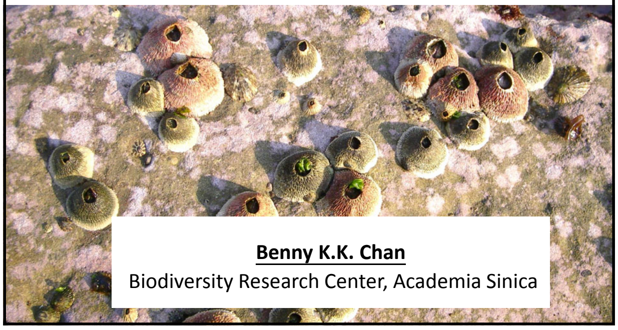
Heat and cold stress of intertidal barnacles revealed from biomimetic temperature loggers in the tropics and arctic



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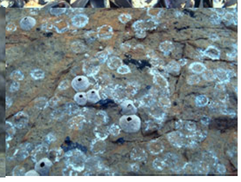
Rocky intertidal – a sensitive system to response global warming

- Intertidal shores – junction between the sea and land – global habitat
- Species immerse in water in high tides, exposed to air during low tides
- Experience both terrestrial and marine climatic change

Seasonal variations in abundance

- Winter: Low water temperature and great waves
- Summer: High temperature - Air temperature: 34 °C
- Max Rock surface temperature: 50 °C. Rock pools: 40 °C
- High mortality of species



Septifer (mussel) and *Tetraclita* (barnacle) beds

Photo courtesy: Gray A. Williams

Range shift in intertidal species?

- Under the effect of global warming, marine species have shown to having range shift in Atlantic Ocean and Eastern Pacific.

Species	Geographic region	Impact	Survey	Resurvey
Mytilus edulis	Bear Island, Svalbard	Range extension 500 km N,[a] range extension 500 km N[b]	1979 (first record in 1000 years)	1994, 2004
Gibbula umbilicalis	North Scotland, south England, north Wales, south England	Range extension 55 km N, range extension 125 km E; increased recruitment success near range edges[c,d]	1985, 1985	2001–2004 2001–2004
Osilinus lineatus	North Wales, south England	Re-extension 40 km N, range extension 55 km E; increased recruitment success near range edges[d,e]	1964, 1980s, 1986	2001–2004 2001–2004
Chthamalus montagui	North Scotland	Range extension 75 km along cooler North Sea coast[d,f]	1980s	2001–2004
Chthamalus stellatus	North Scotland	Range extension 40 km along cooler North Sea coast[d,f]	1980s	2001–2004
Patella depressa	South England	Range extension 30 km E[d]	1964, 1980s	2001–2004
Patella ulyssiponensis	South England	Range extension 120 km E[d]	1964, 1980s	2004
Balanus perforatus	South England	Range extension 170 km E[g]	1960s	1993–2001
Bifurcaria bifurcata	South England	Re-extension 150 km E[d]	1902, 1936	2002
Patella rustica	North Portugal	Infilling of gap 39.3° N–43.2° N at southern end of range[h]	1950s	2003
Kelletia kelletii	California	Range extension 400 km N[i]	1970s	1980s
Codium fragile	Gulf of Maine	Range extension N; warmer summers facilitating reproduction[j]	1975–present	1990
Alaria esculenta	North England, south England	Range contraction >120 km N[d]; range contraction 120 km E[f]	1950s	1990s, 2004
Tectura tessulata	Irish Sea	Loss of species from south of Isle of Man[d]	1980s	2001–2004
Fissurella crassa	Chile	Range contraction 3° latitude N[k]	1962	1998–2000
Enoplochiton niger	Chile	Range contraction 3.5° latitude N[k]	1962	1998–2000
Echinolittorina peruviana	Chile	Range contraction 5° latitude N[k]	1962	1998–2000
Thais haematoma	Chile	Range contraction 8° latitude N[k]	1962	1998–2000
Gastropods, anthozoans, barnacles	California	Increases in abundance of warm-water species[l]	1930s	1998–2000
Anthozoans and limpets	California	Decreases in abundance of cold-water species[l]	1930s	1998–2000
Asterias forbesi	Gulf of Maine	Increase in abundance[m]		
Asterias vulgaris	Gulf of Maine	Decrease in abundance[m]		

Helmuth et al. Annu. Rev. Ecol. Evol. Syst. 2006. 37:373–404

Patterns from the Atlantic/E Pacific

Helmuth (1998): Ecol Mongr 68:51-74

- air temperature – not a reliable proxy for body temperature of mussels.
- Body temperature of mussels – multiple env. factors, size and morphology and interactions with neighbours

Helmuth et al. (2002) Science 298:1015-1017

- Heat stress in west coast of USA – not following a latitudinal gradient
- Southern shores - low tides at night – less stress than northern shores

Seabra et al. (2011) JEMBE 400: 200-208

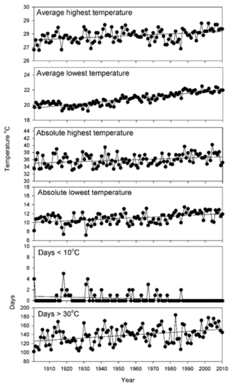
- Side matters rather than latitudes – European shores

Climatic changes in the West Pacific

100 year's climatic variation in Eastern Taiwan

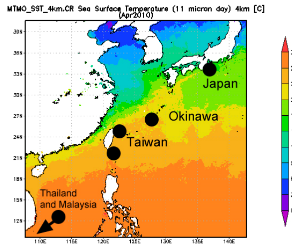
A clear pattern of getting a warmer climate

Barnacles – *T. japonica* and *Hexechamasipho pilsbryi* already have northward range shift



Questions of interests

- What is the thermal profile of barnacles in the W Pacific?
- Does heat stress of intertidal species follow a latitudinal gradient or are there any "mosaic" pattern of hot spots of heat stress?



Develop a sensor to measure thermal stress of organisms

- Air temperature is not a good estimation of body temperature of intertidal species
- Need to develop a sensor that can collect data for long-term and fine temporal scales
- The temperature of the sensor should resemble the temperature of the real animals

Robo-limpets constructions – Original method

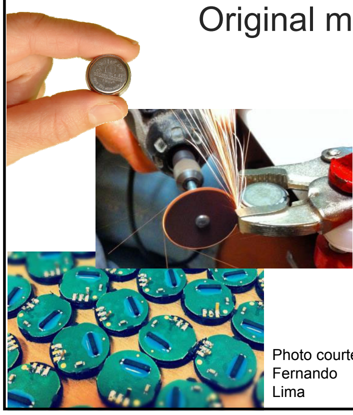
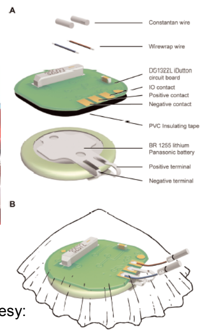


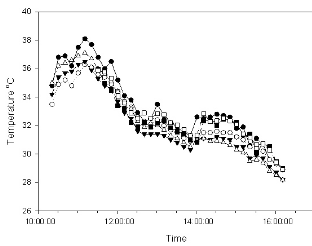
Photo courtesy: Fernando Lima



Lima and Wethey 2009

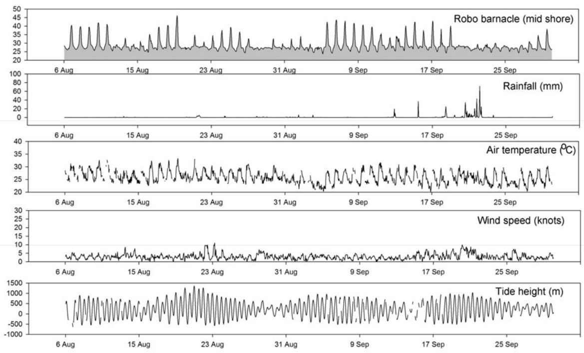
Modified design from Lima and Wethey (2009) Copper Eletro-plating the whole iButton

Comparison of robobarnacle and live barnacle body temperature



Robo-barnacles at work on the shores

Robo temperature – variation in 1 month, in response to env. factors



5 sites in Taiwan, 3 sites in HK and 1 site in Thailand

Sampling period: June to September 2013

Hourly data collection

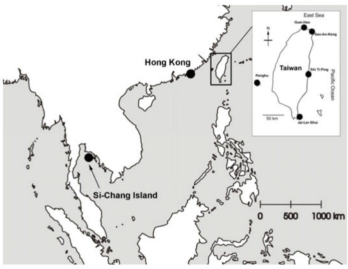
Sampling design

Shore

East facing — West facing

H — M — L

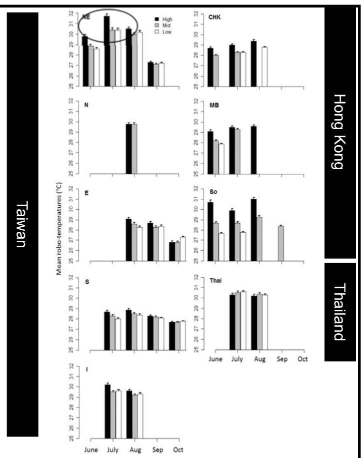
4 robobarnacles



Each site – 24 robobarnacles installed

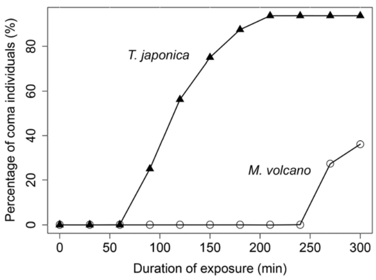
Results

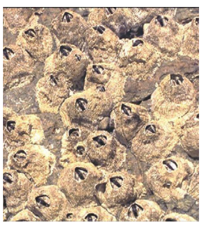
- Daily maximum body temperature can reach 45°C in some days
- High shores consistently having greater stress than low shores populations
- Aspects – not clear pattern
- In July, highest mean temperature is recorded in NE Taiwan.



Laboratory physiological thermal tolerance

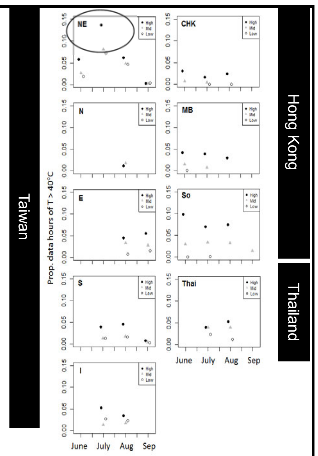
Tetraclita barnacles – will become coma (open the opercular valve without movement) when under intense heating





Latitudinal variation on stress period

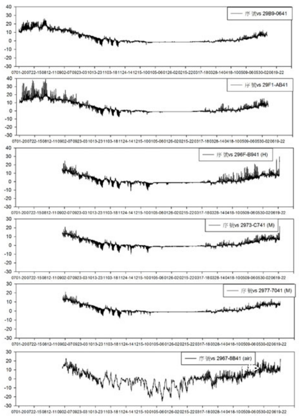
- Stress period: 40°C, >1 hour period and observed how frequent such period happens across latitudes and tidal levels
- Clear difference between tidal populations
- NE coast, highest frequency of having stress than southern locations

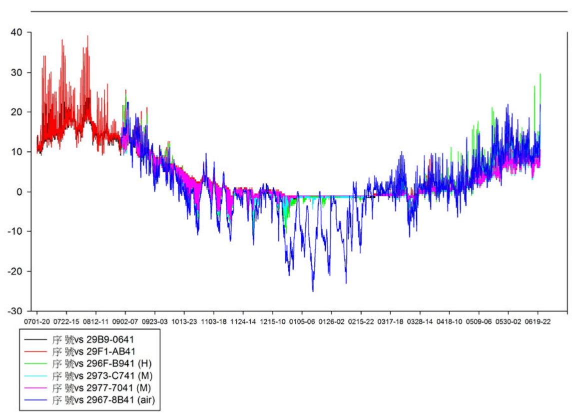


Arctic deployment

White Sea Marine Biological Station, Moscow State University, Russia

Russian white sea – intertidal region





Overall summary

- Bio-mimetic loggers (Robo-barnacles) is a reliable sensor to mimic body temperature of intertidal barnacles in W. Pacific
- In the W. Pacific, thermal profile of intertidal species did not follow a latitudinal gradient. NE Taiwan highest profile than HK and Thailand. Note all sites have daytime low tides.
- In Taiwan – air temperature appears to be the dominant predictor for body temperature of intertidal species, followed by tide patterns. This pattern is different from the Atlantic counterpart.

Suggested collaborations with PAS-AS

- Deploy robo-barnacles in the tropics (Taiwan), Polish Arctic and Antarctic station
- Determine the level of stress of organisms in the poles and in the tropics.

Acknowledgement

- Supported by a grant in National Ministry of Science and Technology, Taiwan.
- My lab including students and assistants to support the field work and lab works.