NMN Reference Station Network

Doing new things in new places – South Australian Gulfs

Paul van Ruth[1], Charlie Huveneers[2], Mark Doubell[1], Paul Malthouse[1], Ana Redondo-Rodriguez[1], John Middleton[1]

[1] SARDI Aquatic Sciences
[2] Flinders University

IMOS Integrated **Marine Observing** System

Annual Planning Meeting 2019

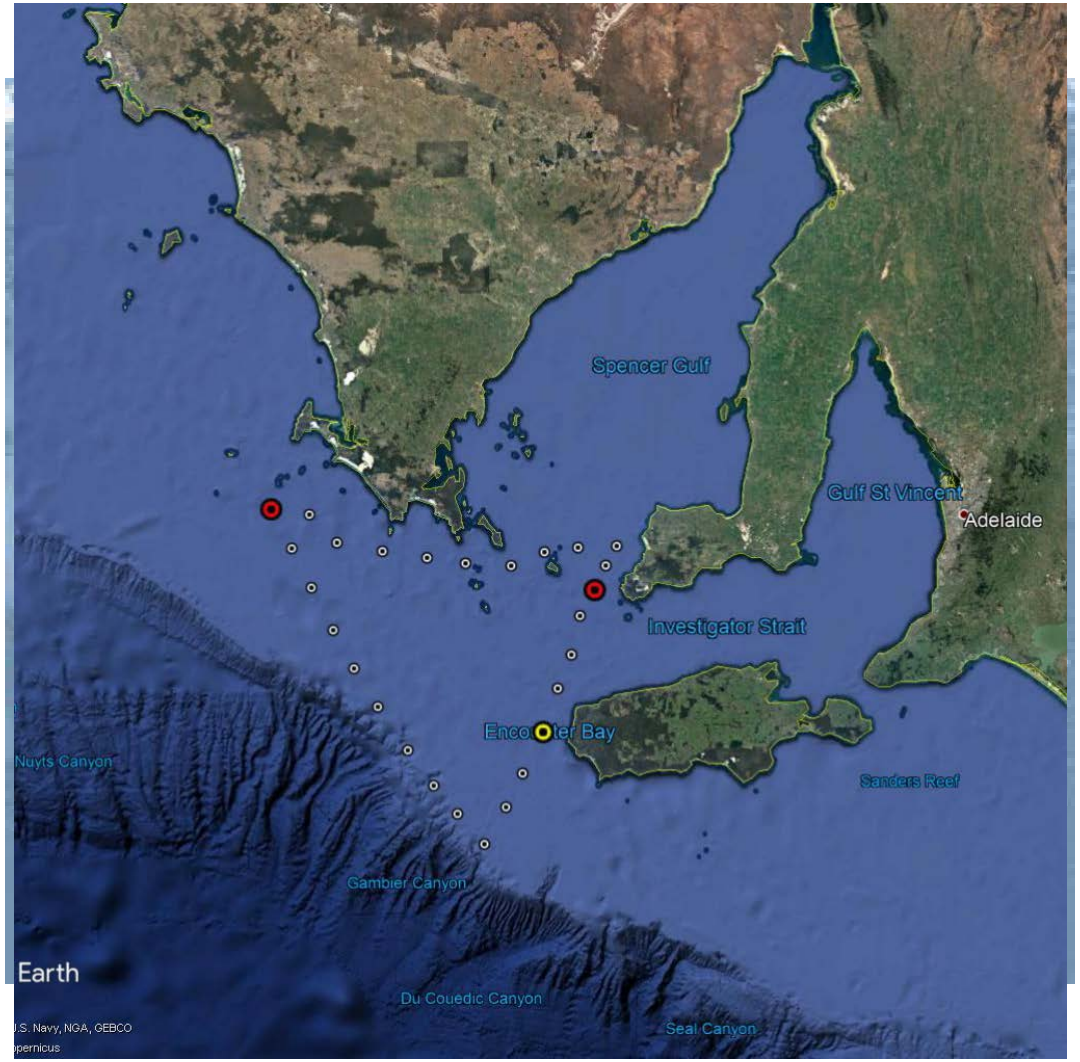
SAIMOS Gulfs moorings

Gulf St Vincent (GSV), Spencer Gulf (SG)

- Shallow, semi-enclosed, inverse estuaries
  - Seasonally flushed
  - Limited communication with shelf and oceanic waters (esp. Nth)

- V. important for SA economy
  - Fishing, aquaculture, shipping, ecotourism

- Under increasing pressure
  - Mining, shipping, heavy industry, growing population, changing climate



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SAIMOS Gulfs moorings

New funding: extend the SAIMOS mooring array into GSV and northern SG

- Moorings in 20 m of water
  - ADCP, CTD, acoustic receiver

- Seasonal BGC sampling (Jan/Apr/Jul/Nov)
  - CTD profiles (with fluor, DO, turbidity)
  - Nutrients (NO_x, NH_4, PO_4, Si)
  - Viruses, bacteria, picophytoplankton
  - Pigments (>/<5 µm, HPLC)
  - Phytoplankton
  - Zooplankton
  - PIM/POM/TSS

Drivers of variation in water quality and lower trophic ecosystem dynamics

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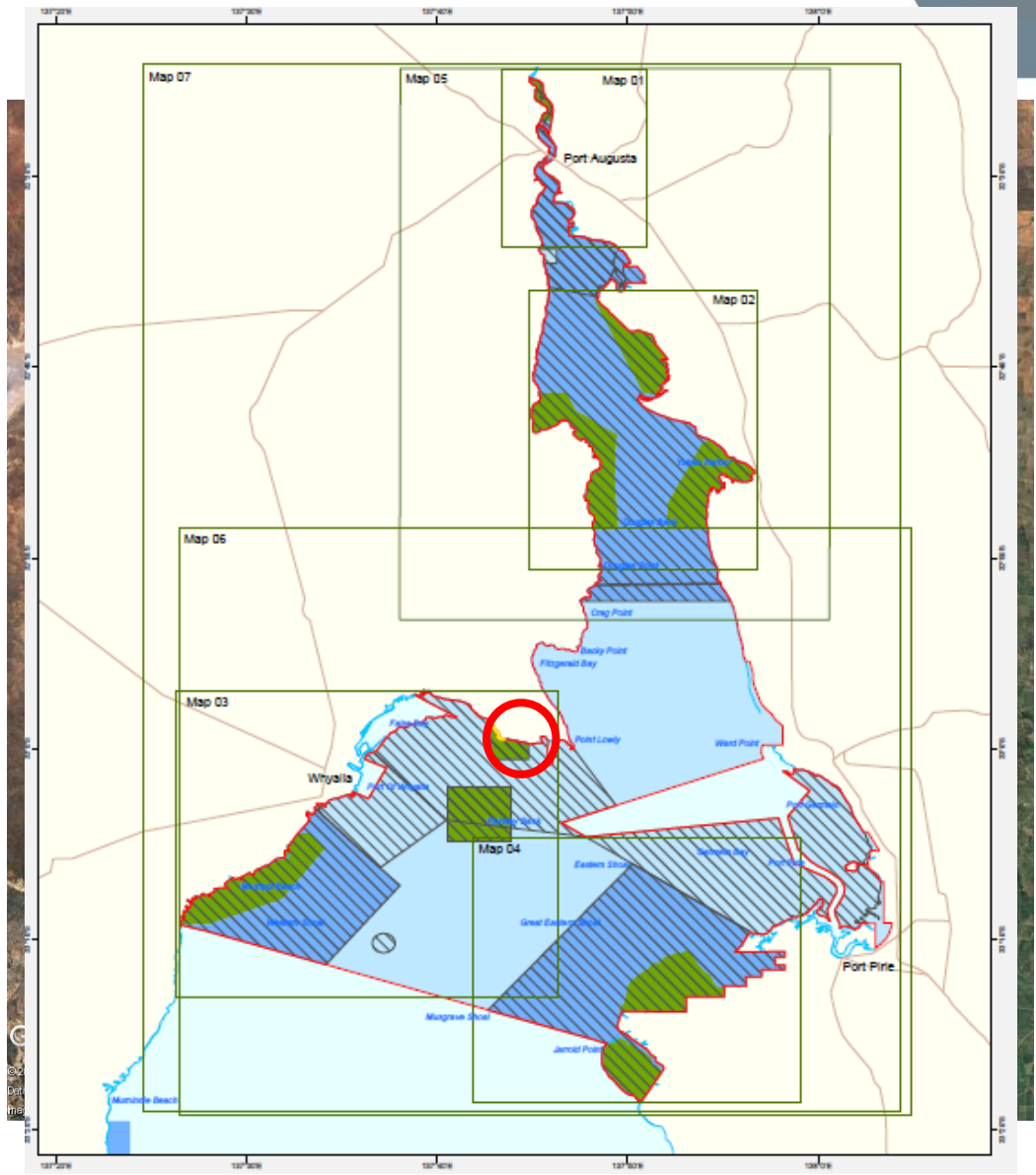
SAIMOS Gulfs moorings – Northern SG

- Co-investment:
  - SA Water contributing $80K for mooring
  - SARDI salary in-kind

- Pathways to uptake/use/impact:
  - University research - SGEDI
  - eSA Marine model calibration/validation
  - Environmental management plans/regulatory requirements (e.g. new ports, coastal development, desalination plants)
  - Marine park management plans
  - Iconic species population management plans (Giant cuttlefish etc)
  - Management of aquaculture expansion
  - Fisheries management



SAIMOS Gulfs moorings - GSV

- Co-investment:
  - SA EPA providing vessel/salary in-kind
  - SARDI salary in-kind
  - SA Water contributing $50K for mooring
  - Flinders Uni supplying ADCP & current meter

- Pathways to uptake/use/impact:
  - University research – coastal dynamics, sediment transport, eutrophication
  - eSA Marine model calibration/validation
  - Environmental management plans/regulatory requirements (e.g. stormwater management, wastewater treatment, coastal development, desalination)
  - Coastal management (e.g. sediment transport, seagrass rehabilitation)
  - Fisheries management

SAIMOS Gulfs moorings

- Other contributors:
  - SARDI Aquatic Sciences – Gavin Begg, Tim Ward, Charles James
  - Flinders University – Graziela Miot da Silva, Jim Mitchell, Jochen Kampf, Ryan Baring
  - University of Adelaide – Bronwyn Gillanders, Justin Brookes, Alice Jones
  - SA Water – Tim Kildea, Milena Fernandes
  - SA EPA – Sam Gaylard
  - SA DEW – Simon Bryars

Government of South Australia
Primary Industries and Regions SA

SARDI
South Australian Research and Development Institute

Flinders University

The University of Adelaide

Government of South Australia

SA Water

Government of South Australia
Department for Environment and Water

EPA South Australia

NCRIS
National Research Infrastructure for Australia
An Australian Government Initiative

IMOS is a national collaborative research infrastructure, supported by Australian Government. It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent. **www.imos.org.au**

PRINCIPAL PARTICIPANTS

University of Tasmania
(Lead Agent)

Australian Government
Australian Institute of Marine Science

Australian Government
Bureau of Meteorology

CSIRO

Government of South Australia

SARDI
South Australian Research and Development Institute

The University of Western Australia

sims
sydney institute of marine science

UTS

The University of Sydney

Macquarie University

UNSW Sydney

SIMS is a partnership involving four Universities.

ASSOCIATE PARTICIPANTS

Curtin University

Australian Government
Department of the Environment and Energy
Australian Antarctic Division

National Mooring Network – reference station network

Leveraging the NRS network to monitor larval fish

Iain M Suthers[1], Charles Hinchliffe[1], James A. Smith[1,2],
Jason D. Everett[1], Ana Lara-Lopez[3],
Anthony G. Miskiewicz[1], Anthony J. Richardsonson[4,5]

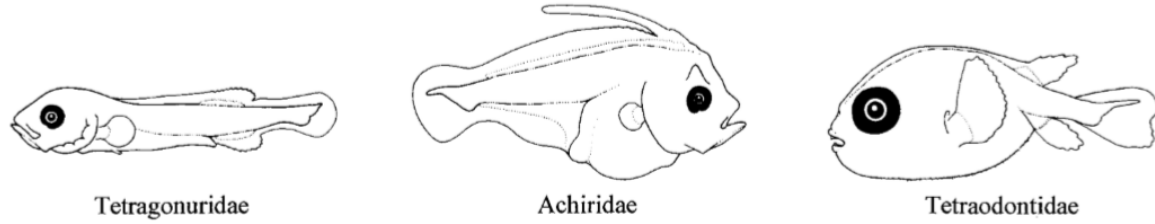
IMOS Integrated Marine Observing System

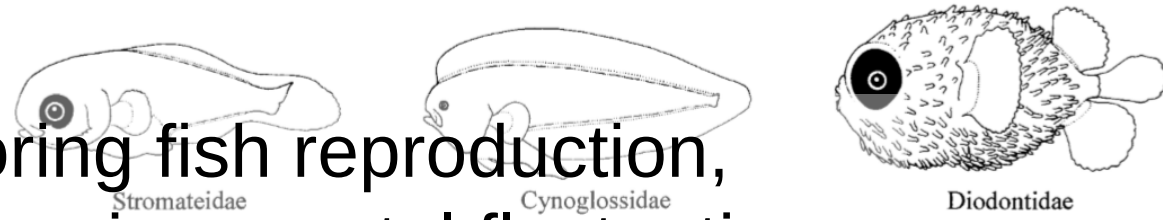
Annual Planning Meeting 2019

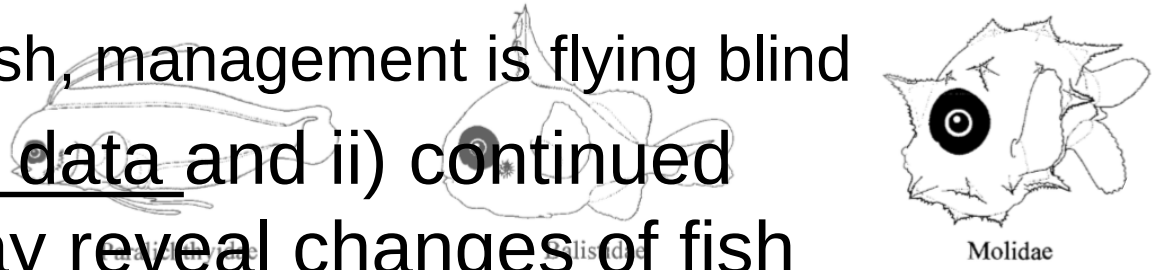
[1]UNSW & SIMS, [2]CIMEC, [3]UTas, [4]CSIRO, [5]UQ

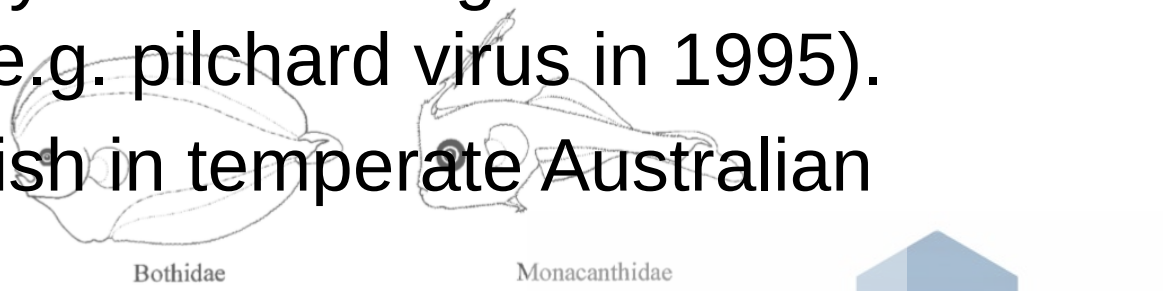

2
1
OceanTest Equipment, Inc.

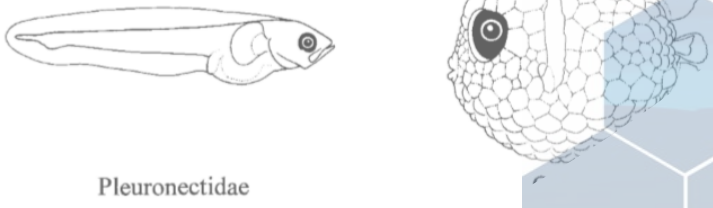
Larval fish monitoring









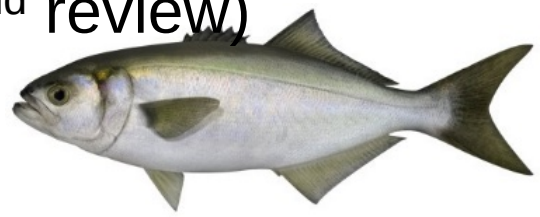


- A fishery-independent tool for monitoring fish reproduction, seasonality, phenology, influence of environmental fluctuations;
  - E.g. when trawlers aren't landing gemfish, management is flying blind
- 1) Investigation of i) historical spatial data and ii) continued NRS-monitoring of temporal data may reveal changes of fish and fisheries in a changing climate (e.g. pilchard virus in 1995).
- 2) Seasonality, phenology of larval fish in temperate Australian waters is not well understood,
  - continuous sampling of larvae at IMOS National Reference Stations began in 2015
  - (but needed coordination, QC/QA).

Initial output

Smith et al. 2018

- Standardised 218 taxa (!)
  - Distinctive, commercial
- Assembled most historical data since ‘83
- Reported first 2 years of NRS monitoring
  - Lacked seasonal signal, to quantify long-term trends
- Already identified a second late-summer spawning area by tailor off northern NSW
  - (Schilling et al. in 2nd review)



www.nature.com/scientificdata

SCIENTIFIC DATA

OPEN

Received: 23 April 2018
Accepted: 13 August 2018
Published: 16 October 2018

Data Descriptor: A database of marine larval fish assemblages in Australian temperate and subtropical waters

James A. Smith[1,2], Anthony G. Miskiewicz[1,3,4,5], Lynnath E. Beckley[4], Jason D. Everett[1,2], Valquíria Garcia[6], Charles A. Gray[1,7], David Holliday[4], Alan R. Jordan[8], John Keane[9], Ana Lara-Lopez[9], Jeffrey M. Leis[5,9], Paloma A. Matis[10], Barbara A. Muhling[4,11,12], Francisco J. Neira[13], Anthony J. Richardson[14,15], Kimberley A. Smith[16], Kerrie M. Swadling[9,17], Augy Syahailatua[18], Matthew D. Taylor[1,2,19], Paul D. van Ruth[20], Tim M. Ward[20] & Iain M. Suthers[1,2]

Larval fishes are a useful metric of marine ecosystem state and change, as well as species-specific patterns in phenology. The high level of taxonomic expertise required to identify larval fishes to species level, and the considerable effort required to collect samples, make these data very valuable. Here we collate 3178 samples of larval fish assemblages, from 12 research projects from 1983-present, from temperate and subtropical Australian pelagic waters. This forms a benchmark for the larval fish assemblage for the region, and includes recent monitoring of larval fishes at coastal oceanographic reference stations. Comparing larval fishes among projects can be problematic due to differences in taxonomic resolution, and identifying all taxa to species is challenging, so this study reports a standard taxonomic resolution (of 218 taxa) for this region to help guide future research. This larval fish database serves as a data repository for surveys of larval fish assemblages in the region, and can contribute to analysis of climate-driven changes in the location and timing of the spawning of marine fishes.

*(funded by an AFMA grant)

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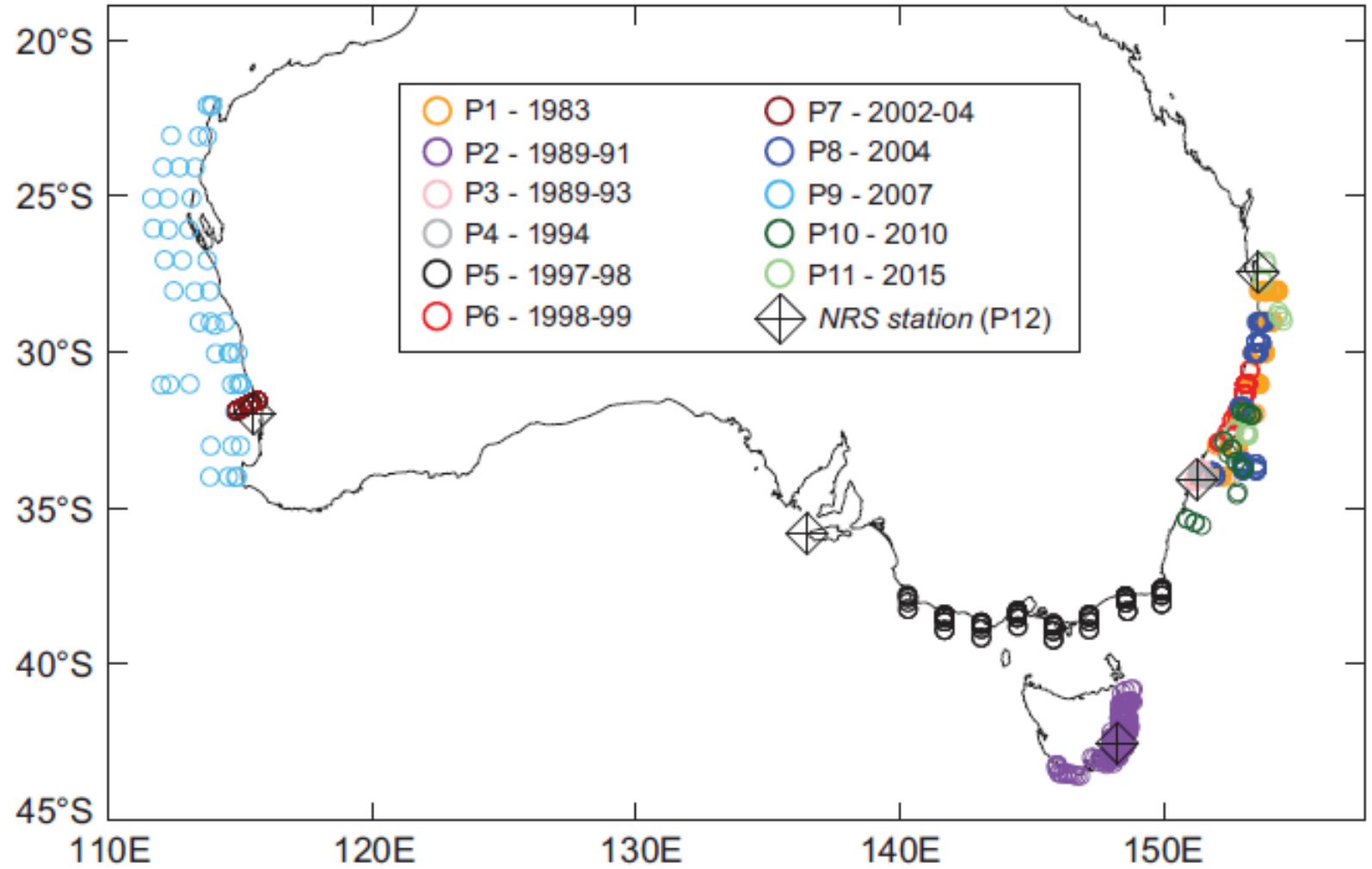
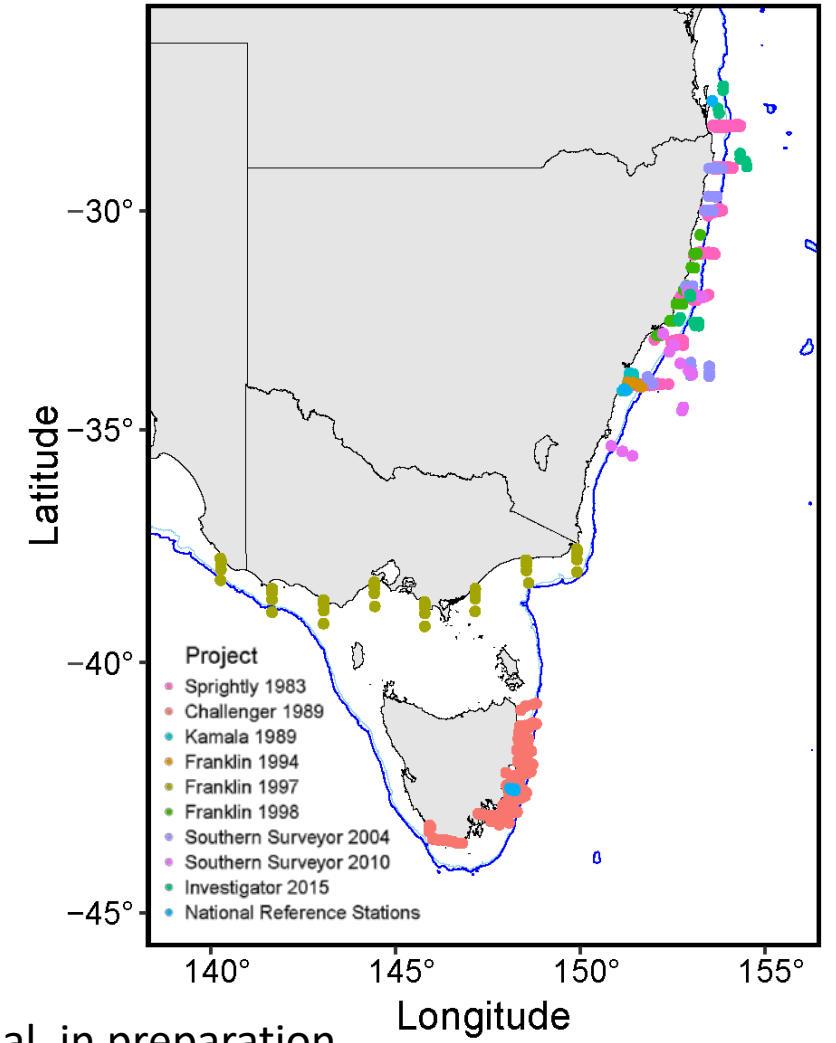
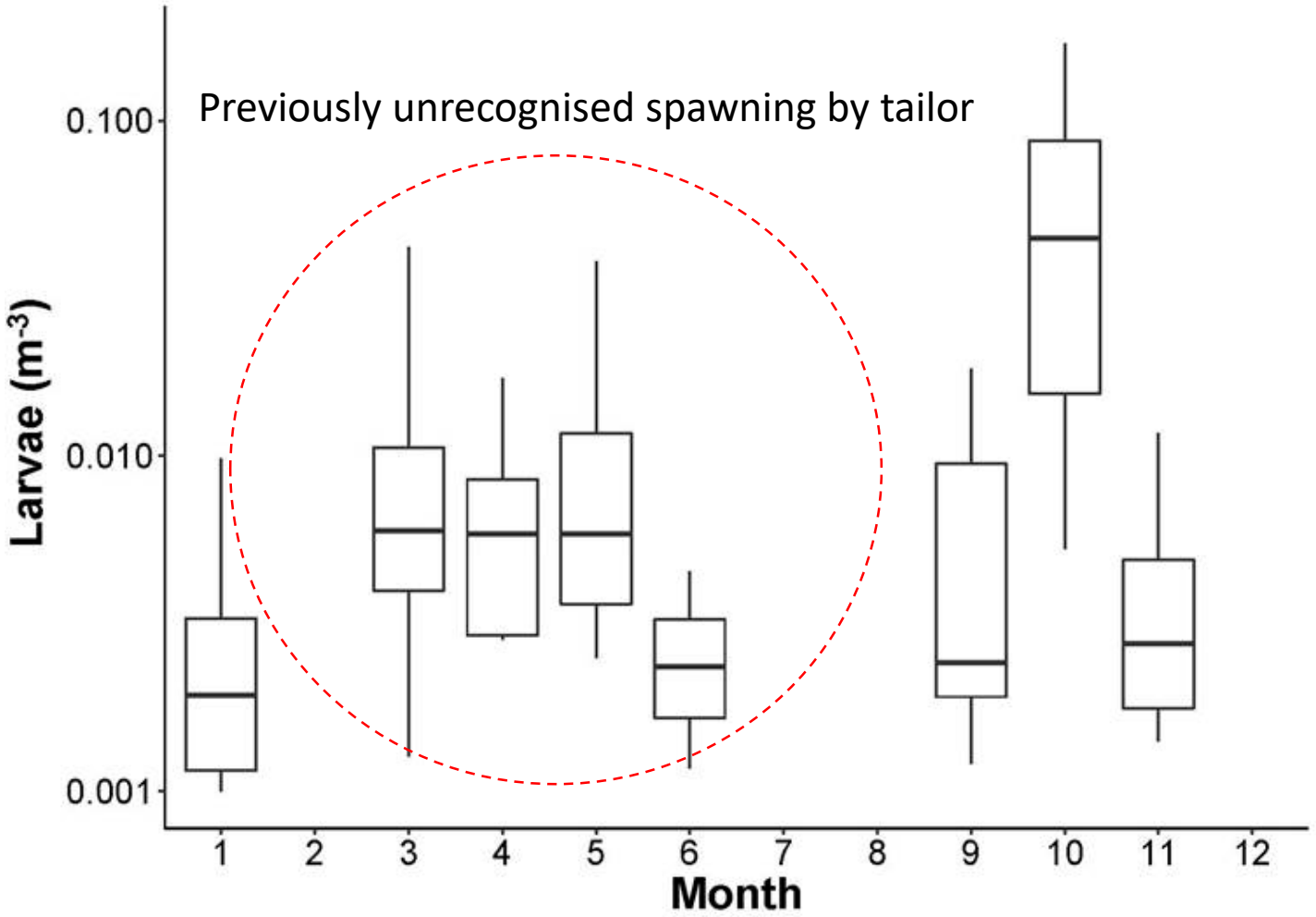
Historical (MNF) spatial + NRS-temporal

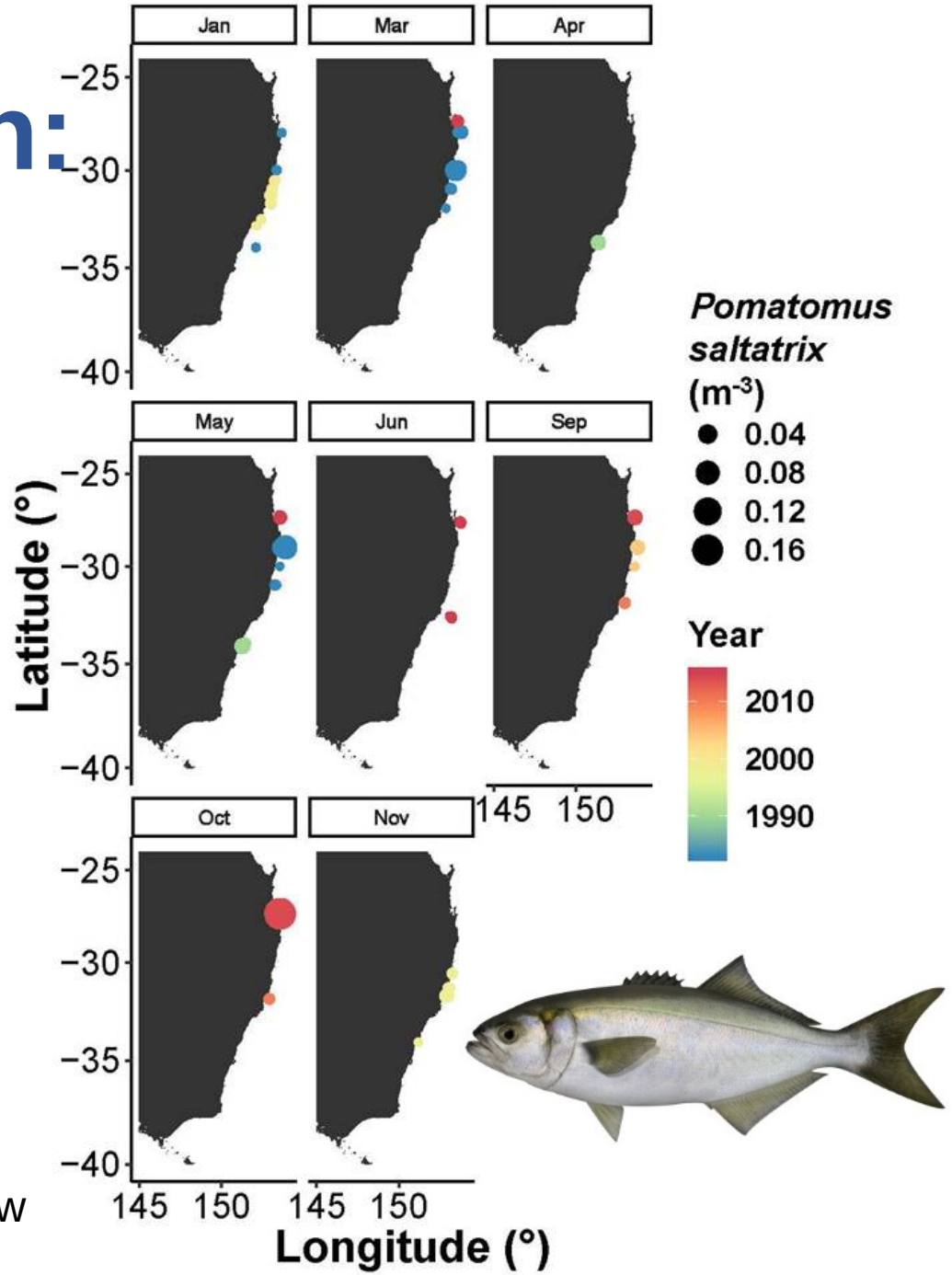




Hinchliffe et al. in preparation

From historical larval fish:

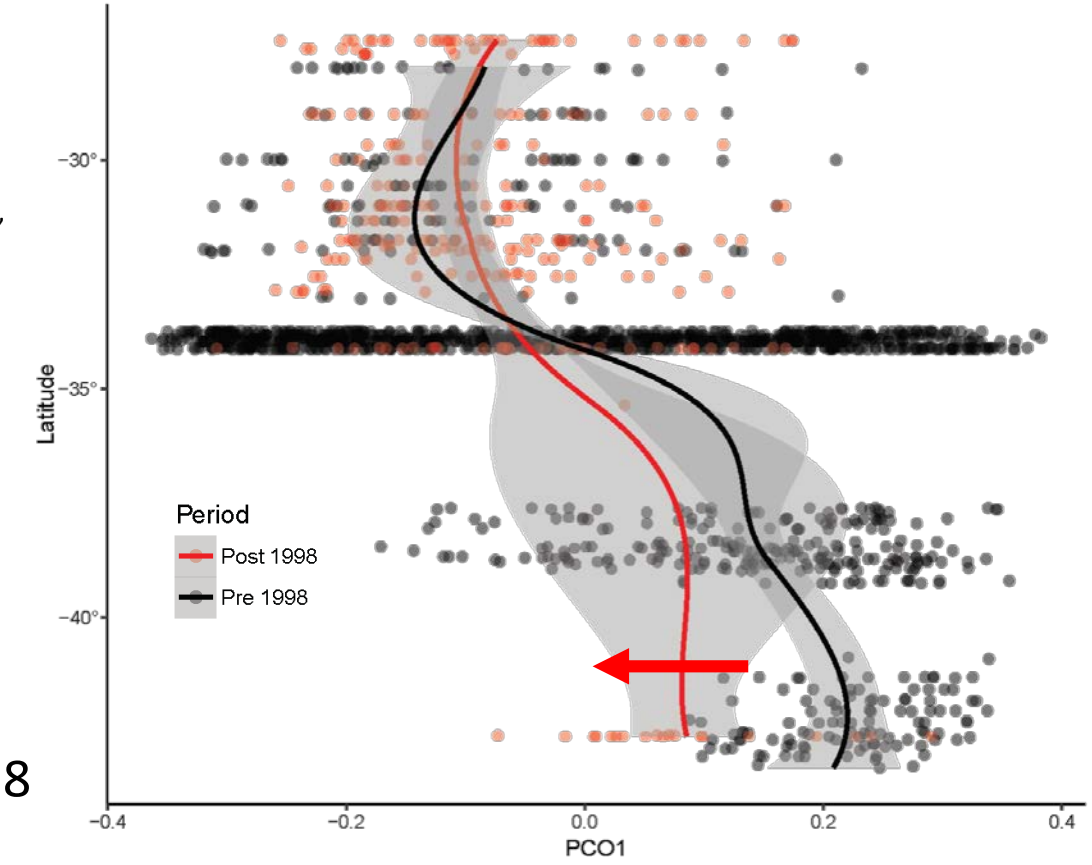




Schilling et al. in 2nd review

Changes since the ‘97/‘98 El Niño event

- Large El Niño event occurred in 1997/1998 lasting ecological impacts. (Chandra et al., 1998; Sánchez-Velasco et al., 2004)
- Apparent shift in PCO loadings of recent samples in southern sites.
- ISA analysis identified 21 taxa which differ significantly between pre- and post 1998 samples.
  - 5 Taxa less common, 16 more common post 1998
- Appearance of Pacific sardine, Australian anchovy and wrasse may be evidence of a southward latitudinal range shift.



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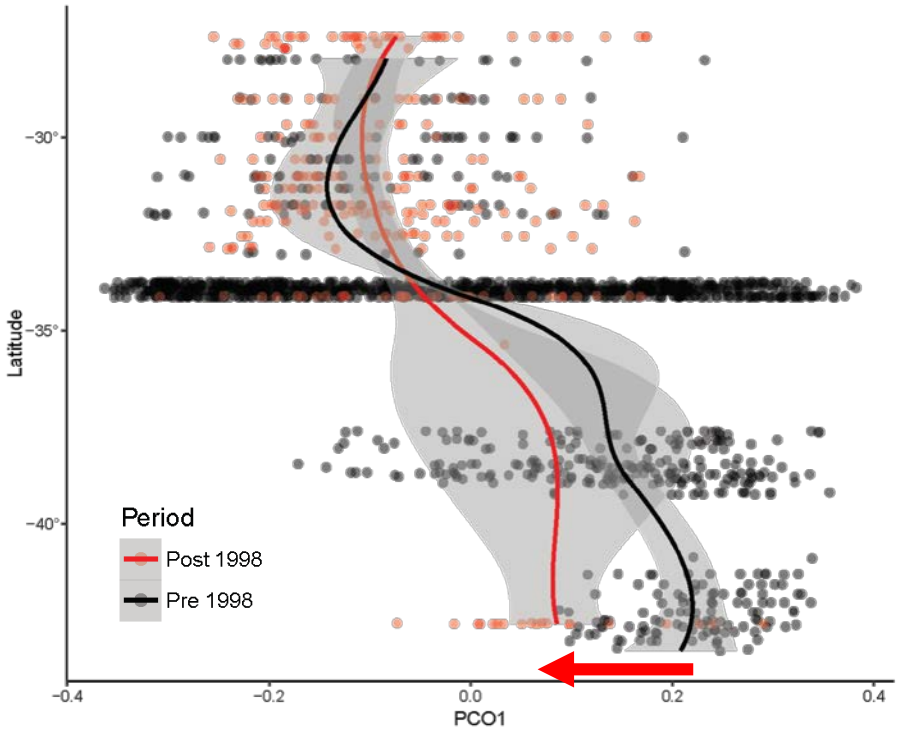
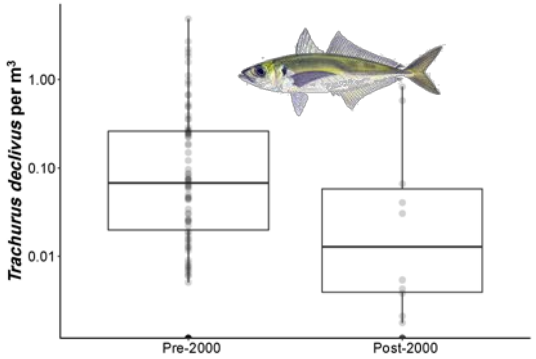
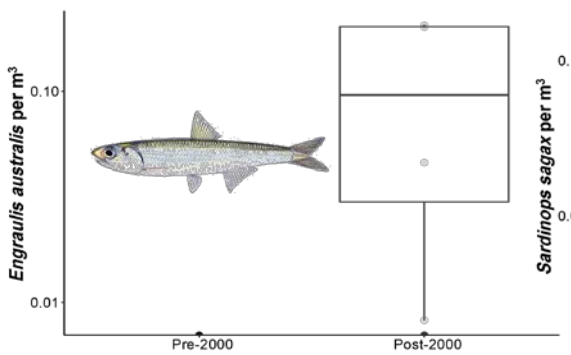


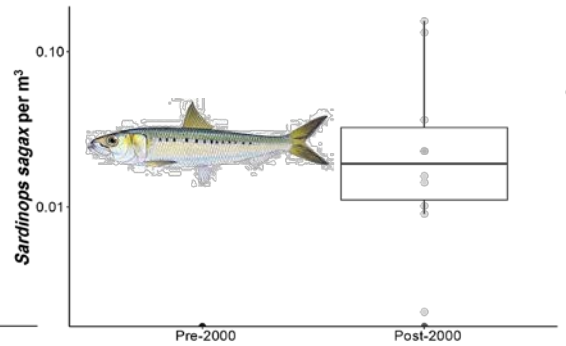
Hinchliffe et al. in preparation



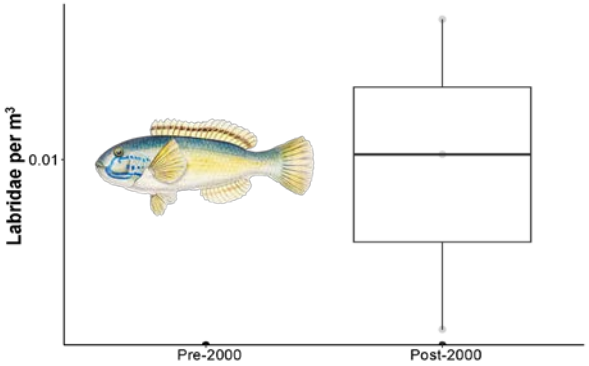
Jack Mackerel



Anchovy



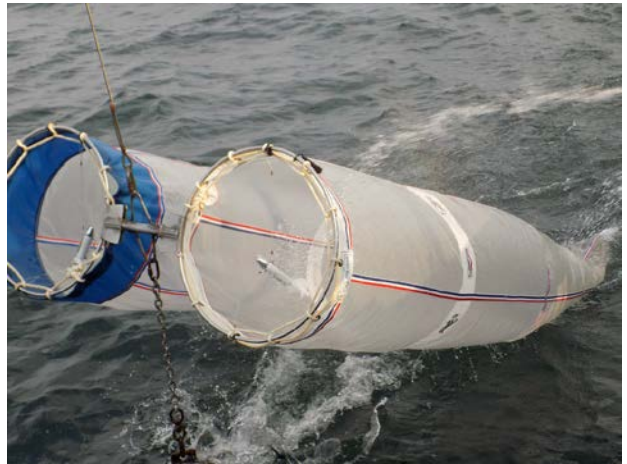
Sardine



Wrasse

IMOS-Larval fish monitoring

- Two years (2019-2020) technical support
  - to provide a 5 y of seasonal patterns (2016-2020);
- Changed to standard “bongo” nets, with better flow meters
  - Visits to each NRS for QC/QA
  - One net formalin, other in 95% ethanol (for DNA)
- Monthly sampling at 5 (temperate) NRS – the backbone;
  - Sporadic spatial sampling around backbone
- Incorporate remaining key data
  - (e.g. E. coast Tasmania after 1998);
- Discussions with Yongala



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SARDI proposal to FRDC for DNA barcoding

- Can we identify species using DNA barcoding?
  - Species or family identification using mitochondrial cytochrome oxidase gene;
  - Not only presence-absence of species
    - If combined with image of fish (area~cell numbers)
    - Still experimental, but exciting option to reduce costs in future

- 3 surveys in 2019 for pelagic fish eggs and spawning biomass
  - 100 samples per survey for DNA barcoding;
  - Led by Tim Ward (SARDI)

Formalin induced DNA decay in larval fish?

Supervisors: Ana Lara-Lopez (UTas), Sharon Appleyard (CSIRO), Safia Maher (CSIRO)

Larval fish fixed in formalin fixes proteins for future morphological examination but degrades DNA;

For genetic ID samples should be fresh, frozen or stored in 95% alcohol

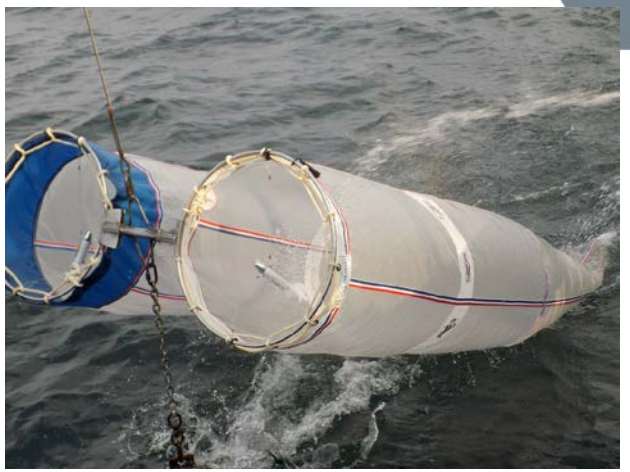
GOAL: Find the optimal preservation treatments to larval fish and voucher specimens that enable both morphological (i.e. microscopy) and genetic species identification.

AIMS:

1. Determine the optimal time that larval samples can be exposed to formalin while enabling successful sequencing of DNA in preserved larval fish
2. investigate the effect of formalin on cytochrome oxidase subunit I (COI) barcoding

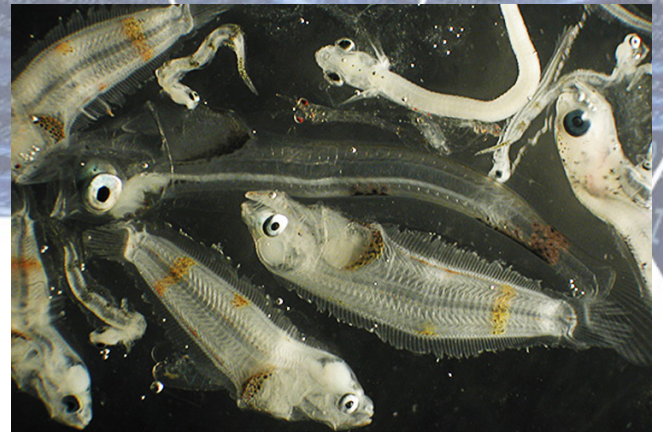
Vision for the future?

- Analysis of power of limited sampling effort (2/mo per NRS)
  - Larval fish community realistic; not single species monitoring?
  - Correlations with zooplankton and microbes?
    - RAAP post-doc Peter Yates (at SIMS)
- Well-understood seasonality to fish reproduction;
  - Robust analysis of long-term trends;
- To reduce costs with DNA barcoding;
- To encourage data uptake by community
- **Already preparing for on-going IMOS-LFM to 2029**



Conclusions and data uptake

- Research Providers Network
  - AFMA [instigated NIMO in 2015; needs fisheries independent signals of fish reproduction];
  - ABARES, [Fisheries status reports]
  - CSIRO, [David Smith/Hobday, baseline phenology and connectivity larval fish]
  - SARDI, [Tim Ward, and Andrew Oxley, for testing DNA barcoding methods from three daily egg production surveys in 2019]
  - DPI Fisheries NSW [Lowry, Taylor and Moltschaniwskyj, for input to MEMA Initiatives 3 and 6]
  - DPIRD WA, [baseline phenology and connectivity larval fish]
  - IMAS UTas, [baseline phenology and connectivity larval fish]
  - NT Fisheries [baseline phenology and connectivity larval fish]
- NSW-IMOS community
  - Seymour, Doblin, Roughan, Williams, Harcourt [three RAAP post-docs]



Especial acknowledgement to many marine scientists in this room who believed in the potential of long-term observing of larval fish.

NCRIS
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An Australian Government Initiative

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PRINCIPAL PARTICIPANTS

UNIVERSITY of TASMANIA
(Lead Agent)

Australian Government
Australian Institute of Marine Science

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South Australian Research and Development Institute

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SIMS is a partnership involving four Universities.

ASSOCIATE PARTICIPANTS

Curtin University

Australian Government
Department of the Environment and Energy
Australian Antarctic Division

Conclusions – is your name missing?

- Research Providers Network
  - AFMA [instigated NIMO in 2015; needs fisheries independent signals of fish reproduction];
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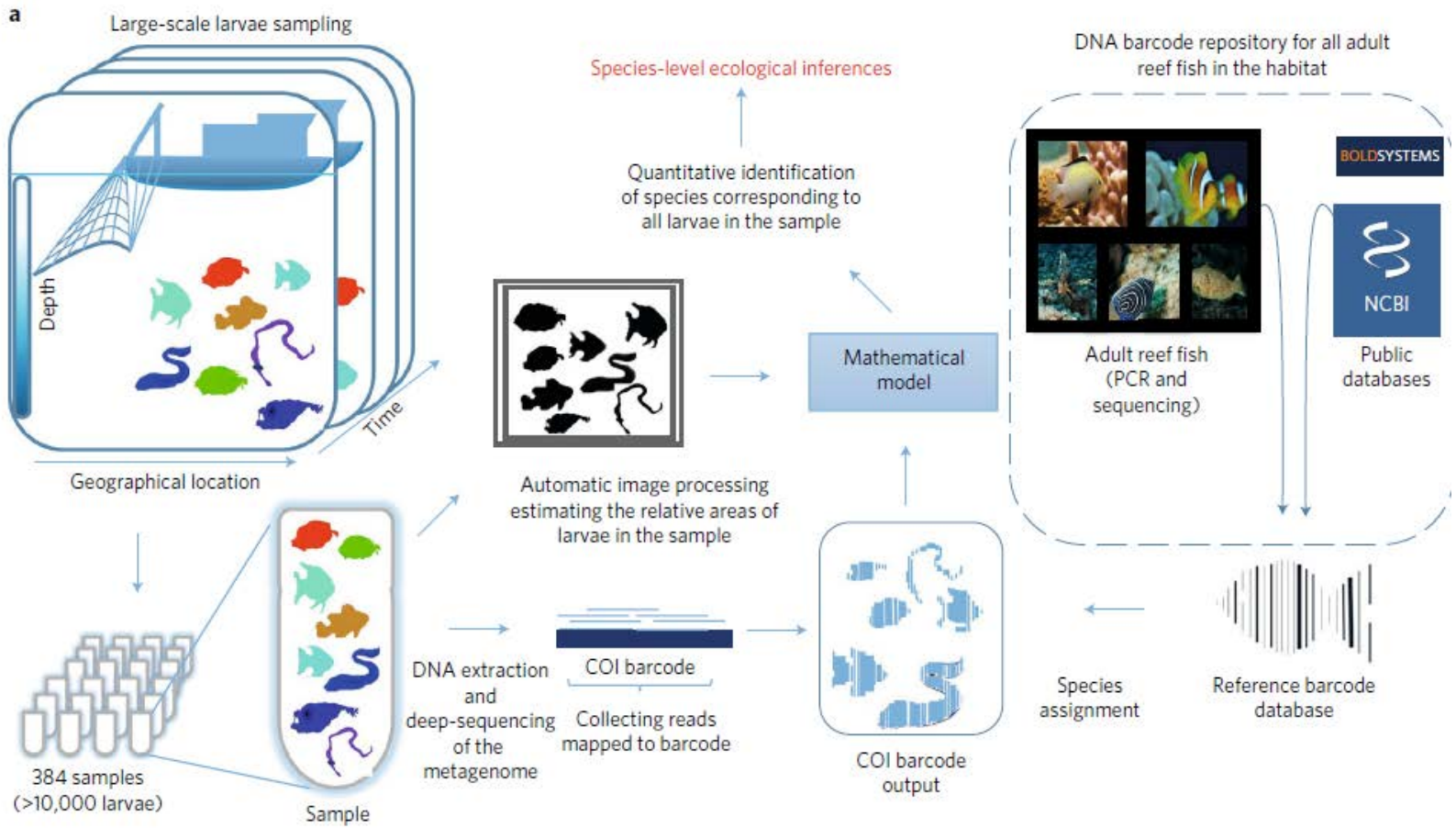
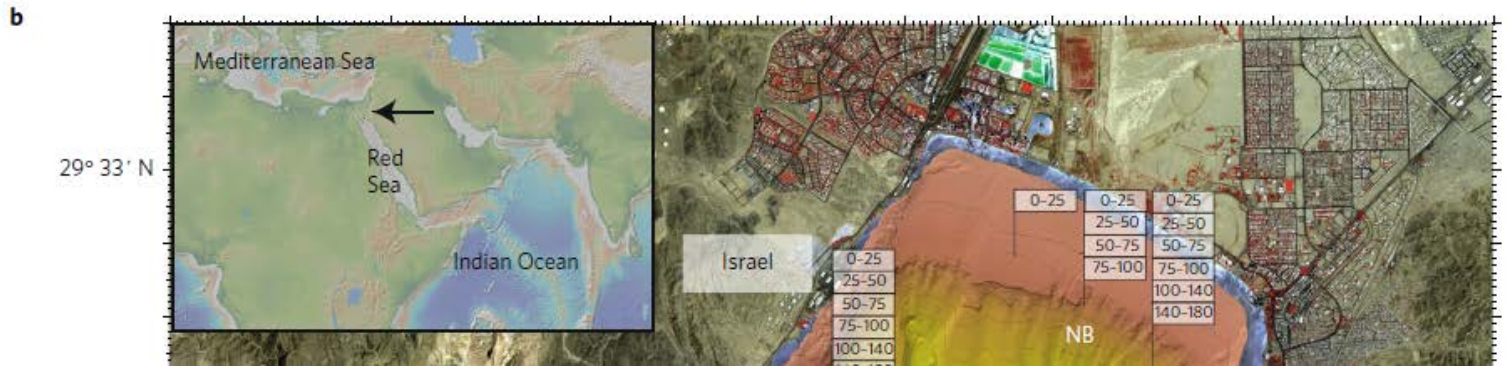
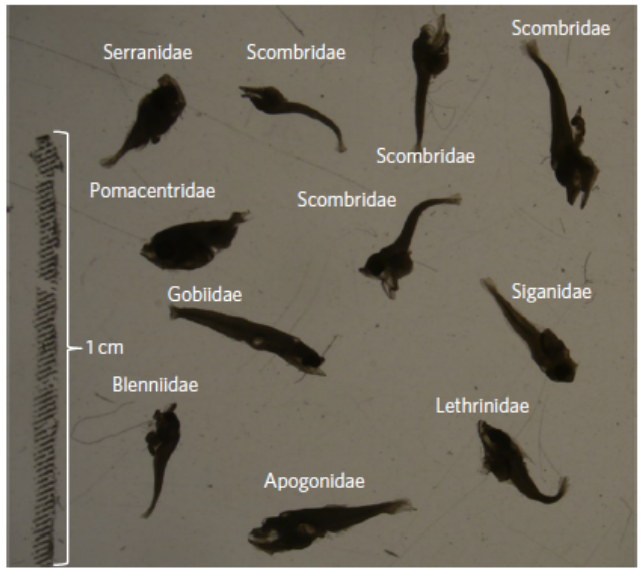
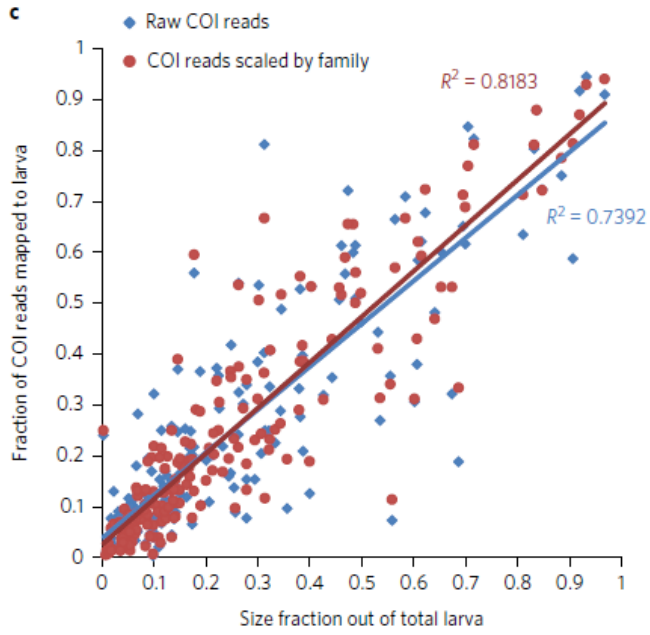
Family-NIMO	Common-NIMO	Species-NIMO
Acanthuridae	Surgeonfish	
Acropomatidae	Threespine cardinalfish	Apogonops anomalus
Acropomatidae	Lanternbelly	Synagrops spp
Acropomatidae	Lanternbelly	other
Ammodytidae	Sand lance	
Anguilliformes	Order of eels	
Antennariidae	Anglerfish	
Anthiinae	Sea perch	
Aploactinidae	Velvetfish	Matsubarichthys inusitatus
Aploactinidae	Velvetfish	other
Aplodactylidae	Sea carp	Aplodactylus spp
Apogonidae	Cardinal fish	
Argentinidae	Herring smelt	
Arripidae	Australian salmon	Arripis trutta
Arripidae	Australian salmon	other
Astronesthidae	Dragonfish	
Atherinidae	Hardyhead	
Aulopidae	Sergeant Baker	Hime spp
Balistidae	Triggerfish	
Bathylagidae	Deepsea smelt	
Berycidae	Redfish	Centroberyx affinis
Berycidae	Redfish	Beryx spp
Berycidae	Redfish	other
Blenniidae	Blenny	Plagiotremus spp
Blenniidae	Blenny	Petroscirtes lupus
Blenniidae	Blenny	Omobranchus anolius
Blenniidae	Blenny	Parablennius spp
Blenniidae	Blenny	other
Bothidae	Flatfish	Crossorhombus spp
Bothidae	Flatfish	Engyprosopon spp
Bothidae	Flatfish	Grammatobothus spp
Bothidae	Flatfish	Lophonectes gallus
Bothidae	Flatfish	Arnoglossus spp
Bothidae	Flatfish	Asterorhombus spp
Bothidae	Flatfish	other
Bovichtidae	Thornfishes	Bovichtus augustifrons
Bovichtidae	Thornfishes	Pseudaphritis urvilli
Bramidae	Pomfret	Brama spp
Bregmacerotidae	Codlets	Bregmaceros spp
Callanthiidae	Splendid perch	Callanthias australis
Callanthiidae		other
Callionymidae	Dragonets	
Caproidae	Boarfishes	Antigonia spp
Carangidae	Scad	Pseudocaranx georgianus
Carangidae	Jack mackerel	Trachurus declivus
Carangidae	Scad	Decapterus spp
Carangidae	Yellowtail scad	Trachurus novaezelandiae
Carangidae	Kingfish	Seriola spp
Carangidae	Scad	other
Carapidae	Pearlfish	
Centrolophidae	Trevallas	Seriolella spp
Cepolidae	Bandfish	Acanthocepola spp
Cepolidae	Bandfish	Owstonia spp
Cepolidae	Bandfish	Cepola australis
Cepolidae	Bandfish	other
Cetomimidae	Whalefish	
Chaetodontidae	Butterfly fish	
Champsodontidae	Gapers	
Chandidae	Port Jackson perchlet	Ambassis jacksoniensis
Chandidae	Estuary perchlet	Ambassis marianus
Chandidae	Glassfish	other
Chauliodontidae	Viperfish	
Cheilodactylidae	Jackass morwong	Nemadactylus macropterus
Cheilodactylidae	Morwong	Cheilodactylus spp
Chiasmodontidae	Swallowers	
Chironemidae	Marblefish	Chironemus spp
Chlorophthalmidae	Greeneyes	Chlorophthalmus spp
Cirrhitidae	Hawkfish	
Clinidae	Weedfish	
Clupeidae	Pilchard	Sardinops sagax
Clupeidae	Maray	Etrumeus teres
Clupeidae	Sandy sprat	Hyperlophus vittatus
Clupeidae	Blue sprat	Spartelloides robustus
Clupeidae	Herring	other
Coryphaenidae	Dolphin fish	Coryphena spp
Creediidae	Sand burrower	Creedia spp
Creediidae	Sand burrower	Limnichthys spp
Creediidae	Sand burrower	other
Cynoglossidae	Tongue sole	
Dactylopteridae	Flying gurnard	Dactyloptena spp
Dinolestidae	Longfin pike	Dinolestis lewini
Diretmidae	Discfish	Diretmus spp
Emmelichthys	Redbait	Emmelichthys nitidus
Engraulidae	Anchovy	Engraulis australis
Engraulidae	Anchovy	other
Enoplosidae	Old wife	Enoplosus armatus
Epinephelinae	Grouper	
Evermannellidae	Sabretooth	
Exocoetidae	Flying fish	
Fistulariidae	Flutemouth	
Gempylidae	Barracouda	Thyrsites atun
Gempylidae	Gemfish	Rexea solandri
Gempylidae	Snake mackeral	Gempylus serpens
Gempylidae		other
Gerreidae	Silver belly	Gerres subfasciatus
Gerreidae	Silver belly	Parequula melbournensis
Girellidae	Luderick	Girella tricuspidata
Girellidae	Luderick	Girella spp
Gobiidae	Goby	
Gobiesocidae	Clingfish	Alabes spp
Gobiesocidae	Clingfish	other
Gonorhynchidae	Beak salmon	Gonorhynchus greyi
Gonostomatidae	Bristlemouth	
Grammistidae	Soapfish	
Haemulidae	Sweetlips	
Hemiramphidae	Garfish	Hemiramphus spp
Holocentridae	Squirelfish	
Hoplichthyidae	Ghost flathead	Hoplichthys spp
Howellidae	Pelagic bass	Howella spp
Idiacanthidae	Black dragonfish	Idiacanthus spp
Ipnopidae	Tripodfish	
Istiophoridae	Marlin	
Kyphosidae	Drummer	Kyphosus spp
Labridae	Wrasse	
Lampridiformes	Ribbonfish	
Latridae	Trumpeter	Latris lineata
Latridae	Trumpeter	other
Leiognathidae	Ponyfish	
Leptobramidae	Beach salmon	
Leptoscopidae	Sandfish	
Lethrinidae	Emperor	Lethrinus spp
Lophiiformes	Anglerfish	
Lutjanidae	Snapper	
Macroramphosidae	Bellowsfish	Macroramphosus spp
Macrouridae	Rattail	
Malacanthidae	Tilefish	Branchiostegus spp
Malacanthidae	Blanquillo	Malacanthus spp
Melamphaidae	Bigscale	
Melanostomiidae	Black dragonfish	
Microcanthidae	Mado	Atypichthys strigatus
Microcanthidae	Stripey	Microcanthus strigatus
Microcanthidae		other
Microdesmidae	Wormfish	
Molidae	Sunfish	
Monacanthidae	Leatherjacket	
Monodactylidae	Diamondfish	Monodactylus argenteus
Monodactylidae	Pomfred	Schuetta spp
Moridae	Beardies	
Mugilidae	Mullet	Liza argentea
Mugilidae	Mullet	other
Mullidae	Goatfish	
Myctophidae	Lanternfish	
Nemipteridae	Threadfin bream	
Nomeidae	Driftfish	
Notosudidae	Paperbones	
Odacidae	Rock cale	
Ophidiidae	Ling	Brotula spp
Ophidiidae	Ling	Genyptrus spp
Ophidiidae	Ling	other
Ostraciidae	Cowfish	

Paralepididae	Barracudinas	
Paralichthyidae	Large tooth flounder	Pseudorhombus spp
Pegasidae	Sea moth	Pegasus spp
Pempheridae	Bullseye	Pempheris spp
Percophidae	Duckbills	
Phosichthyidae	Lightfishes	
Pinguipedidae	Grub fish	
Platycephalidae	Flathead	Platycephalus fuscus
Platycephalidae	Flathead	other
Plesiopidae	Prettyfins	
Pleuronectidae	Flounder	Rhombosolea spp
Pleuronectidae	Flounder	other
Pomacentridae	Damselfish	
Pomatomidae	Tailor	Pomatomus saltatrix
Priacanthidae	Bigeyes	
Pseudochromidae	Dottyback	
Rhombosoleidae	Flounder	Ammotretis spp
Samaridae	Flatfish	
Scaridae	Parrotfish	
Schindleriidae	Floater	Schindleria spp
Sciaenidae	Mulloway	Agyrosomus japonicus
Sciaenidae	Teraglin	Atractoscion aequidens
Sciaenidae		other
Scomberesocidae	Saury	Scomberesox saurus
Scombridae	Blue mackerel	Scomber australasicus
Scombridae	Tuna	Auxis spp
Scombridae	Tuna	other
Scopelarchidae	Pearleyes	
Scorpaenidae	Ocean perch	Helicolenus spp
Scorpaenidae	Gurnard perch	Neosebastes spp
Scorpaenidae	Cobbler	Gymnapistes marmoratus
Scorpaenidae	Fortescue	Centropogon australis
Scorpaenidae		other
Scorpididae	Sweep	Scorpis spp
Serraninae	Wirrahs	Acanthistius spp
Siganidae	Rabbitfish	Siganus spp
Sillaginidae	Stout whiting	Sillago robusta
Sillaginidae	Eastern school whiting	Sillago flindersi
Sillaginidae	Sand whiting	Sillago ciliata
Sillaginidae	Southern school whiting	Sillago bassensis
Sillaginidae	King George whiting	Sillaginodes punctatus
Sillaginidae	Whiting	other
Soleidae	Sole	
Sparidae	Snapper	Chrysophrys auratus
Sparidae	Yellowfin bream	Acanthopagrus australis
Sparidae	Tarwhine	Rhabdosargus sarba
Sparidae		other
Sphyraenidae	Barracudas	Sphyraena spp
Sternoptychidae	Hatchet fish	
Syngnathidae	Pipefish	Stigmatopora nigra
Syngnathidae	Pipefish	other
Synodontidae	Lizardfish	
Terapontidae	Trumpeter	Pelates spp
Terapontidae	Trumpeter	other
Tetragonuridae	Squaretail	Tetragonurus spp
Tetraodontidae	Toadfish	
Trachichthyidae	Roughy	Aulotrachichthys spp
Trachichthyidae	Roughy	other
Trichiuridae	Frostfish	Lepidopus caudatus
Trichiuridae	Cutlassfish	other
Trichonotidae	Sanddivers	Trichonotus spp
Triglidae	Gurnard	Lepidotrigla papilio
Triglidae	Gurnard	Lepidotrigla spp
Triglidae	Gurnard	other
Tripterygiidae	Triplefins	
Uranoscopidae	Stargazers	
Xiphiidae	Swordfish	Xiphias gladius
Zeidae	Dory	
Unknown		
Damaged		
Other		


a
Large-scale larvae sampling
Depth
Time
Geographical location
384 samples
(>10,000 larvae)
Sample
Automatic image processing
estimating the relative areas of
larvae in the sample
Species-level ecological inferences
Quantitative identification
of species corresponding to
all larvae in the sample
Mathematical
model
DNA barcode repository for all adult
reef fish in the habitat
BOLDSYSTEMS
NCBI
Public
databases
Adult reef fish
(PCR and
sequencing)
DNA extraction
and
deep-sequencing
of the
metagenome
COI barcode
Collecting reads
mapped to barcode
COI barcode
output
Species
assignment
Reference barcode
database


b
Mediterranean Sea
Red
Sea
Indian Ocean
29° 33′ N
Israel
NB
0-25
25-50
50-75
75-100
100-140
140-180





b

Family	Species	Size (pixels)	COI reads	Size fraction %	Fraction of COI reads %
Apogonidae	*Pristiapogon fraenatus*	97,129	75	12.66	15.99
Blenniidae	*Cirripectes stigmaticus*	46,559	34	6.07	7.25
Gobiidae	Unknown (assembled COI)	85,908	72	11.20	15.35
Lethrinidae	*Lethrinus lentjan*	65,137	13	8.49	2.77
Pomacentridae	*Dascyllus trimaculatus*	91,610	66	11.94	14.07
Scombridae	*Katsuwonus pelamis*	247,311	117	32.24	24.95
Serranidae	Unknown (assembled COI)	70,285	51	9.16	10.87
Siganidae	*Siganus sutor*	63,202	41	8.24	8.74

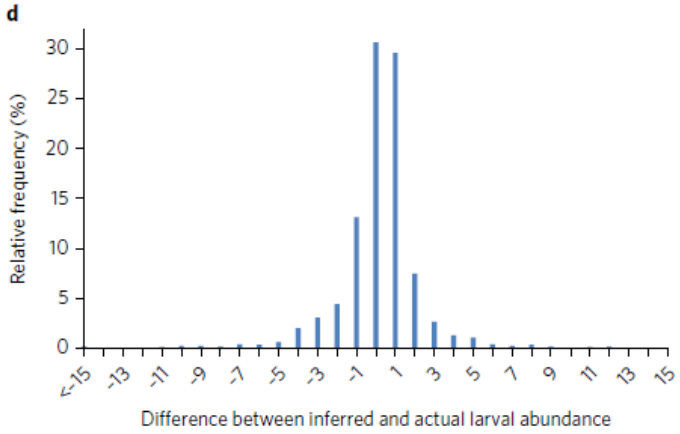


Fig. 3 | Size-based model for quantitative inference of species abundance. a, Silhouette picture of larvae from sample 97, collected on 19 October 2010 from a depth layer of 25–50 m of the mid-Gulf site. Family identity per larva was inferred based on morphological, meristic and pigmentation criteria. **b**, Species identified in sample 97, based on COI mapping. Larval sizes were inferred from the silhouette picture (see Methods). **c**, Correlation between relative larval size and the fraction of mapped COI reads in 47 samples in which all larvae ($n = 303$; subset 2 in Supplementary Table 2) were taxonomically assigned by both morphology (to the family level) and sequencing (to the species level). **d**, Differences between the number of larvae estimated using morphological assignments and the number estimated using COI sequencing and our quantitative model. Data were based on a larger set of 3,736 larvae from 234 samples (subset 3 in Supplementary Table 2) that were taxonomically assigned to the family level using the morphological criteria (see Methods).

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First U.S. Commissioner
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of *Fishery Bulletin*

Integrating DNA barcoding of fish eggs into ichthyoplankton monitoring programs

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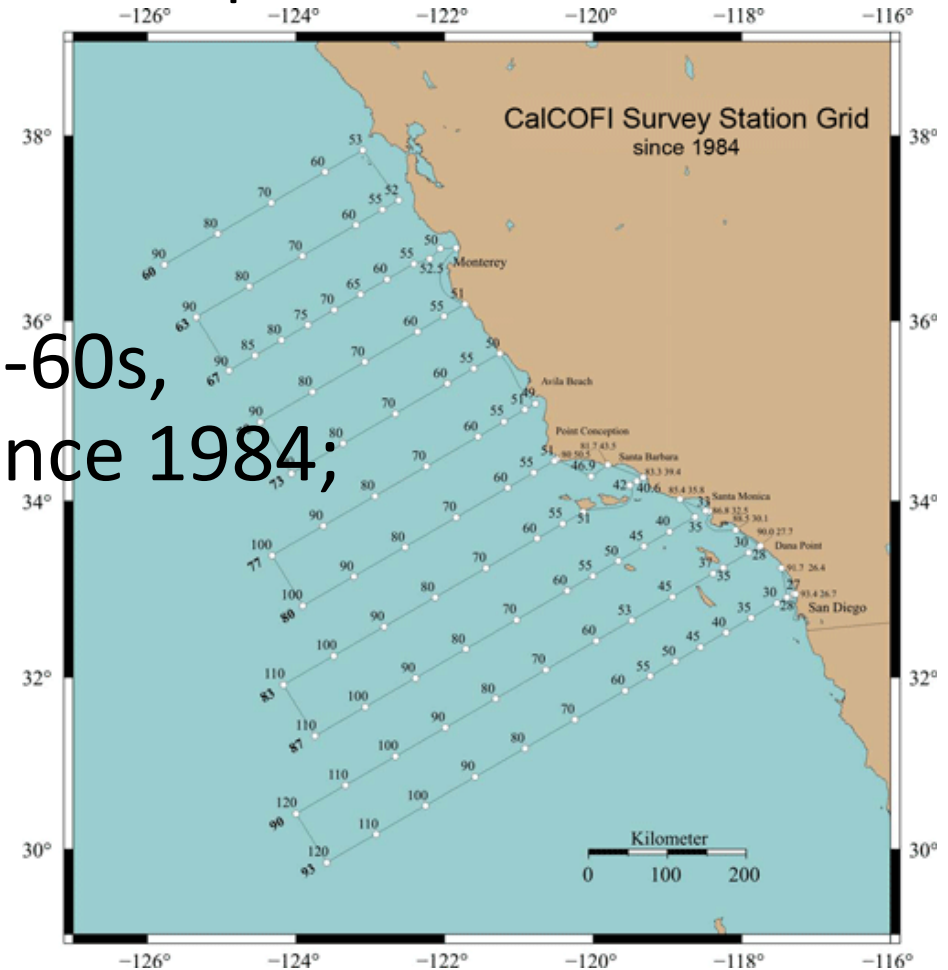
Abstract—The data collected through ichthyoplankton monitoring surveys provide valuable insight into the spawning dynamics of multiple species. Fish eggs, more than larvae, offer a more precise evaluation of species-specific spawning characteristics; however, egg collections are greatly underused because of the limitations associated with morphology-based identifications. In recent years, a new means of molecular identification, termed *DNA barcoding*, has made species identification readily available across a broad range of taxa. We used DNA barcoding to identify ethanol-preserved fish eggs collected during 2002–2012 along the northeastern U.S. continental shelf. A subsampling protocol was used to select 1603 unidentified eggs for analysis. DNA sequences

CalCOFI (California Cooperative Oceanic Fisheries Investigations)

- Formed in 1949 when sardine collapsed
- Annual funding!
- Scripps, NOAA, Cal Fish & Wildlife
- monthly sampling 1950-60s, to *quarterly* sampling since 1984;
- Daily egg production methods to estimate spawning stock biomass



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Seasonal variation in horizontal and vertical structure of larval fish assemblages off south-western Australia, with implications for larval transport

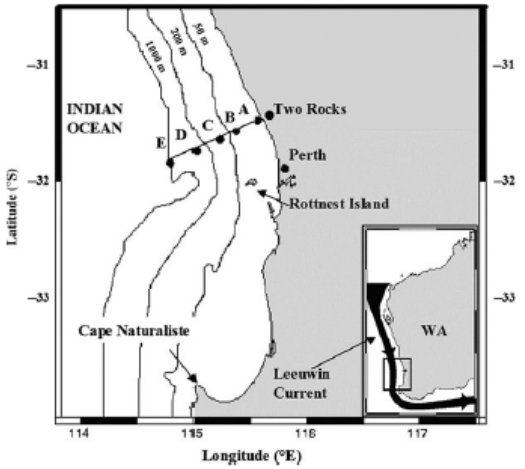

Fig. 1. Schematic diagram showing the study area off south-western Australia, including the Two Rocks transect, and the approximate location and direction of flow of the Leeuwin Current off the coast of Western Australia.

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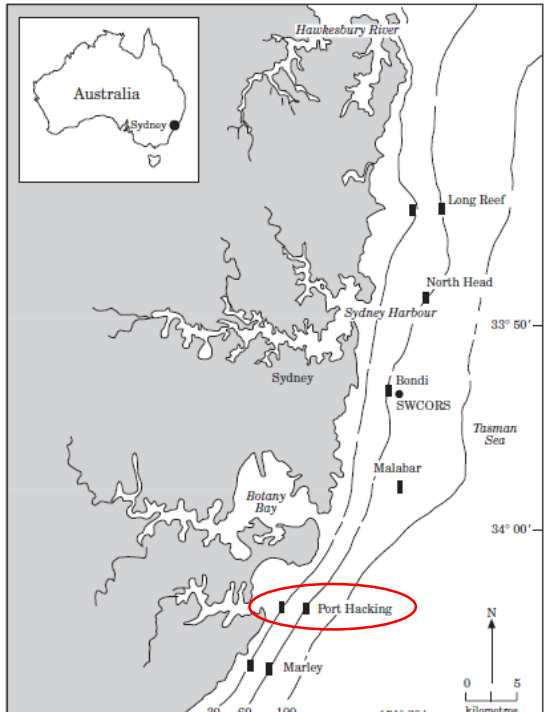

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Larval Fish Assemblages in South-east Australian Coastal Waters: Seasonal and Spatial Structure

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Total taxa surface

Total taxa midwater

Total individuals surface

Total individuals midwater