    

Food webs of the wet-dry tropics: Multiple sources of primary production fuel animal biomass

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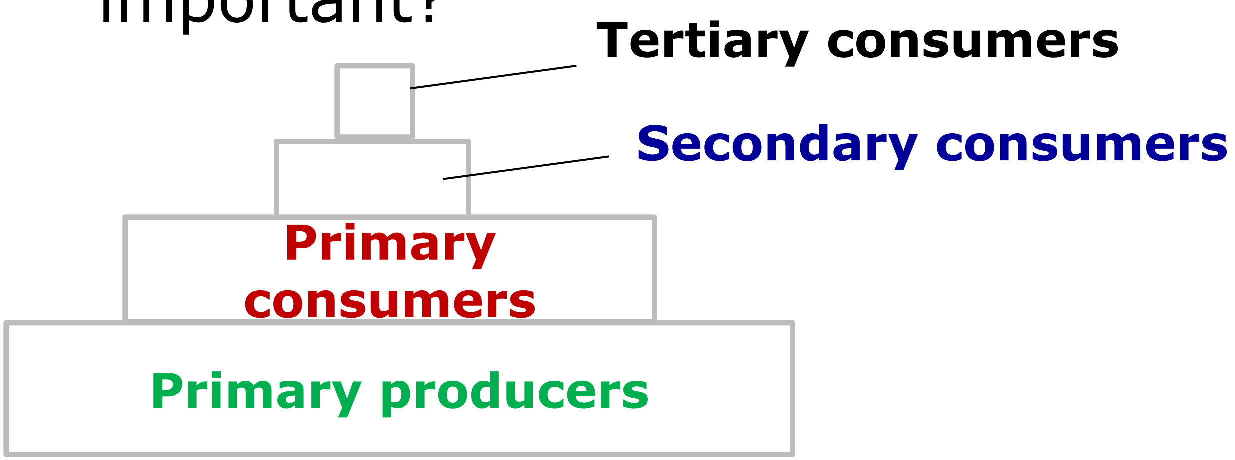
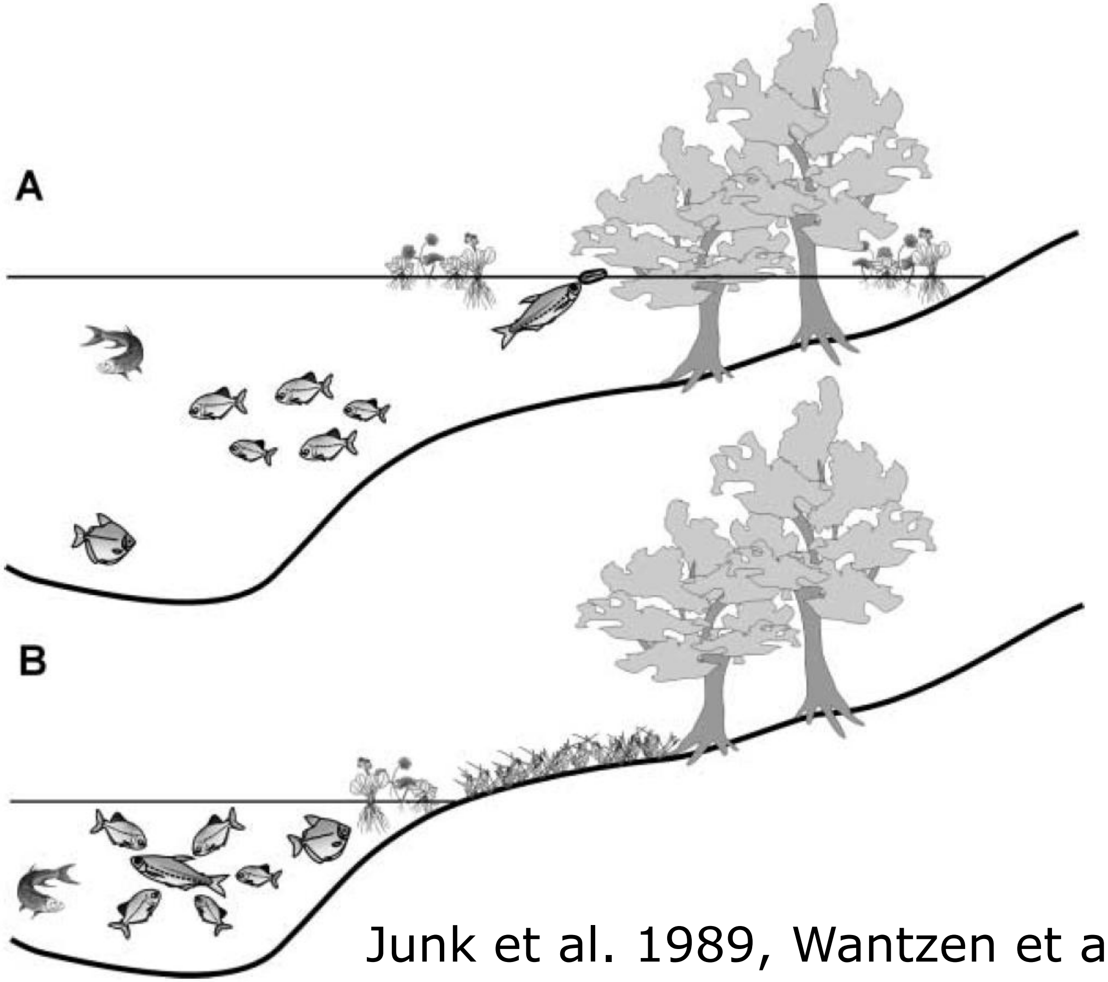
The rationale

- Animal production is limited by primary production at the base of the food web
- Sustainable animal populations require an abundant, high quality food supply
- Tropical food webs are diverse and productive; what food source pathways are most important?



The paradigm



Floods bring animals into contact with terrestrial food sources

Production within the waterbody contributes little to the food web

Junk et al. 1989, Wantzen et al. 2002

The paradigm

A strong role for terrestrial C advocated in the Flood Pulse Concept (Junk et al. 1989)

•…..many species directly use **pollen, fruits, seeds**, and…..**terrestrial insects**. **Detritus** plays a major part in the food webs in floodplains (Junk et al. 1989)
•**Primary productivity is so low** that a food chain could not be built up from endogenous sources alone to support such a large biomass of animals (Goulding 1980)
•The **rainforest**, in its floodplain manifestation, has come to the **trophic rescue** of these aquatic ecosystems (Goulding 1980)
•The overall trophic roles of phytoplankton and periphyton are minor. Fish depending on **higher plants**….very significant (Bayley 1989)
•……**terrestrial carbon**…….such as **terrestrial invertebrates, fruits and seeds**, are incorporated in the aquatic food webs……(Junk & Wantzen 2004)

Algal production is dwarfed by the large influx of terrestrial material

Fisheries Production

Carbon source	Carbon production: as tonnes of carbon per km^2 per yr.	as tonnes of carbon per yr	as % of total primary production
Phytoplankton[b]	290	191 000	5.4
Periphyton[c]	280	52 000	1.5
Aquatic macrophytes[d]	2 000	818 000	22.9
Terrestrial macrophytes[d]	2 000	1 638 000	45.9
Flooded, várzea forest (litter only)[e]	500	870 000	24.4
Total annual primary production		3 569 000	100
Annual fish production[f]		36 600	1.03
Annual fishery yield [g]		960	0.027

Bayley 1989

The alternative view

Algal organic matter is superior in quality to terrestrial organic matter
Overcomes its lower production per unit area

	Macrophyte leaves*		Tree leaves†	Seeds and fruits‡	Whole algae§
	C_4	C_3			
Na	0.03	0.55	0.02	...	0.10
K	2.43	3.22	0.86	...	0.80
Mg	0.20	0.30	0.26	...	0.60
Si	2.02	1.34	...	...	...
P	0.13	0.20	0.10	...	1.80
N	1.34	2.04	2.14	...	...
Ca	0.36	1.01	0.22	...	0.40
Dry mass (%)	22.5	12.0	41.2	61.5	...
Ash	11.1	14.9	4.80	2.6	9.0
Protein	8.4	12.8	8.10	7.8	51.0
Fiber	71.4	54.4	63.1	26.8	6.0
Energy (kJ/g)	17.0	16.5	20.7	22.1	15.0

Forsberg et al. 1993 Ecology

High protein content compared to other sources

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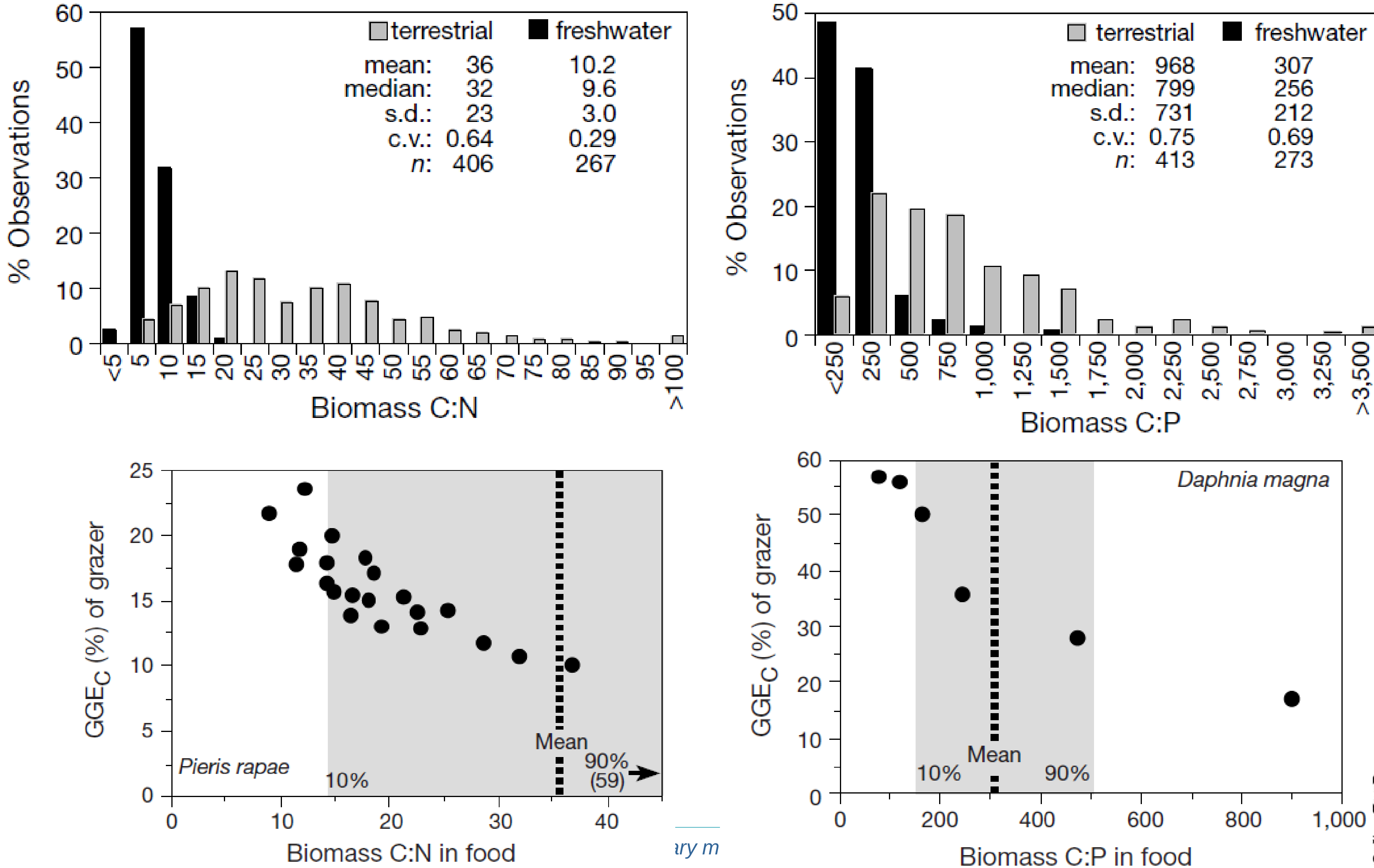
Higher proportion of N and P in diet leads to better growth performance by grazers

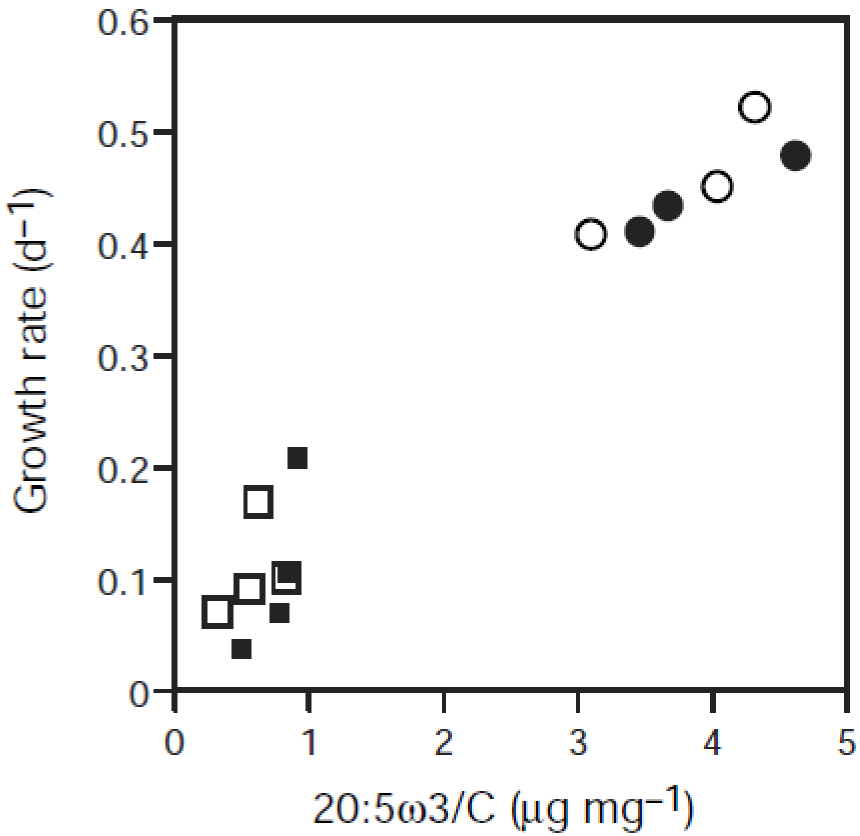
The alternative view

Elser et al. 2000 Nature

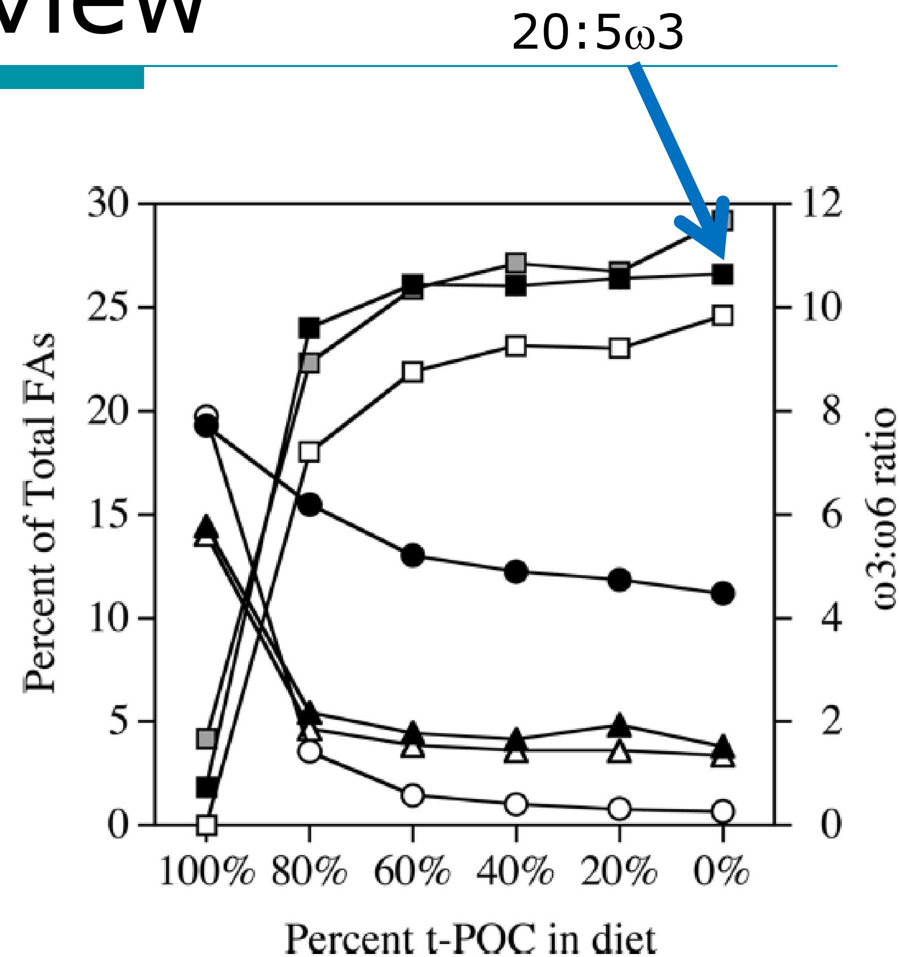


Algal carbon richer in essential fatty acids – leads to stronger growth of zooplankton

The alternative view



Muller-Navarra et al. 2000 Nature



Brett et al. 2009 PNAS

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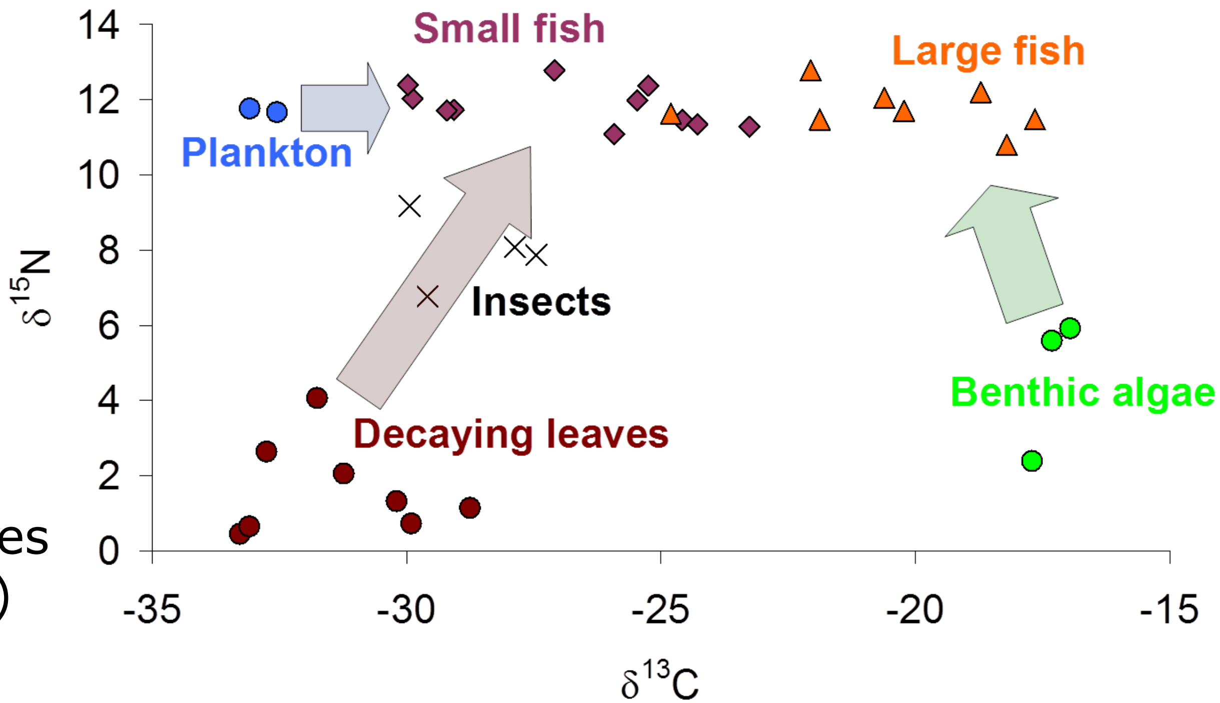
Stable isotopes as tracers

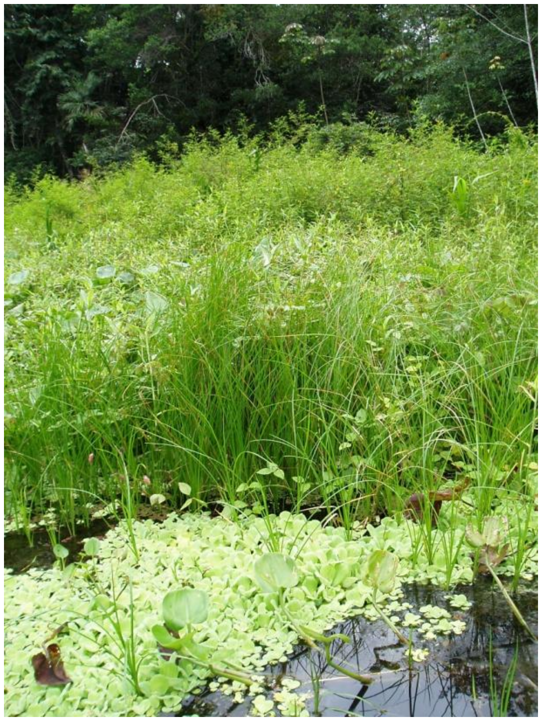
Isotope ratios of carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$) and sulfur ($^{34}S/^{32}S$) in animal tissues show high fidelity to those of underlying diet sources

Allow estimation of the importance of various primary production sources (and mixtures of sources) to animal biomass



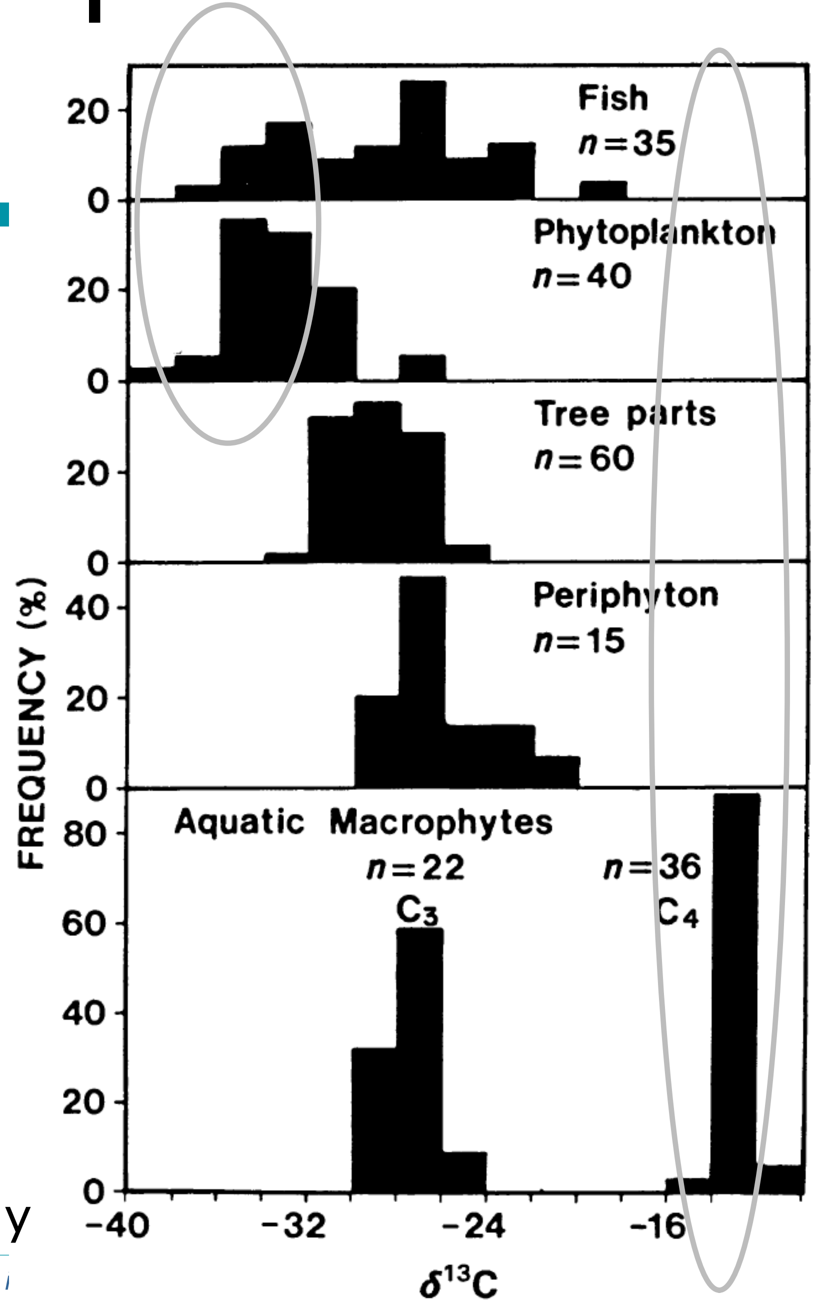
This talk: Review past and recent isotope efforts to resolve food source pathways in the wet-dry tropics

What do stable isotopes tell us?



Central Amazon

Lush aquatic vegetation (C4)



*many fish must rely on plankton

*few fish rely on C4 macrophytes

Forsberg et al. 1993 Ecology

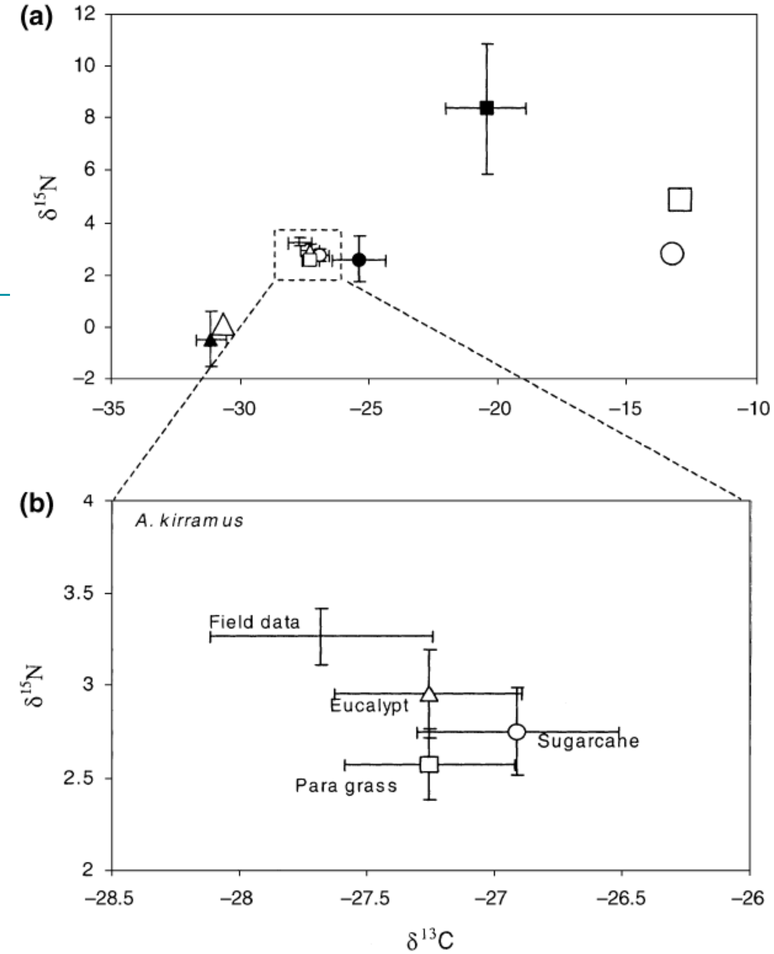
What do stable isotopes tell us?

Clapcott and Bunn 2003 FW Biology

Controlled experiments – NE Australia

Tree leaves (C3) consumed more rapidly than grasses (C4)

	C3	C4	C4
Treatment	Eucalyptus	Sugarcane	Para grass
Experiment 1			
Disc losses	0.939 ± 0.043	0.134 ± 0.024	0.047 ± 0.028
Leaching losses	0.041 ($n = 1$)	0.058 ($n = 1$)	0.033 ($n = 1$)
FPOM	1.056 ± 0.091	0.280 ± 0.039	0.171 ± 0.010
Experiment 2			
Disc losses	0.271 ± 0.062	0.050 ± 0.009	0.004 ± 0.003
Leaching losses	0.096 ± 0.061	0.073 ± 0.003	0.023 ± 0.000
FPOM	–	–	–



Herbivores fed a variety of treatments had C3 isotope ratios

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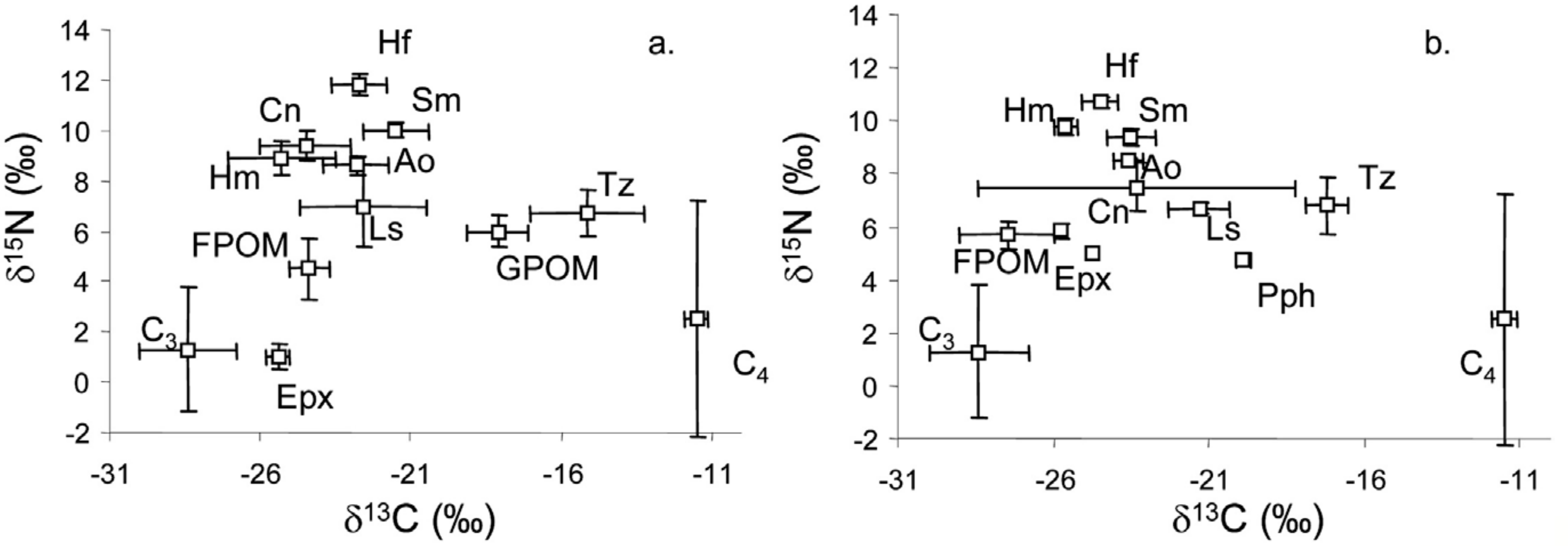
What do stable isotopes tell us?

Reservoirs in Mali (West Africa)

Fish community reliant on a mix of sources

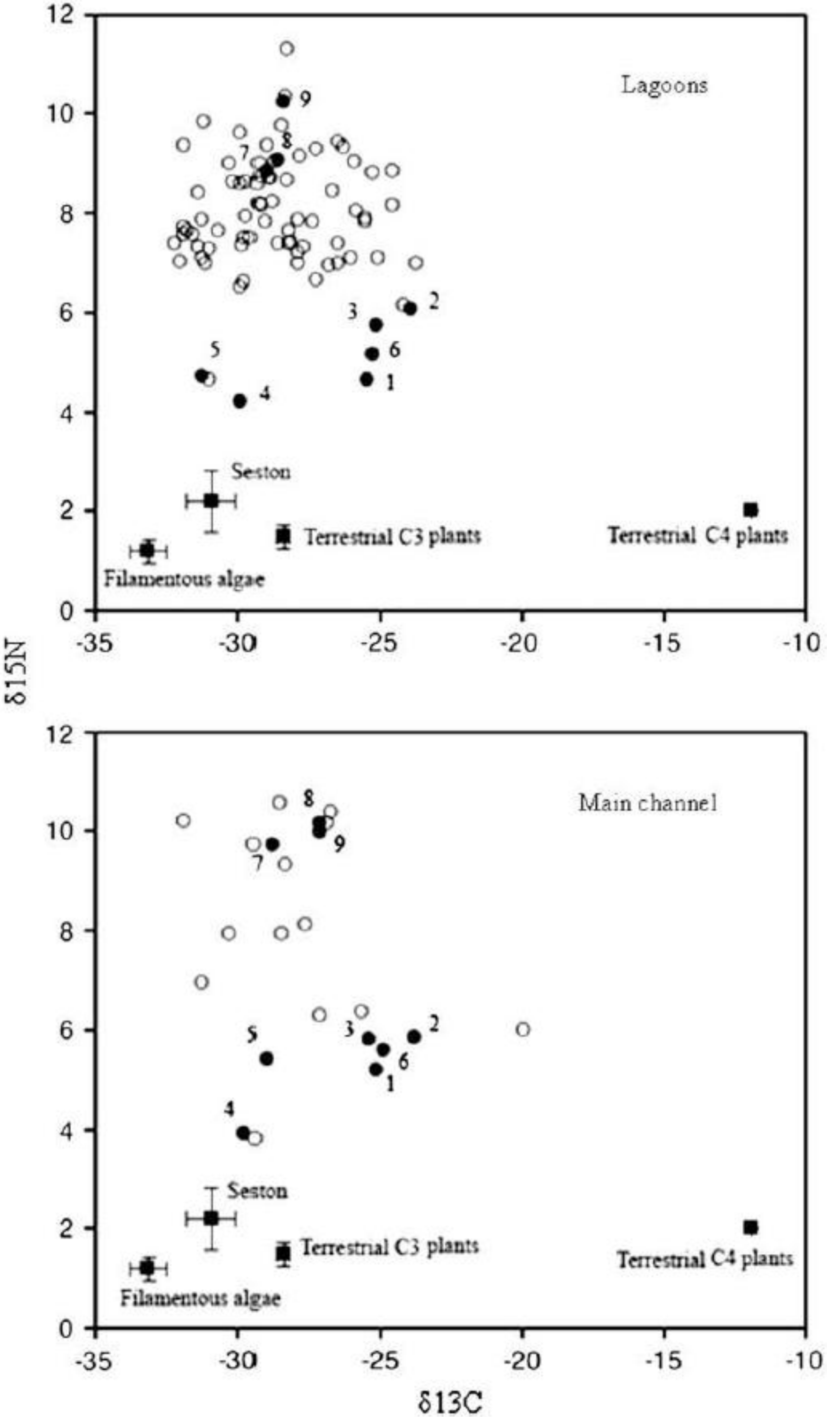
Tilapia zilii (Tz) is a herbivore – direct consumption of C4 plants

This specialization may be rare but important to quantify when present



Perga et al. 2005 IEHS

What do stable isotopes tell us?



Cinaruco River, Venezuela

C4 plants of limited importance

Seston, C3 plants and benthic algae contribute to mixture

Main channel and off-channel sites similar – movement of fishes between habitats?

Roach et al. 2009 Acta Oecologica

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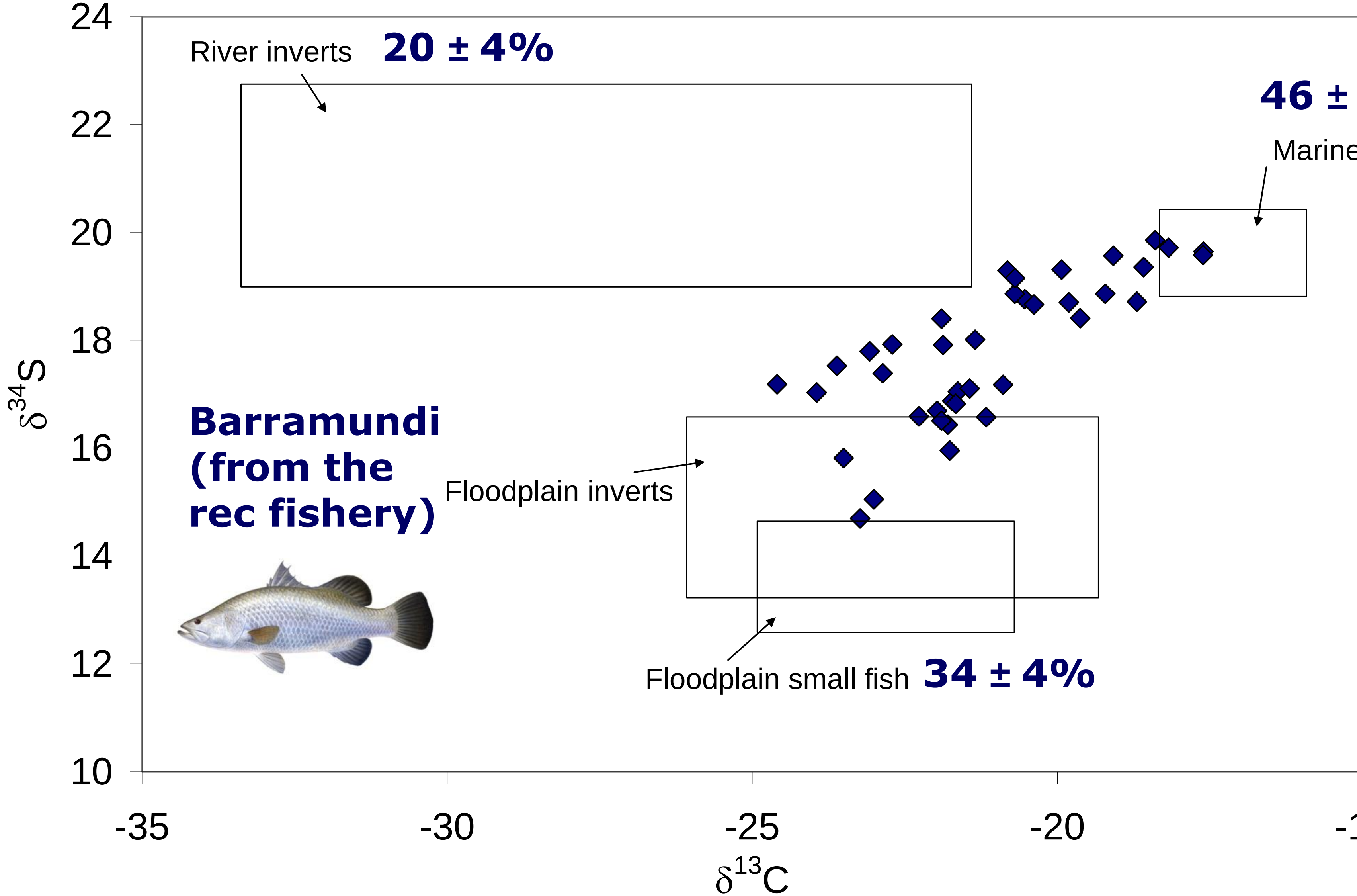
What do stable isotopes tell us?

Mitchell River
Northern Australia



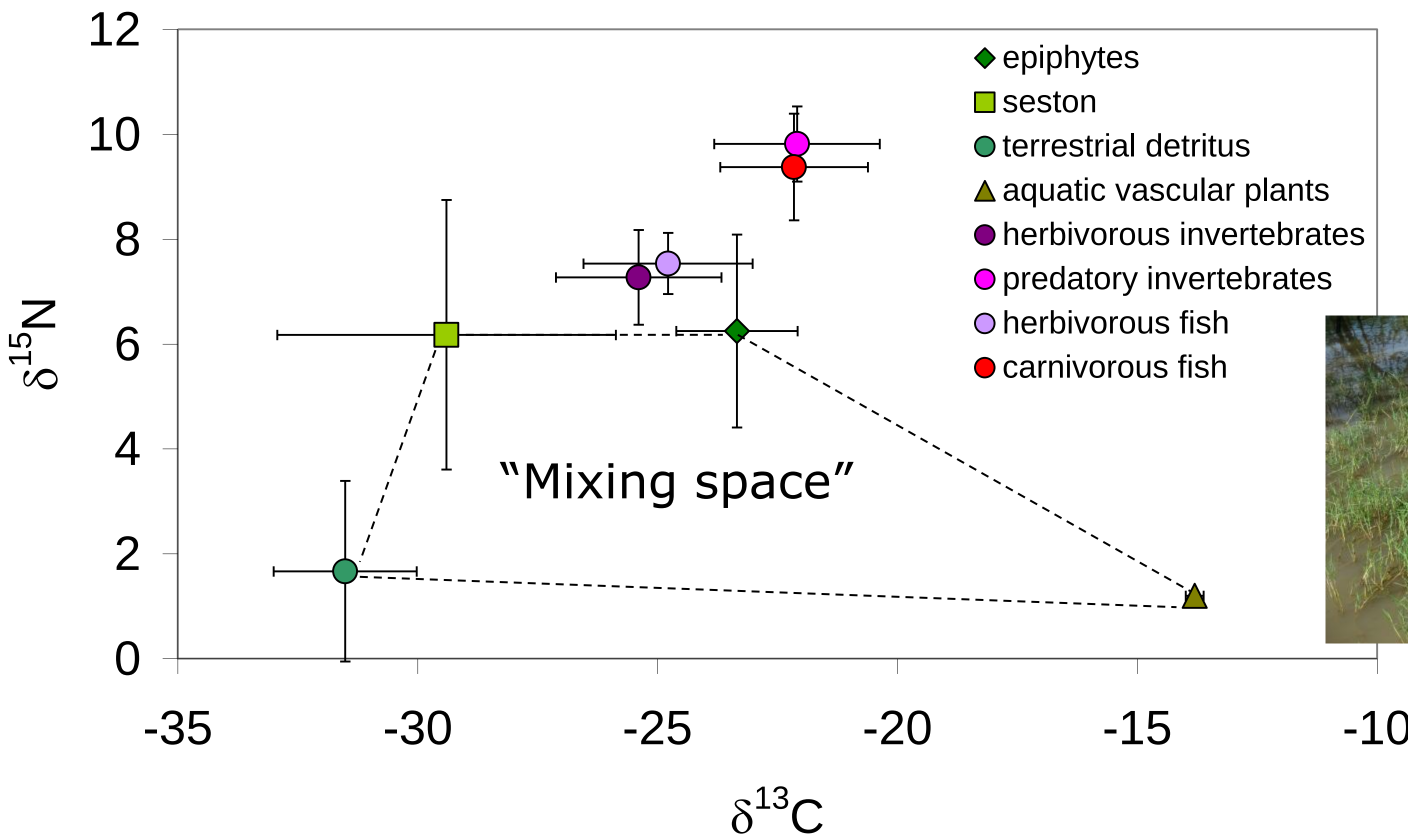
Seasonally available floodplain resources more important than permanent dry season habitats

Jardine et al. 2012 Oecologia

What do stable isotopes tell us?

Mitchell River
Northern Australia

			Feasible source contributions to:			
			Invertebrates		Fishes	
Source	$\delta^{13}C$ ± S.D. (n)	$\delta^{15}N$ ± S.D. (n)	Herbivores	Predators	Herbivores	Predators
Epiphytic algae	-23.3 ± 1.3 (10)	6.2 ± 1.8 (10)	0-78%	**79-90%**	**20-84%**	**57-90%**
Macrophytes (*Pseudoraphis* sp.)	-13.8 ± 0.2 (3)	1.2 ± 0.1 (3)	0-24%	**10-14%**	0-20%	**10-22%**
Seston	-29.4 ± 3.5 (4)	6.2 ± 2.6 (4)	0-76%	0-7%	0-60%	0-21%
Decaying leaves	-31.5 ± 1.5 (11)	1.7 ± 1.7 (11)	0-26%	0-2%	0-21%	0-7%



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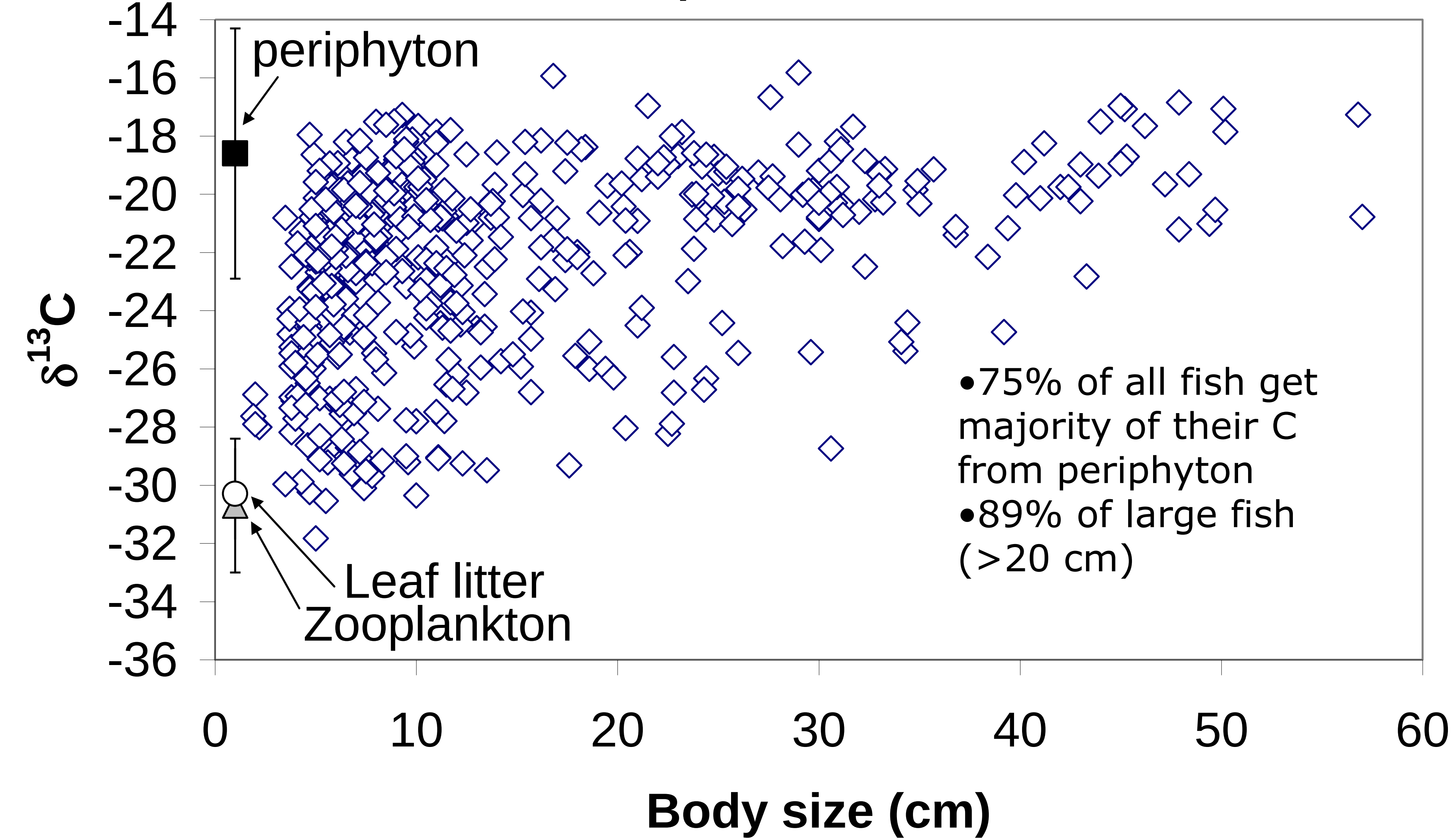
What do stable isotopes tell us?



Waterholes of the Flinders River, Australia

Jardine et al. in press River Res. Appl.

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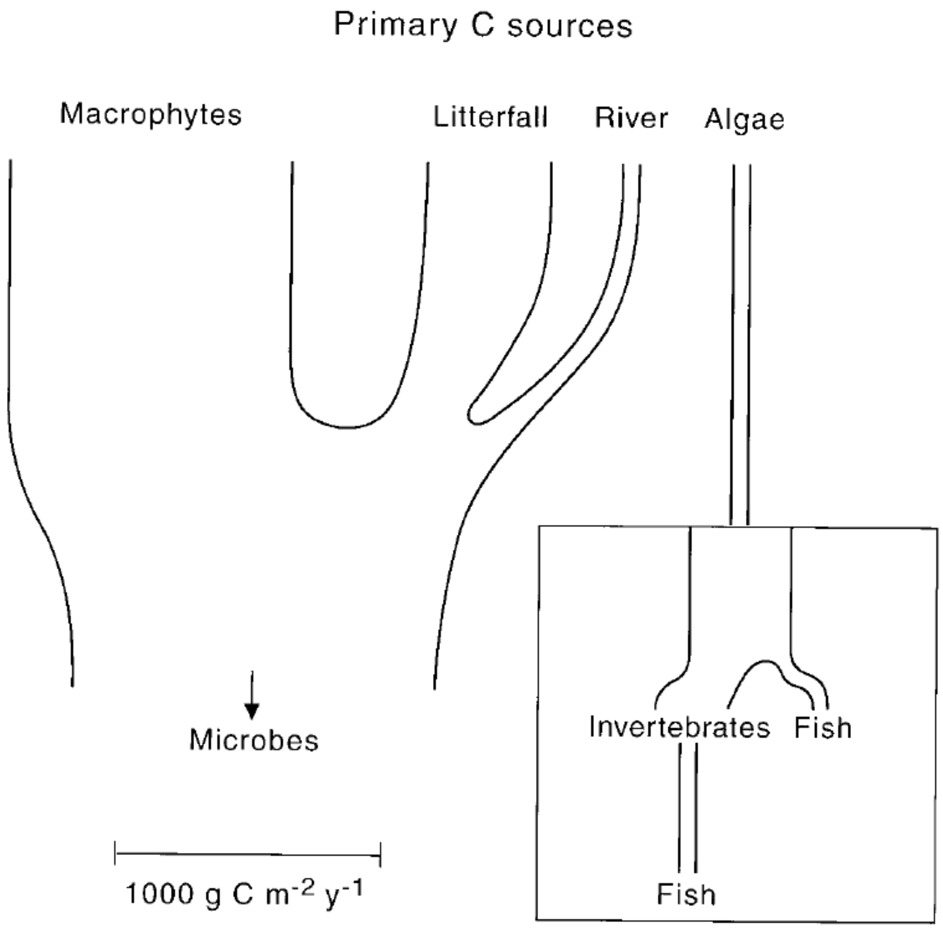
More does not necessarily mean more important



Inconspicuous food sources can drive animal production if the conditions are met for algal growth

Lewis et al. 2001 JNABS

Tropical floodplain rivers

From simple to complex systems

Photo: S. Hamilton

- Short-duration floodplains
- Sparse catchment vegetation
- Absent aquatic vegetation

Photo: S. Hamilton

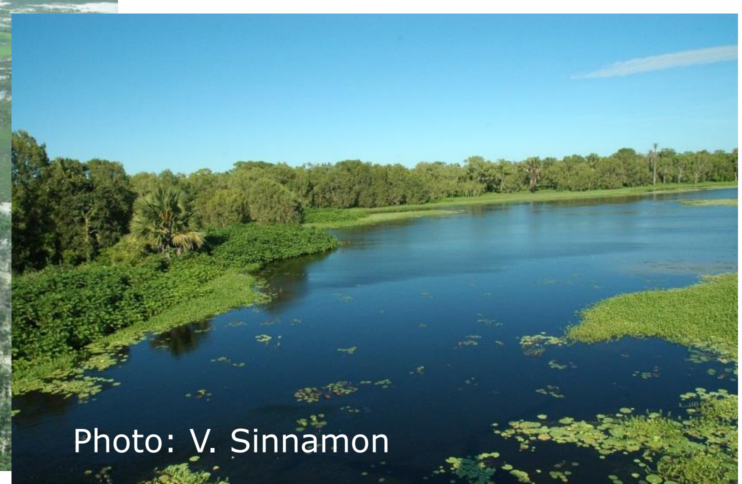
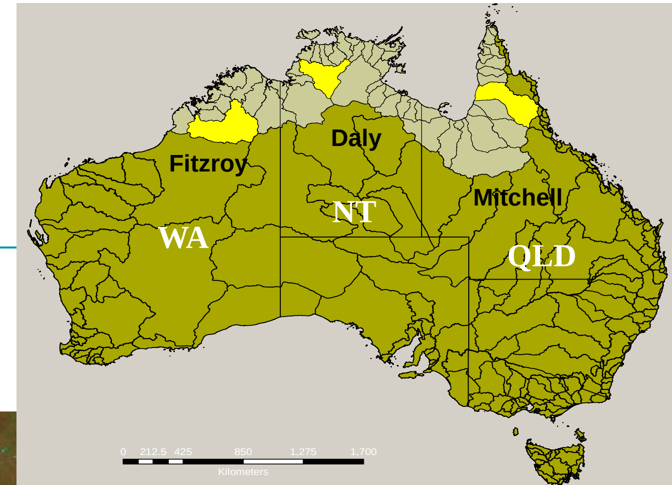


Photo: V. Sinnamon

- Vast, slowly-receding floodplains
- Forested
- Heavily vegetated off-channel lagoons
- Groundwater inputs

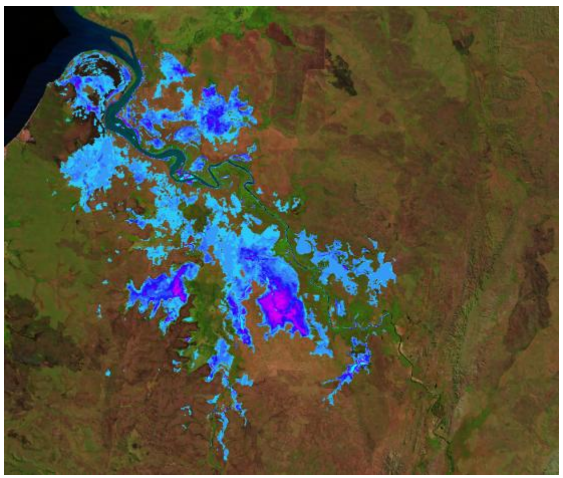
Variation in river type

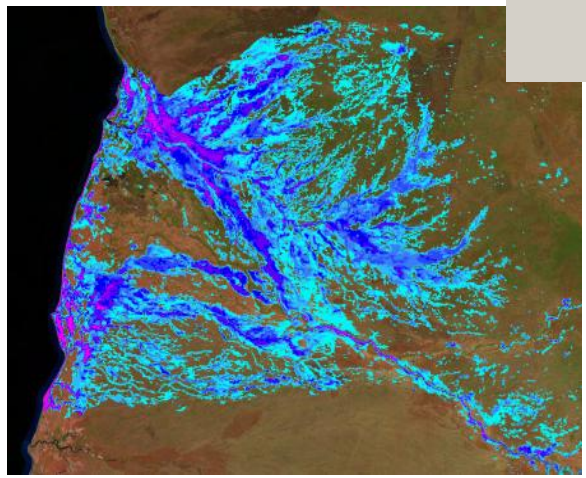
Ward et al. unpublished

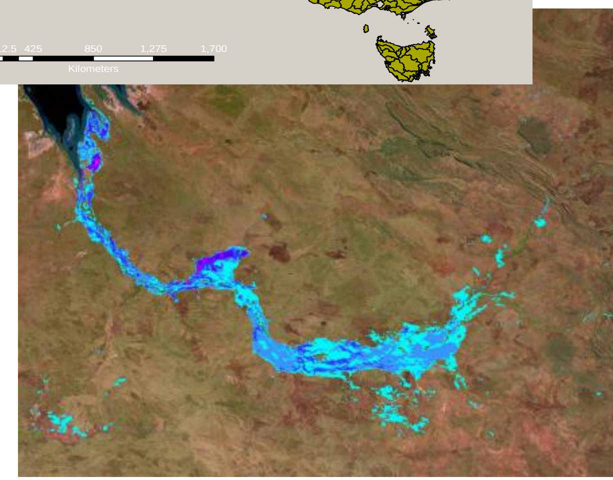


Hydrologic connectivity in rivers from across the region

(Kennard et al. 2010 FWB)







<u>Daly River</u>

- **Flood duration > 6 months**
- Floodplain has mixed seasonal aquatic and terrestrial vegetation
- High degree of hydrologic connectivity (GW inputs)

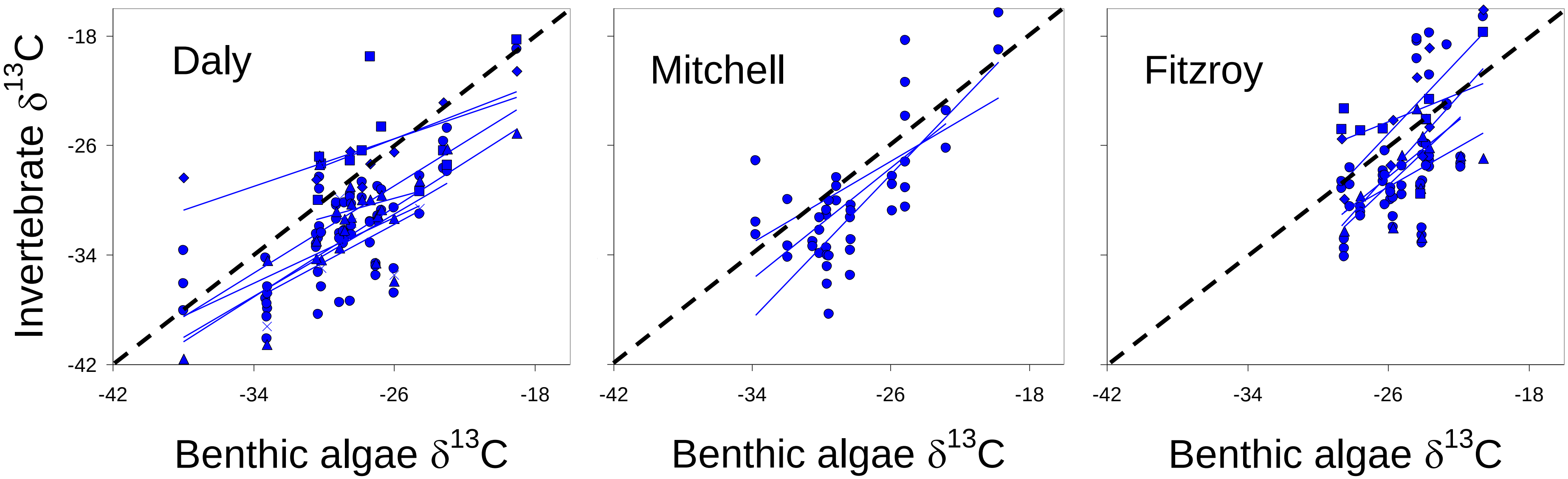
<u>Mitchell River</u>

- **Flood duration approx 2 to 3 months**
- Floodplain has mostly terrestrial vegetation
- Moderate degree of hydrologic connectivity

<u>Fitzroy River</u>

- **Flood duration < 1 month**
- Floodplain has mostly terrestrial vegetation
- Low connectivity (main channel contracts to waterholes)

Variation in reliance on algal carbon



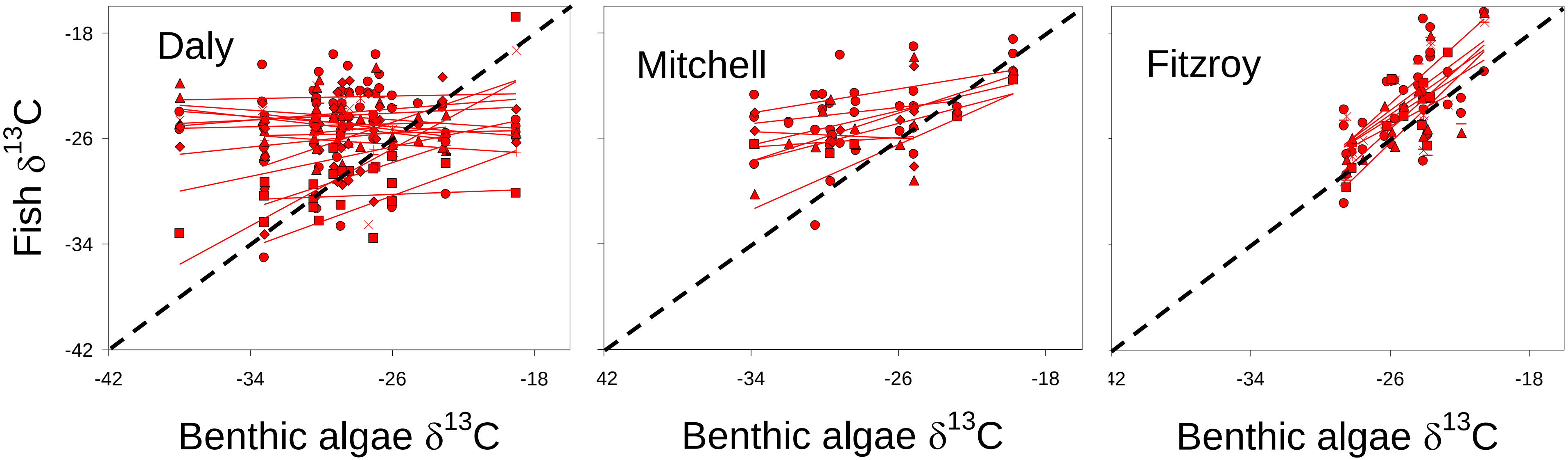
Invertebrates show strong alignment with local benthic algae

Slopes range from 0.35 to 1.43

Daly average slope = 0.65
Mitchell average slope = 1.02
Fitzroy average slope = 1.05

Jardine et al. 2012 JAE

Wet rivers have fish that use a greater variety of production sources than fish from dry rivers



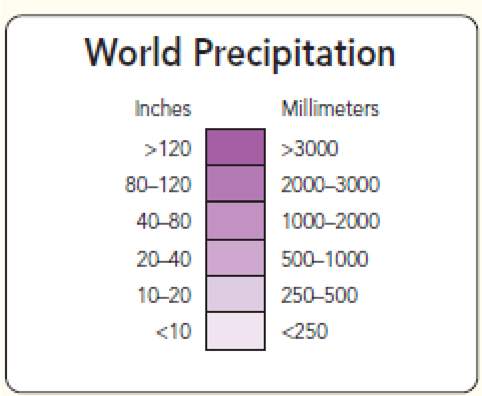
Daly
Average slope = 0.13
Fish are getting all their carbon from other sources

Mitchell
Average slope = 0.42
Fish are getting half of their carbon from other sources

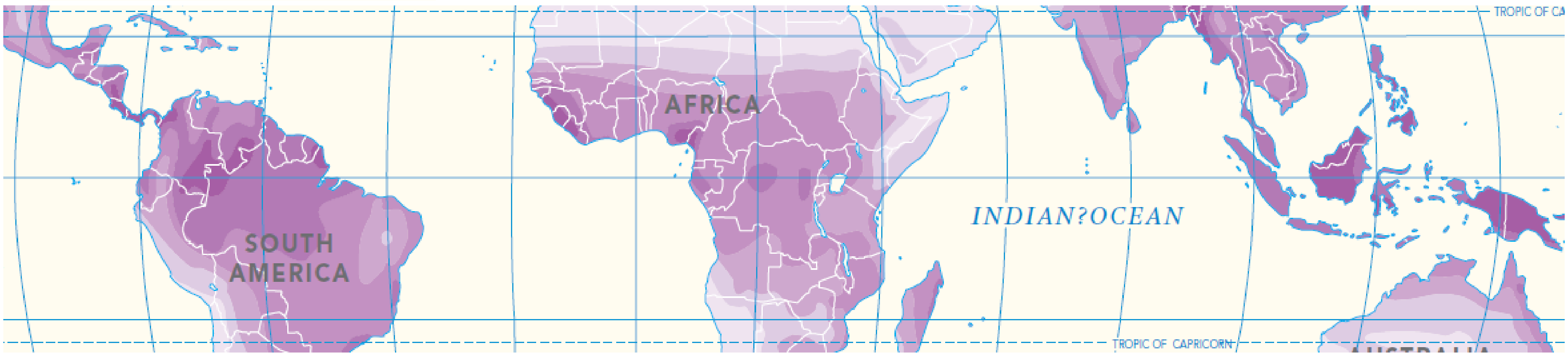
Fitzroy
Average slope = 1.06
Fish are tightly linked to local sources

Jardine et al. 2012 JAE

High Connectivity Low



Wet-dry tropics



The wet-dry tropics includes very wet rivers and very dry rivers
Order of magnitude range in precipitation

Local conditions (vegetation, nutrients, etc.) can vary within a system

Both regional and local factors likely influence the importance of algal production for the food web

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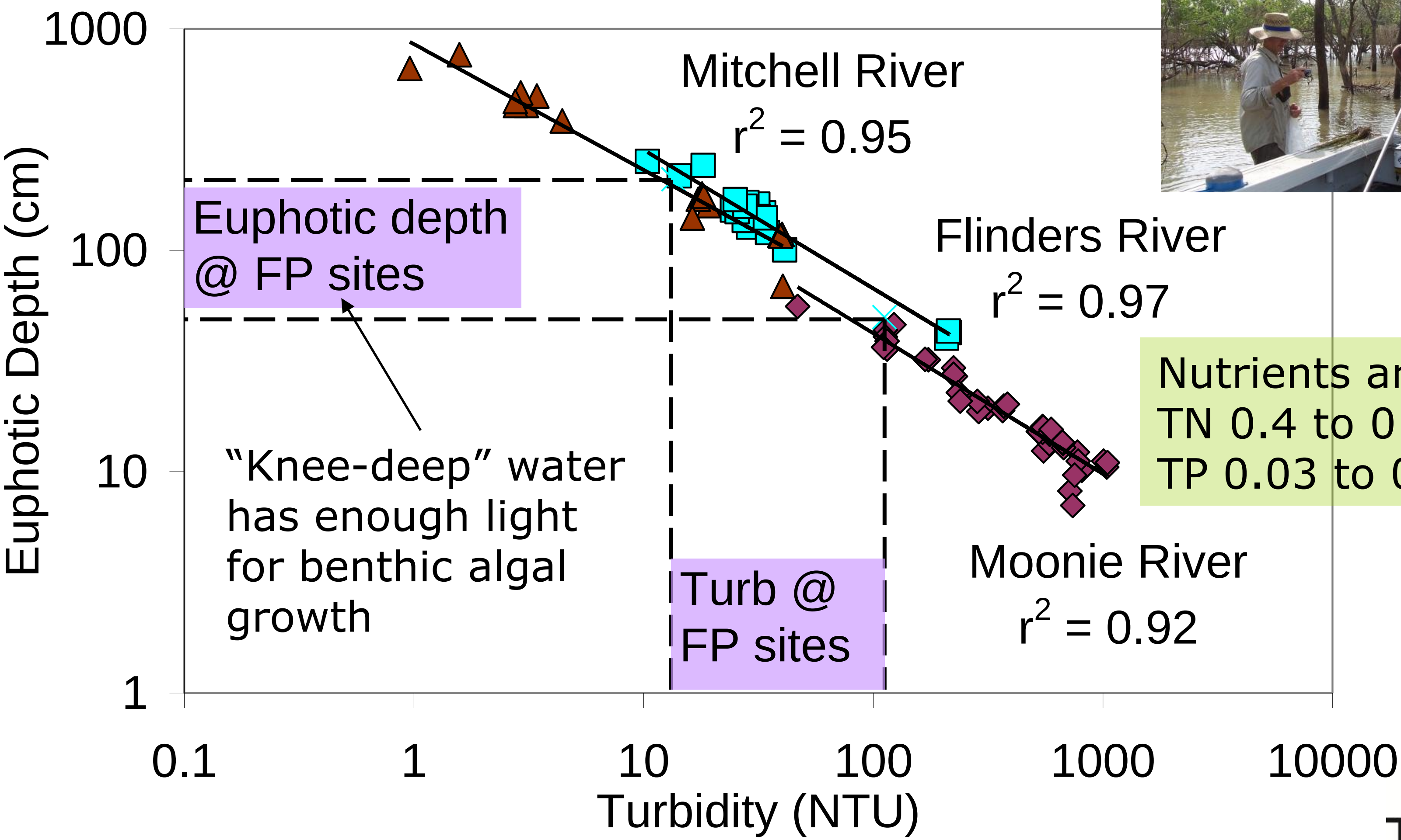
Limits to algal production on floodplains



Nutrients are sufficient
TN 0.4 to 0.6 mg/L
TP 0.03 to 0.04 mg/L

Benthic metabolism

Calculated using DO change in small replicate chambers

Surprise Creek salt flat
GPP = 0.21 ± 0.11 g C m^{-2} day^{-1}
NER = 0.19 ± 0.05 g C m^{-2} day^{-1}
P/R = 1.1

Net producer of C

Mitchell-Alice River forested site
GPP = <0.01 ± 0.04 g C m^{-2} day^{-1}
NER = 0.12 ± 0.07 g C m^{-2} day^{-1}
P/R = 0.4

Net consumer of C

Summary

- Connectivity – important in all cases
  - Consequences of water impoundments, extractions, and diversions
- Sources of food differ greatly from place to place
  - Riparian vegetation (or lack thereof) may be the driver
- Need to rethink our food web models
  - Investigate factors known to regulate algal production

Acknowledgments

Organizations

- KALNRMO
- Pormpuraaw Wild River Rangers
- Queensland Department of Environment and Resource Management
- Mitchell R. Watershed Management Committee
- Mitchell R. Traditional Custodians Advisory Group

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Sustainable solutions for rivers, coasts and catchments