The seasonal cycle of zooplankton in the California Current System: a predator's perspective


Photo by D. Robertson

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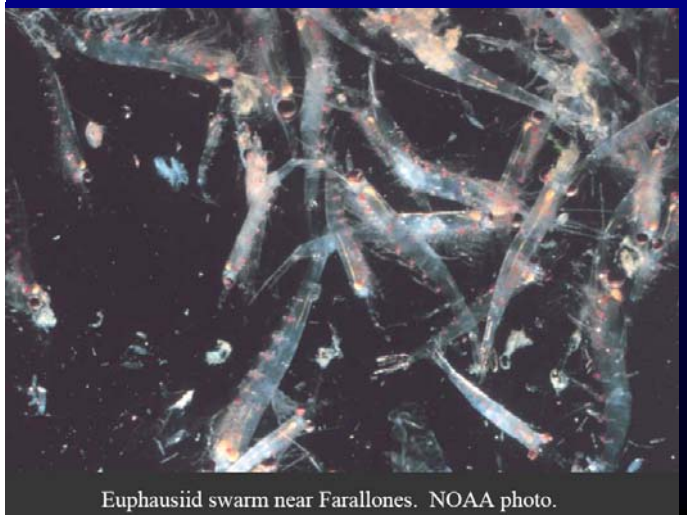
Introduction

- Abundance of euphausiids varies spatially and temporally
- Abundance influenced by local and basin-scale ocean climate conditions (e.g. SST, upwelling)
- Few studies of within-season trends in euphausiid abundance in California Current System (CCS)



Euphausiid swarm near Farallones. NOAA photo.

Objectives:

(1) To examine the seasonal patterns of relative abundance of euphausiid crustaceans in the diet of an upper trophic level marine predator in the central CCS (Gulf of the Farallones)

(2) To describe relationships between relative euphausiid abundance in predator diet and sea-surface temperature (SST), unlagged and lagged up to 4 months prior to collection

Cassin's Auklet

(*Ptychoramphus aleuticus*)

Photo: Donald E. White

- Ranges from Alaska to Baja California
- Preys on meso/macro-zooplankton (primarily euphausiids and/or copepods)
- Forages (via wing-propelled pursuit diving) at depths of 20-40m
- Regurgitate undigested prey to nestlings

Sampling Methodology

- Zooplankton samples taken from auklets provisioning young
- Diet collection started in May and ended in August
- 8-10 samples collected weekly; ~100 samples collected annually
- Analyses of each diet sample included:
  - species identification
  - separation of age classes/developmental stages
  - count of each species
  - total wet and dry mass/species/sample

Characteristics of focal euphausiid prey species

- ***Euphausia pacifica:*** oceanic, young phases coastal, adults to ~2.5cm

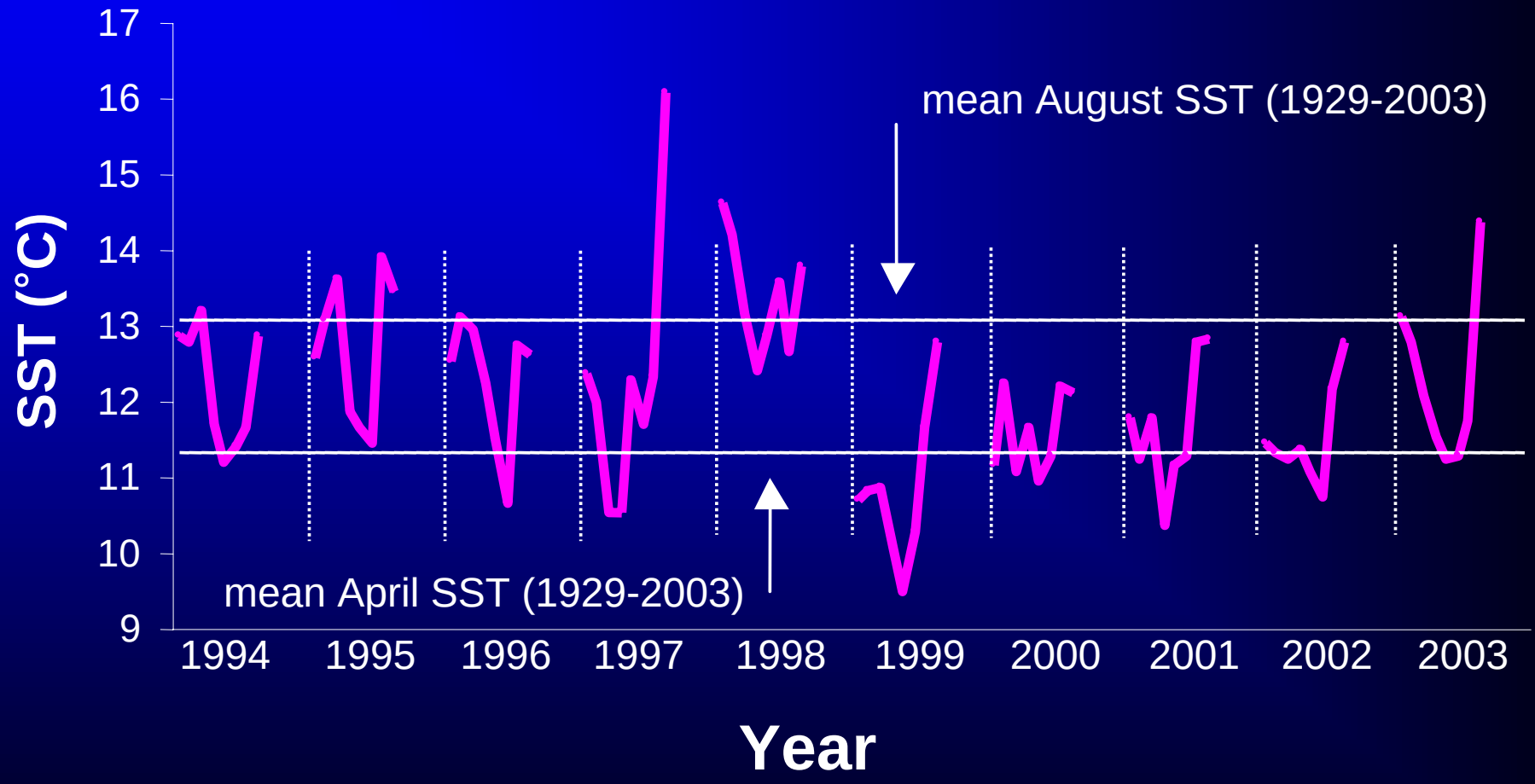
- ***Thysanoessa spinifera:*** coastal, adults to ~3cm

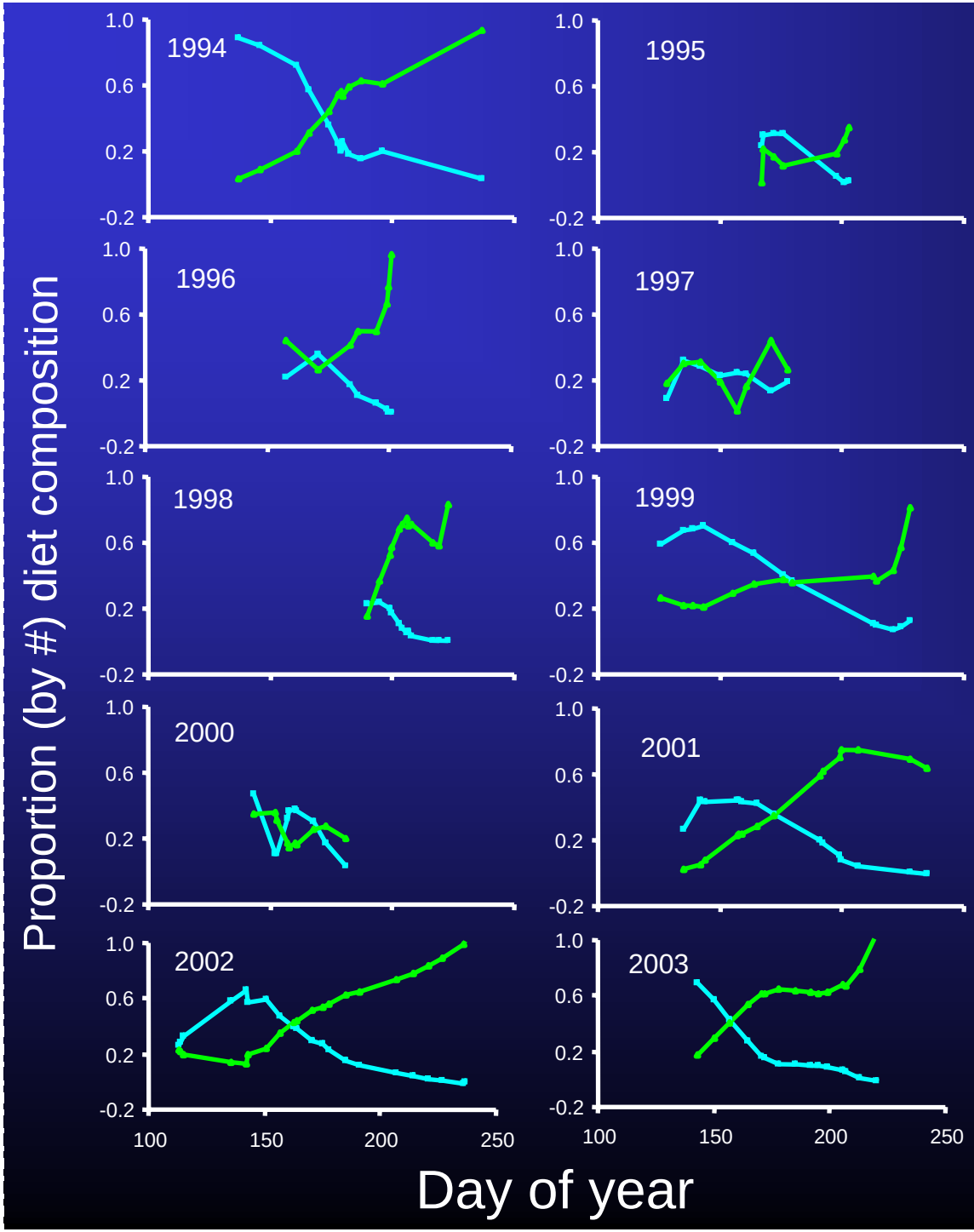
- Species are similar in size and energy density (~5 kcal $g^{-1)}$

- Describing seasonal population characteristics and trends in actual abundance of these euphausiids is difficult due to infrequent vessel-based sampling

Background: bioluminescent euphausiids, Peter Batson

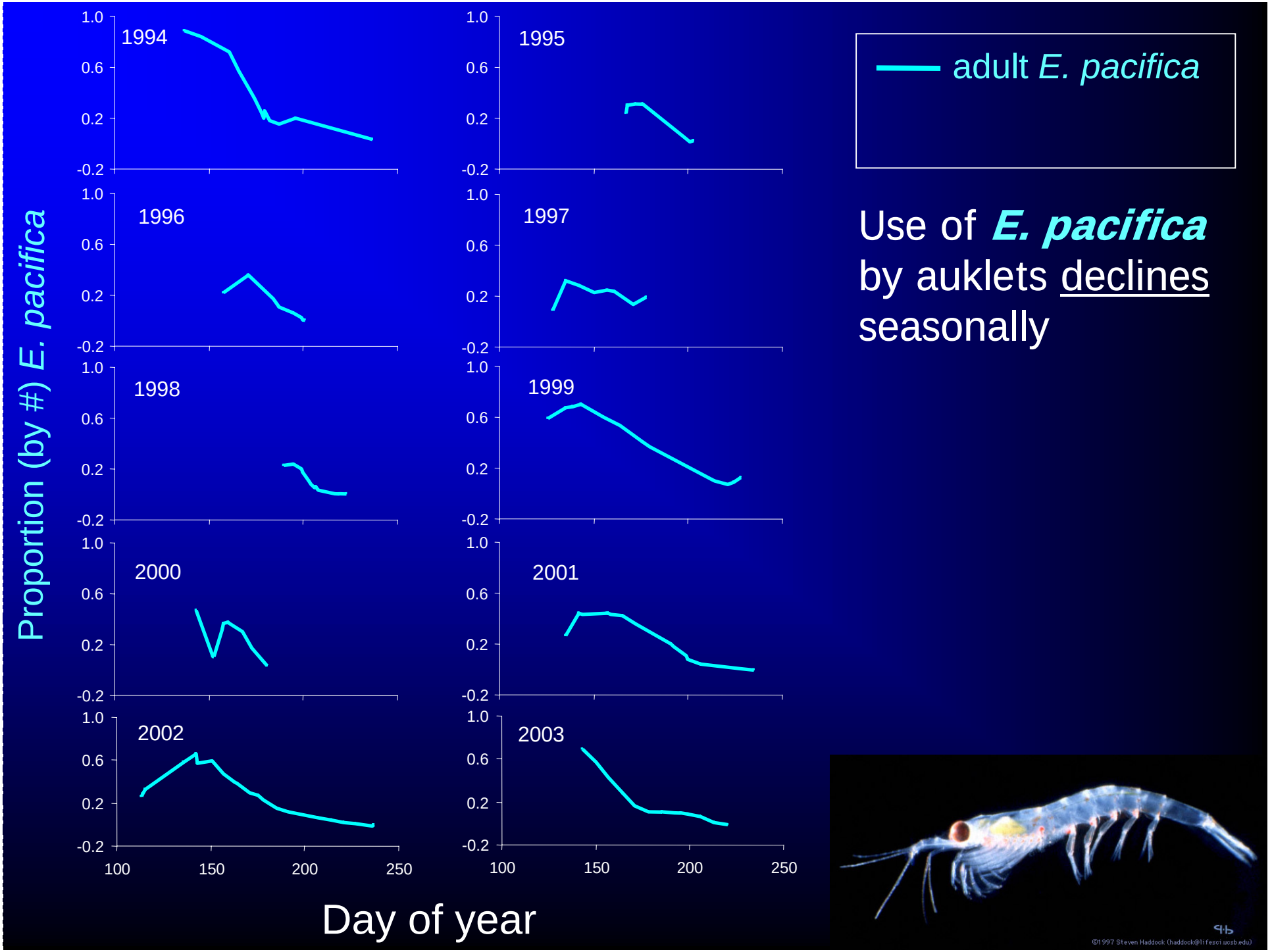
Central CCS: Seasonal (January-August) patterns of SST





Lines represent locally-weighted regressions

Use of ***E. pacifica*** and ***T. spinifera*** by auklets show opposing seasonal trends


Proportion (by #) E. pacifica
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
1.0
0.6
0.2
-0.2
100
150
200
250
Day of year
adult E. pacifica
Use of E. pacifica by auklets declines seasonally
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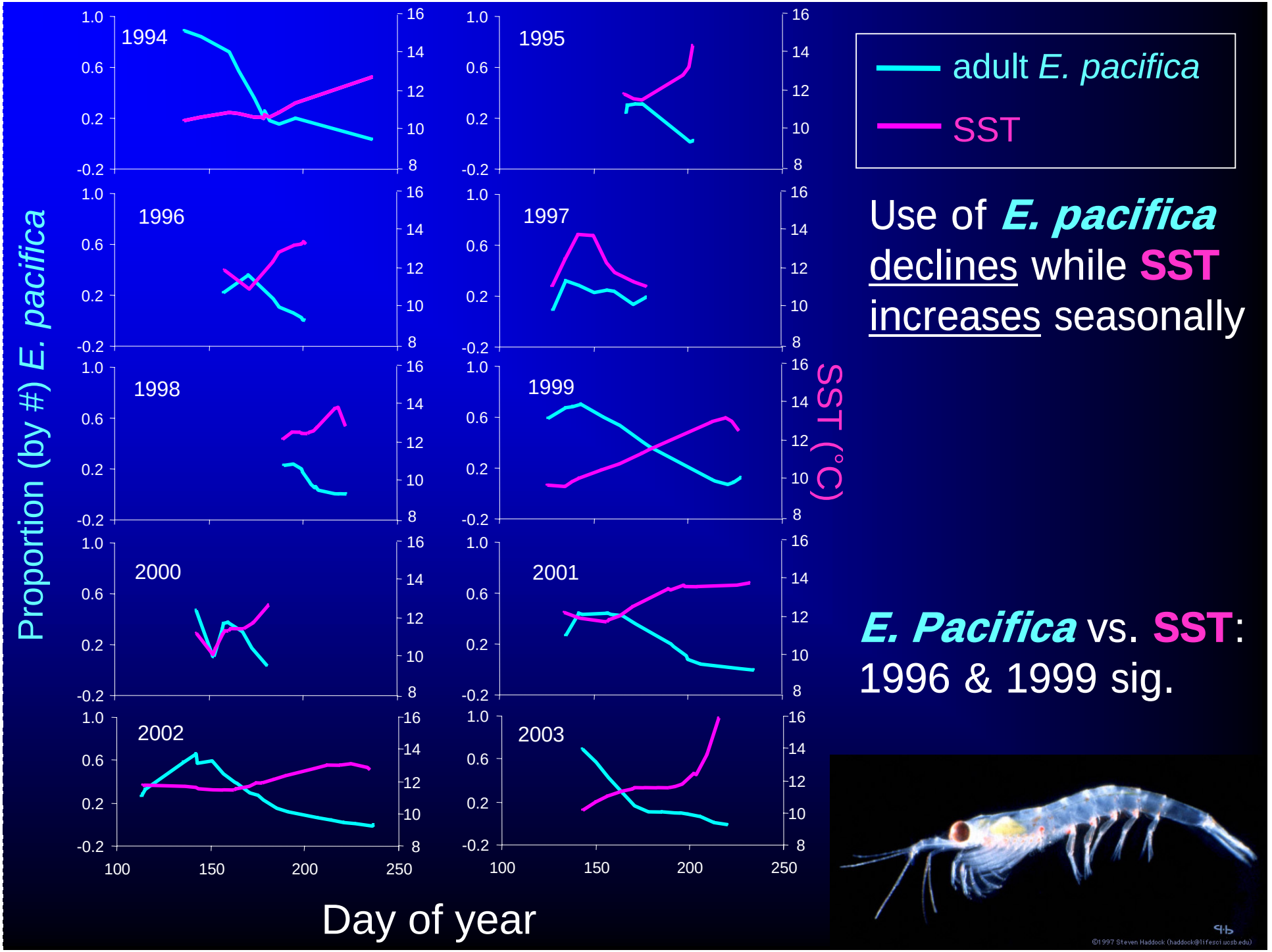
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Proportion (by #) E. pacifica
SST (°C)
Day of year
adult E. pacifica
SST
Use of E. pacifica declines while SST increases seasonally
E. Pacifica vs. SST: 1996 & 1999 sig.
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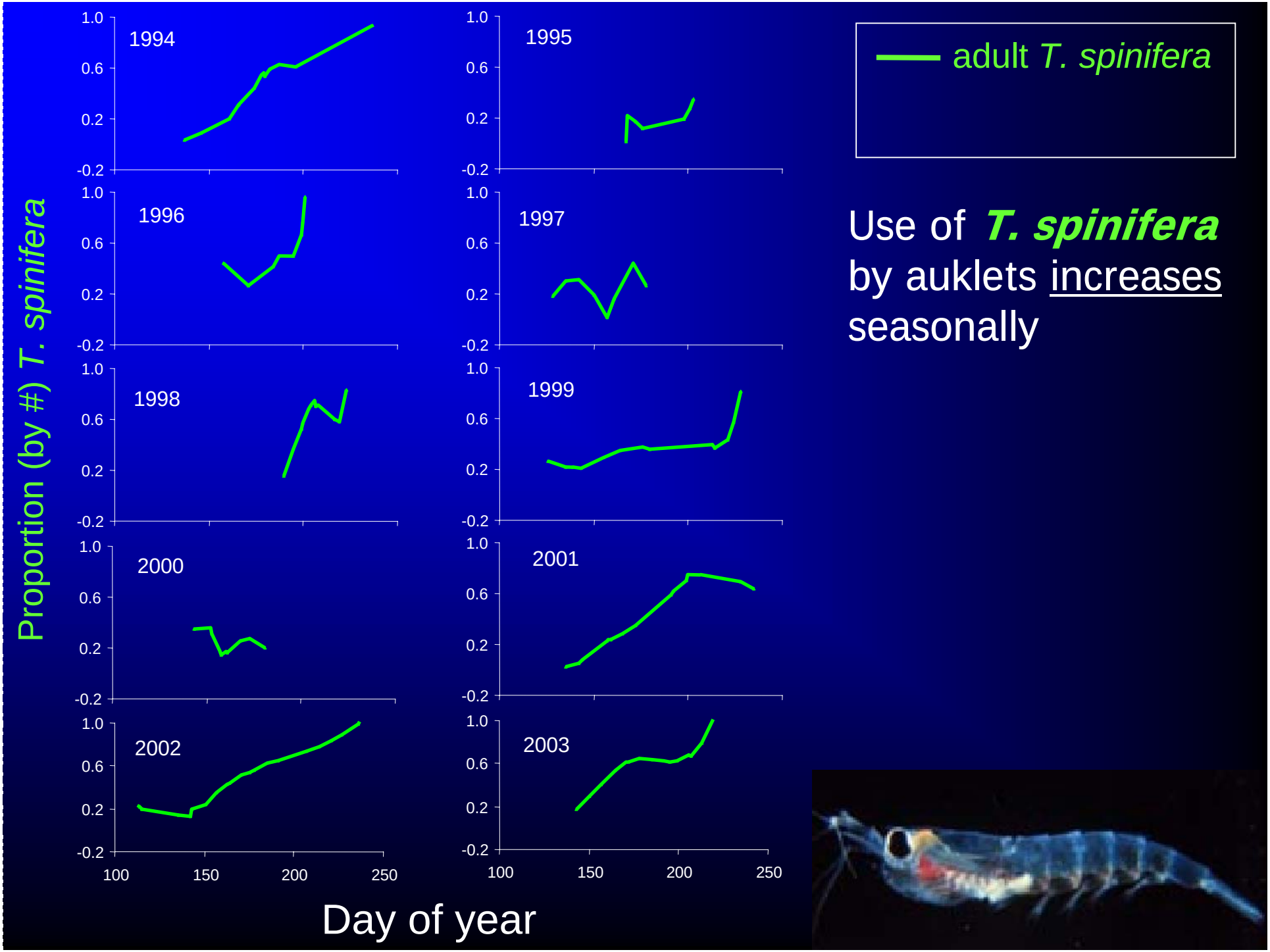
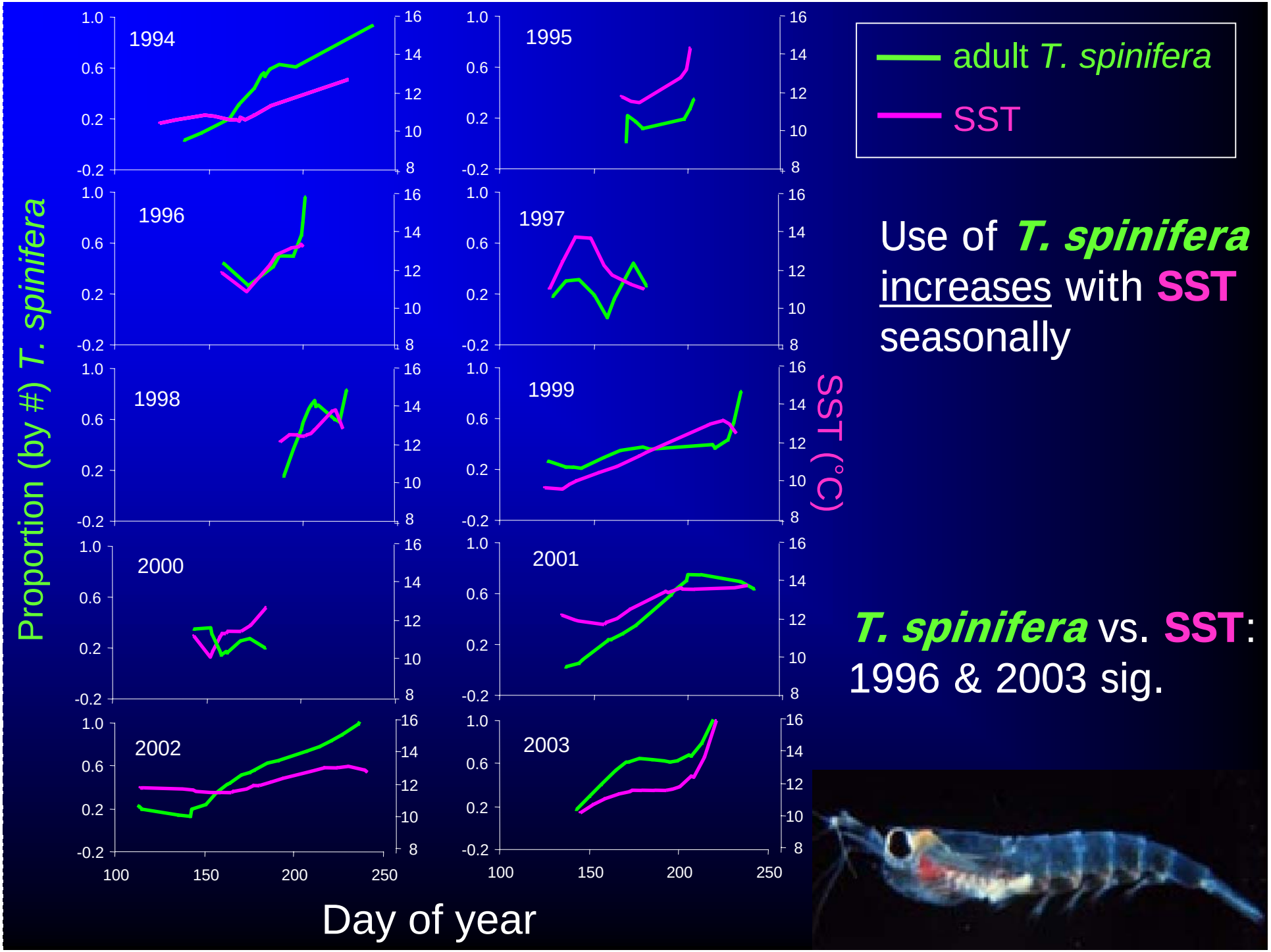

Proportion (by #) T. spinifera
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
1.0
0.6
0.2
-0.2
100
150
200
250
Day of year
adult T. spinifera
Use of T. spinifera by auklets increases seasonally


1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Proportion (by #) T. spinifera
SST (°C)
Day of year
adult T. spinifera
SST
Use of T. spinifera increases with SST seasonally
T. spinifera vs. SST: 1996 & 2003 sig.

Multiple regression for each euphausiid species, effects of SST controlling for DATE, YEAR

Where SST in models was:

1. not lagged (SST on diet collection date)
2. mean of SST 0-30 d prior to collection date
3. mean of SST 30-60 d " "
4. mean of SST 60-90 d " "
5. mean of SST 90-120 d " "

Multiple regression for effects of SST on *E. pacifica*, controlling for DATE, YEAR

SST lag (days)	SST coefficient	SST p-value
none	-0.006	0.806
0-30	-0.025	0.626
30-60	0.075	0.193
60-90	0.200	0.003
90-120	-0.056	0.399

Multiple regression for effects of SST on *T. spinifera*, controlling for DATE, YEAR

SST lag (days)	SST coefficient	SST p-value
none	-0.041	0.263
0-30	-0.053	0.485
30-60	-0.074	0.374
60-90	-0.020	0.842
90-120	0.124	0.203

Summary and Discussion

- In the central CCS, ***E. pacifica*** and ***T. spinifera*** show opposing seasonal trends in use by auklets (***E. pacifica*** ↓ and ***T. spinifera*** ↑)

- Results of multiple regressions:
  - Proportion of ***E. pacifica*** in diet positively related to **SST** 60-90 days prior to collection
  - No significant relationships between proportion of ***T. spinifera*** in diet and **SST**

- Significant correlations between each species and SST in some years, but results of multiple regressions suggest that we can't always use these relationships to determine causal significance

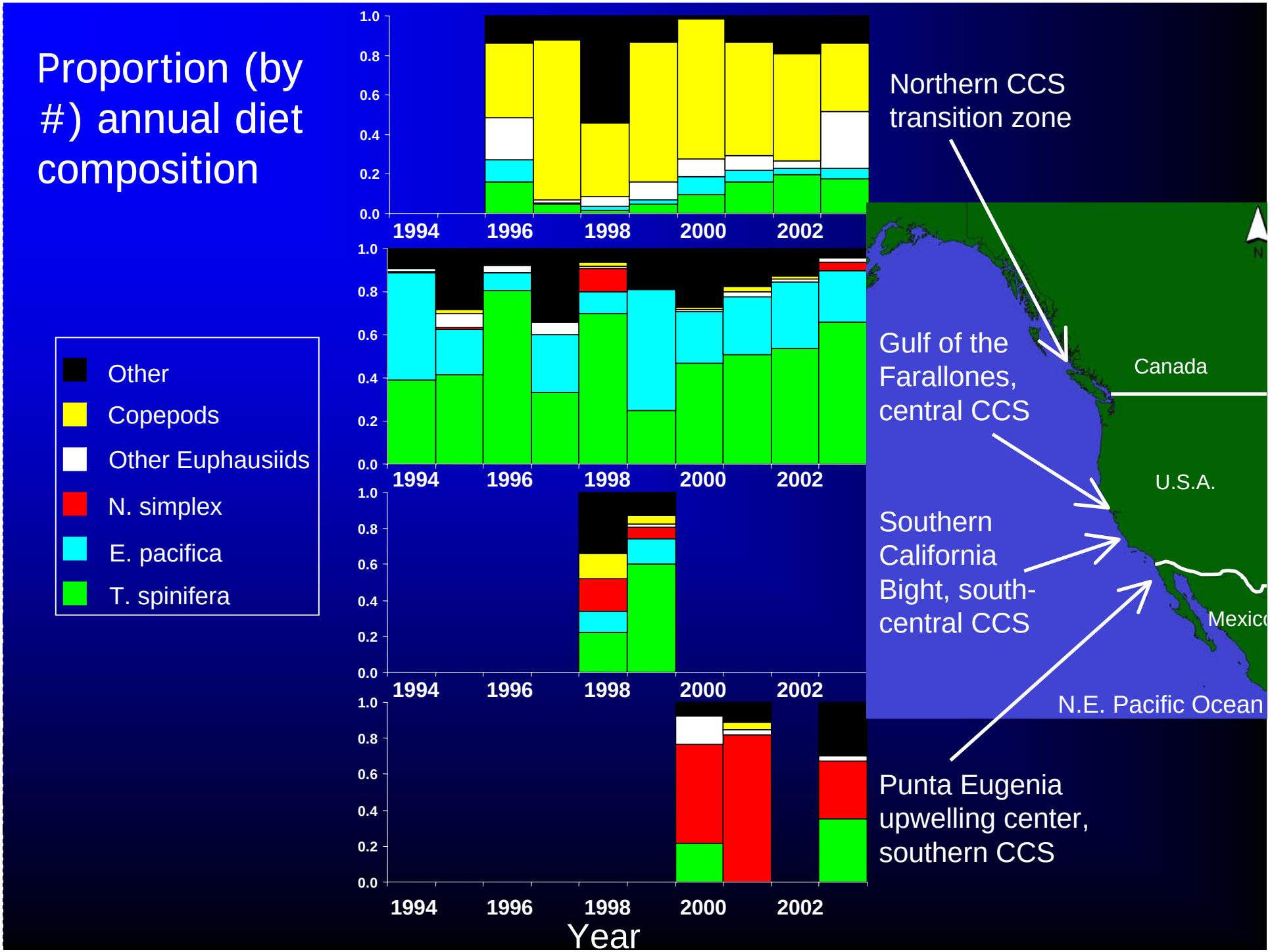
Summary and Discussion

- Use caution when interpreting results

- Auklets may actively prey-switch within seasons, possibly in response to changing energetic requirements and/or nutritional demands, or in response to changes in prey availability or behavior

- Auklets may be unable to access prey >40 meters deep

Proportion (by #) annual diet composition



COPEPODA

Acartia californensis
Acartia danae
Acartia longiremis
Acartia tonsa
Aetidieus divergens
Calanus marshallae
Calanus pacificus
Calanus plumchrus
Caligus chalimus 3
Centropages abdominalis
Centropages bradyi
Clausocalanus furcatus
Clausocalanus lividus
Clausocalanus parapergens
Corycaeus amazonicus
Corycaeus angelicus
Ctenocalanus vanus
Epilabidocera sp
Euacalanus californicus
Mesocalanus tenuicornis v
Metridia pacifica
Neocalanus cristatus v
Neocalanus plumchrus
Paracalanus parvus
Pleuromamma xiphias
Pontellopsis
Pseudocalanus mimus
Pseudocalanus minutus
Rhinocalanus nasatus
Sapphirina
Scolecithricella minor

OSTRACODA

CIRRIPEDIA

Alepas spp.
Lepas spp.

ISOPODA

AMPHIPODA

Brachycelus crusculum
Corophium sp
Hyperia medusarum
Hyperoche medusarum
Lycaea pulex
Oxycephalus clausi
Paraphronima gracilis
Paraphronima gracipes
Phronima sedentaria
Primno abyssalis
Primno brevidens
Streetsia sp
Themisto pacifica
Vibilia armata
Vibilia australia
Vibilia cultripes
Vibilia propinqua
Vibilia wolterecki

EUPHAUSIIDAE

Euphausia pacifica
Euphausia pacifica juveniles
Euphausiid protozoea
Euphausiid zoea
Euphausiid nauplii
Nematoscelis difficilis
Nyctiphanes simplex
Nyctiphanes simplex juveniles
Thysanoessa gregaria
Thysanoessa gregaria juveniles
Thysanoessa inspinata
Thysanoessa inspinata juveniles
Thysanoessa longipes
Thysanoessa spinifera
Thysanoessa spinifera immature
Thysanoessa spinifera juveniles

STOMATOPODA

Stomatopodan mysis

MYSIDAE

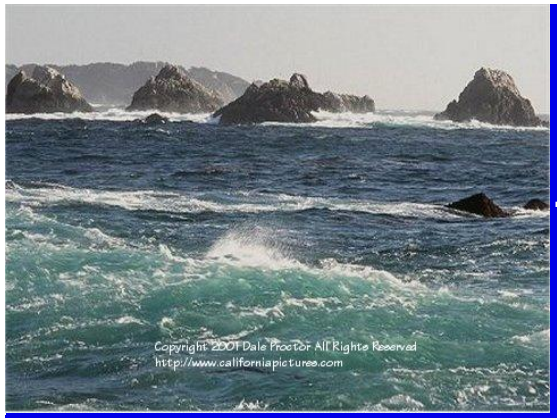
Acanthomysis columbiae
Alienacanthomysis
Columbiaemysis ignota
Holmesimysis sculpta juveniles
Holmesimysis sculpta

DECAPODA

Anomuran zoea
Bentheogennema burkenroadi
Brachyuran megalops
Brachyuran zoea
Cancer magister megalops
Cancer megalops
Cancer productus megalops
Caridea mysis
Emerita analoga
Eualid mysis
Galatheidae zoea
Galatheidae megalops
Hemigraspus megalops
Lysmata mysis
Majidae megalops
Munida
Pagurid megalops
Pagurid zoea
Pandalid mysis
Pandalus jordani
Pandalus stenolepis
Pandalopsis dispar
Panulirus interruptus
Penaeoidea mysis
Pinnixa megalops
Pinnotherid megalops
Telimessis megalops

Data for all latitudes combined includes:

- 9 taxonomic groups within Crustacea
- 67 genera
- 66 species
- developmental stage for some species



Ocean climate

Zooplankton

Marine predator

- Spatial and temporal prey distribution and abundance must be considered
- Seabird foraging strategy and response to ecosystem fluctuations may vary differently within and between years/decades
- We are deploying seasonal hydroacoustic surveys of the auklet prey base in the central CCS to further elucidate these relationships

Acknowledgments

- USFWS/Farallon National Wildlife Refuge
- Dave Mackas, Moira Galbraith (DFO Canada)
- Laura Tranquila (SFU)
- Julie Thayer, Nadav Nur (PRBO)