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- **Limpus, C. and Nicholls, N. (2000). ENSO regulation of Indo-Pacific green turtle populations. Hammer, G., Nicholls, N., and Mitchell, C. "Applications of Seasonal Climate Forecasting in Agricultural and Natural Ecosystems." Pp. 399-408. (Kluwer Academic Publishers: Dordrecht)**

- **Poloczanska, E. S., Limpus, C. J., and Hays, G. C. (2009). Vulnerability of marine turtles to climate change. *Advances in Marine Biology* 56, 151-211.**

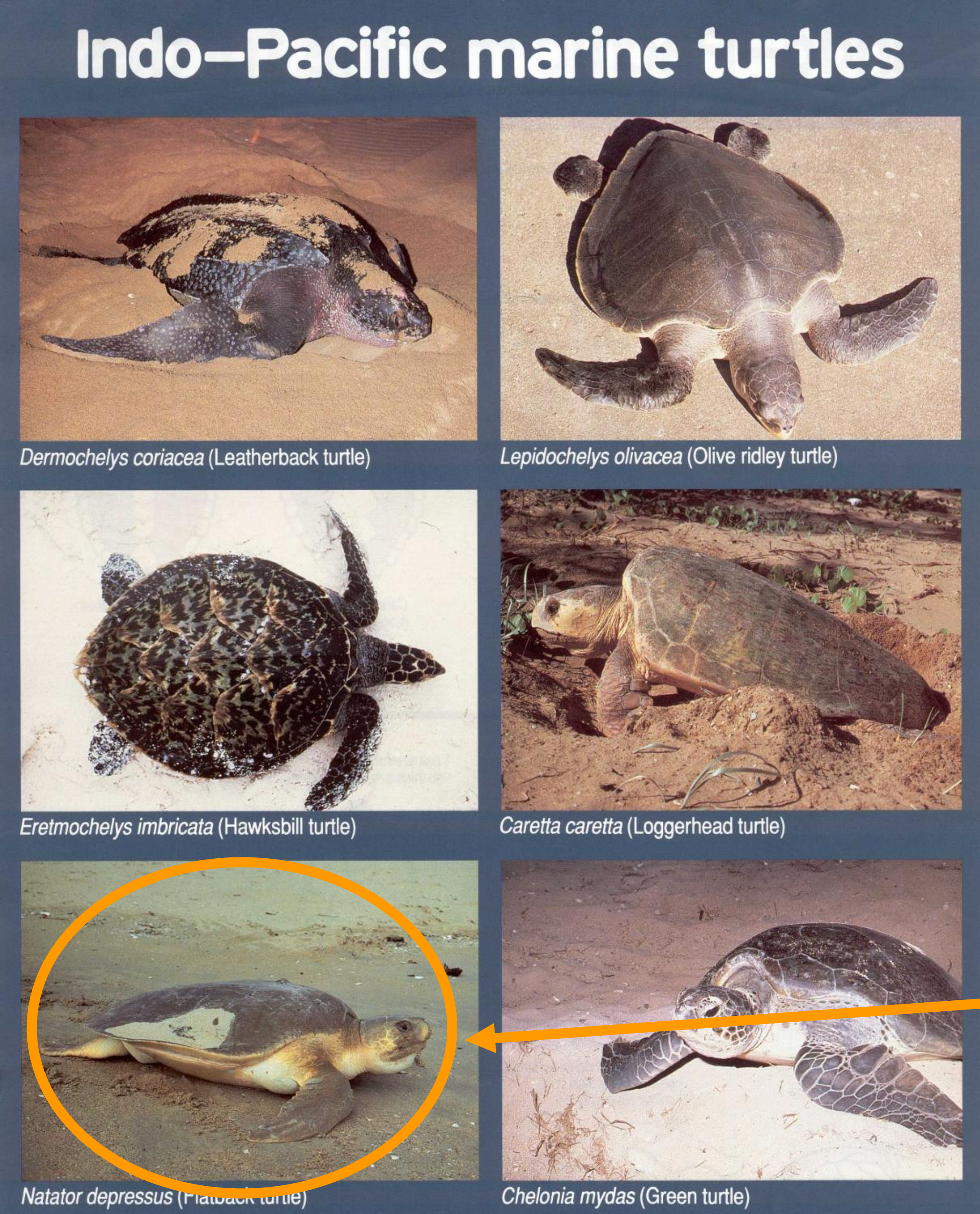
# ADAPTING TO CLIMATE CHANGE: A CASE STUDY OF THE FLATBACK TURTLE, *Natator depressus*

COLIN J. LIMPUS

Queensland Government

# *Protostega gigas* : GIANT MARINE TURTLE, EXTINCT FAMILY
# LATE CRETACEOUS (60-80x$10^6$ YR), KANSAS

**FOSSIL RECORDS SHOW**
**WIDER MARINE TURTLE DIVERSITY IN PAST: 5 FAMILIES**

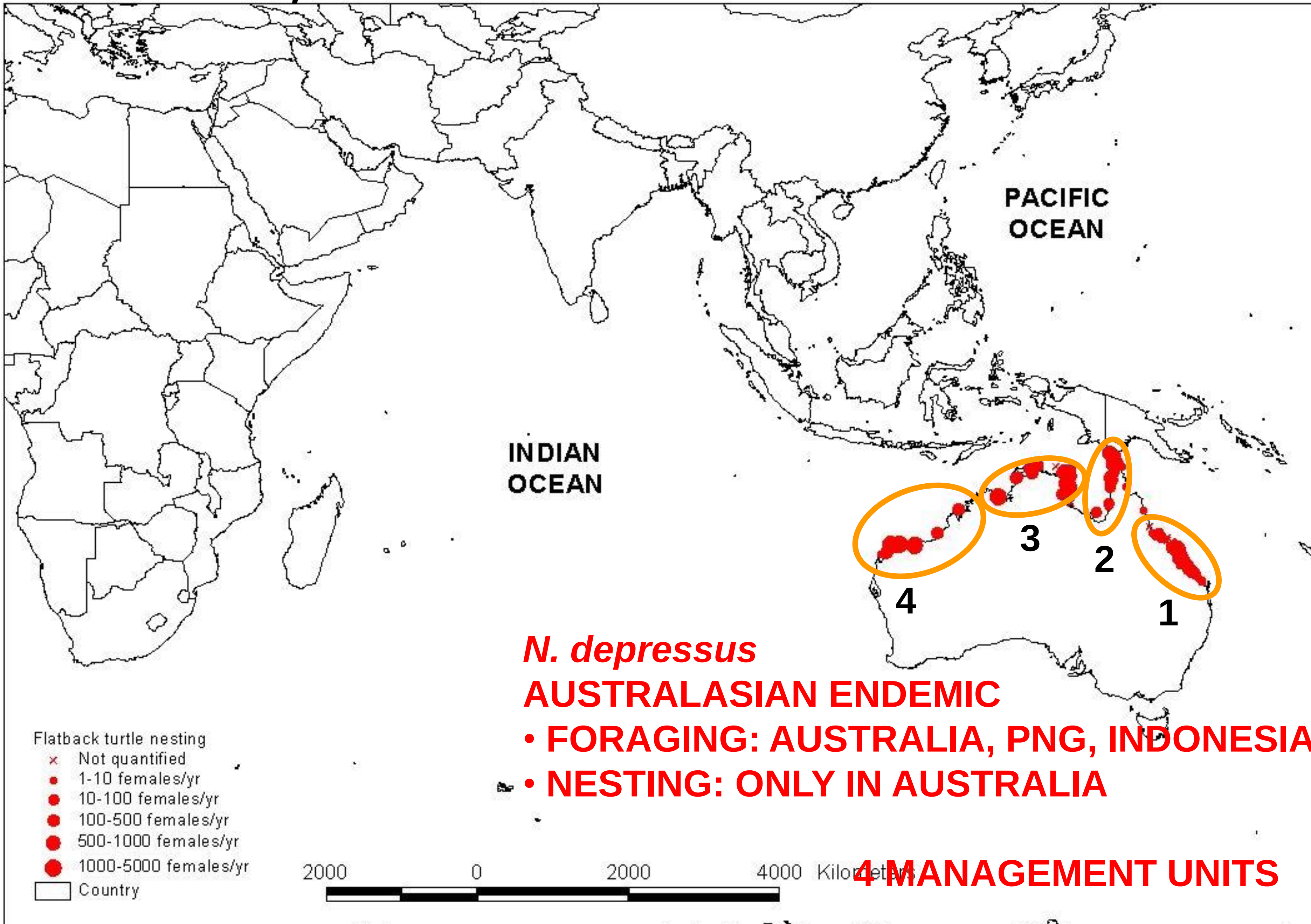



# EXTANT MARINE TURTLES

**WORLD WIDE:**
- 2 FAMILIES
- 6 GENERA
- 7 SPECIES

**SE ASIA & W.PACIFIC:**
- 6 GENERA
- 6 SPECIES
  - 1 ENDEMIC

# *Natator depressus*: MANAGEMENT UNITS / GENETIC STOCKS




***N. depressus***

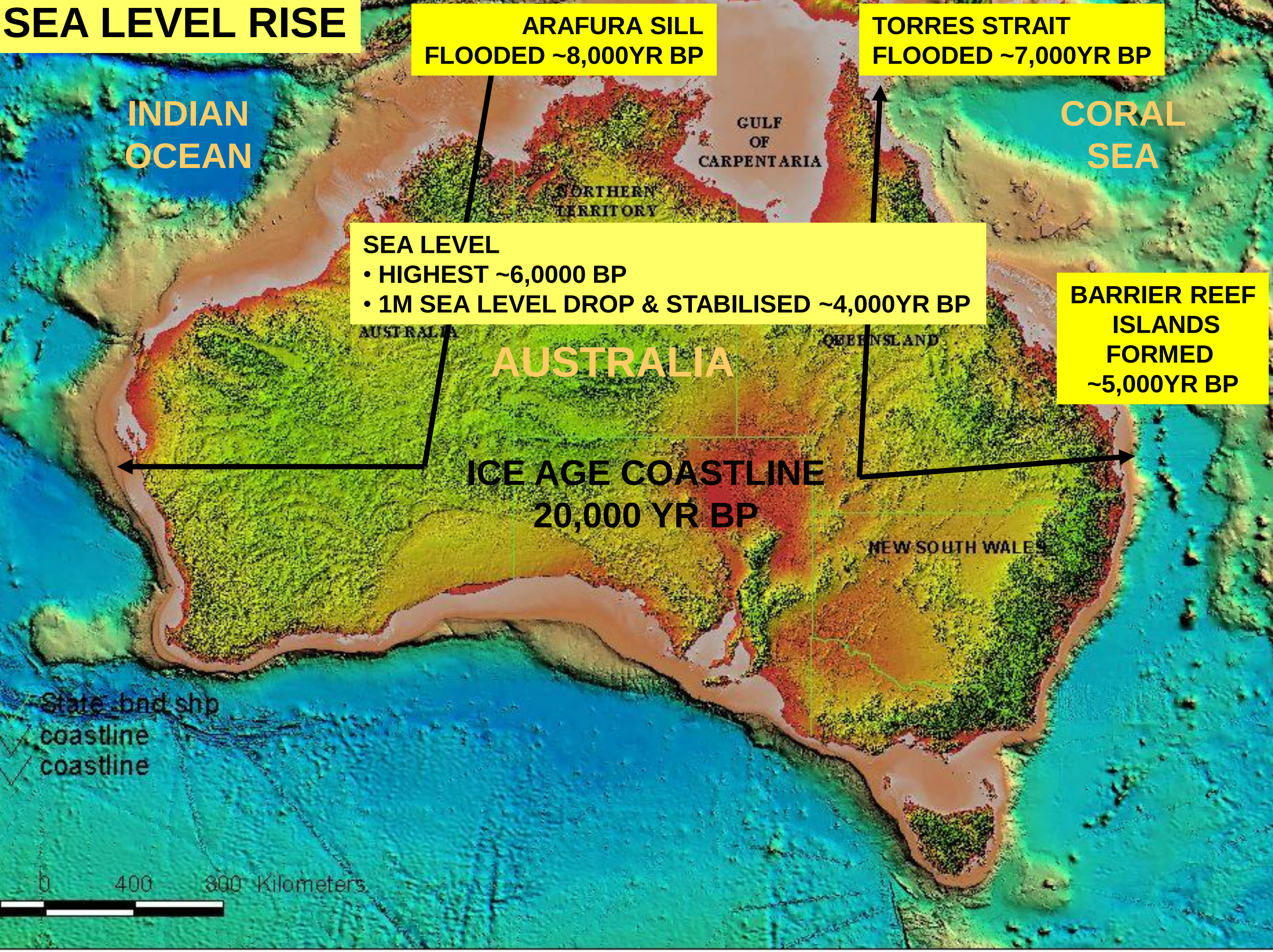
**AUSTRALASIAN ENDEMIC**

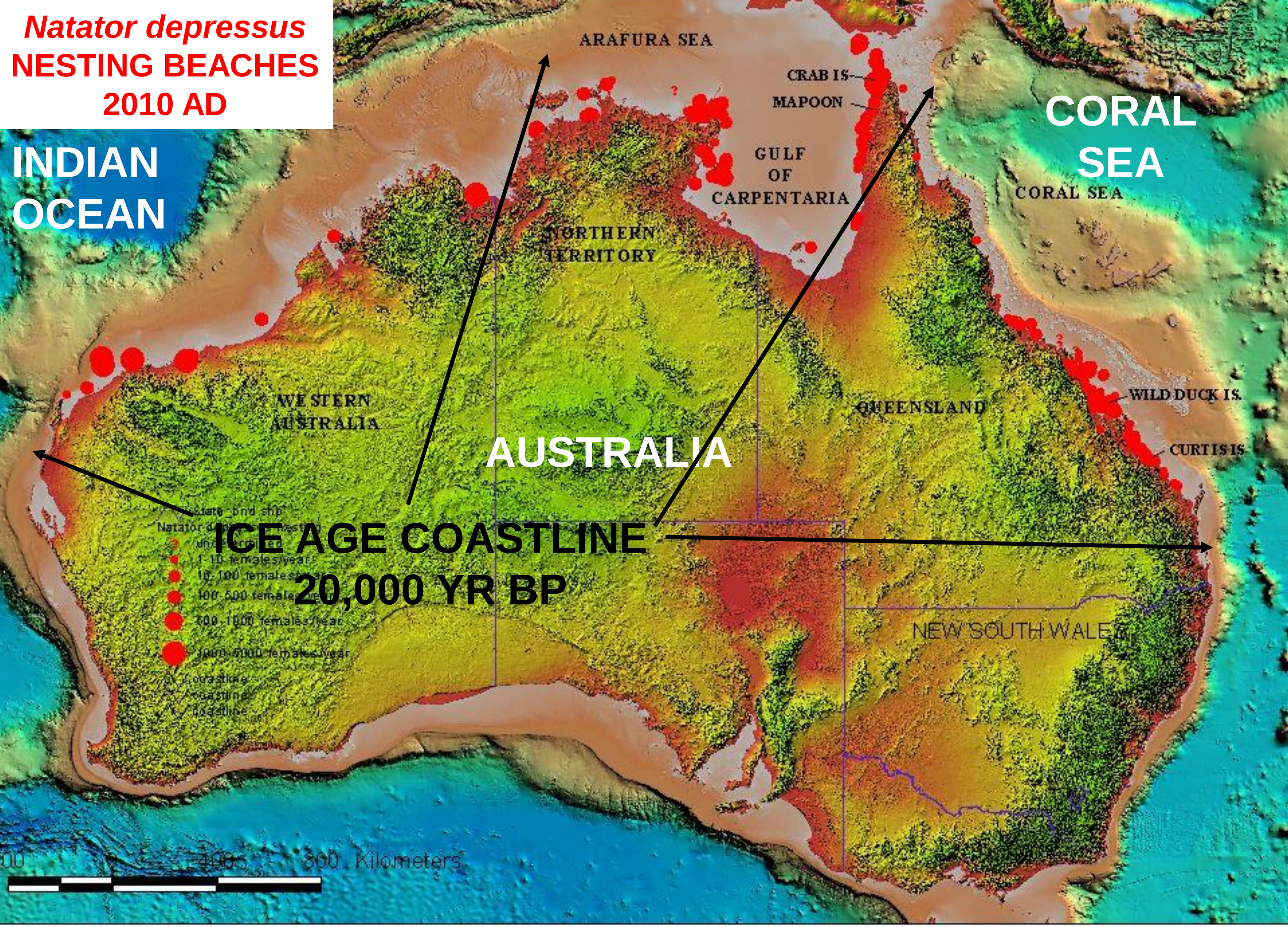
- **FORAGING: AUSTRALIA, PNG, INDONESIA**
- **NESTING: ONLY IN AUSTRALIA**

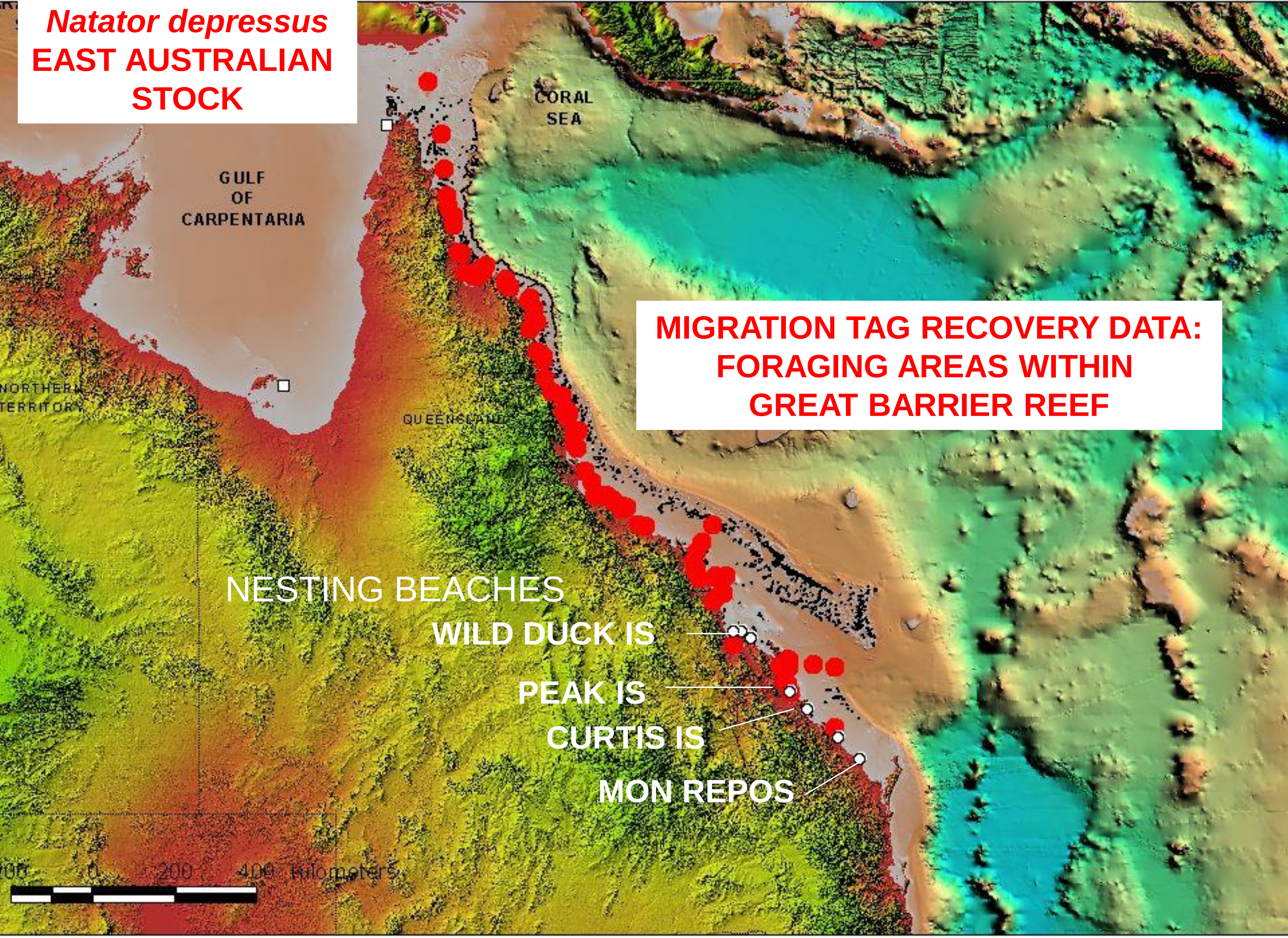
**4 MANAGEMENT UNITS**

## ADAPTING TO CLIMATE CHANGE:
## A CASE STUDY OF THE FLATBACK TURTLE, *Natator depressus*

- **ENDEMIC TO AUSTRALIAN CONTINENTAL SHELF**
- **ANCIENT TRIBE, NATATORINI, WITHIN CHELONIIDAE**
- **POSSIBLE GONDWANALAND RELECT SPECIES**


SEA LEVEL RISE
ARAFURA SILL
FLOODED ~8,000YR BP
TORRES STRAIT
FLOODED ~7,000YR BP
INDIAN
OCEAN
GULF
OF
CARPENTARIA
NORTHERN
TERRITORY
CORAL
SEA
SEA LEVEL
• HIGHEST ~6,0000 BP
• 1M SEA LEVEL DROP & STABILISED ~4,000YR BP
BARRIER REEF
ISLANDS
FORMED
~5,000YR BP
AUSTRALIA
QUEENSLAND
AUSTRALIA
ICE AGE COASTLINE
20,000 YR BP
NEW SOUTH WALES
State_bnd.shp
coastline
coastline
0 400 800 Kilometers


Natator depressus
NESTING BEACHES
2010 AD
INDIAN
OCEAN
ARAFURA SEA
CRAB IS.
MAPOON
GULF
OF
CARPENTARIA
CORAL
SEA
CORAL SEA
NORTHERN
TERRITORY
WESTERN
AUSTRALIA
QUEENSLAND
WILD DUCK IS.
CURTIS IS.
AUSTRALIA
ICE AGE COASTLINE
20,000 YR BP
NEW SOUTH WALES
800 Kilometers



*Natator depressus*
EAST AUSTRALIAN STOCK
CORAL SEA
GULF OF CARPENTARIA
NORTHERN TERRITORY
QUEENSLAND
MIGRATION TAG RECOVERY DATA: FORAGING AREAS WITHIN GREAT BARRIER REEF
NESTING BEACHES
WILD DUCK IS
PEAK IS
CURTIS IS
MON REPOS
200 0 200 400 Kilometers

*N. depressus* **HAS SUCCESSFULLY RESPONDED TO PAST CLIMATE CHANGE & SEA LEVEL RISE:**

- **NEW NESTING SITES**
- **NEW FORAGING AREAS**
- **NEW MIGRATORY ROUTES**

**LOOKING TO THE FUTURE:**

**CAN TODAY'S THREATENED TURTLE POPULATIONS RESPOND EQUALLY WELL TO NEW CLIMATE CHANGE IMPACTS?**

## WITH SEA LEVEL RISE:

**ON NESTING BEACHES WITH ELEVATED DUNES, TURTLES WILL CRAWL HIGHER TO LAY?**

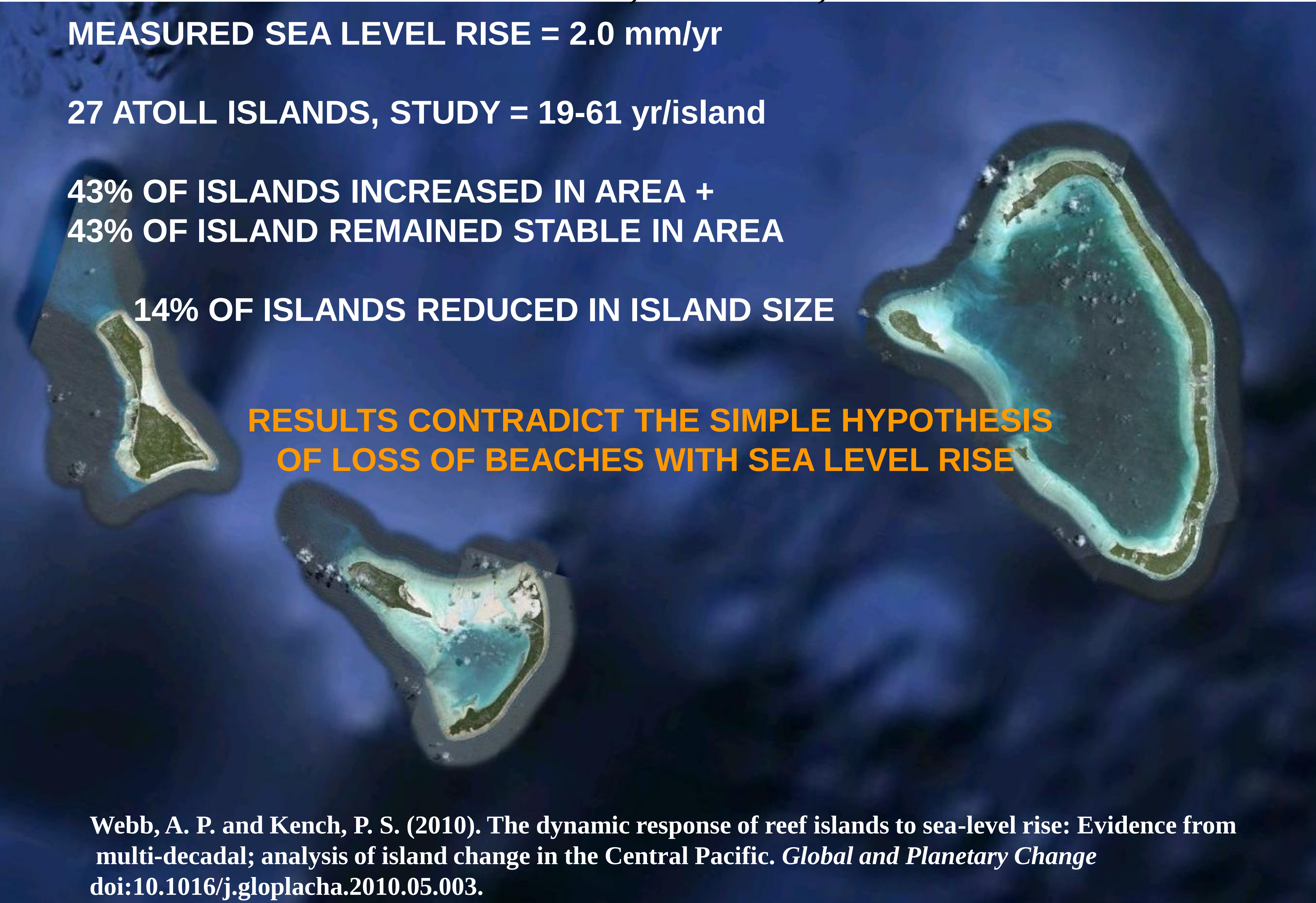

**HYPOTHESIS:**
**WITH GLOBAL WARMING & SEA LEVEL RISE, SOME BEACHES WILL BE LOST & NEW ONES FORM**
**BREEDING FEMALES WILL ADJUST NESTING DISTRIBUTION ON AVAILABLE BEACHES**


**ON LOW SAND ISLANDS, HIGH RISK OF EROSION & EVENTUAL ISLAND LOSS**

**HIGH RISK AT ONLY SOME SITES,**

**TURTLES MOVE TO NEST AT NEARBY SITES?**

# LONG-TERM STUDY OF ATOLL ISLANDS IN PACIFIC ISLAND NATIONS: FS MICRONESIA, KIRIBATI, TUVALU



**MEASURED SEA LEVEL RISE = 2.0 mm/yr**

**27 ATOLL ISLANDS, STUDY = 19-61 yr/island**

**43% OF ISLANDS INCREASED IN AREA +**
**43% OF ISLAND REMAINED STABLE IN AREA**

**14% OF ISLANDS REDUCED IN ISLAND SIZE**

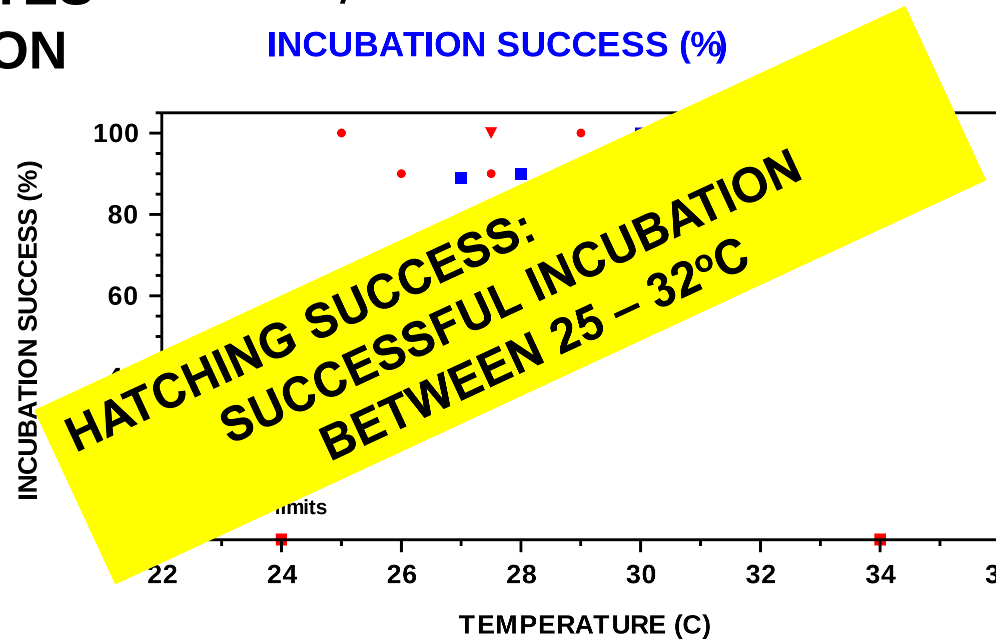
**RESULTS CONTRADICT THE SIMPLE HYPOTHESIS OF LOSS OF BEACHES WITH SEA LEVEL RISE**

**Webb, A. P. and Kench, P. S. (2010). The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal; analysis of island change in the Central Pacific. *Global and Planetary Change* doi:10.1016/j.gloplacha.2010.05.003.**

# TEMPERATURE REGULATES TURTLE EGG INCUBATION

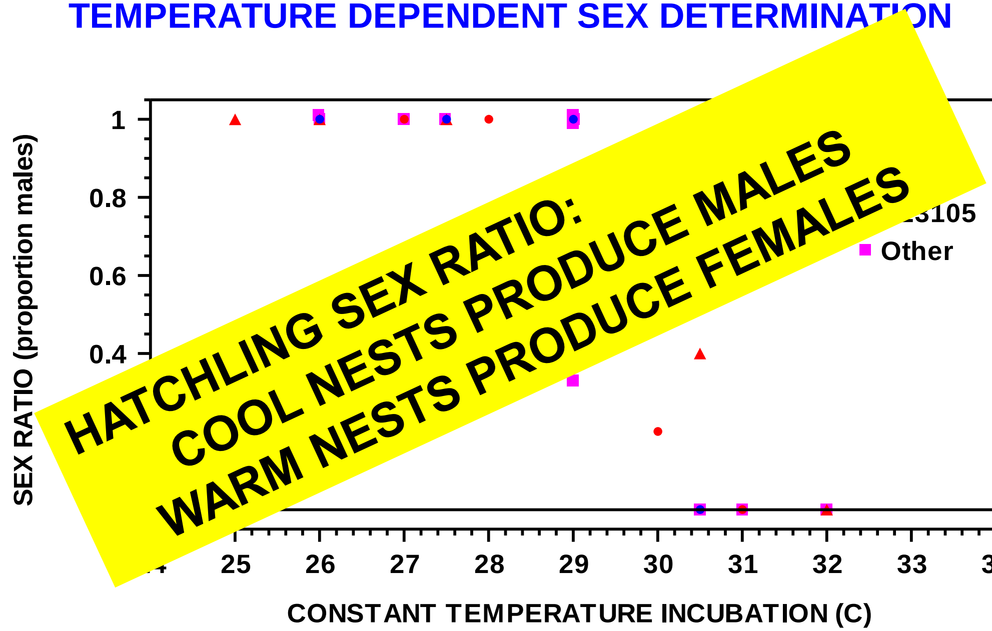
***Natator depressus*** **: EAST AUST. STOCK**

**INCUBATION SUCCESS (%)**



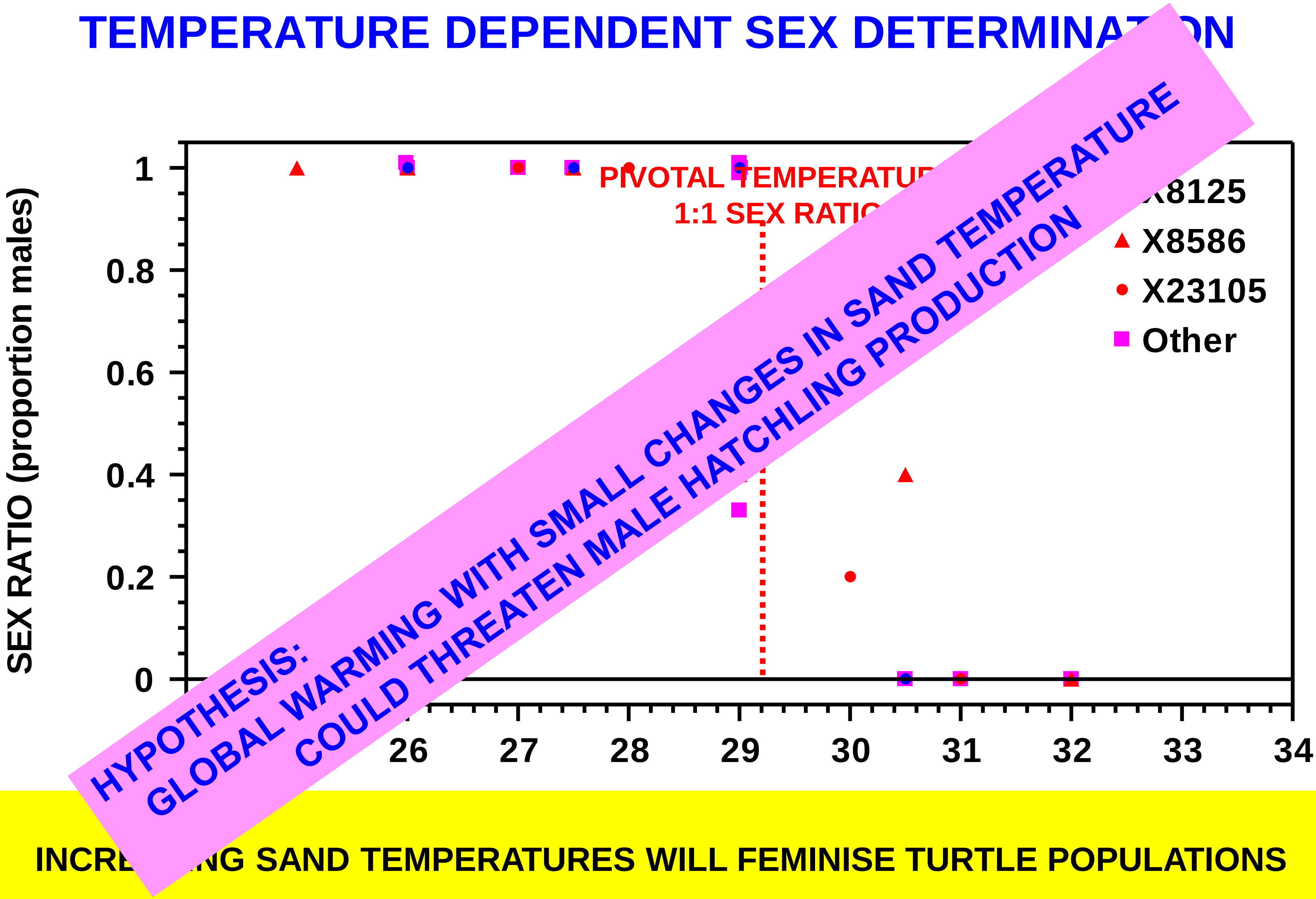

***Natator depressus*** **: MON REPOS**

**TEMPERATURE DEPENDENT SEX DETERMINATION**



# *Natator depressus*: MON REPOS

## TEMPERATURE DEPENDENT SEX DETERMINATION




**INCRE NG SAND TEMPERATURES WILL FEMINISE TURTLE POPULATIONS**

MON REPOS SAND TEMPERATURE: 1969 (October) – 1970(May)

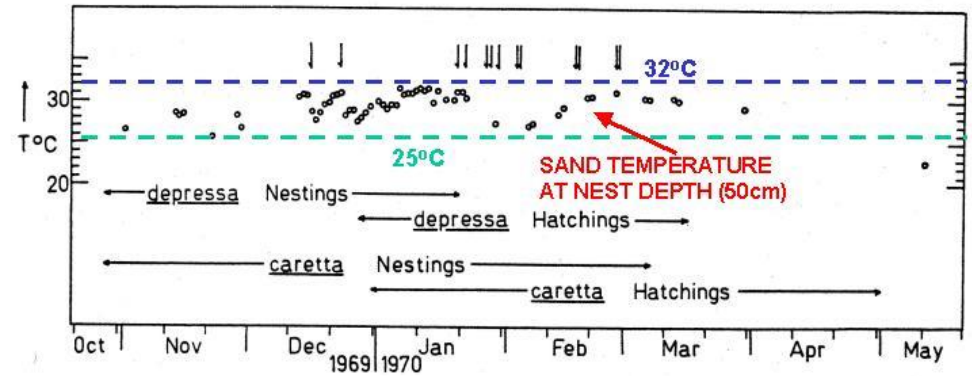
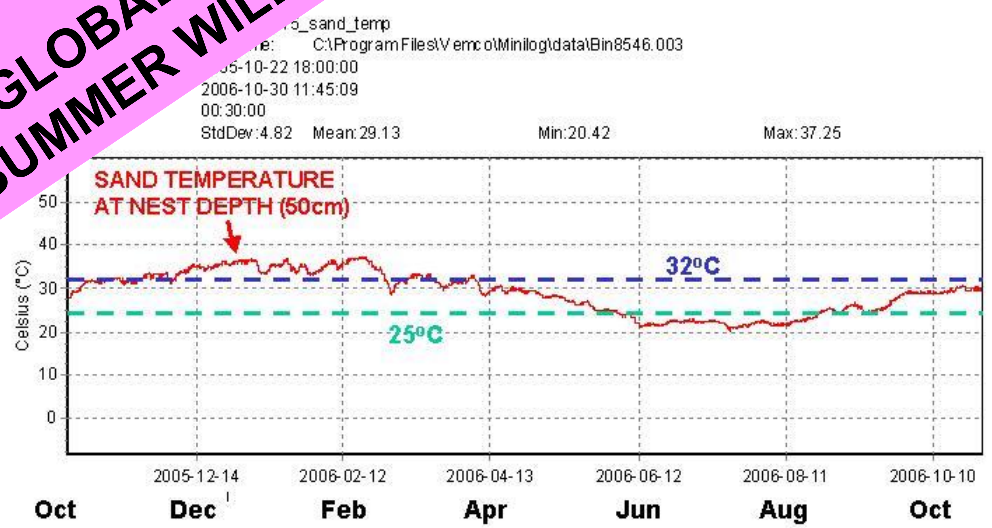



FIG. 3.—The breeding season for loggerheads (*Caretta caretta*) and flatbacks (*Chelonia depressa*) at Mon Repos. The mean sand temperature measured at 50 cm below the surface is shown for the breeding season. Days on which there was more than 50 points of rain are checked. LIMPUS, 1971

GOOD HATCH SUCCESS AT 25-3

HYPOTHESIS: WITH CONTINUED GLOBAL WARMING TROPICAL NESTING BEACHES IN SUMMER WILL BE POOR INCUBATORS

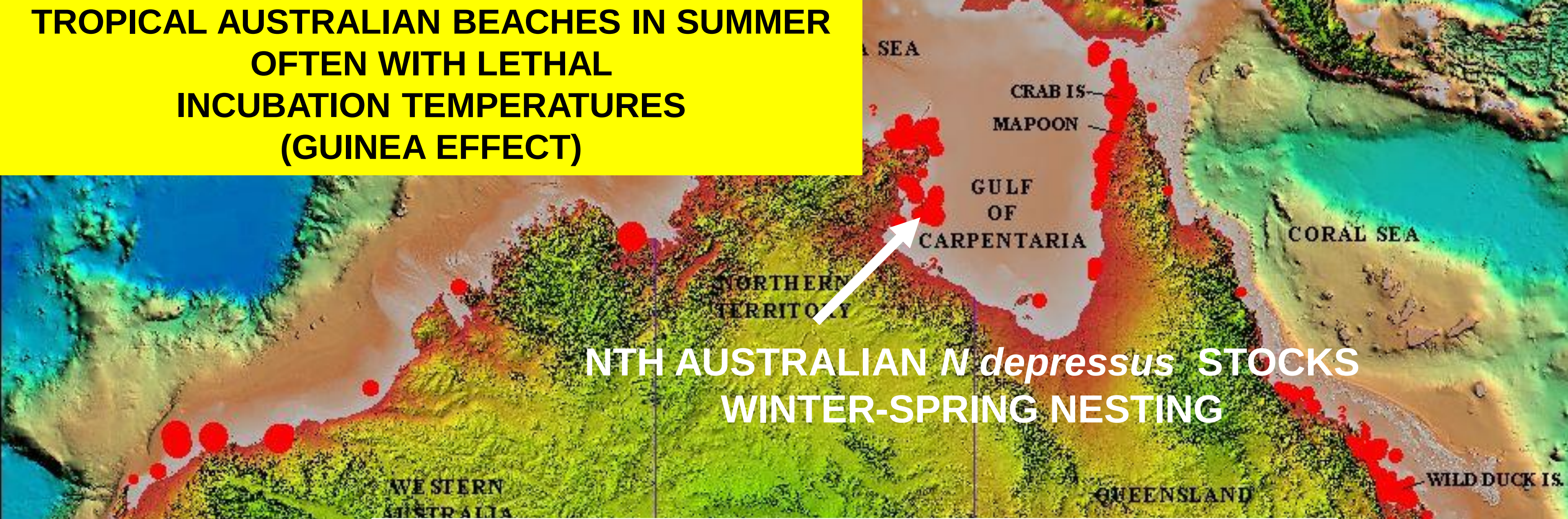
ERATURE: 2005 (October) – 2006 (October)



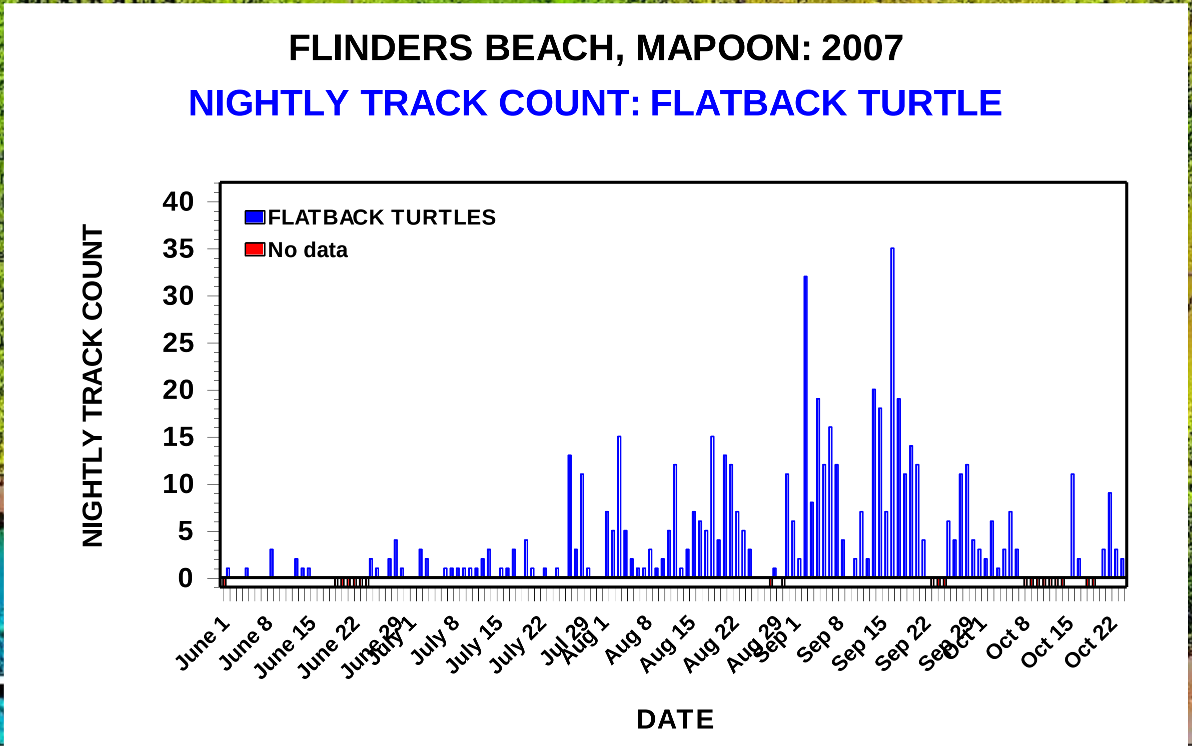

TEMPERATURE RANGE FOR OPTIMAL INCUBATION SUCCESS: 25-32ºC

**BEACHES WITH GOOD INCUBATION SUCCESS 40 YR AGO NOW WITH DECREASED INCUBATION SUCCESS**

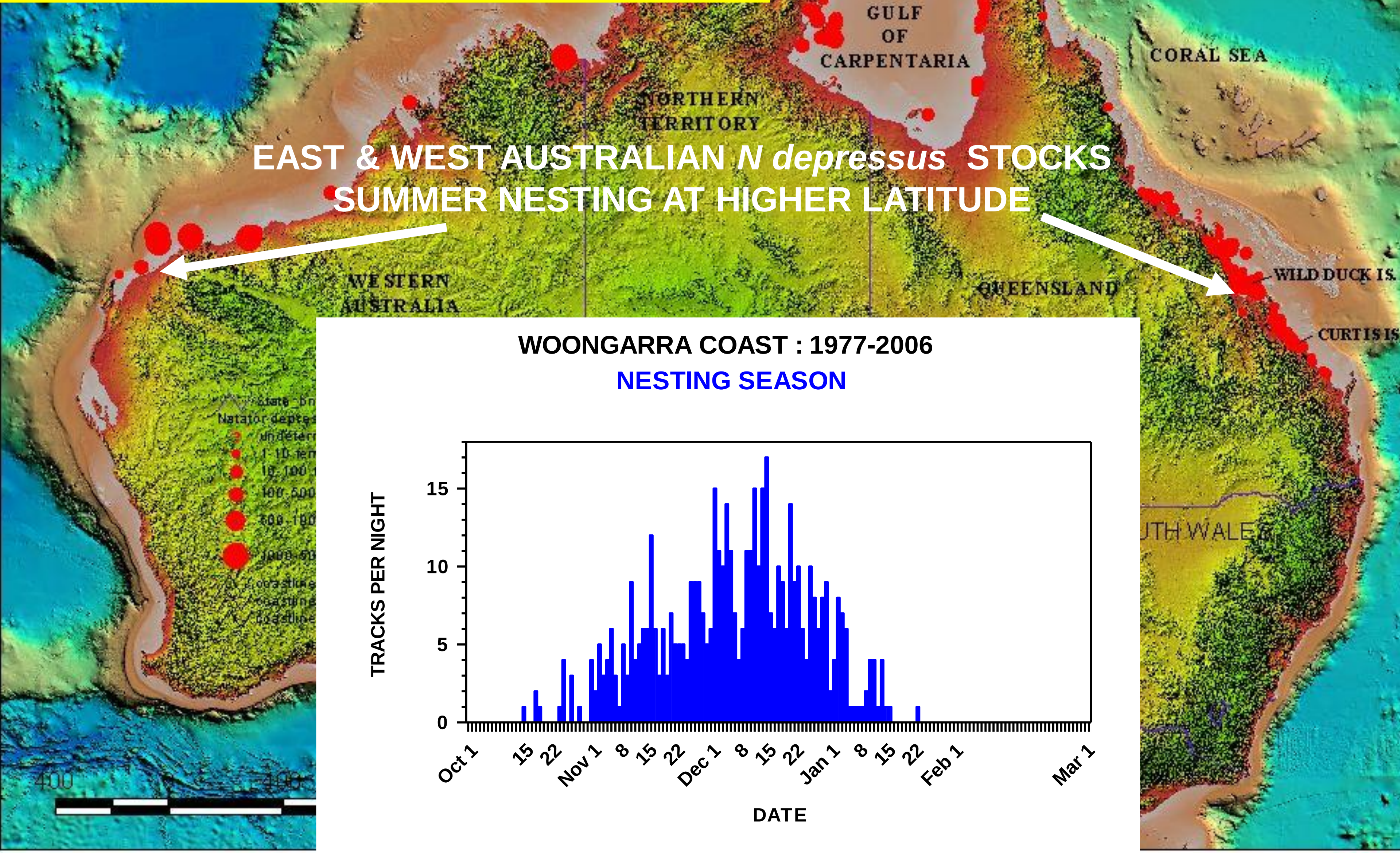
# TROPICAL AUSTRALIAN BEACHES IN SUMMER OFTEN WITH LETHAL INCUBATION TEMPERATURES (GUINEA EFFECT)

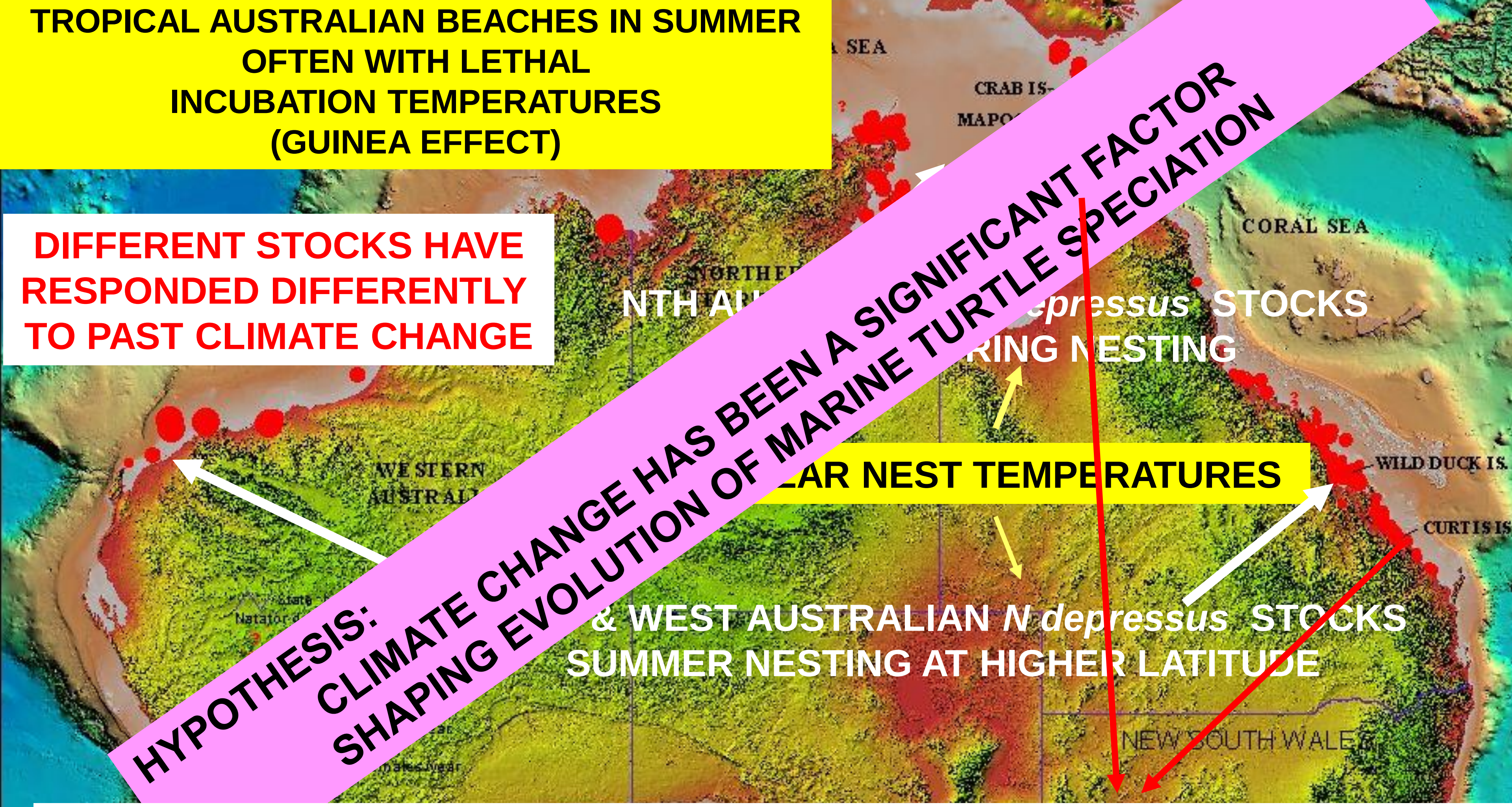



**NTH AUSTRALIAN *N depressus* STOCKS WINTER-SPRING NESTING**



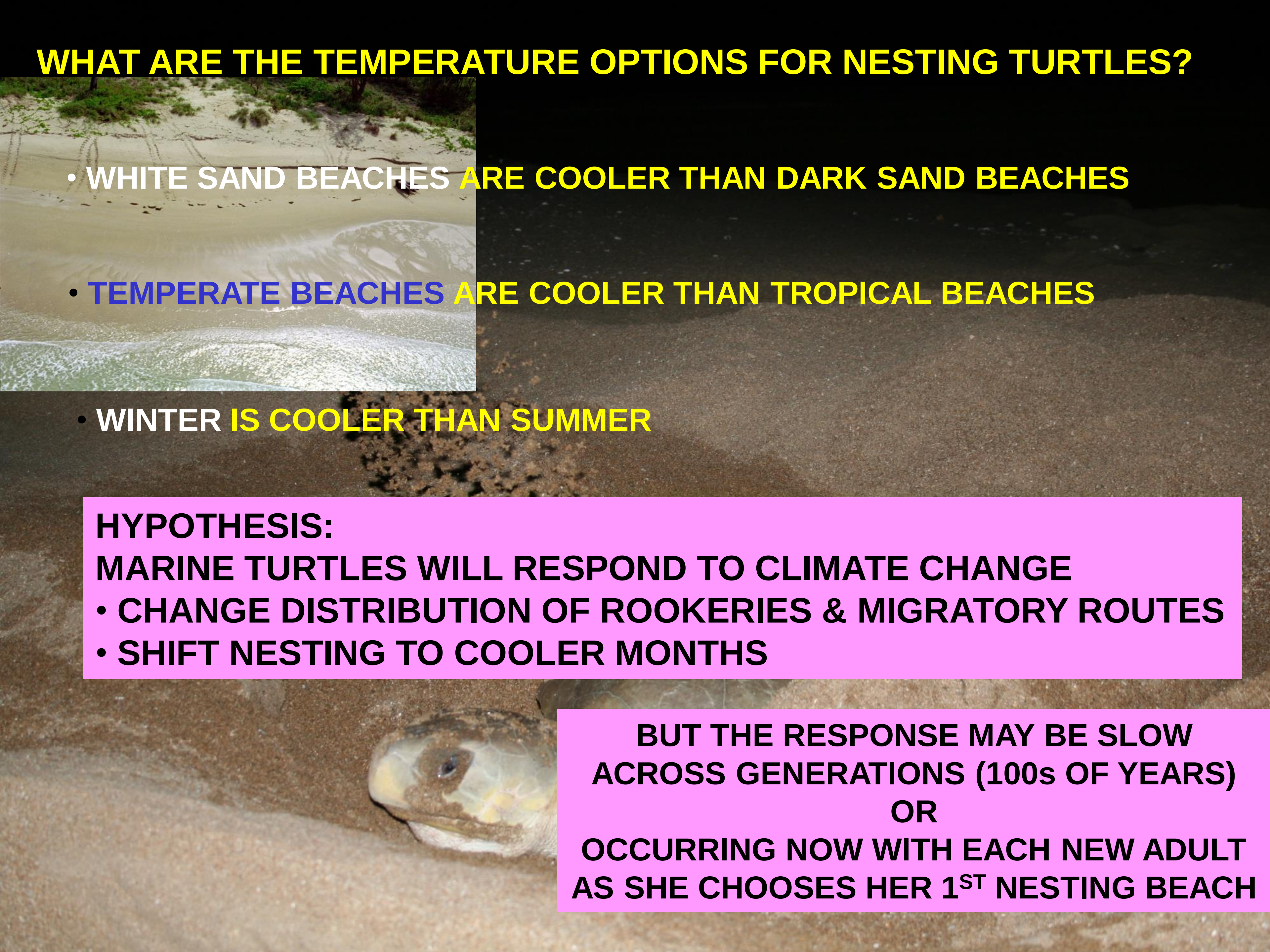
# TROPICAL AUSTRALIAN BEACHES IN SUMMER OFTEN WITH LETHAL INCUBATION TEMPERATURES (GUINEA EFFECT)






**THESE GENETICALLY DIFFERENT STOCKS ARE REPRODUCTIVELY DIFFERENT**

- **REPRODUCTIVE ISOLATION**
- **ADULT FEMALES SIZE**
- **EGGS PER CLUTCH**
- **SIZE OF EGGS**
- **SIZE OF HATCHLINGS**


WHAT ARE THE TEMPERATURE OPTIONS FOR NESTING TURTLES?
• WHITE SAND BEACHES ARE COOLER THAN DARK SAND BEACHES
• TEMPERATE BEACHES ARE COOLER THAN TROPICAL BEACHES
• WINTER IS COOLER THAN SUMMER
HYPOTHESIS:
MARINE TURTLES WILL RESPOND TO CLIMATE CHANGE
• CHANGE DISTRIBUTION OF ROOKERIES & MIGRATORY ROUTES
• SHIFT NESTING TO COOLER MONTHS
BUT THE RESPONSE MAY BE SLOW
ACROSS GENERATIONS (100s OF YEARS)
OR
OCCURRING NOW WITH EACH NEW ADULT
AS SHE CHOOSES HER 1ST NESTING BEACH


AFTER CURRENT CLIMATE CHANGE?
THERE WILL BE SUITABLE TURTLE HABITAT,
BUT NOT NECESSARILY WHERE/ WHEN IT IS TODAY

**WITHOUT POSITIVE ACTION TO IMPROVE THEIR CONSERVATION,**

**THREATENED SPECIES + CLIMATE CHANGE**
**= THREATENED SPECIES AT GREATER RISK**

**SUCCESS IN CONSERVATION MANAGEMENT OF MIGRATORY MARINE TURTLES WITH THEIR DEPENDENCE ON MULTIPLE HABITATS WILL BE A GOOD INDICATOR OF SUCCESS IN MAINTAINING BIODIVERSITY THROUGHOUT OUR OCEANS AND COASTAL WATERS.**

**LOOKING TO THE FUTURE:**

**TODAY'S THREATENED TURTLE POPULATIONS WILL RESPOND TO THE NEW CLIMATE CHANGE IMPACTS, IF WE ALLOW THEM THE OPPORTUNITY**