Response of Macrozooplankton to Environmental variation.

Euphausia superba
Hopcroft/UAF/CoML

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Session 3. The diversity and role of macrozooplankton in marine ecosystems.

ICES/PICES 6th International Symposium on Zooplankton Production, Bergen, Norway, May 9- 13, 2016.

Session 3. The diversity and role of macrozooplankton in marine ecosystems.

Goal of the session is to have presentations on investigations of the ecology and spatio-temporal distribution of macrozooplankton, as well as their biogeochemical roles, life cycles, ecophysiology, and behaviours, in order to further our understanding of their role in a changing ocean.

Over the past 50+ years, increased Ocean temperature, higher CO_2, lower pH, and lower oxygen have resulted from both natural oscillations and human activities.

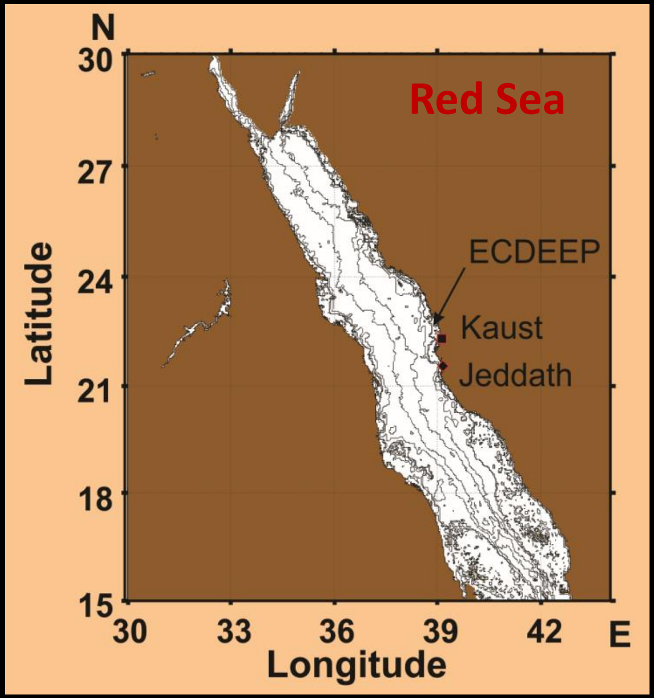
Session 3. The diversity and role of macrozooplankton in marine ecosystems.

Insight into the response of species to environmental change can be gained from study of species in extreme habitats such as the Red Sea.

High mesopelagic temperatures (~22˚C) cause high metabolic demands, making the low food supplies and oxygen concentrations stressful.

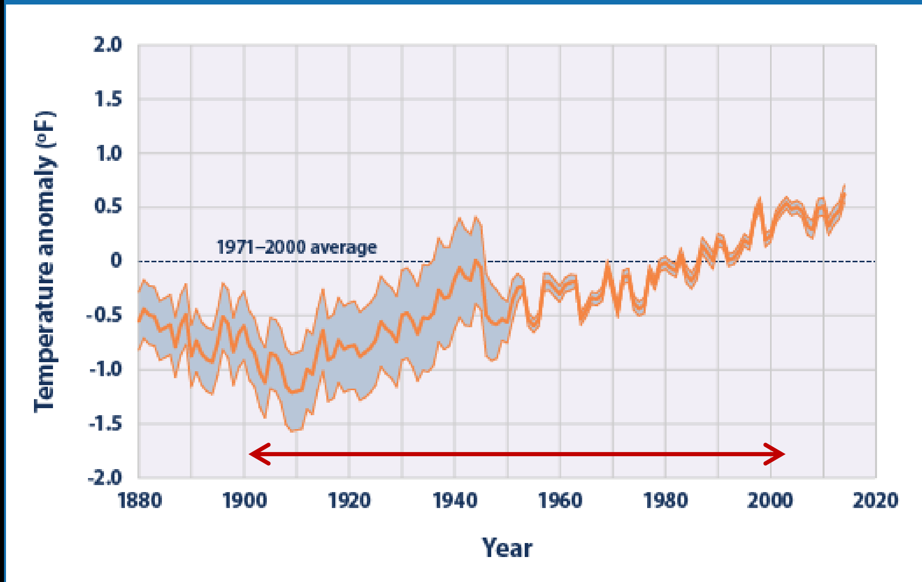
Mismatch between demand for oxygen and capacity of oxygen supply to tissues is a first mechanism to restrict whole-animal tolerance to thermal extremes (Somero, 2011**).**

In the Red Sea, food limitation due to very low zooplankton concentrations and rapid digestion in the very warm waters appears to require the entire population of mesopelagic fish to migrate to upper layers each night to feed (Klevjer et al. (2012)**.**

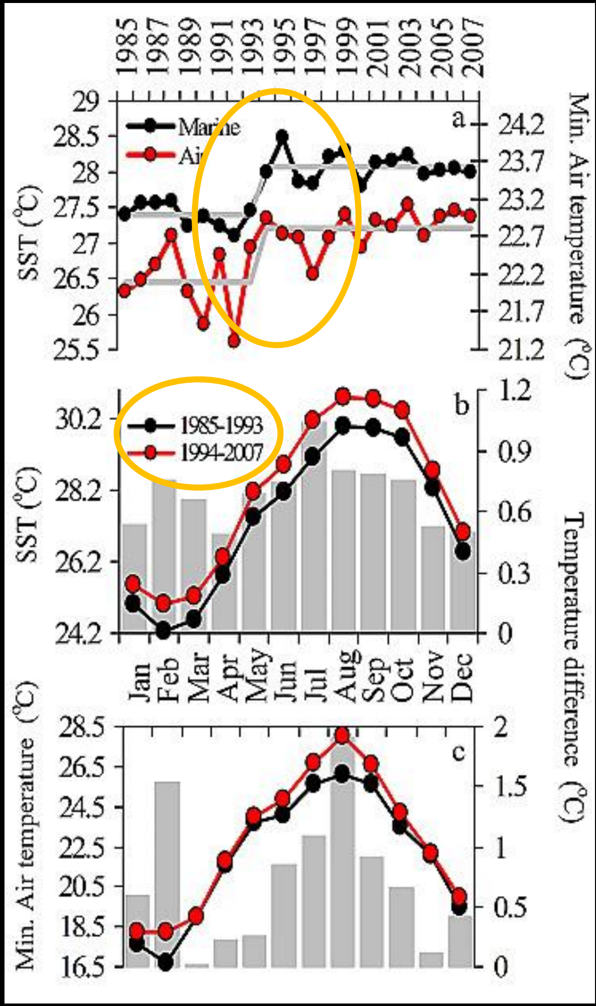


Global Seawater Temperature has changed

Figure 1. Average Global Sea Surface Temperature, 1880–2014



Abrupt warming of the Red Sea in 1994



From 1900 to 2012, Global SST has increased 0.8 C.

Between 1985 and 2007, the Red Sea SST increased 0.7 C with a regime shift in 1994.

Raitsos, D.E., Hoteit, I., Prihartato, P.K., Chronis, T., Triantafyllou, G., and Abualnaja, Y. (2011) Abrupt warming of the Red Sea. Geophysical Res. Let., 38, L14601, doi:10.1029/2011GL047984.
2011https://www3.epa.gov/climatechange/science/indicators/oceans/sea-surface-temp.html

Objectives of this study

1) Determine the vertical distribution and migration behavior of euphausiids in relation to hydrographic structure and environmental conditions of the Red Sea;
2) Use DNA barcodes to confirm species identification and compare with conspecific populations in other ocean regions (Pacific, Atlantic, and Arabian Sea).

Focus

Focus is on two euphausiid genera: *Euphausia* and *Stylocheiron*

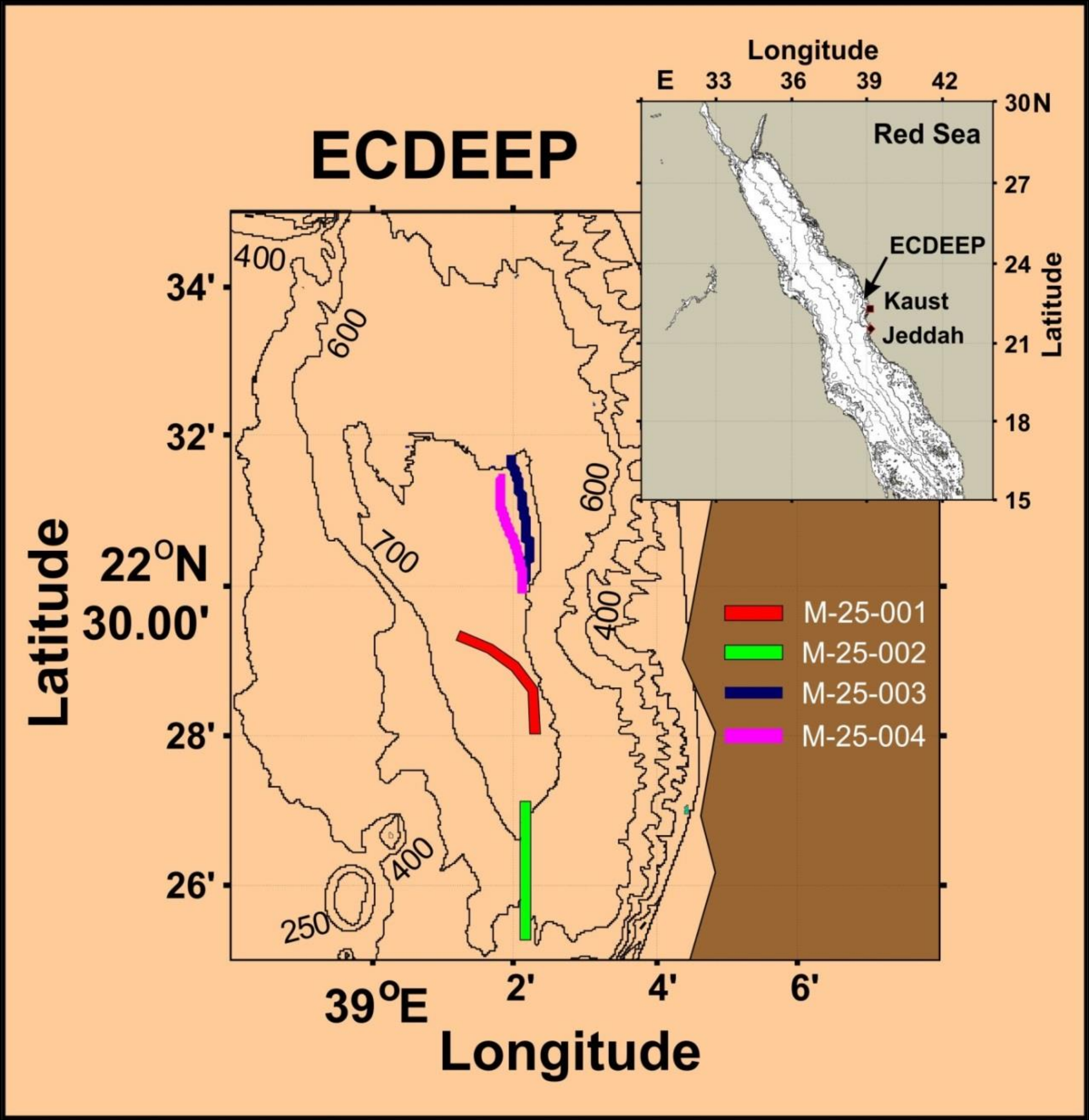
Hypotheses

1) High temperatures and low oxygen concentration will restrict the vertical daytime distribution of *Euphausia* species to shallower depths than in other ocean regions.

2) Species of *Stylocheiron*, which reside in mesopelagic depths both day and night take nocturnal upward migrations in the Red Sea or occur at shallower depths than in other ocean regions where they occur.

3) Species of Red Sea euphausiids have identical COI barcode sequences to individuals of the same species in other geographic regions.

Sampling locations to collect Red Sea Euphausiids.



Kaust is 85 km north of Jeddah. ECDEEP is about 1 hour's steam north of Kaust

ECDEEP MOCNESS tows:

M-25-001 / 002 - day

M-25-003 / 004 - night.

Sample Data:

Vertical distribution and abundance

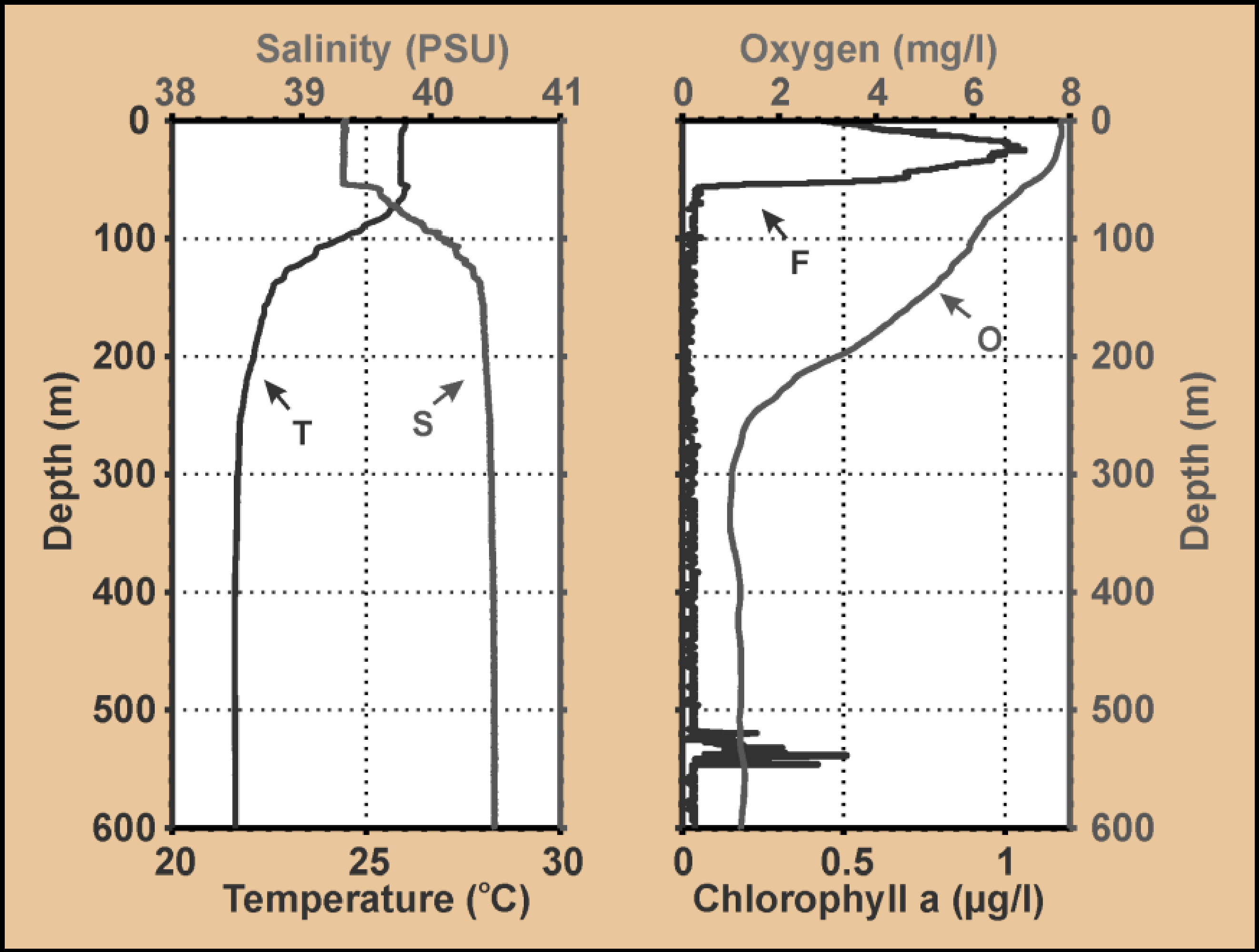
Genetics / species barcodes

S. affine morphometric measurements

Sampling from KAUST's R/V Thuwal

Sampling for zooplankton done with day and night 1/4m MOCNESS tows.

Vertical distribution of temperature (°C), salinity (PSU), chlorophyll a (mg/l), and oxygen (mg/l) based on the ECDEEP CTD up-trace conducted on 13 January 2014.



Highlights

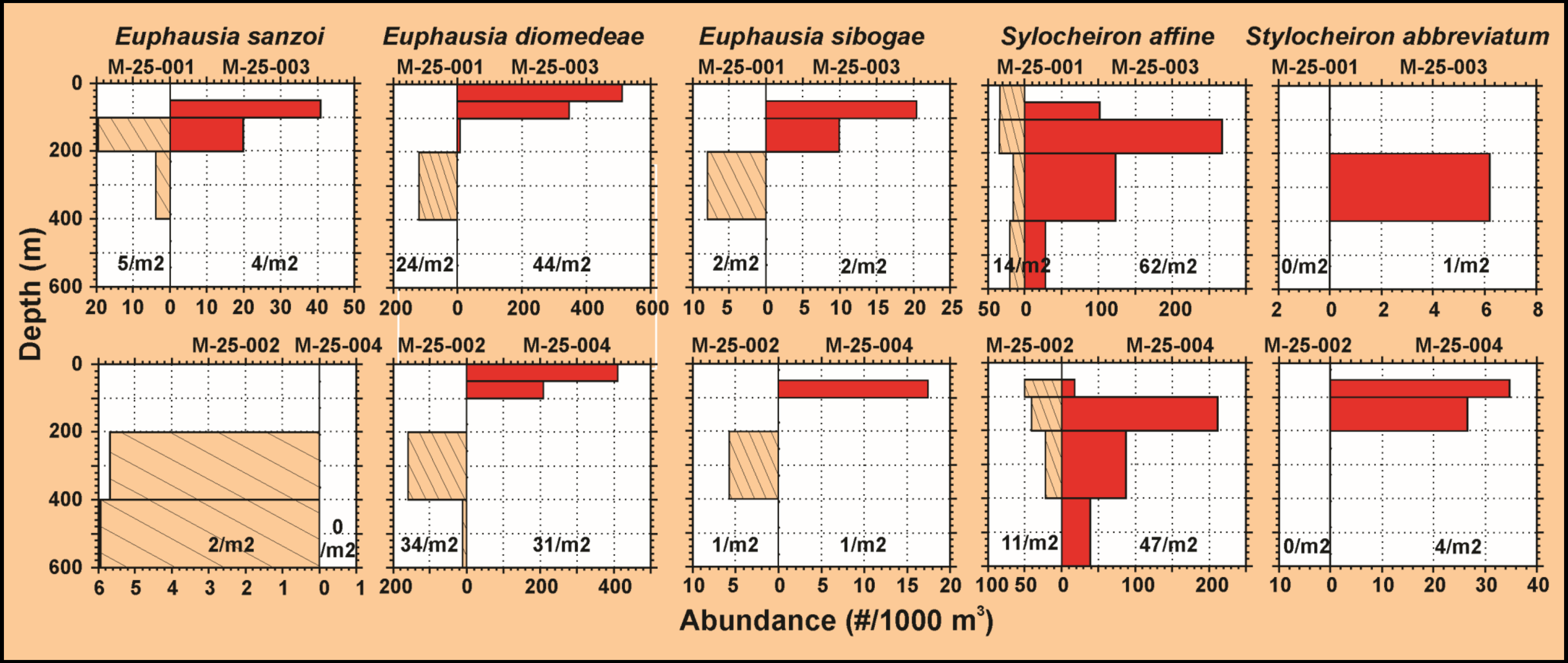
Surface temperatures were high (~26°C) , decreased from 50 - 200 m, and reached isothermal conditions (~21.5°C) below 200.

Surface salinity ~39.4 PSU increased rapidly to over 40 PSU at 150 m; and became isohaline below 200 m.

Surface oxygen was above 7.5 mg/l and rapidly declined from 50 - 220m from 7.3 to 2.3 mg/l. Below 220 m, low oxygen values averaged ~ 1.21 mg/l.

Chlorophyll *a* increased from the surface to a peak at about 35 m and went to zero below 50 m

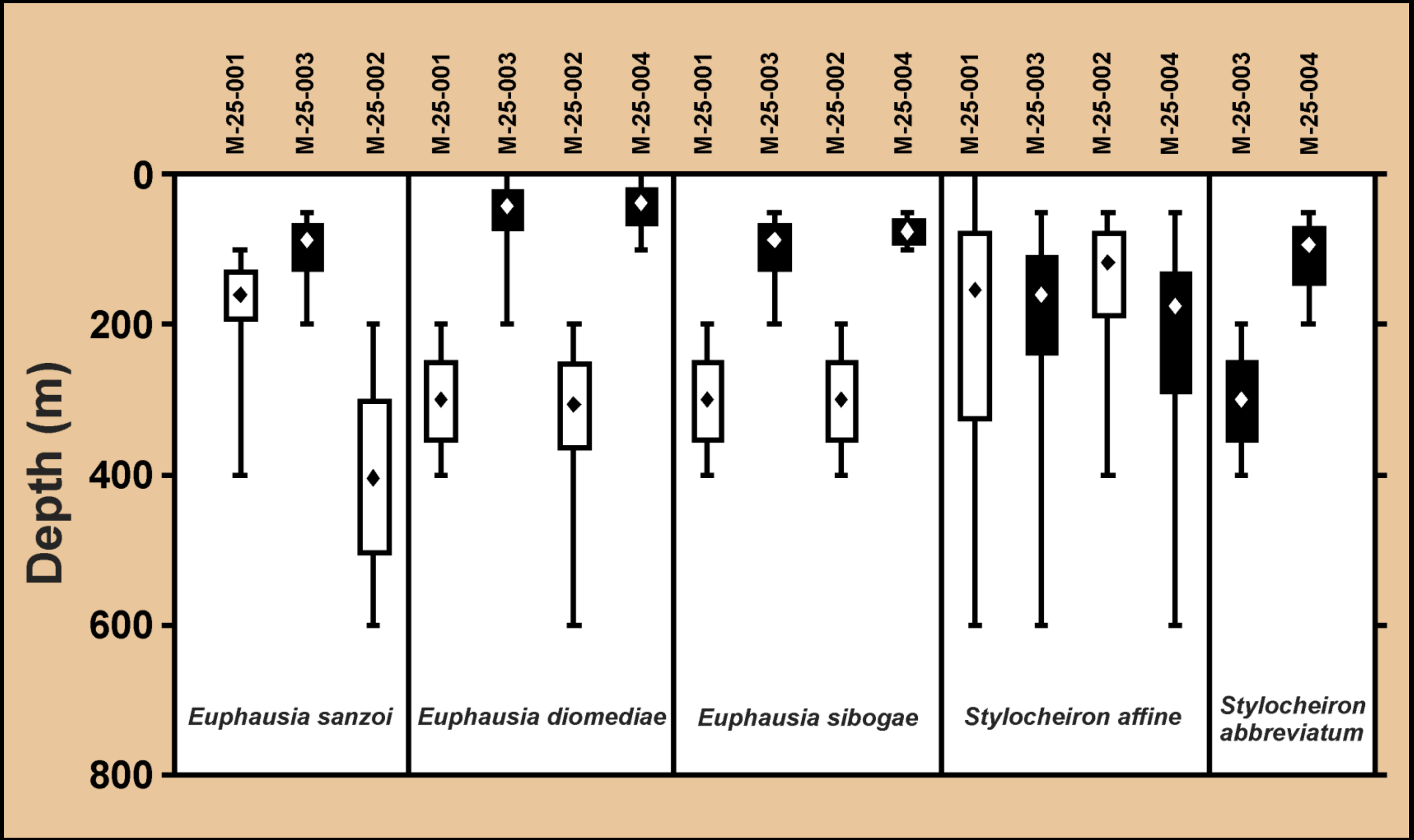
ECDEEP Euphausiid Vertical Distribution and Abundance



***Euphausia diomedeae* and *Stylocheiron affine* were the most abundant.**
The other species occurred in much lower abundance.

Species	D	N	Mean
Euphausia diomedeae	29	37.5	33.25
Euphausia sanzoi	3.5	2	2.75
Euphausia sibogae	1.5	1.5	1.5
Stylocheiron affine	12.5	54.5	33.5
Stylocheiron abbreviatum	0	2.5	1.25

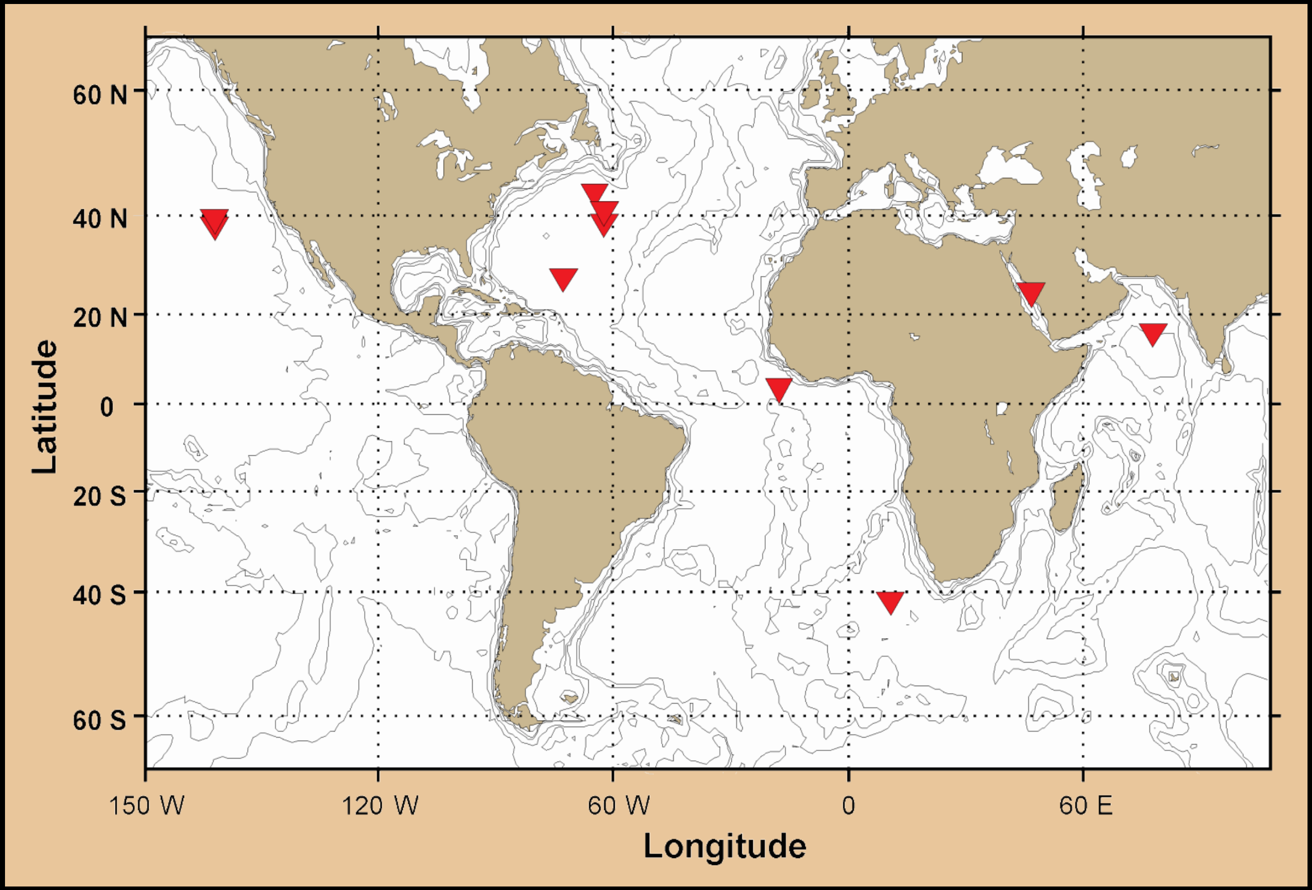
Cumulative percentages of euphausiids from the day and night MOCNESS tows



Euphausia diomedeae, Euphausia sibogae, and *E. sanzoi* performed diel vertical migration from <200m in daytime to >100m at night.

Stylocheiron affine and *S. abbreviatum* did not exhibit DVM.

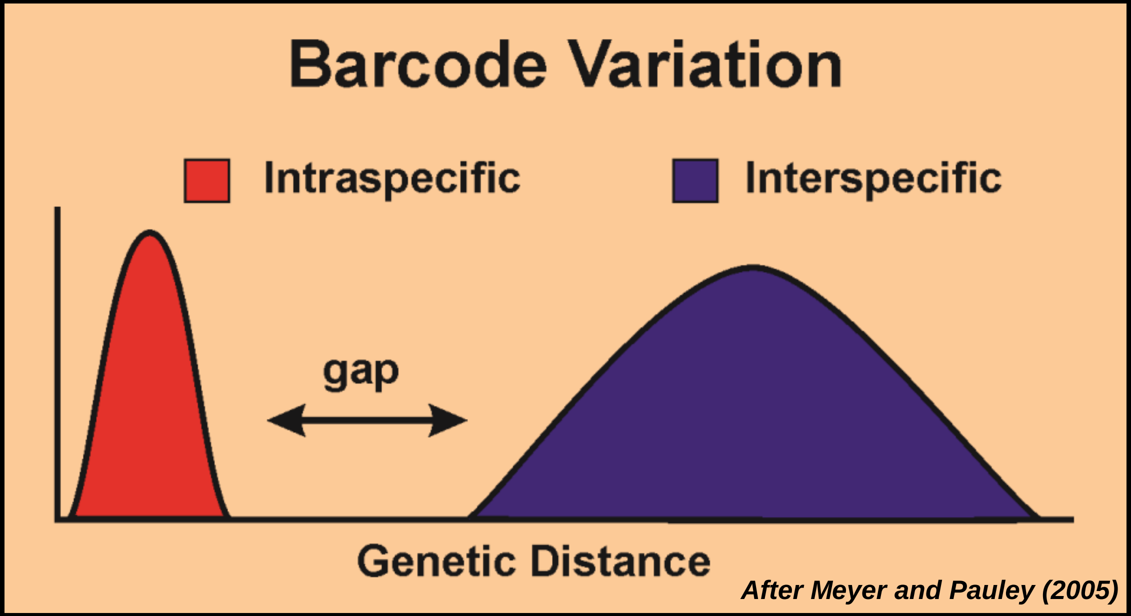
Red Sea species comparison stations in other oceans.



NE Pacific; NW, NE, and SE Atlantic and Arabian Sea stations from which specimens of four euphausiid species were identified and barcoded for comparison with DNA barcode data from the Red Sea specimens.

Typical within and between species barcode differences

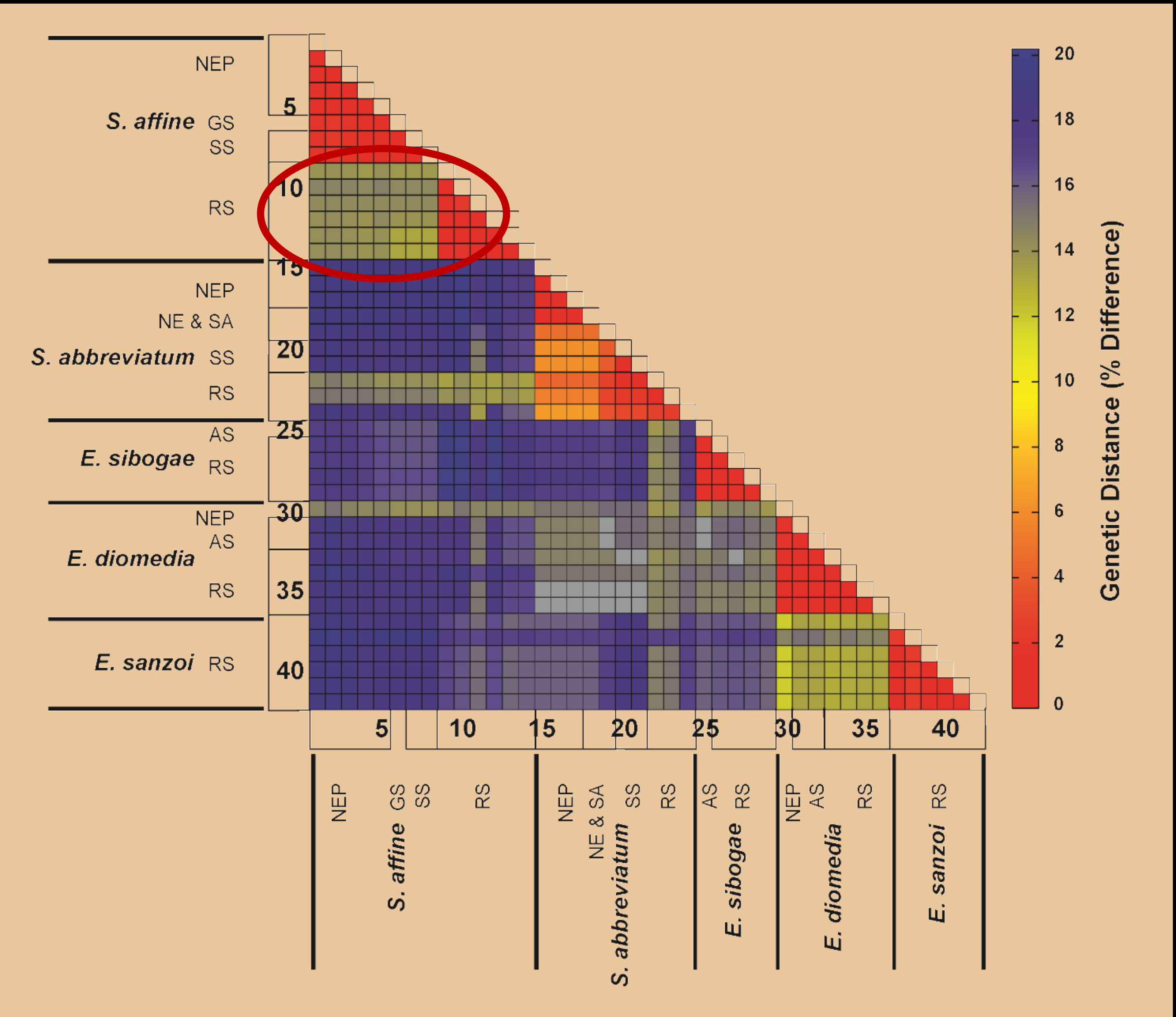
Barcodes are short DNA sequences that enable species recognition and discrimination. For animals, the usual barcode is 658 base-pair fragment of mitochondrial cytochrome oxidase I (COI).



For crustacean species COI differences :

9% - 25% between species;
1% - 4% within species;
intraspecific variation > 2% between geographic populations

DNA Barcode Variation



Heat map of pairwise DNA sequence differences, within and between the five species of euphausiids collected in the Red Sea.

Intraspecific differences were typical of other crustacean zooplankton species analyzed, with the exception of *S. affine* (~14% difference between specimens from the Red Sea versus Atlantic / Pacific).

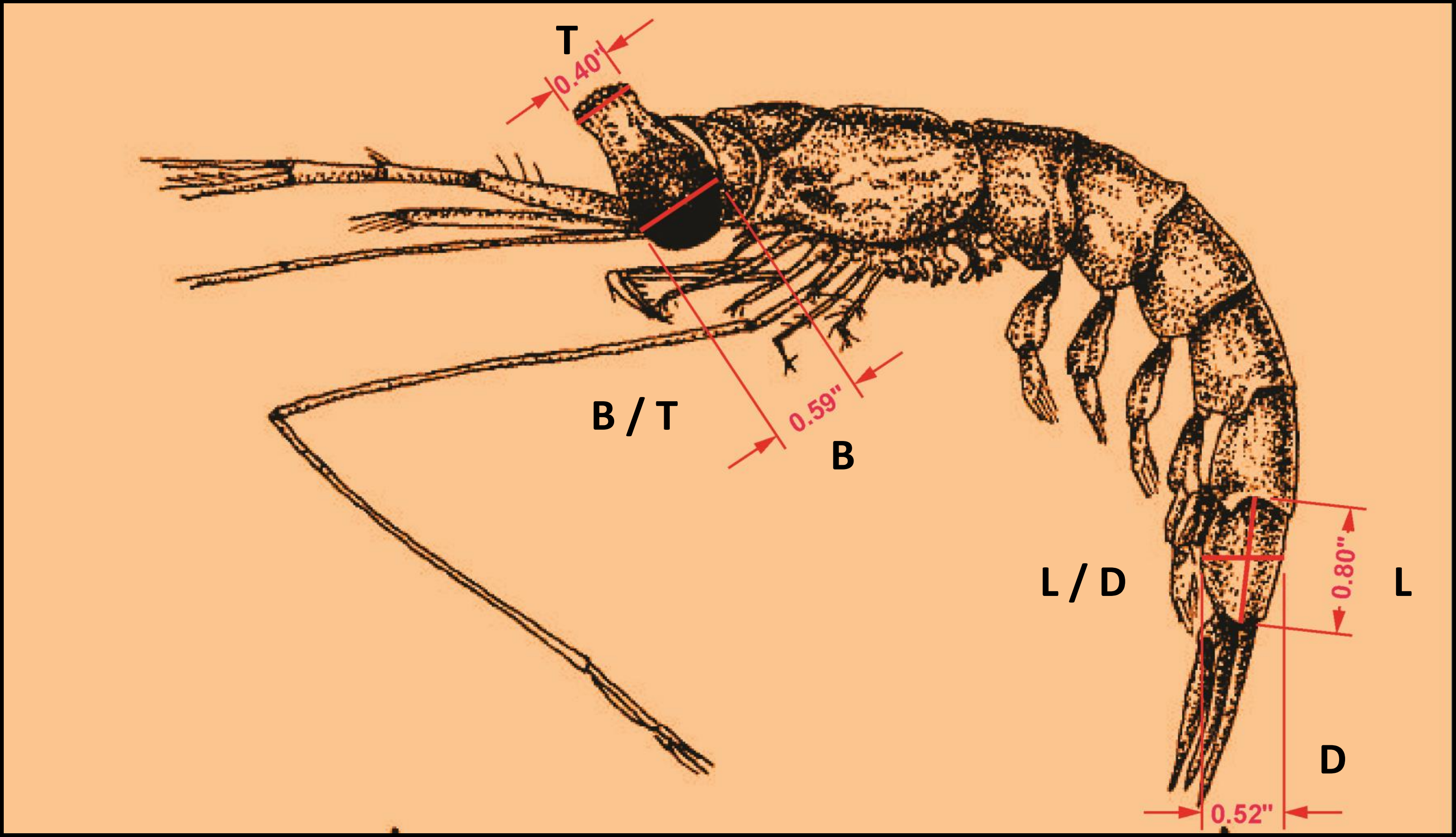
Neighbor Joining tree with Kimura-2-Parameter genetic distances

100% bootstrap values resolve all species except *S. affine.*

S. affine in Red Sea differs 14% from conspecific populations in other ocean regions.

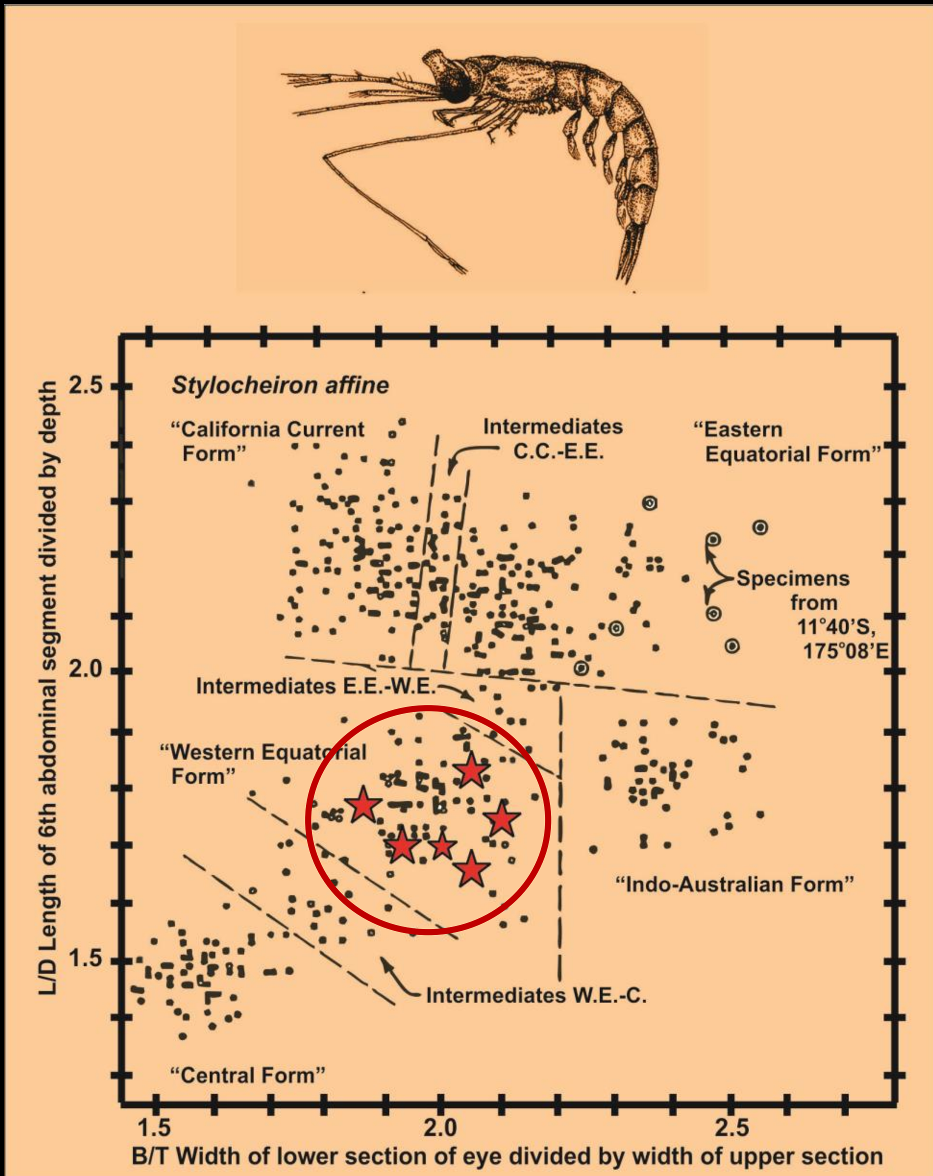
Some regional differentiation of populations is shown for *S. abbreviatum.*

Morphometric measurements used to determine *Stylocheiron affine Red Sea form.*



forms defined by Brinton (1962).

Stylocheiron affine in the Red Sea is a "Western Equatorial Form"



Morphometric distinction of five ecophenotypic forms of *S. affine* in the Pacific Ocean based on 6th abdominal segment L/D and eye B/T (Brinton, 1962).

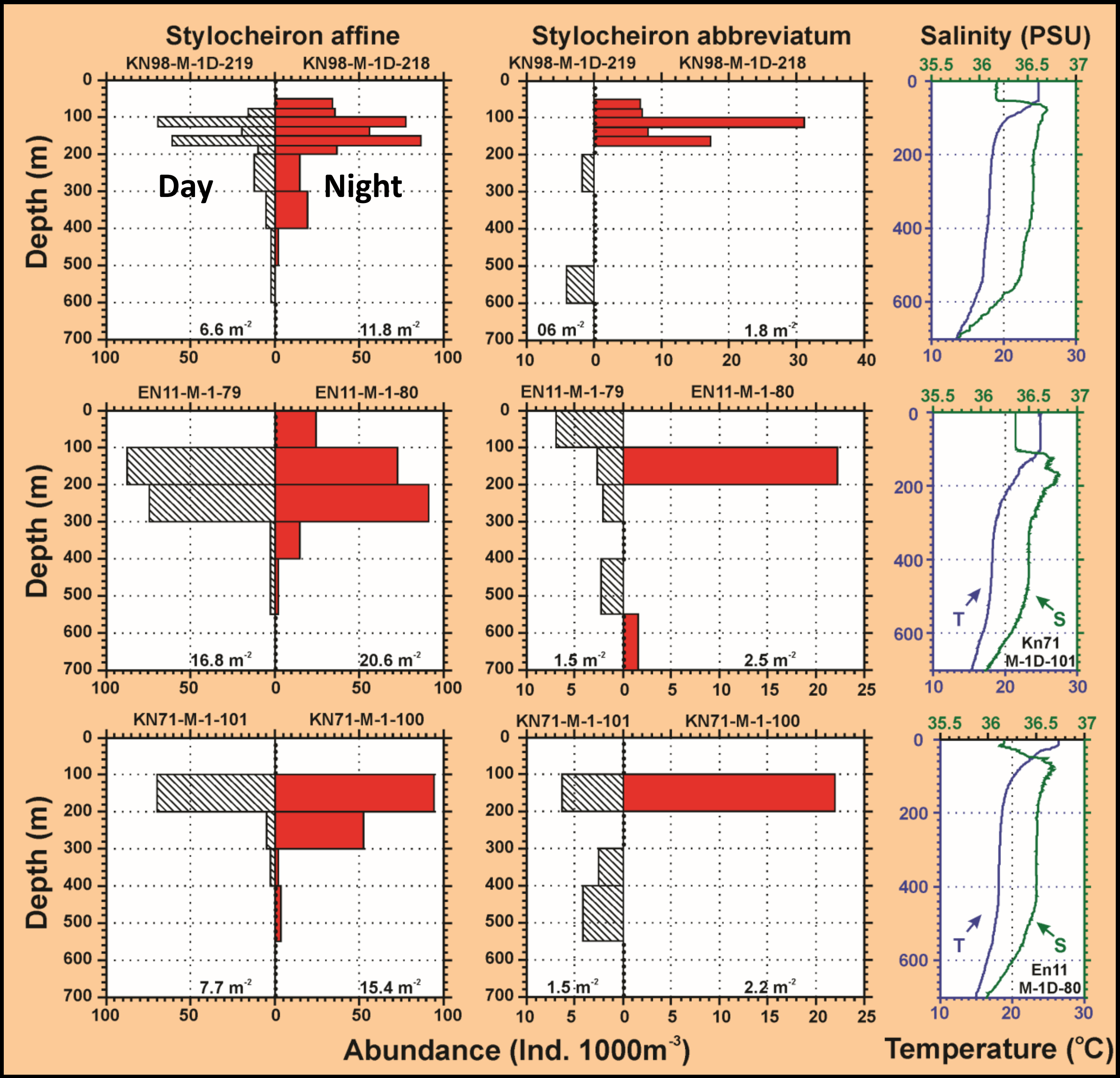
★

The stars mark the measurements made on six Red Sea individuals.

Casanova (1990) found this form of *S. affine* in the Red Sea: noted exceptional development of gills (low oxygen adaptation) and mentioned possible incipient speciation.

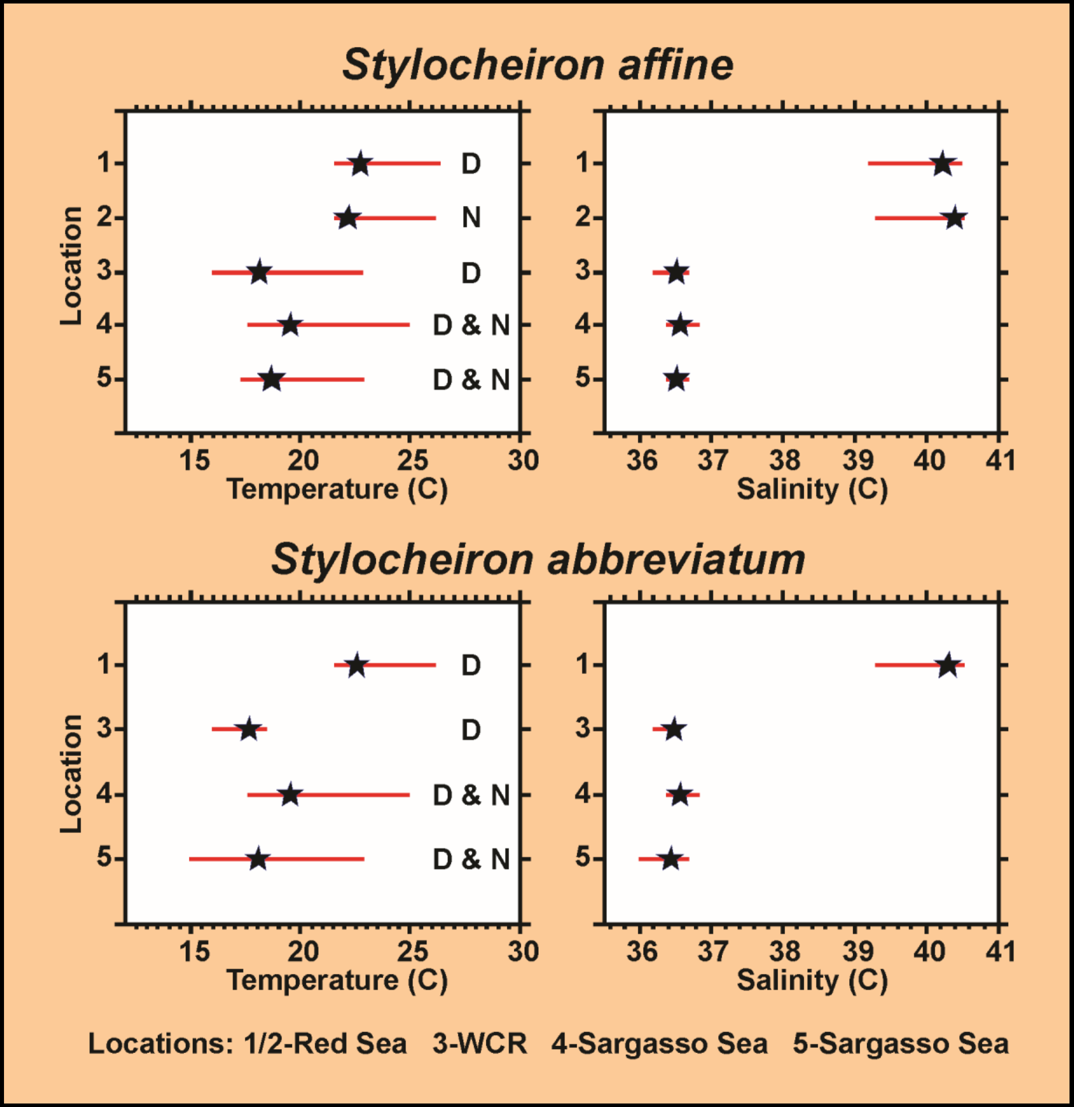
Casanova, B. (1990) Biologie et biogeographie des Euphausiaces de la mer Rouge Relations avec les mers voisines. *Bulletin de l'Institut Oceanographique (Monaco)*, 117-129 No. Special 7. Accession: 037976518

Stylocheiron affine and *S. abbreviatum* North Atlantic vertical distributions.



These two species are non-migrators in the North Atlantic and have centers of distribution below the mixed layer and seasonal thermocline.

The *Stylocheiron* in the Red Sea experienced significantly higher mean temperatures and salinities compared to NW Atlantic Ocean.



The "D", "N", and "D & N" indicate data from day tows, night tows, or both day and night tows averaged together.

Max, min, and average temperature and salinity values for *Stylocheiron affine* and *S. abbreviatum* based on the vertical distribution of the species in the Red Sea and the Northwest Atlantic Ocean (Sargasso Sea).

Averages

	t	s
Saff RS	22.5	40.3
Saff SAR	18.5	36.5
Sabb RS	22.6	40.3
Sabb SAR	18.5	36.5

Summary / Conclusions

Five euphausiid species previously reported from the Red Sea were collected with vertically-stratified sampling during January 2014.

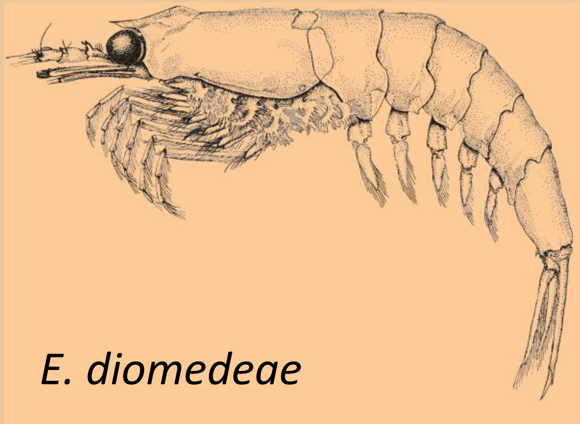
***Euphausia diomedeae*, *E. sanzoi*, and *E. sibogae* exhibited clear patterns of diel vertical migration (DVM) similar to the species populations in other ocean regions .**

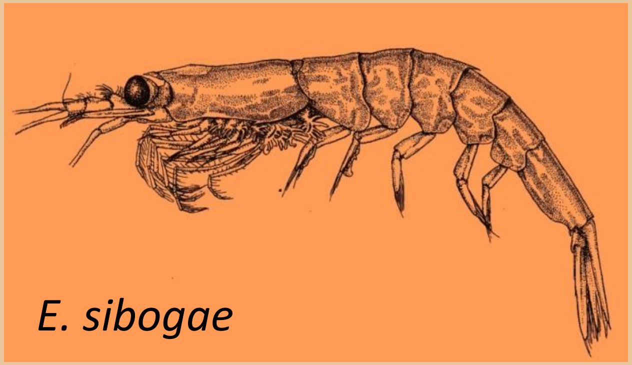
***Stylocheiron abbreviatum* and *S. affine did not migrate and* were found at depth ranges similar to those in other oceans, despite much higher temperatures and salinities, and lower oxygen concentrations.**

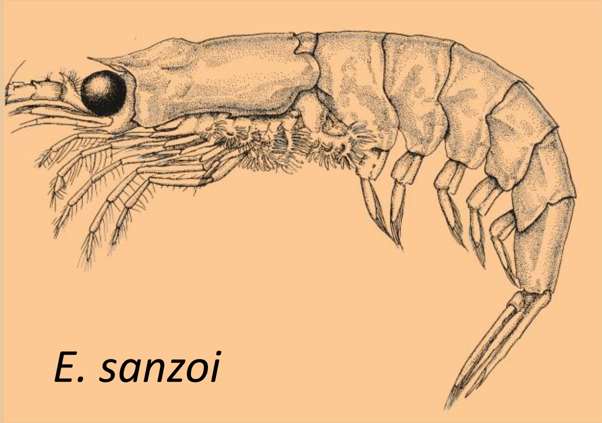
DNA barcodes supported the species identification of four of the five species; *E. sanzoi* not previously barcoded.

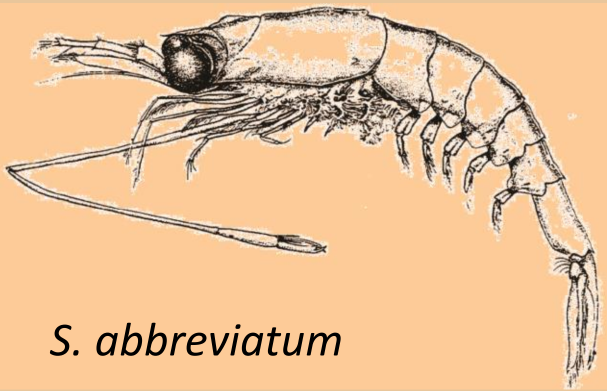
***Stylocheiron affine* in Red Sea differed 14% from Atlantic and Pacific Oceans populations, suggesting cryptic, species-level variation.**

Red Sea euphausiids demonstrated exceptionally broad tolerance ranges for key environmental parameters (temperature, salinity, dissolved oxygen).









Questions?

Wiebe, P.H., Bucklin, A., Kaartvedt, S., Røstad, A., and Blanco-Bercial, L. Vertical distribution and migration of Euphausiid species in the Red Sea. In Press. Journal of Plankton Research.

Images from: Brinton, E., (1975) Euphausiids of Southeast Asian waters. Naga Report, Scientific Results of Marine Investigations of the South China Sea and the Gulf of Thailand. 4(5): 1-287.