Go with the flow:
Larval fishes and the Leeuwin Current

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Quick primer on larval fish ecology

Environmental Factors
- Bathymetry
- Temperature regimes
- Circulation patterns
- Water mass structure
- Plankton production

Distributional Range of Adults

Spawning Strategies
- Timing/duration
- Location
- Pelagic/demersal
- Fecundity

Larval Abundance / Distribution
- Larval drift
- Larval behaviour
- Food availability
- Predator abundance
- Larval growth & survival

Temporal Scale
- Evolutionary
- Annual

Spatial Scale
- 1000-100 km²
- Evolutionary
- Annual

<100 km²
- Seasonal
- Diel

(Adapted from Doyle et al. 1993)

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Major boundary current systems

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Many latitudinal studies of larval fish assemblages in major boundary current systems (e.g. Moser & Smith 1993, Doyle et al. 1993, Olivar & Shelton 1993, Hare et al. 2001).
Agulhas Current ichthyoplankton

3 cruises
9 line X 4 station grid
Oblique bongo tows
CTD measurements

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Poleward dispersal of larvae of tropical fishes by western boundary currents

- East Australian Current (Miskiewicz 1989, Gray 1993)
- Gulf Stream (Hare et al. 2002)

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Leeuwin Current?

- However, no specific study of the ichthyoplankton of the Leeuwin Current to date.
- Several larval fish studies in various areas off the WA coast.
- Synthesize results of these and relate to the Leeuwin Current.

Source: Bluelink

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Leeuwin Current ichthyoplankton review structure

► North-west shelf
► West coast
  ▪ Specific studies
  ▪ SRFME
  ▪ Eddies
► South coast
► Current & future work

North-west Shelf

- Young *et al.* (1986) described distributional patterns of larval fishes across 2 transects near Dampier and Port Hedland.
- Major discontinuity in larval fish composition (open ocean and slope vs shelf).
- Larvae on shelf mainly those of neritic species (e.g. Clupeiodei, Carangidae, Gobiidae, Apogonidae, Lutjanidae etc).
Exmouth Gulf


- Also examined factors affecting growth rate of damsel fish larvae (Meekan et al. 2003)

- Sampey et al. (2004) examined Bongo net samples from 2 stations (20m and 100m depth)

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Exmouth Gulf

- Meekan *et al.* (2001) found post-flexion larvae of Clupeidae and reef fishes such as Pomacentridae, Blenniidae & Lethrinidae to be dominant in light traps.
- Cross-shelf patterns were mapped equally well by both traps.
- Inshore stations were split from mid-shelf and offshore stations.
- Sampey *et al.* (2004) found weak cross-shelf pattern but only had 2 stations (no evidence of Leeuwin Current in CTD profiles).

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Ningaloo Reef

- Shelf is narrow and the inshore Ningaloo Current flows counter to the Leeuwin Current in summer.
- McIlwain (1997, 2002, 2003) studied hydrodynamic flows, flux of larval fishes across the reef, and fine scale temporal and spatial patterns of larval supply each day during the summer months of 1994/95 and 1995/96.
- Used reef crest nets in the surf zone near Tantabiddi.

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Ningaloo Reef

► Most larvae arrived in November-December when Leeuwin Current is weak

► Semi-lunar periodicity (15d) and lunar periodicity common

► Many larvae were completely stochastic in arrival at reef

► Multi-specific patches of larvae at least 5km wide crossed the reef crest into the lagoon

► Timing of patches was often chaotic and rarely lasted longer than 24h

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West coast

► WA Department of Fisheries has conducted various sampling programmes for some teleost species of commercial importance

► SRFME biophysical oceanography programme at Two Rocks transect included ichthyoplankton component (Koslow et al. 2006)

► Leeuwin Current eddies study of 2003 (Waite et al. 2007) also included ichthyoplankton project

Pseudocaranx sp.
*Pagrus auratus* (pink snapper)

- Tidal currents were identified as the primary transport mechanism
- Leeuwin Current reported to have negligible influence on recruitment of gulf snapper populations

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Sardinella lemuru (tropical sardine)

- Gaughan & Mitchell (2000) studied biology of *S. lemuru* between Kalbarri and Dongara
- Summer spawning over outer part of shelf
- Influence of Leeuwin Current explored but concluded that northward transport more likely under influence of southerly winds in summer

**Pomatomus saltatrix** (tailor)

- Chisholm (2004) examined archived DoF and CSIRO plankton samples to establish distribution of tailor larvae.
- Tailor larvae found around Geraldton in surface tows taken from RV *Franklin* in March 1996.
- Also found in May 1999 surface tows off Rottnest (23-330m).
- AusConnie modelling showed no influence of Leeuwin Current in March 1996 but some influence in May 1999.

**Hyperlophus vittatus** (whitebait)

- Series of shelf sampling stations between Perth & Busselton (1992-1994)
- Eggs & larvae of whitebait occur primarily in winter months (Gaughan *et al.* 1996)
- Principally in shallow inner-shelf waters of Cockburn Sound, Warnbro Sound & Koombana Bay
- No apparent influence of the Leeuwin Current

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**Sardinops sagax** (sardine)

- Numerous DoF surveys off West coast from 1993-2004 for eggs & larvae (e.g. Fletcher et al. 1996, Gaughan et al. 2004, 2007)
- Daily egg production method for estimation of stock size

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Sardinops sagax (sardine)

- Muhling *et al.* (submitted) synthesized all available data on sardine early life history and linked it to regional biological oceanography
- GSI peak in winter, but egg and larval concentrations also high in summer
- Autumn-winter maximum in primary productivity occurs at time of least favourable retention for pelagic eggs and larvae on the mid-outer shelf
- Mismatch may be additional factor leading to insignificant clupeoid stocks off SW Australia compared to other eastern boundary current systems

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- Two Rocks transect, north of Perth
- Monthly cruises to 100m depth, quarterly cruises to 1000m
- Physical, chemical and biological sampling at each station
- Plankton collected with replicated oblique bongo net tows to < 150m
- Fish larvae extracted, identified and assemblages enumerated

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Larval fish concentrations

- Muhling *et al.* (in press FO) identified larvae of 148 taxa from 93 teleost families.
- Larvae at coastal station (A) were strongly seasonal.
- Shelf stations (B & C) showed much inter-annual variability.
- Concentrations at offshore LC stations (D & E) were lower.

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Larval fish composition

- Larvae at coastal station often from taxa with benthic eggs
- High species diversity at the shelf stations - larvae of pelagic and reef fishes common
- Larvae at offshore Leeuwin Current stations were mostly from oceanic and deep-sea families
Each dot represents one sample, the closer two points are, the more similar their larval fish assemblages (Muhling et al. in press FO).
Conceptual model

- Larval fish assemblages:
  1. Seasonal inshore assemblages
  2. Leeuwin Current assemblages
  3. STSW assemblage
  4. Capes Current assemblages

- Water masses:
  - Leeuwin Current
  - Capes Current
  - Inshore water
  - Sub-Tropical Surface Water

Conceptual diagram of the relationship between larval fish assemblage structure in winter and summer oceanographic conditions. The SRFME transect stations, larval fish assemblages, and different water masses are shown.

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Vertical and horizontal distributions

- Using depth-stratified sampling with an EZ net, Muhling & Beckley (in press JPR) showed larvae to be in upper 100m
- Seasonal variation in horizontal distribution patterns relative to Ekman transport (summer) and Leeuwin Current (winter)

[Graphs showing distribution patterns for different species and seasons]
Southward transport of larvae of tropical fishes by the Leeuwin Current

- Tropical reef fishes recruit at Rottnest from autumn until early spring (Hutchins, 1991)
- Larvae of tropical fishes such as Pomacentridae and Ostraciidae collected on the SRFME Two Rocks transect

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Autumn: Leeuwin Current strengthens, tropical species found across shelf and slope. Time of peak tropical fish recruitment at Rottnest

Summer: Tropical species still present in Leeuwin Current, but Capes Current probably prevents them reaching Rottnest to settle
Larval fish and Leeuwin Current eddies

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Cruise track
Features of Oct 2003 LC eddy pair

Cold-core

Warm-core

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Larval fish assemblages in eddies

Warm-core eddy

n = 459

- Myctophidae
- Phosichthydae
- Gonostomatidae
- Stomiidae
- Others

Cold-core eddy

n = 1032

- Myctophidae
- Phosichthydae
- Gonostomatidae
- Stomiidae
- Others

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(Muhling, Beckley & Olivar 2007)
Larval fish assemblages in eddies

- Warm-core eddy had shelf diatoms but cold-core eddy had oceanic phytoplankton
- In both eddies, larval fishes were those of oceanic species although some differences between eddies
- Very few neritic fish larvae (couple of Labridae in jet between two eddies)
- Larval duration of neritic fish larvae (weeks) less than the age of eddy (6 months)
- So, if larvae entrained from the coast, then they would have metamorphosed and dropped out of the plankton by time we studied the eddy (Muhling et al. 2007)

Source: CSIRO

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South coast

- DoF work has focussed on eggs & larvae of sardines
- Studies initially in Albany – Esperance region but also a cruise across Great Australian Bight

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Sardinops sagax (sardines)

- Most spawning of *S. sagax* on shelf inshore of Leeuwin Current (Fletcher & Tregonning 1992)

- Inter-seasonal study by Fletcher *et al.* (1994) concluded that Leeuwin Current had direct effect

- In winter, eggs more to the west, larvae to east, drift of 30-40 km d⁻¹ with stronger LC

- In summer, eggs & larvae throughout study area with no obvious effect of weak LC

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Many sardine ELS surveys

- Daily egg production method for estimation of stock size of sardines (Fletcher et al. 1996)
- Examination of regrowth of sardine stock after 1998/99 mass mortality (Gaughan et al. 2004, 2007)

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Great Australian Bight survey 1994

- Transport of larval sardines from WA to SA examined by Gaughan *et al.* (2001)
- Hatch date and ages of larvae across GAB determined
- Age increased from west to east but mean flow of 0.1 m s\(^{-1}\) (ADCP & wind stress) was insufficient to support hypothesis
- However, LC weak in study period & authors contend that larval dispersal needs consideration in fisheries management

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Larval sardine growth rate from GAB

- Gaughan *et al.* (2001) determined growth rate of sardine larvae across GAB
- Mean of 0.48 mm d$^{-1}$ is very low compared to other regions
- Concluded that lower productivity, partly induced by Leeuwin Current, was responsible for low growth rate
- But, recent work by Jones (2006) has indicated larval sardine growth rates on west coast to be unexpectedly high (0.70 – 0.89 mm day$^{-1}$). Higher water temperature?

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Current and future work

► Cross-shelf transport of neritic biota induced by Leeuwin Current eddies (Holliday & Beckley)
  ▪ See poster by Holliday et al.
► Latitudinal study of Leeuwin Current ichthyoplankton (Beckley & Holliday)
► Systematics and descriptions of larval fishes from Western Australia

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May 2006 Eddies cruise

- RV *Southern Surveyor* cruise to examine cross-shelf transport of nutrients, phytoplankton and fish larvae associated with formation of a warm-core eddy at shelf-edge off WA coast
- Oceanographic and biological characteristics of an evolving eddy studied over 25 days

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May/June 2007 latitudinal study of Leeuwin Current ichthyoplankton

Sampling

- 13 latitudinal transects
- 2000m, 300m and 50m stations for ichthyoplankton
- Neuston & replicate bongos
- Eddy side trip!

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Systematics and descriptions

- Good texts exist for larvae of oceanic and Indo-Pacific reef fishes
- Temperate reef species still relatively poorly described
  - Especially speciose families like Labridae
    - [http://researchrepository.murdoch.edu.au/15095/]
Summary

► Larval fish assemblages of the Leeuwin Current comprise a mixture of oceanic, slope, shelf (tropical and temperate) species

► Reflect both the source waters, and advection into the current during its 5,000 km trajectory around WA

► Seasonality in strength & location of Leeuwin Current has profound effects on ecology of larval fishes off WA

► Great opportunities for studies of ecological processes associated with the Leeuwin Current

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