overview

What is synchrony?

What is synchrony?

- Populations that oscillate in space so they go up and down together? (or exactly 180 degrees out of phase?) Or different populations at the same location?
- Nerves that fire together?
- Circadian rhythms?
- ?

- Synchronous oscillatory activity is a universal phenomenon that occurs in biological systems ranging from the level of intracellular dynamics to population dynamics across thousands of kilometers.
- The study of synchrony from a mathematical standpoint has had a very long history going back at least as far as Huygens in the 1600's. However, there are still many unanswered questions involving synchronization that are of central biological importance.

The dynamics of synchrony has significant biological implications across a range of fields

- spatiotemporal dynamics of childhood diseases
- In ecology, the absence of spatial synchrony is often thought to play an important role in persistence of species.
- In neural systems, synchrony plays a role in the coordination of locomotion and respiration, in the dynamics of diseases such as Parkinson's and epilepsy, and in sensory processing and cognition.
- Synchronous oscillations in systems of coupled oscillators are also prevalent in the fields of circadian rhythms, intracellular dynamics, as well as various areas of physics and chemistry and engineering.
- The importance of synchrony in these wide range of fields has led to large bodies of literature on synchrony that have surprisingly little cross-referencing. So a goal here is to increase communication.

Examples of synchrony in nature

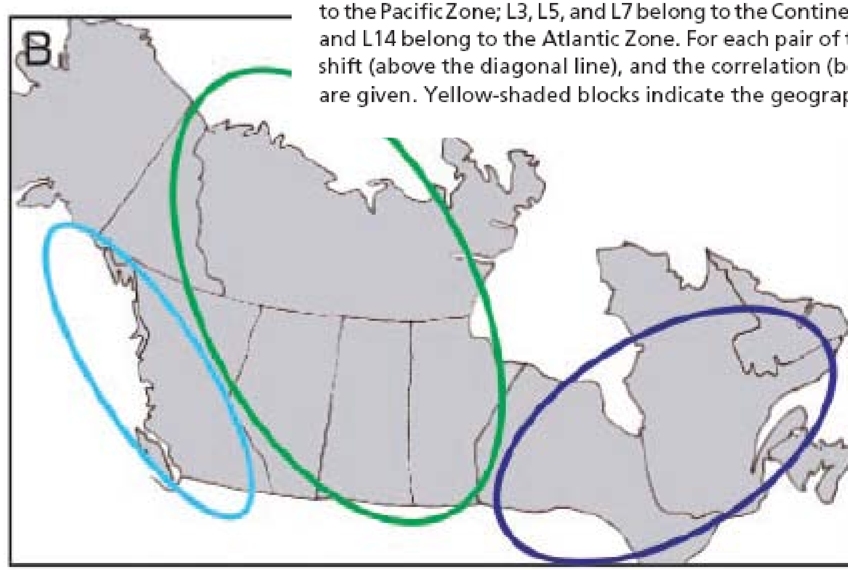
- Predator-prey cycles across space (hare and lynx in Canada)-table and figure from Stenseth et al., PNAS 2004

Table 1. Synchrony between pairs of lynx time series defined in the period 1897–1934

Correlation between a pair of time series (below the diagonal); Phase-synchrony between a pair of time series (above the diagonal)

	Pacific	Continental			Atlantic		
	L2	L3	L5	L7	L11	L12	L14
L2	0 / 1.00	1	1	0	0	0	0
L3	0.75	0 / 1.00	0	0	-1	-1	-1
L5	0.78	0.80	0 / 1.00	0	-1	-1	-1
L7	0.66	0.59	0.81	0 / 1.00	-1	-1	-2
L11	0.75	0.60	0.48	0.50	0 / 1.00	0	0
L12	0.78	0.55	0.48	0.56	0.83	0 / 1.00	0
L14	0.50	0.29	0.21	0.21	0.57	0.79	0 / 1.00

The names of the series are those defined in Stenseth *et al.* (4): L2, West; L3, MacKenzie River; L5, Athabasca Basin (northern Alberta); L7, West Central (northern Saskatchewan); L11, James Bay; L12, Lakes; and L14, Gulf. L2 belongs to the Pacific Zone; L3, L5, and L7 belong to the Continental Zone; and L11, L12, and L14 belong to the Atlantic Zone. For each pair of time series, the optimal shift (above the diagonal line), and the correlation (below the diagonal line) are given. Yellow-shaded blocks indicate the geographical zone structure.



Examples of synchrony in nature

- Synchronized species – voles and other small mammals
- Data for western Finland from Huitu et al. Ecography 2003

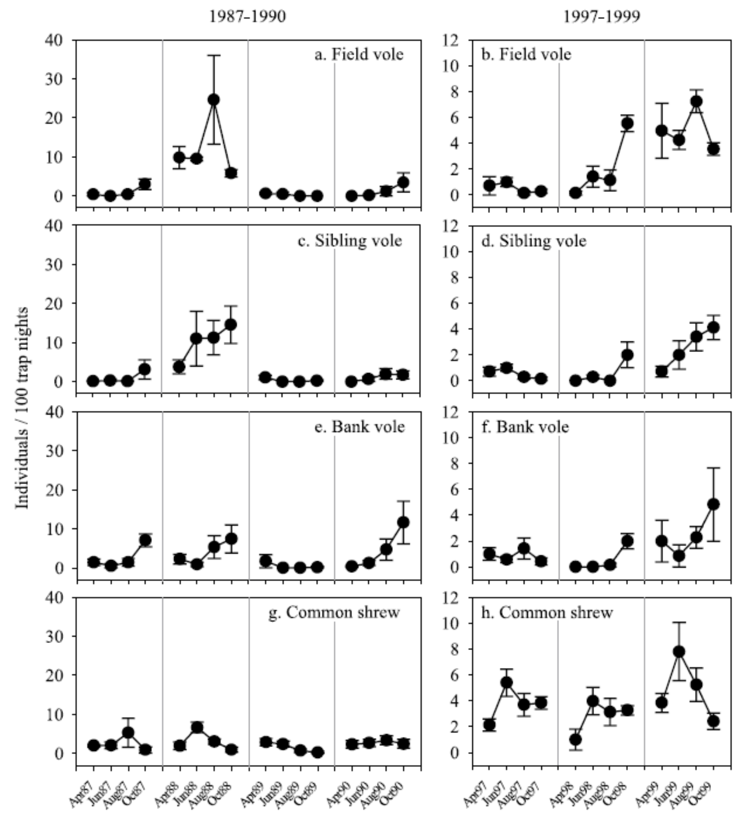


Fig. 1. Mean (±SE) number of small mammal individuals caught per trapping area during two population cycles of voles during 1987–1990 (left hand panels) and 1997–1999 (right hand panels). The number of areas trapped per session was three during the first cycle, and four during the second cycle. Panels (a) and (b) indicate numbers of field voles, panels (c) and (d) numbers of sibling voles, panels (e) and (f) numbers of bank voles, and panels (g) and (h) numbers of common shrews. Note different scaling on the y-axis between the two cycles in the left and right hand panels.

Examples of synchrony in nature

- Masting – one example from a New Zealand tree, Norton and Kelly 1998 Functional Ecology

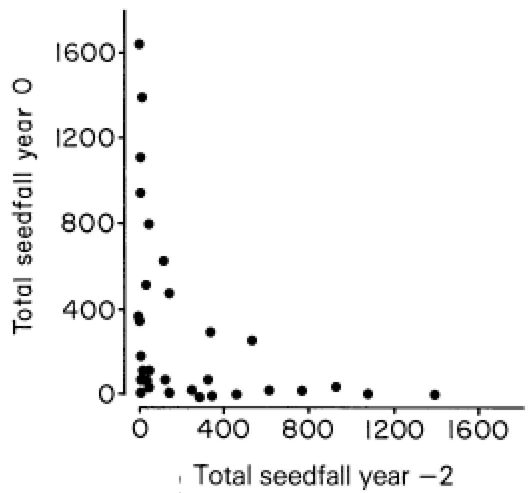


Fig. 4. Relationship for rimu between total seedfall in one year and total seedfall two years previously. $r = -0{\cdot}49$, $P < 0{\cdot}01$ (log transformed). $n = 31$.

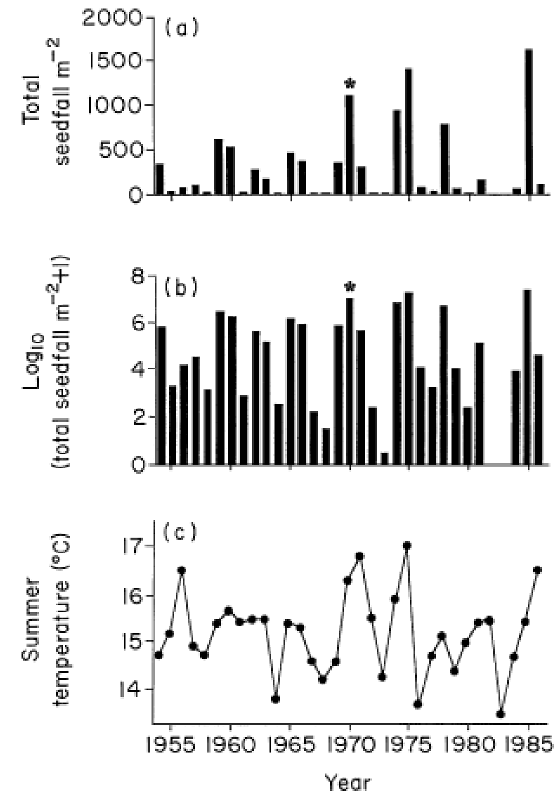


Fig. 2. Total seedfall (sound plus unfilled seeds) in rimu (*Dacrydium cupressinum*) over 33 years at a site near Harihari, West Coast, South Island New Zealand (February to May total seedfall m^{-2}) and Hokitika summer (December–February) temperature. The seedfall value for 1970 (*) is extrapolated from data at a nearby site (see text). (a) Seedfall, linear scale. (b) Seedfall, log base 10 (x + 1) scale. (c) Summer temperature.

Examples of synchrony in nature

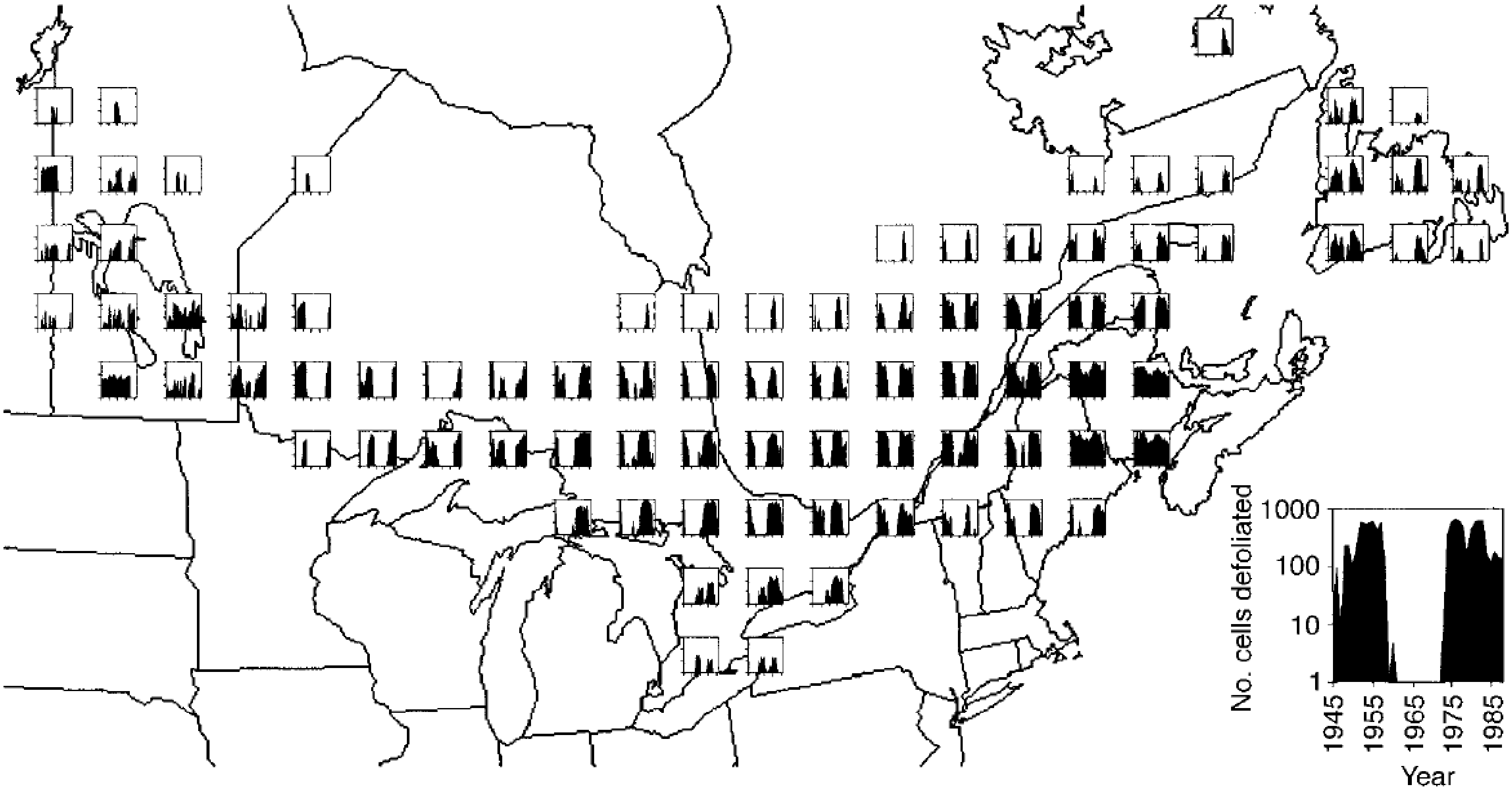
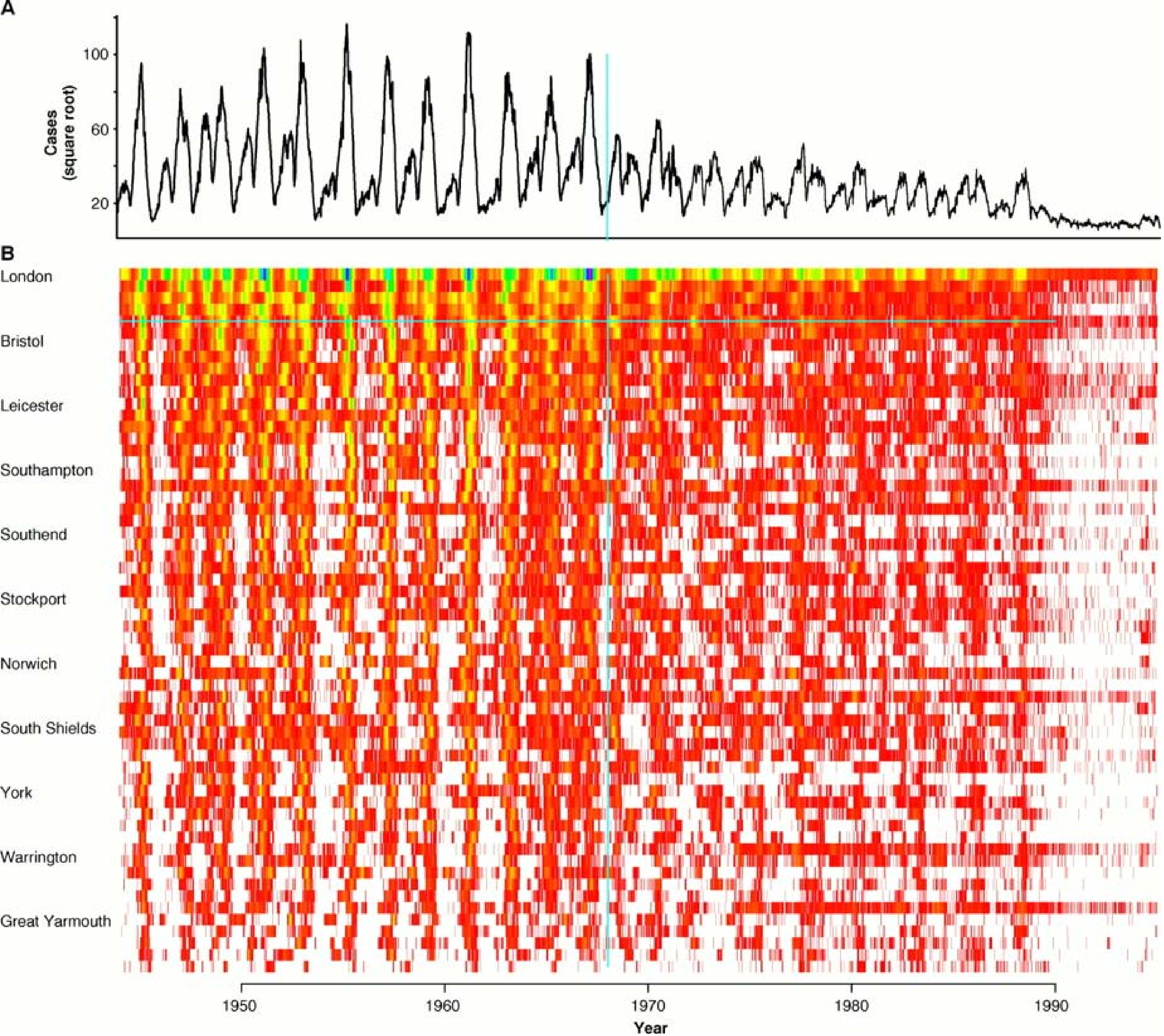


FIG. 2. Time series of detectable defoliation by eastern spruce budworm in 160 × 160 km cells in eastern North America over the 44-yr period from 1945 to 1988. The large cell at the lower right provides a key.

- Insect outbreaks – Williams and Liebhold Ecology 2000



Time series of total weekly measles notifications for 60 towns and cities in England and Wales, for the period 1944 to 1994; the vertical blue line represents the onset of mass vaccination around 1968. (Levin, Grenfell, Hastings, Perelson, Science 1997)

Spatial synchrony is found on many scales Liebhold et al. Ann. Rev. Ecol. Syst. 2004

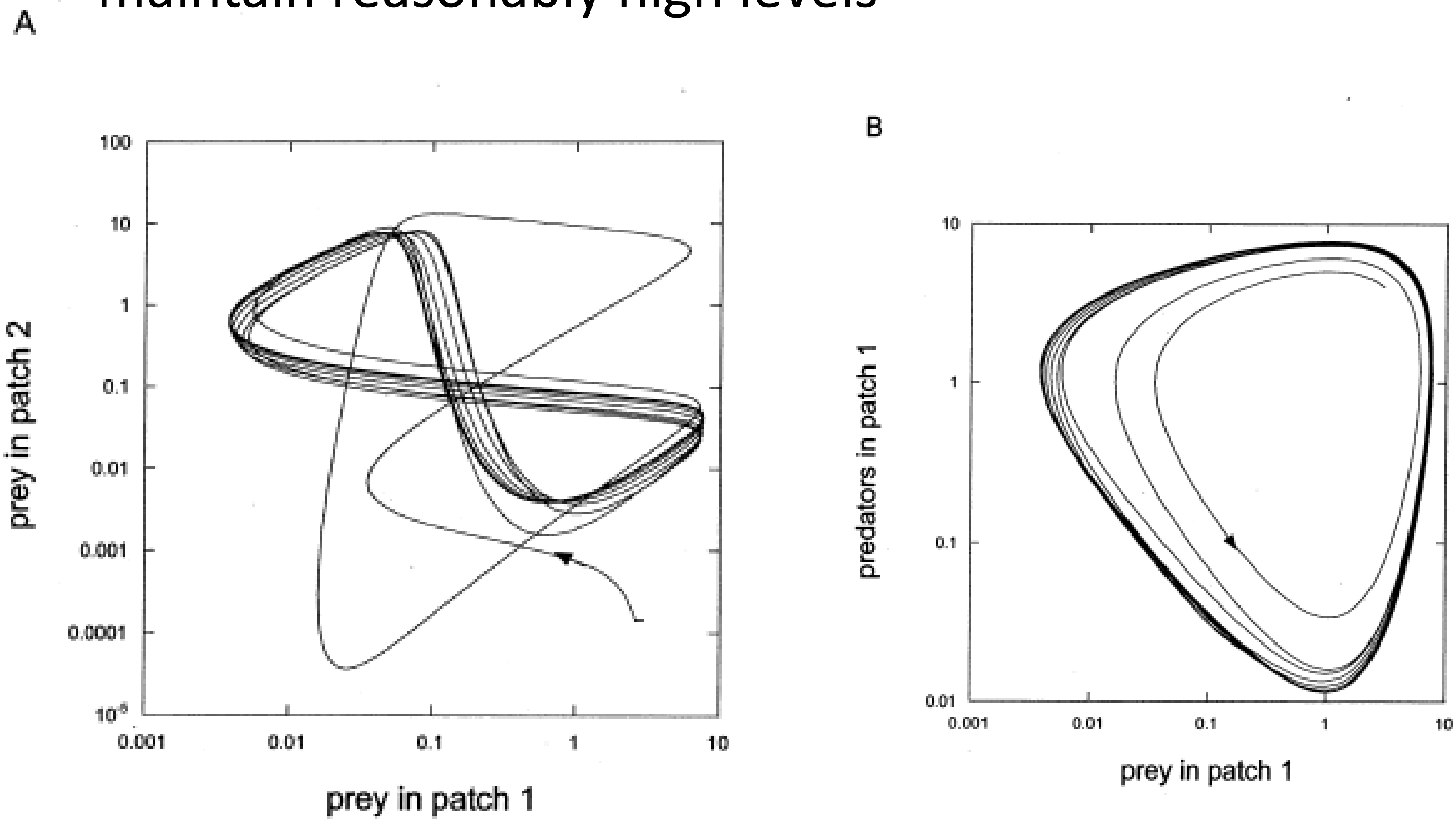
TABLE 1 Summary of records of intraspecific spatially synchronous population dynamics among all taxa

Taxa	Geographical extent of synchrony	References
Protista: ciliophora	10–500 cm (microcosm)	Holyoak & Lawler 1996
Fungal plant pathogen	0.5–3 km	Thrall et al. 2001
Viral human pathogen	1–1000 km	Bolker & Grenfell 1996, Rohani et al. 1999, Viboud et al. 2004
Insect detritivores	5–20 m	Tobin & Bjørnstad 2003
Insect herbivores	1–1000 km	Hanski & Woiwod 1993; Hawkins & Holyoak 1998; Liebhold et al. 1996; Liebhold & Kamata 2000; Myers 1990, 1998; Peltonen & Hanski 1991; Peltonen et al. 2002; Pollard 1991; Raimondo et al. 2004; Rossi & Fowler 2003; Shepherd et al. 1988; Sutcliffe et al. 1996; Tenow 1972; Williams & Liebhold 1995, 2000b; Zhang & Alfaro 2003
Insect predators and parasitoids	10 m–400 km	Baars & Van Dijk 1984, Rossi & Fowler 2003, Satake et al. 2004, Tobin & Bjømstad 2003
Fish	10–500 km	Fromentin et al. 2000; Myers et al. 1995, 1997; Ranta et al. 1995a
Amphibians	0.2–100 km	Trenham et al. 2001, 2003
Birds	5–2000 km	Bellamy et al. 2003; Bock & Lepthien 1976; Cattadori et al. 1999; Jones et al. 2003; Small et al. 1993; Ranta et al. 1995a,b; Koenig 1998, 2001, 2002; Moss et al. 2000; Paradis et al. 1999, 2000; Watson et al. 2000
Mammals	10–1000 km	Bjørnstad et al. 1999b; Christiansen 1983; Elton & Nicholson 1942; Grenfell et al. 1998; Ims & Andreassen 2000; Mackin-Rogalska & Nabaglo 1990; Moran 1953b; Post & Forchhammer 2002; Ranta et al. 1995a,b, 1997a,b, 1998; Small et al. 1993; Smith 1983; Swanson & Johnson 1999
Mollusks	2–30 km	Burrows et al. 2002

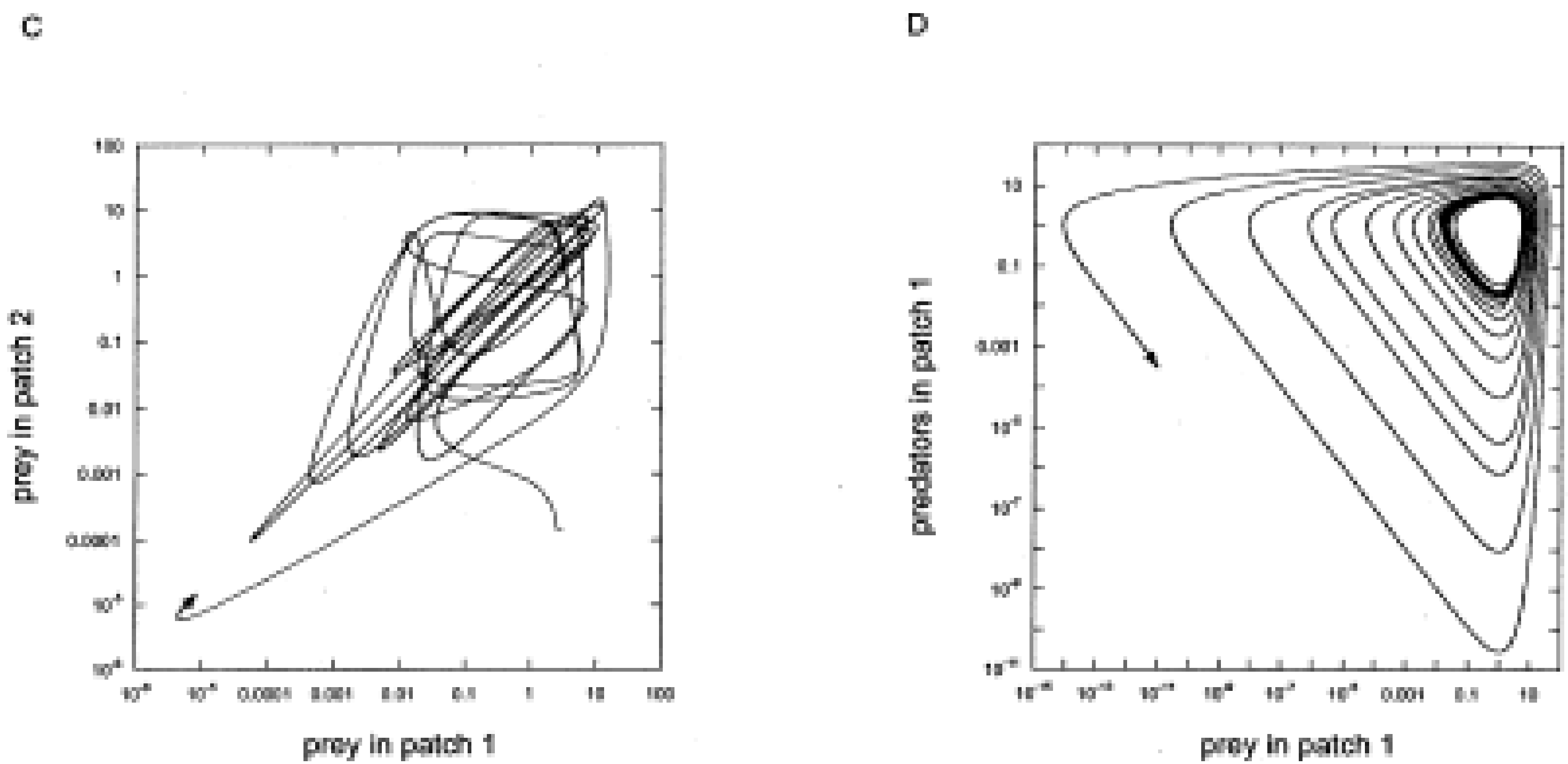
Much of the mathematical theory on synchronization makes assumptions that may or may not fit the biological system

- For example, one theoretical framework to study synchronization assumes that input due to coupling is pulsatile and the system quickly returns to its normal periodic cycle before subsequent input arrives.
- Another framework assumes that coupling is weak (i.e. intrinsic dynamics dominate the effects of weak coupling).
- While most theories can be extended to include heterogeneity and noise, they are assumed to be sufficiently weak.

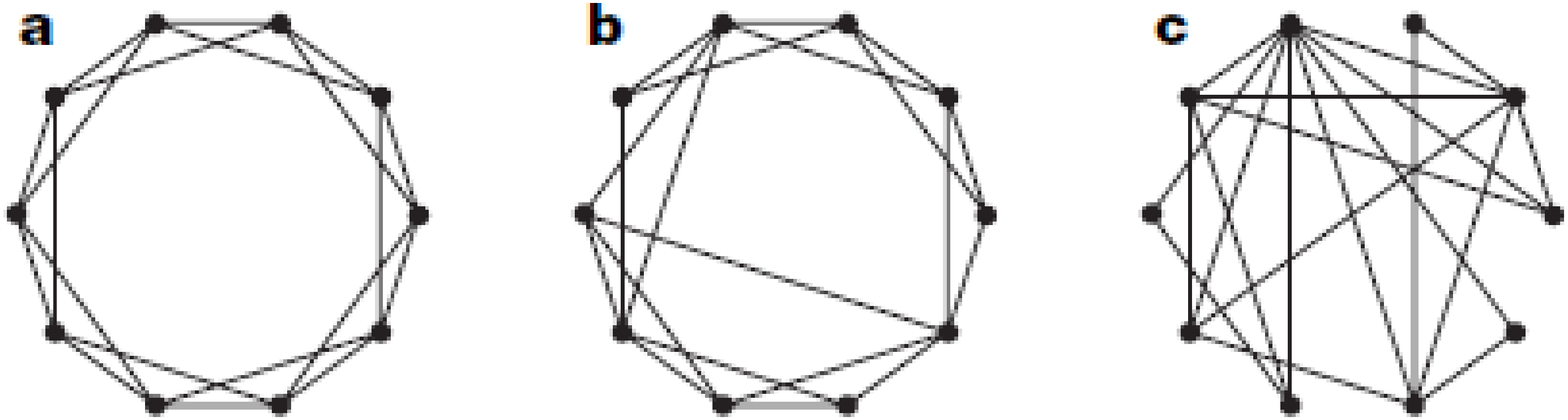
With out of phase dynamics, predator and prey maintain reasonably high levels



With out of phase dynamics, predator and prey maintain reasonably high levels, but when synchrony finally occurs the population crashes

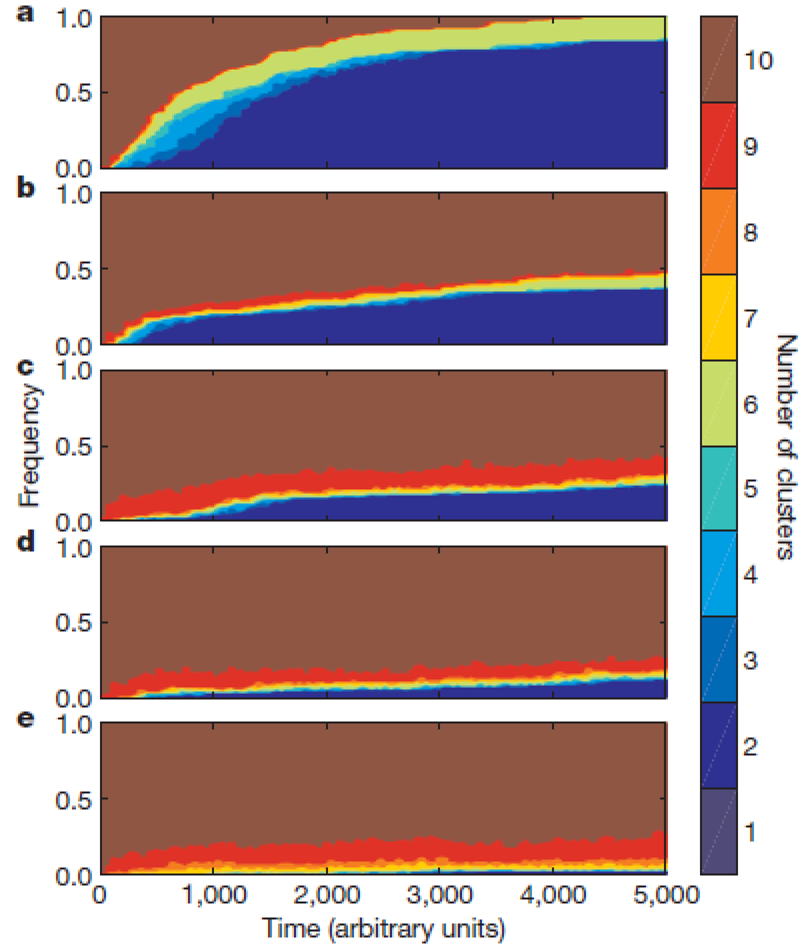


And spatial arrangement matters



Structure affects dynamics

- More regular on top
- Less regular on bottom
- Less regular more stable because it has more clusters



Goals

- Look for cross-fertilization
- Identify gaps in the theory
- Look for possible approaches to fill the gaps

Goals

- "Write" a review paper
- Generate new ideas
  - To study measures of synchrony
  - To determine new approaches for dynamics of synchrony
    - Heterogeneity, stochasticity, and more
- Foster future collaboration
  - Working groups at NIMBioS
  - Other ways