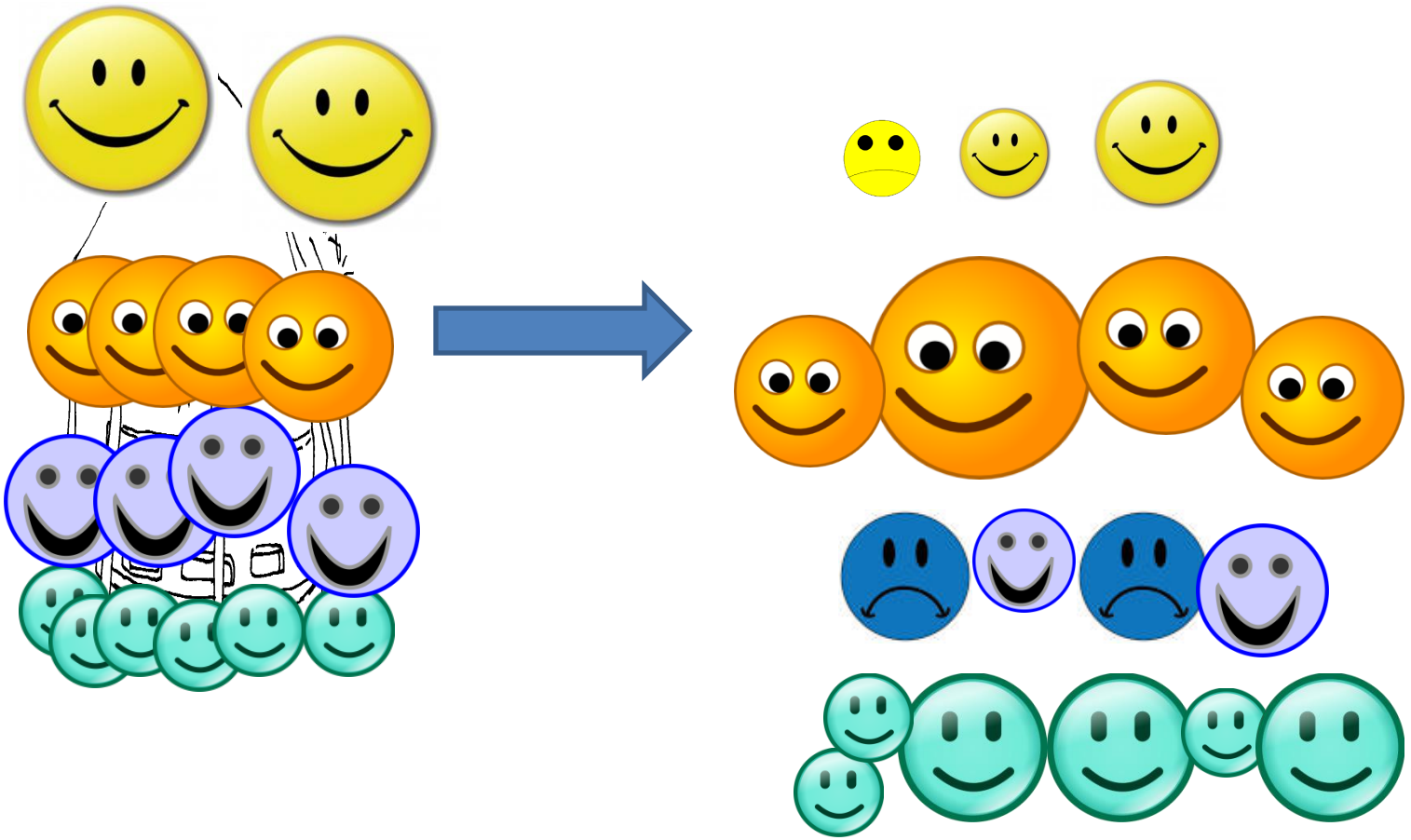

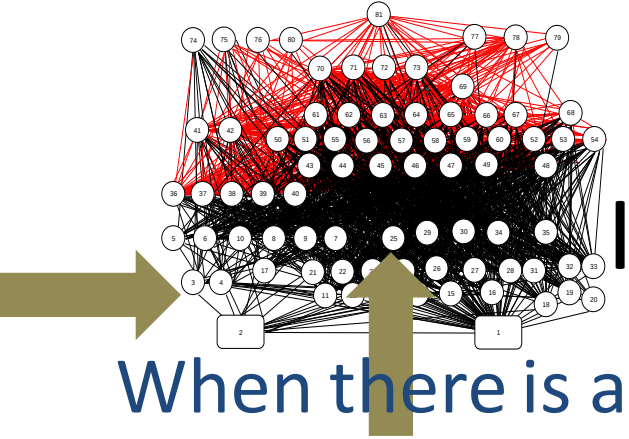

The Hut Hypotheses
II.B. Removing from the Base

When there is a removal or a decline in production for basal (especially PP) lower TL spp

- H.II.B.1- this exhibits bottom-up effects and generally decreases production at all TL
- H.II.B.2- this decrease production in only some parts of the food web, but a net overall decline
- H.II.B.3- this decreases competition and increases production of other lower TL spp
- H.II.B.Alt- no or minimal response

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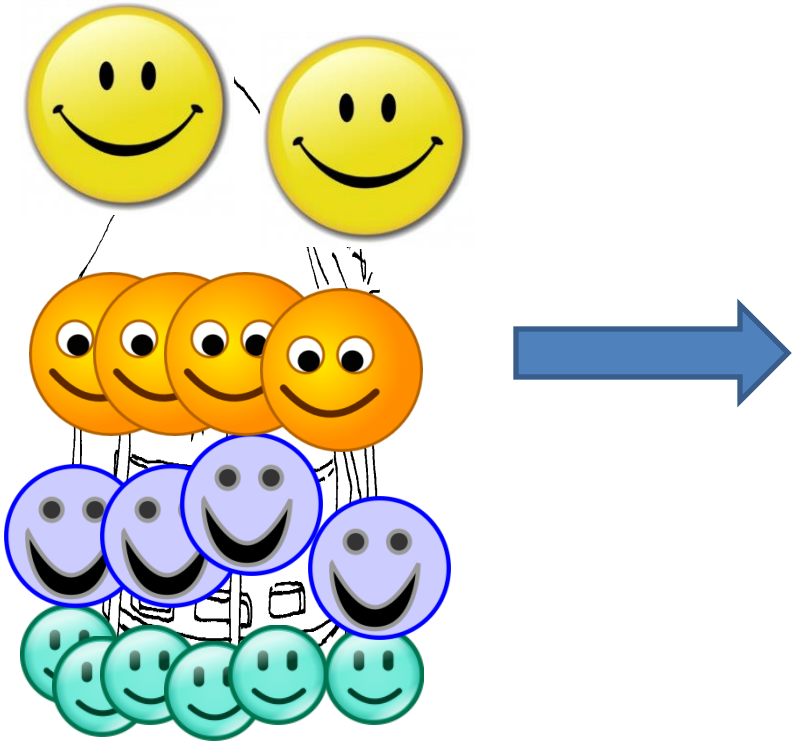

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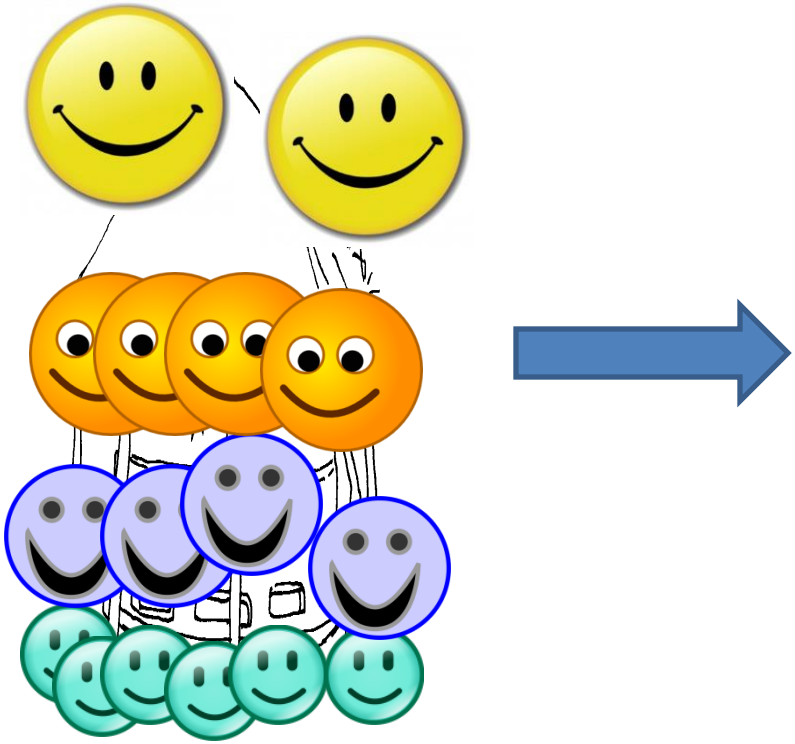

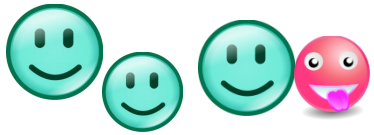

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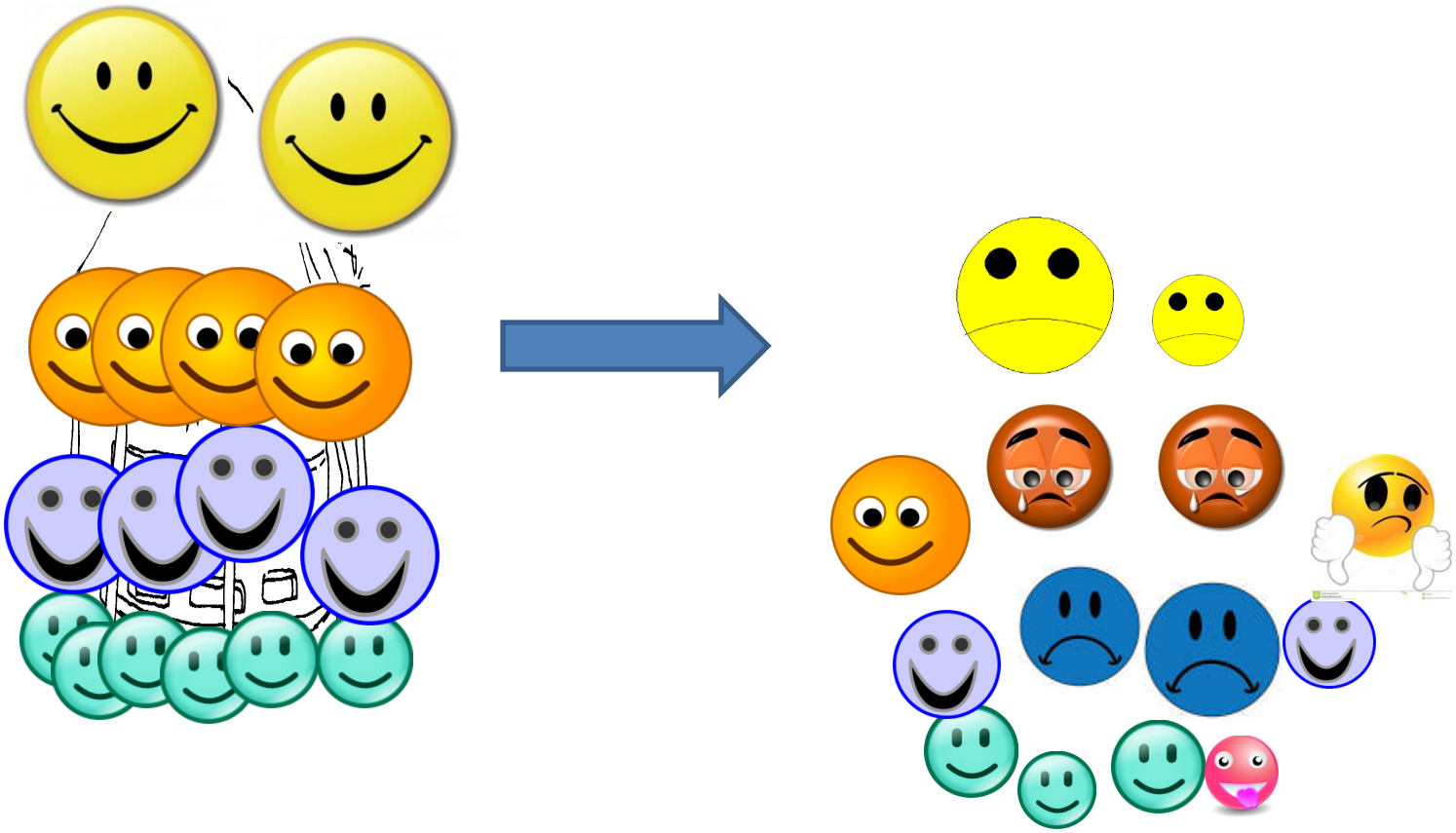
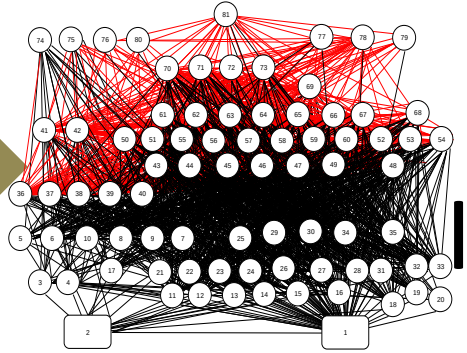


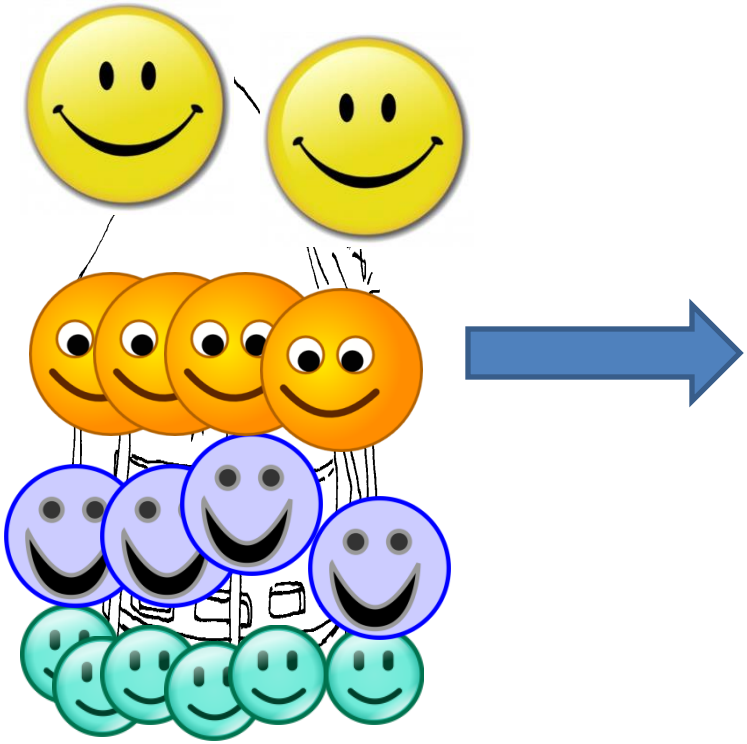


The Hut Hypotheses
II.C. Removing from the Inside

When there is a removal or decline of N or B or size, for mid TL spp

- H.II.C.1- this decreases competition and increases production of other mid TL spp
- H.II.C.2- new energy pathways are formed, and other mid TL spp become important
- H.II.C.Alt- no or minimal response

The Hut Hypotheses
II.C. Removing from the Inside



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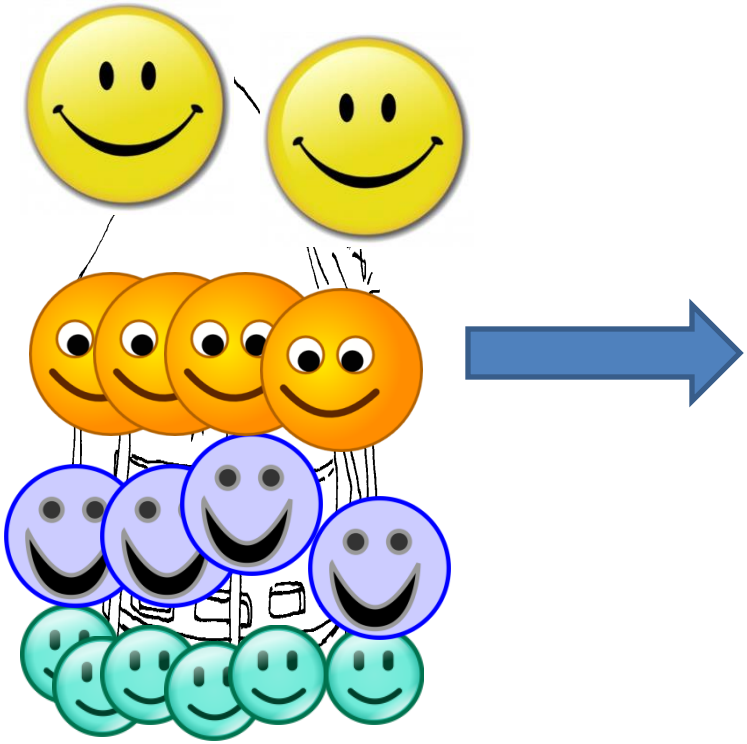

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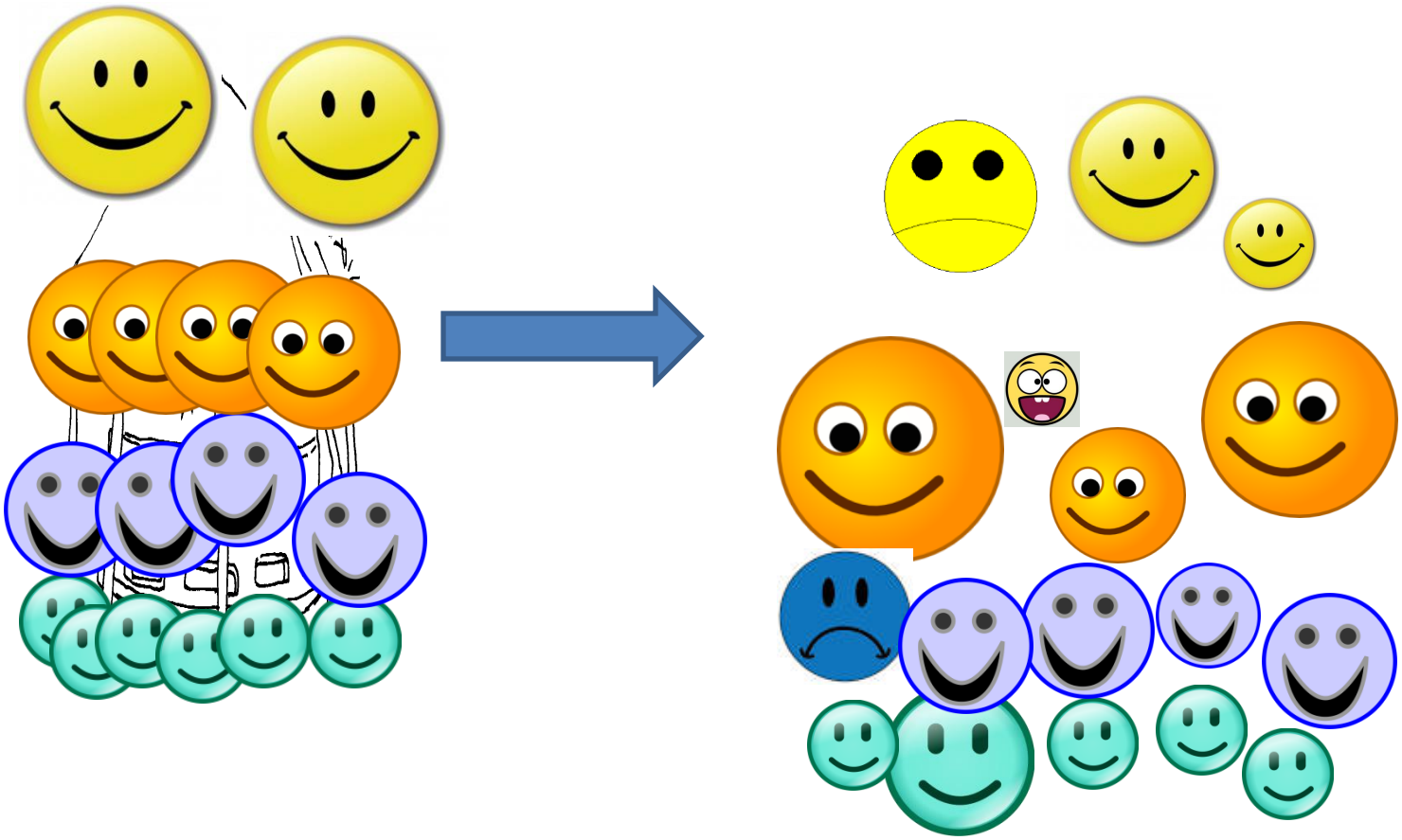
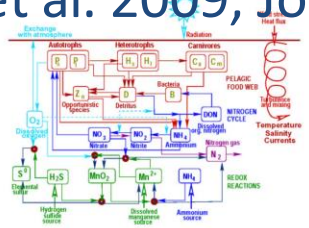


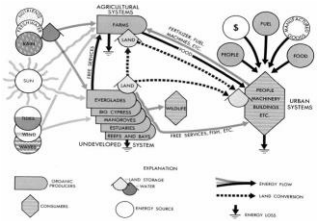
What do we tend to see?- Roof

- Very difficult to detect upper TL effects, not typically strongly observed
  - e.g. Baum and Worm 2009, Pershing et al. 2015, Gaichas et al. 2012
- Many E2E simulations suggest minimal overall effects on food web
  - e.g. Kaplan et al. 2013, Nye et al. 2012, Griffith and Fulton 2014
- Effects strongest in:
  - Smaller-scale ecosystems- e.g. Jochum et al. 2012, Fox et al. 2010
  - Simpler, less (strongly) connected food webs- e.g. Link 2002,
  - Studies that emphasize on just one group of taxa (e.g. HMS)- e.g. Young et al. 2015, Bond and Lavers 2014, Olson et al. 2014
  - Benthic systems with less mobile taxa- e.g. Pecl et al. 2009, Jochum et al. 2012, Fox et al. 2010, Jones et al. 2014



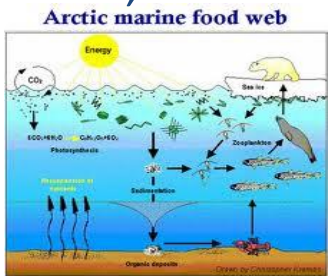
What do we tend to see?- Base

- Removing, shifting, or decreasing basal productivity can have major effects seen throughout the food web
  - Obvious in upwelling zones- e.g. Jarre et al. 2015, Harley et al. 2006
  - Stronger in oligotrophic systems (e.g. High Seas Tropics)- e.g. Polovina et al. 2008, 2011, Arreguín-Sánchez et al. 2015
- Increasing basal productivity less common example, but some effect
  - Upwelling zones- e.g. Falk-Petersen et al. 2015, Jarre et al. 2015, Cheung et al. 2015
  - Projected for high latitudes- e.g. McBride et al. 2014, Patara et al. 2013, Allan et al. 2013
- Effects strongest in:
  - Local areas/hotspots- e.g. Frusher et al. 2013
  - Less productive systems- e.g. Polovina et al. 2008, Stock et al. 2014



What do we tend to see?- Inside

- Removing or adding spp with high linkage density have strongest effects
  - e.g. Pinnegar et al. 2014, Link et al. 2005
- Removing or adding Keystone spp have strongest effects
  - e.g. Heymans et al. 2014, Libralato et al. 2006
- Relaxation of or increase in Competition depends on number of spp
  - Remains confounded with other factors- e.g. Karnauskis et al. 2015, Mollman et al. 2015
- Effects modulated by both B-U and T-D impacts
  - e.g. Gaichas et al. 2012, Otto et al. 2014
- Effects strongest in:
  - Pelagic ecosystems- e.g. Cury et al. 2000, Jarre et al. 2015, Cheung et al. 2015
  - Smaller-scale ecosystems- e.g. Jochum et al. 2012
  - Simpler, less (strongly) connected food webs- e.g. Link 2002, Link et al. 2005

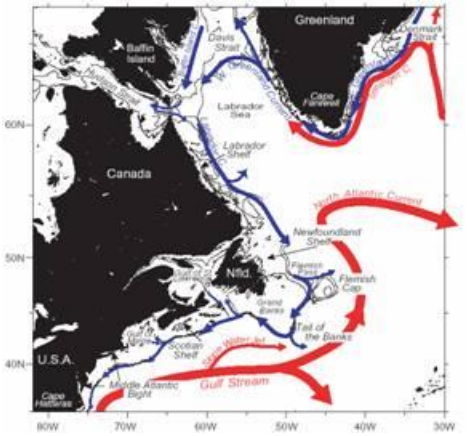


Likelihood of The Hut Hypotheses

	Scale of Ecosystem	Basal Productivity	Exploitation History	# of Spp	# of Links
Adding to					
Roof	More likely if smaller	More likely if initially low	More likely if initially high	More likely if fewer	More likely if fewer
Base	Any	More likely if initially low	More likely if initially low	Any	Any
Inside	Any	Any	Any	More likely if fewer	More likely if fewer
Removing from					
Roof	More likely if smaller	Any	More likely if initially low	More likely if fewer	More likely if fewer
Base	More likely if smaller	More likely if initially low	More likely if initially high	Any	Any
Inside	Any	Any	Any	More likely if fewer	More likely if fewer

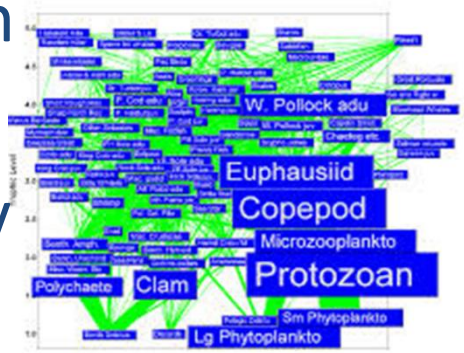
What can we say definitively now?

- Detecting distribution shifts and invasives is readily doable
- Detecting food web effects poses more of a challenge, but is doable
- Interaction-driven resilience metrics likely indeterminate
- There are no, simple binary responses
- There are apt to be both winners and losers in response to these changes



What can we say definitively now?

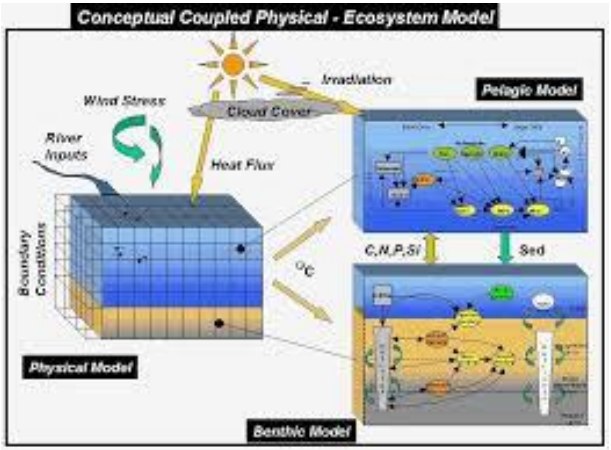
- “Roof” or upper TL effects likely to remain indeterminate
- “Basal” or productivity effects more easily detectable
- “Inside” or mid TL effects likely easiest to detect for keystone or highly linked spp
- Detecting Indirect and 2nd Order effects require Full system/E2E models
- Detecting Cumulative effects likely require Full system/E2E models



What do we need?

- (Continued) Predictions of distribution shifts
  - á la Nye, Cheung, Pinsky, etc.
- Predictions of food web responses
  - á la Pinnegar, Albouy, etc.
- Model coupling enhancements and skill evaluations
  - e.g. Stowe, Rose, Allen, Fulton

- Continued monitoring and observing systems
- Basic food habits sampling
- Clearly stated hypothesis testing




Thank you