SIZE MATTERS...BUT HOW??

A SLIGHTLY MUDDLED CONSIDERATION OF SENSORY BIOLOGY AND PREDATOR-PREY INTERACTIONS

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SCIENCE
(ESPECIALLY COMPUTATIONAL ECOLOGY)
IS ALL ABOUT TRADE-OFFS

REALISM

Fine, but what about the
evident complexity we observe?

What about the implicit
assumptions made as you
simplify a system?

Should we not demonstrate
irrelevance before assuming it?

PRAGMATISM

Principle of Parsimony - Occam’s Razor

*Pluralitas non est ponenda sine neccesitate*

= Pluralities should not be postulated unnecessarily
Applying his principle Occam argues that the answer to the question of “Whether a Higher Angel Knows Through Fewer Species than a Lower” is a definitive YES

SO MUCH FOR METAPHYSICAL NONSENSE

The principle of parsimony (Occam’s Razor) is best applied as a common sense approach to building conceptual, analytical and computational models, NOT as a driving force to any given field of research, lest the models themselves become dogma
PREDATOR-PREY INTERACTIONS DEPEND ON SENSORY BIOLOGY, FUNCTIONAL MORPHOLOGY AND BEHAVIOUR

PREDATOR

\[ P (\text{detection}) = f (\text{hearing, olfaction, vision}) \]
\[ P (\text{capture}) = f (\text{stealth, acceleration, gape, bite}) \]

PREY

\[ P (\text{detected}) = f (\text{camouflage, counter-illumination}) \]
\[ P (\text{captured}) = f (\text{acceleration, turning angle, counter-measures}) \]

Not all of these factors are similarly size-dependent
DETECTION MECHANISMS...

VISION

Acuity-based calculations considerably overestimate reaction distances, as images rapidly decay underwater due to scattering and absorption.

For oceanic predators searching visually for large prey, reactive distance is more likely to be limited by contrast than by visual acuity, and to be only minimally dependent on prey size (Eggers 1977, Breck 1993, Giske et al. 1998).

\[ r^2 e^{cr + kz} = \left| C_0 \right| \frac{A E}{A E + K_e + E_b} \]

PREDATOR
* Visual capacity \( E \)
* Eye saturation parameter \( K_e \)

PREY
* Prey contrast \( C_0 \)
* Prey area \( A \)

ENVIRONMENT
* Background irradiance \( E_b \)
* Depth \( z \)
* Diffuse attenuation coefficient \( k \)
* Beam attenuation coefficient \( c \)

* size-dependant variables/parameters

REFERENCES
Aksnes & Giske 1993
Aksnes & Utne 1997
Jumper & Baird (1991) and Jumper et al. (1996) modelled reaction distance for a point source of pheremone in the ocean.

\[ r = Pt \left( -kt + \ln \frac{M}{h} \right) \frac{2\pi P^2 t^2}{C} \]

**PREDATOR**
- *Threshold concentration for odour detection* \( C \)

**PREY**
- *Chemical decay rate* \( k \)
- *Mass released* \( M \)
- *Vertical dimension of release* \( h \)

**ENVIRONMENT**
- *Diffusion velocity* \( P \)
- *Time* \( t \)

*Size-dependent variables*

**BUT** the equations used cannot describe *predator-prey* interactions, where the odour source is continuous, and in ocean currents exhibiting strain.
The equation for Fickian diffusion:

\[ \frac{\partial C}{\partial t} = K_y \frac{\partial^2 C}{\partial y^2} \]

has a Gaussian solution,

\[ C(x, y) = \frac{Q}{h} \cdot \frac{1}{\sqrt{4\pi K_y x u}} \cdot \exp \left\{ -\frac{y^2 u}{4K_y x} \right\} \]

The equation for diffusion with strain:

\[ \frac{\partial C}{\partial t} = K_y \frac{\partial^2 C}{\partial y^2} + \gamma y \frac{\partial C}{\partial y} \]

has a Gaussian solution

\[ C(x, y) = \frac{Q e^{-\gamma x / u}}{2\pi \sigma h u} \cdot \exp \left\{ -\frac{y^2}{2\sigma^2} \right\} \]

where

\[ \sigma^2 = \left( \frac{K_y}{\gamma} \right) - \left( \frac{K_y}{\gamma} \right) \cdot \exp \left\{ -\frac{2\gamma x}{u} \right\} \]

Both solutions are for a continuous source emitting at rate* \( Q = 1 \text{ g s}^{-1} \)
with a vertically mixed layer of depth \( h = 200 \text{ m} \), in the presence of a rotation- and divergence-free current of magnitude \( u = 0.1 \text{ m s}^{-1} \)
Horizontal diffusivity \( K_y = 10 \text{ m}^2 \text{s}^{-1} \), Effective strain rate \( \gamma = 5 \times 10^{-7} \text{ s}^{-1} \)

*ENTIRELY MADE UP...
Turbulent diffusion and straining of a vertically mixed continuous emission of Tryptophan

- Contour is $10^{-5} \, \mu g \, ml^{-1}$ detection threshold (Atema et al. 1980)
- Dotted line: diffusion only
- Solid line: diffusion with strain
Although predatory bowfin were larger than largemouth bass, they did not eat significantly larger prey.

Jordan F, Arrington DA (2001) Weak trophic interactions between large predatory fishes and herpetofauna in the channelized Kissimmee river, Florida, USA

*Wetlands*

Turtles with carnivorous and durophagous diets are capable of biting harder than species with other diets ... the ability to bite hard [allows them to] consume harder or larger prey [but] might trade off with the ability to feed on fast agile prey.


*Journal of Evolutionary Biology*

Defensive responses significantly declined with increasing body size.

Although this suggests that variation in antipredator behavior is related to body size, some studies have not found this relationship.

Roth ED, Johnson JA (2004) Size-based variation in antipredator behavior within a snake (*Agkistrodon piscivorus*) population

*Behavioral Ecology*
A TRADE-OFF in habitat use between foraging gain and predation risk is more likely for individuals large enough to be resource limited but still small enough to be vulnerable to predation.

Size-dependent resource limitation and foraging-predation risk trade-offs: growth and habitat use in young arctic char
Oikos

Laboratory evidence shows that growth and survival of larval fish are strongly affected by variations in prey and predators; field evidence, in general, does not.

Canadian Journal of Fisheries and Aquatic Sciences
WHO IS PREDATOR AND WHO IS PREY?
THE CASE OF THE COOKIE-CUTTER SHARKS
*Isistius brasiliensis* AND *Isistius plutodus*

From beneath, the cookie-cutter's true silhouette (top) blends in with light filtering from the sky because of the shark's luminescent underside. A dark patch in the glow resembles a smaller fish.
The cookie-cutter shark’s teeth gouge plugs of flesh out of bigger creatures.
SUMMARY AND CONCLUSIONS:

Predator-prey interactions and structuring of oceanic ecosystems depend on morphological, behavioural and environmental factors.

Size matters, but we should consider a ‘vulnerability index’ for predator-prey interactions, based on functional morphology and behaviour, which could be incorporated into ecosystem models.

In order to derive such an index we must:

Keep up the ‘real’ biology, but measure the variables and parameters that comprise the relevant functional relationships.

Keep up the modelling, but design models that are capable of paramatisation by observation and experiment.
BE HONEST – WE ALL KNOW IT AIN’T JUST SIZE THAT MATTERS...

LIFE IS ALL ABOUT TRADE-OFFS

CONSUMPTION PERFORMANCE
Larvae residing in frontal zones face positive consequences with respect to feeding and growth and negative consequences with respect to direct predation mortality, the balance between these determining long-term survival of the population

Munk P (2002) Larval sand lance (Ammodytes sp.) in the diet of small juvenile wolffish (Anarhichas spp.): predatory interactions in frontal water masses off Greenland

*Canadian Journal of Fisheries and Aquatic Sciences*