## Importance of Carbon Pump (esp. Southern Ocean)

* Oceans estimated to absorb a third of anthropogenic CO2 emissions since the industrial revolution.
* Estimated 40% of this oceanic CO2 absorption occurs in the Southern Ocean.

## Importance of Myctophids and their MR

* Contribute to the biological carbon pump.
* Export carbon to deep ocean through:
  + Predation of epipelagic zooplankton and subsequent transport to deep through DVM.
    - Also predation of DVM zooplankton.
  + Deep respiration, defecation and mortality.
* Estimate carbon flux 0.05-0.34 mg C m-2 d-1.
  + Mass and temperature model parameterised by previous respirometry studies.
* All fish used “suffered some mechanical damage” before respirometry. Those which were “lively and pristine” selected for analysis.
  + Damage 🡪 stress onto the fish. May not get representative results.
  + Select for more active/hardy fish.

## Importance of FMR

Copy/paste from First Prog Review

~~While SMR is useful in understanding basal costs, it~~ SMR does not capture to full cost of life for a wild organism; for that, field metabolic rate (FMR) is used.

FMR is the time-averaged energy expenditure of an organism, free-ranging in its natural habitat \cite{RN199, RN259}.

~~FMR is most commonly measured using the doubly-labelled water technique.~~

~~This involves measuring carbon dioxide production, by injecting the animal with labelled water ($^{2}H\_{2}^{18}O$) and using elimination rates to measure carbon dioxide production \cite{lifson1955measurement}.~~

FMR includes energy expended on basal costs, but also incorporates the thermic effect of food (also called specific dynamic action), as well as energy used for growth, reproduction, movement, egestion and excretion \cite{RN259, RN261}.

* Especially important for highly migratory fish like myctophids.

~~It is due to this completeness that FMR is often the more ecologically relevant measure, and may be subject to more direct selection than SMR \cite{RN199, RN259}.~~

~~Despite its relevance, SMR is still a more common measure of metabolic rate than FMR.~~

~~This is because SMR is a more standardised measure, \cite{RN194, RN193} and the doubly-labelled water technique is more logistically challenging, requiring capture and recapture of a wild animal \cite{lifson1955measurement}.~~

## Otolith Isotope Method

Copy/paste from First Prog Review

Otoliths (from the Greek meaning ``ear-stone''), are structures made of calcium carbonate (usually aragonite) and an organic matrix in the inner ears of fishes.

~~Often used in ageing fishes,~~ otoliths grow~~n~~ in layers, similar to the rings of a tree. Once laid down, otoliths are metabolically inert \cite{RN186, RN152}.

The carbon in otolith aragonite derives from carbon in the fish's blood, which is itself made of two ~~main~~ components. The first is dissolved inorganic carbon, ingested from the surrounding seawater.

The second is metabolic carbon, which is produced during cellular respiration, and contains the carbon from the fish's diet.

These two sources of carbon are isotopically distinct (~1.3 DIC, ~-17.0—22.0%o diet).

Based on this isotopic distinction, a simple mixing model can be used to calculate the proportion of metabolic carbon in the blood, $M$ \cite{RN147, trueman2016ecogeochemistry}.

EQUATION

~~The key advantage of this technique for macroevolutionary studies is that otolith collections are numerous and global, due to their use in ageing fishes \cite{RN186}.~~

~~Addtionally, this method integrates all aspects of FMR, % double check~~

~~and does not require the fish to be captured and recaptured.~~

~~Some caveats of this method include its limited resolution at fine temporal scales, and lack of validation for many species.~~

~~One validation study by Chung et al. \cite{RN261} used \textit{Gadus morhua}.~~

~~This study showed that the relationship between oxygen consumption and $M$ is not linear, but exponential.~~

* M value ~~can be calibrated to~~ correlates with oxygen consumption.
  + Done for cod.
* Exponential relationship between M and oxygen consumption.

~~Values of oxygen consumption approaching MMR are poorly differentiated in the $M$ value, due regulation of blood pH by the fish \cite{solomon2006experimental}.~~

~~While important to note, these limitations are relatively minor points in a macroecological study. Fine scale temporal resolution is not required, and $M$ is an adequate proxy for comparing relative FMR across species.~~

~~Additionally, it is unlikely that free-living individuals would sustain a high metabolic rate for long enough to be recorded in the otolith, for the exponential relationship betwen $M$ and oxygen consumption to become problematic. % rework this sentence~~

* Potential exploit to fishery.
  + Fishmeal for aquaculture.
  + Omega-3 dietary supplement.
  + More pressing issue.

## Aims

* Compare M for six species of Southern Ocean myctophids using otolith isotope method.
  + Electrona carlsbergi
  + Electrona Antarctica
  + Gymnoscopelus nicholsi
  + Gymnoscolepus braueri
  + Krefftichthys anderssoni
  + Protomyctophum bolini
* Among the most abundant species of myctophid in the Scotia Sea.