

# Does sex really matter?

## Explaining intraspecies variation in climate change responses

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Gender Summit 15 - Europe  
Bush House, London, 18<sup>th</sup> June 2018

# Does sex really matter?

**Sex** – biological phenotype being the presence of male or female reproductive organs

**Gender** – socially constructed personal identification, based on internal psychological experience

# Does sex really matter?

*Human context*



**National Institutes  
of Health**

1985 – NIH mandated women be included in clinical trials

# Does sex really matter?

*Human context*

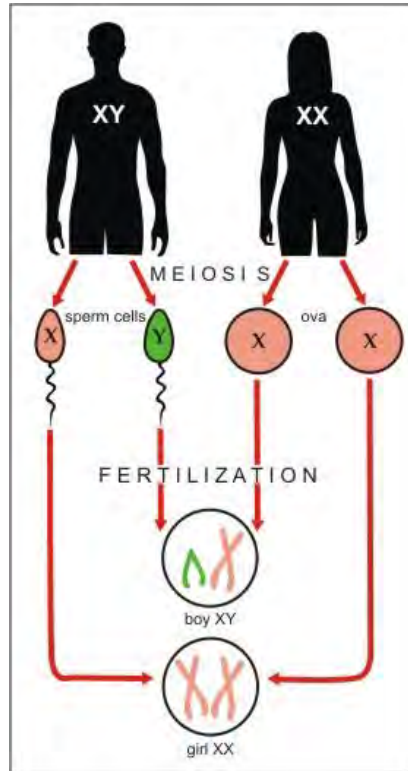


**National Institutes  
of Health**

Molecular, physiological, immunological,  
behaviour and neuro-toxicological sex-based  
differences

# Does sex really matter?

*Human context*



Habituated to assume genetic sex determination the 'norm'

True for mammals, birds, snakes, amphibians, most  
lizards and some fish  
Sex determined at fertilisation and fixed throughout life

Other modes of sex determination aberrant or strange

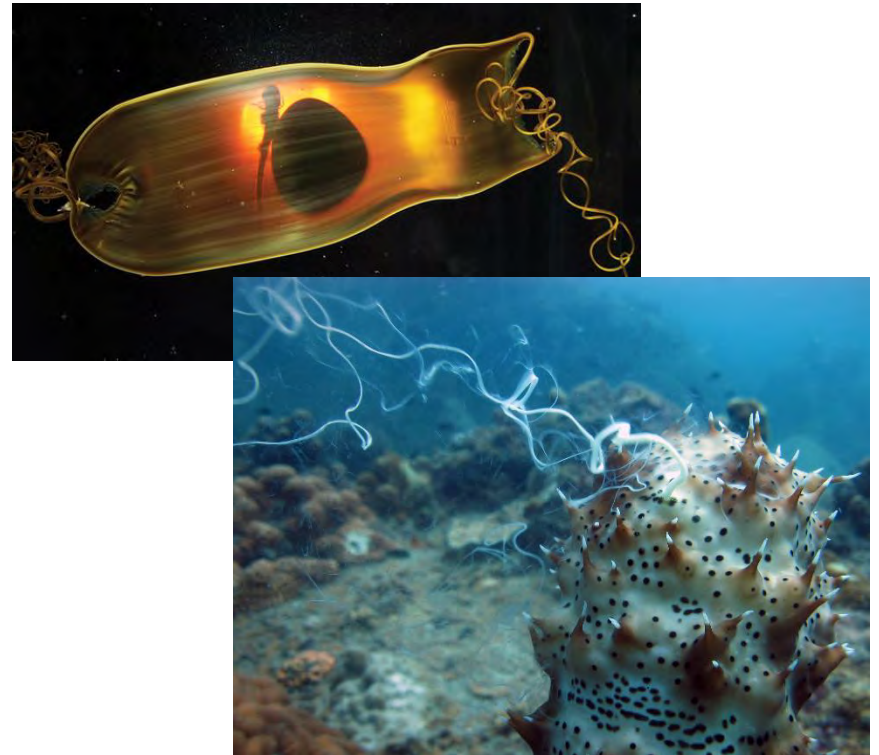
# Sex in the sea

Marine organisms have the highest diversity of reproductive modes on the planet

## *Asexual reproduction*



## *Sexual reproduction*



# Sex in the sea

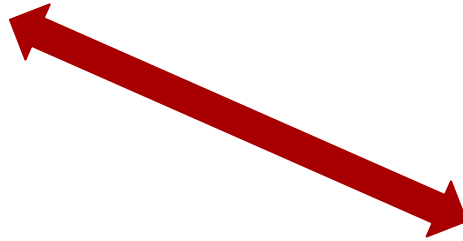
*Energy investment*

***Broadcast spawning***

*no parental care*



Coral releasing eggs/sperm into water



***Internal fertilisation***  
*extensive post-zygotic care*



Mother and daughter humpback

# Sex in the sea

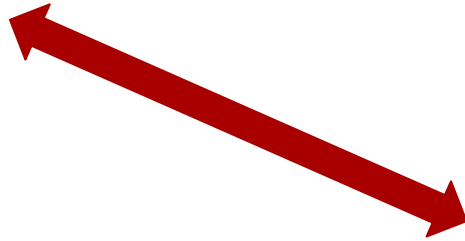
*Sexual form*

***Hermaphroditic***

*both male and female sex organs*



Marine sea slug



***Gonochoristic***

*exclusively male or female for entire life*



Surgeon fish (Dory)

# Sex in the sea

## *Sexual form*

### *Hermaphroditic*

*both male and female sex organs*



Marine sea slug

### *Simultaneous*

*Male and female gametes*



Sea hare mating chain

### *Sequential*

*Male then female / female then male*



Asian sheephead wrasse (Blue Planet II)

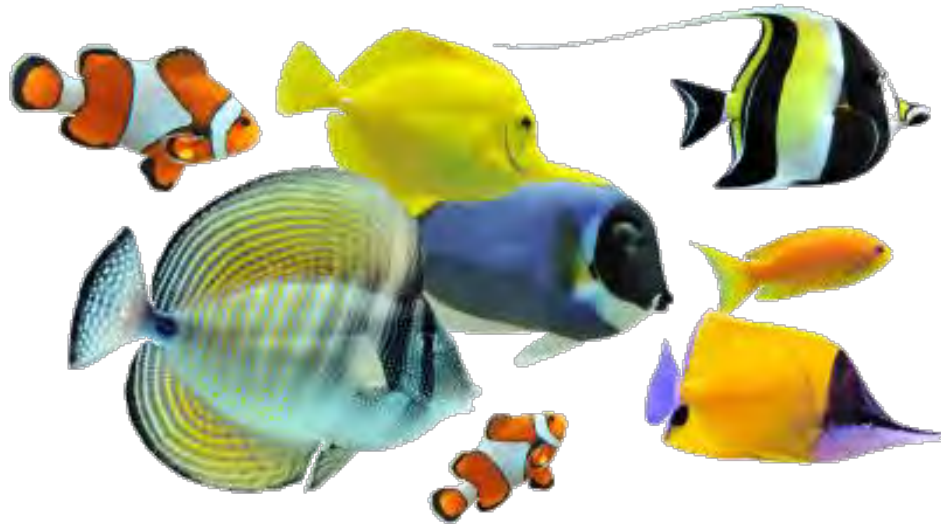
# Sex determination and differentiation

*So many ways of doing it!*

Almost 30,000 of fish (~50% vertebrates)

Colonised nearly all aquatic habitats

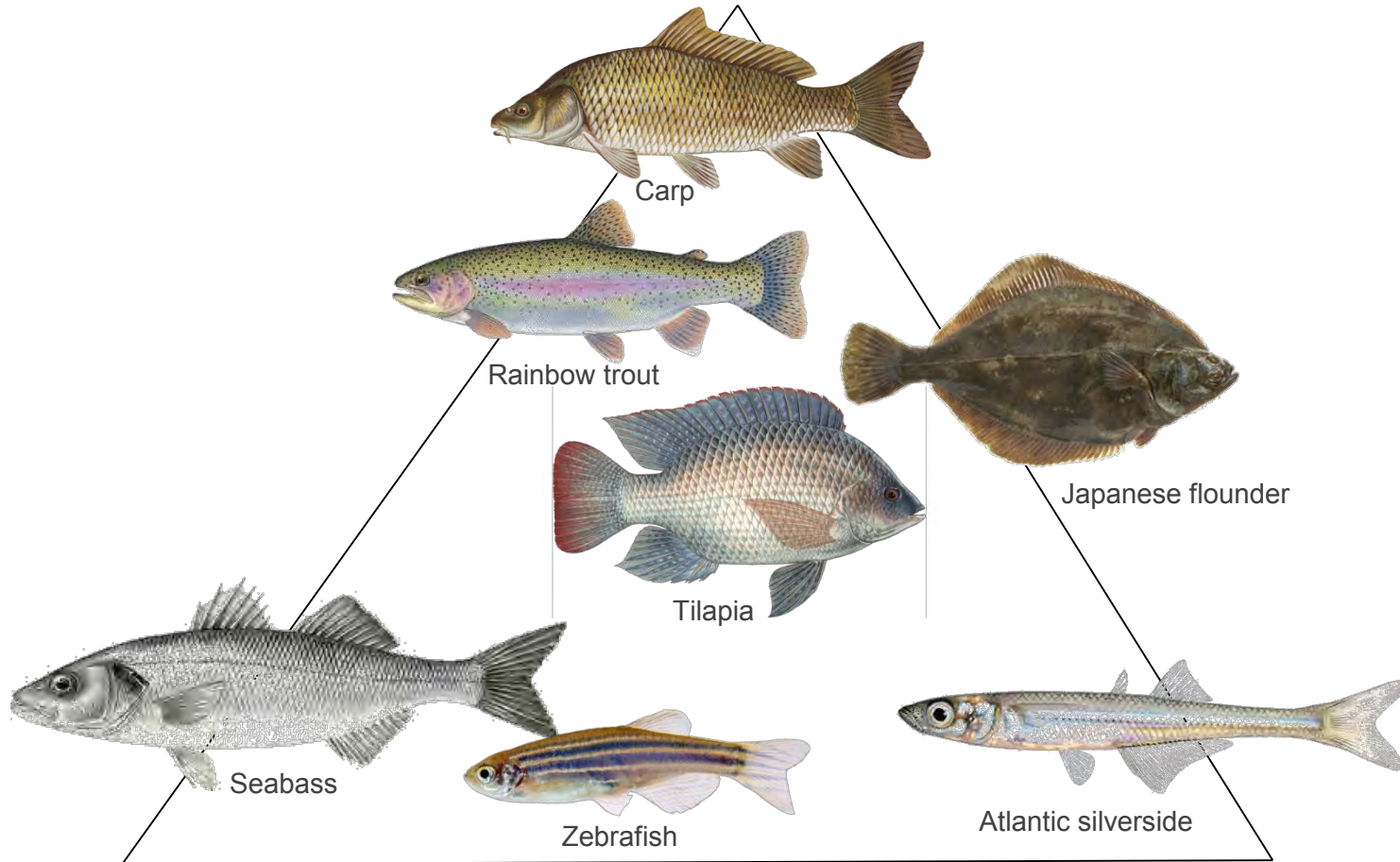
Equally diverse adaptations (e.g. what determines if male or female)



# Sex determination and differentiation

*So many ways of doing it!*

*Major genetic factors (GSD)*



*Minor genetic factors*

*Environmental factors (ESD)*

# Sex determination and differentiation

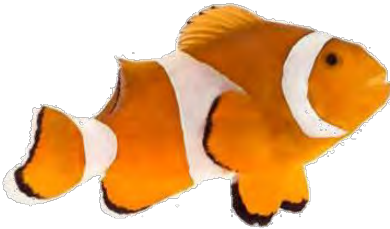
*So many ways of doing it!*

*Density*



Eels – crowding associated with > males

*Social status*



Clownfish – large dominants females

*Growth rate*



Zebrafish – faster growth > females

***Environmental sex determination (ESD)***

*Hypoxia*



Zebrafish – low oxygen > males

*Temperature*



Japanese flounder – male biased < 15°C  
& > 27°C, balanced 20-23°C

*pH*



Cichlids – Inc. pH > females

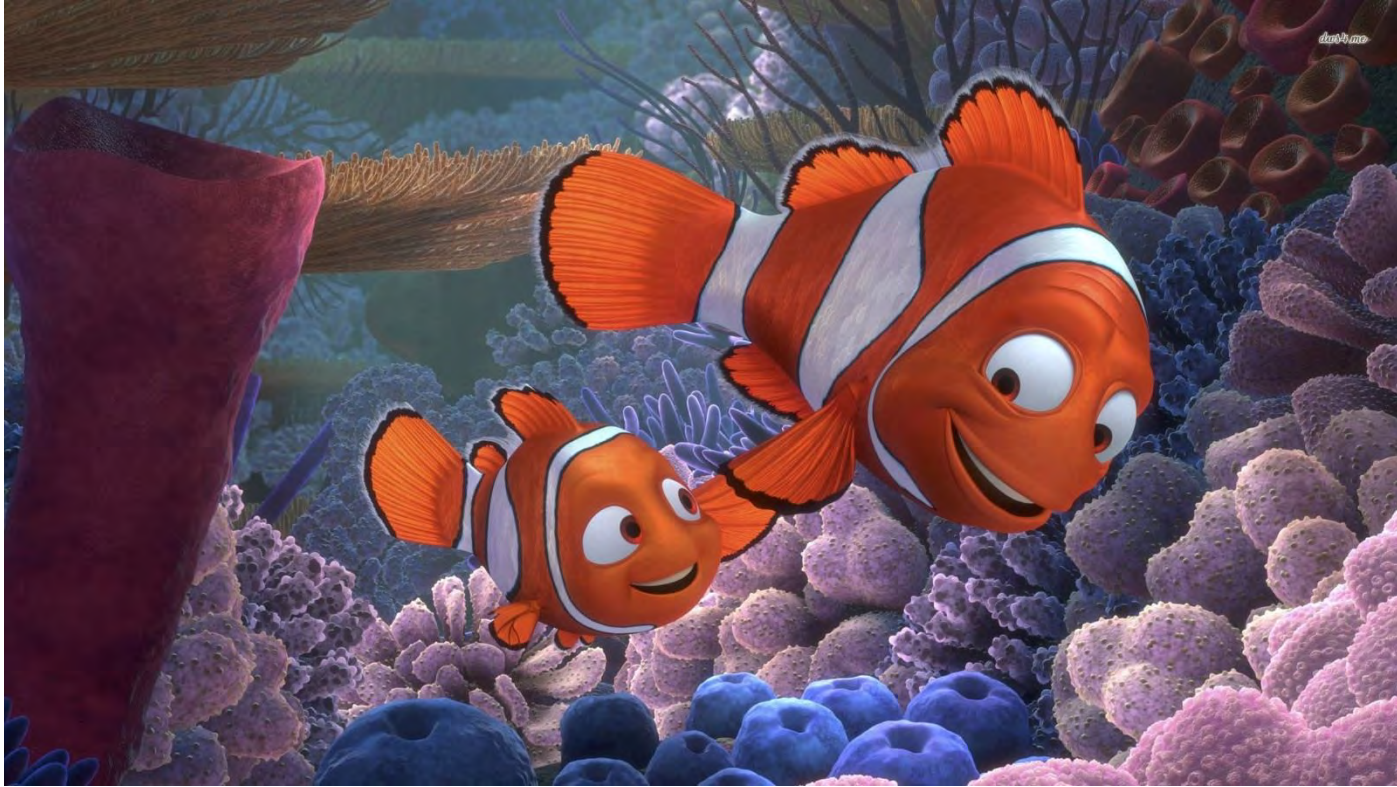
# Social factors



Clownfish – sequential hermaphrodite

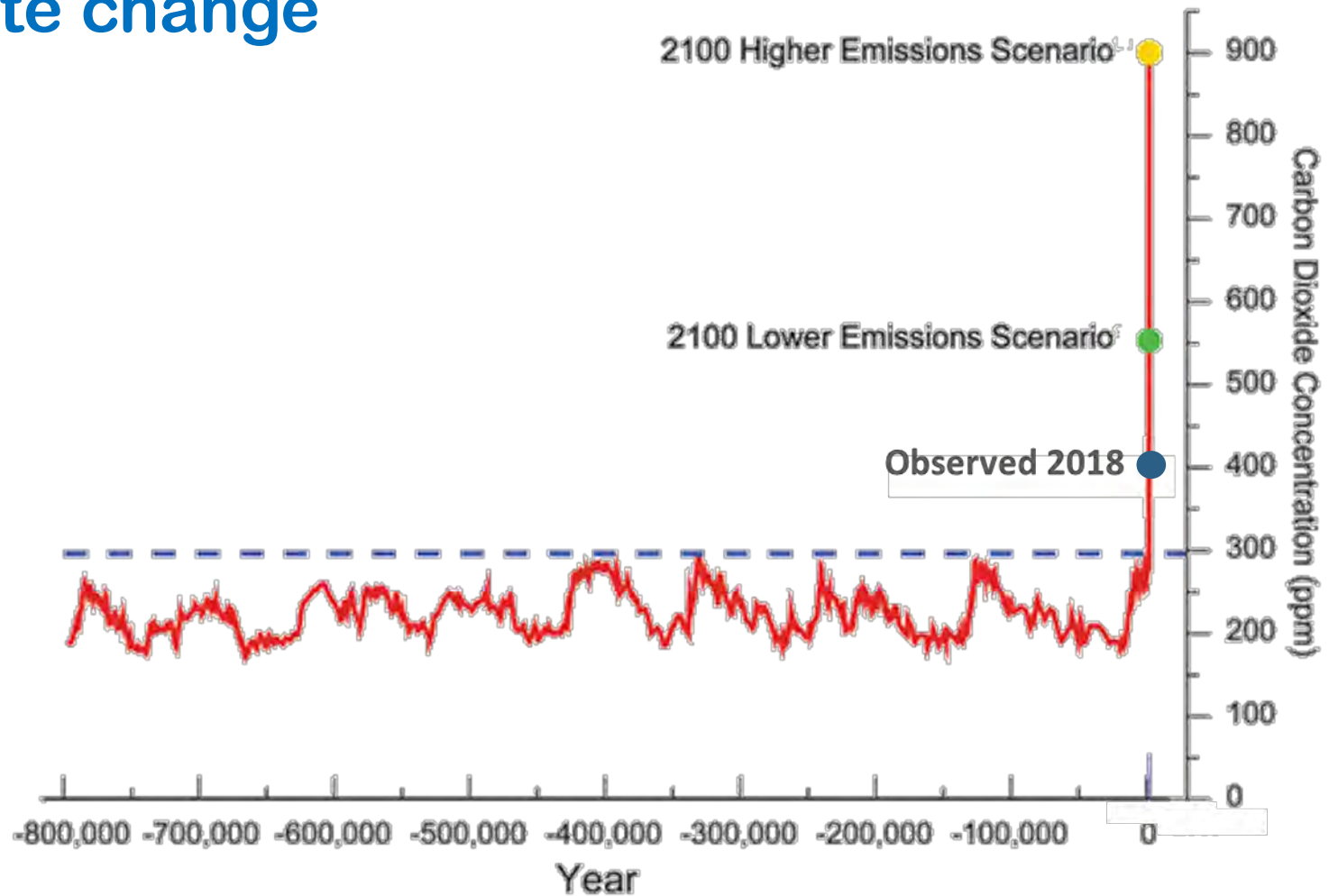
(Video courtesy of Dr Susanne Mills, CRIOBE)

# Sorry Disney, you got this one wrong



Nemo's dad would have become his mum

# Climate change



Global warming  
Ocean acidification  
Ocean deoxygenation

# Sex-based differences

Mortality of female shrimp higher than males exposed to elevated  $\text{CO}_2$

(Kurihara et al 2008 J. Exp. Mar. Biol. Ecol. 367 41-46)



Male and female mussels respond differently to increased  $\text{pCO}_2$ , with differences in energy metabolism

(Ellis et al 2014 Env. Sci. Tech. )

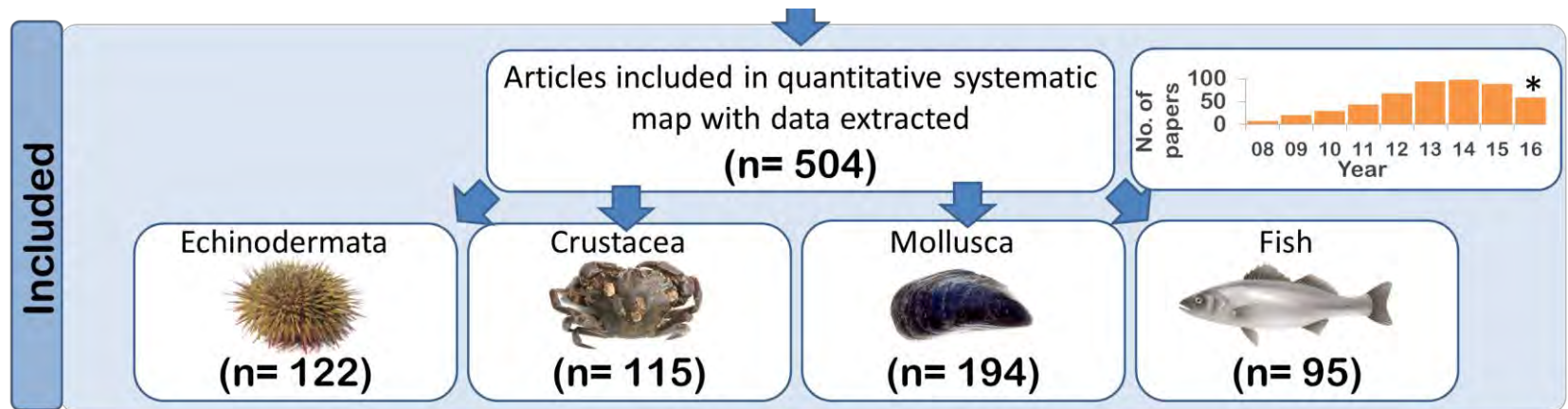
Exposure to reduced seawater pH led to 16% more females in oysters

(Parker et al 2018 *Proc. Roy. Soc. B.* 285:20172869)



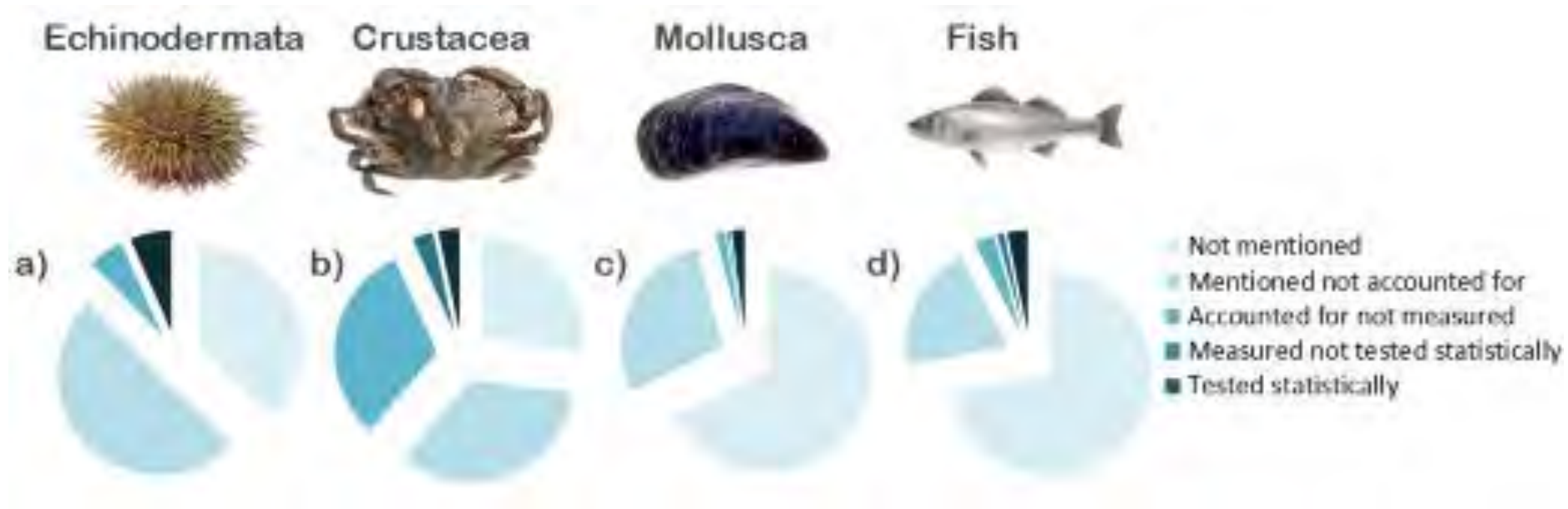
# Sex and climate change

Systematic map of 4216 ocean acidification studies published between 2008 and 2016



Each study classified into one of five categories based on sex inclusion

# Sex and climate change



Just 3.77% of studies investigating ocean acidification tested for sex-based differences!

# Barriers to inclusion

Assumption – beyond reproduction, sex not important

Ability to determine sex non-invasively, due to lack of sexual dimorphism in adults



Ability to determine sex of early life stages of individuals



# Does sex really matter?

Pooled response – the average phenotype



Assume response of individual is representative of the population



(Ellis et al 2014 Env. Sci. Tech. )

# Population effects of ESD



Turtles – males low / females high incubation temperature

# Population effects of ESD



Key role of temperature in dinosaur extinction 65 MYA?

# Summary

**Sex in the ocean is diverse, complex and in many cases environmentally determined**

**Sex impacts physiology, behaviour and reproduction, potential for population effects**

**Less than 4% of climate change studies tested sex-based differences**

**Failure to account for sex-based differences may impact climate change predictions**



**Climate  
change  
scientists  
should think  
more about sex!**