

Interdecadal variability in predator–prey interactions of juvenile North Pacific albacore in the California Current System

Sarah M. Glaser

Integrative Oceanography Division, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California 92093-0218, USA

Present address: Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, Kansas 66047, USA

Email: sglaser@ucsd.edu

Marine Ecology Progress Series 414:209–221 (2010)

Supplement. Variability in prey energy density values

Variability in intra- and interspecies energy density (*ED*) (kJ g^{-1}) was assessed from values reported in the literature (Table S1). Taxonomic aggregation was based on species categories used in data analysis, and represent those categories that occurred in 10 or more stomachs in any of the 4 studies (McHugh 1952, Iversen 1962, Pinkas et al. 1971, this study). For many prey consumed by juvenile albacore, species-specific energetic values were available. For others, closely related or ecologically similar species were used. Furthermore, the taxonomic resolution of diet categories often necessitated aggregation of species *ED* values. For crustaceans, mean and standard deviation (SD) was available for *Pleuroncodes planipes*; otherwise, values were reported as taxonomic aggregations (amphipods and euphausiids) and values for the 'Crustaceans (other)' category were calculated from 25 species of decapods and mysids. In the case of cephalopods, values came from 4 species that are consumed by albacore, 3 species in the same family as species consumed by albacore, and 2 values that have been reported for

the categories Octopoda and Decapoda, generally. The SD was calculated for cephalopods using these 9 values, some of which were themselves means.

Finally, for fishes, values were available for most species, unless otherwise noted in Table S1. The SD used for all categories of fishes was based on data from Tirelli et al. (2006) because they calculated variability for juvenile fishes (the greatest degree of intraspecies variability in *ED* occurs in adults during spawning). They found low SDs (8% of the mean) for *Engraulis encrasicolus* ranging from 40 to 59 mm in length, the size range of fish prey found in juvenile albacore diet. Therefore, similarly low levels of *ED* variability for the other juvenile fish species were used in this study. Values for *Vinciguerria lucetia* were unavailable; instead, the mean value calculated for 5 categories of Myctophidae was used, because the similarities between ecological niches (vertically migrating mesopelagic fishes) suggest similar body chemistry. The SD for the category 'Fishes (other)' is the SD of the values collected from the literature for all fishes.

Table S1. Energy density values used to calculate distributions for parameters in an albacore bioenergetics model

Species category	Mean ED	ED values from literature (letters refer to citations)	Notes on means	SD	Notes on SDs
Amphipods	2.5	2.5 ^c		0.9	Literature
<i>Pleuroncodes planipes</i>	3	2.09 ^a , 3.93 ^b		1.3	2 studies
Euphausiids	3.1	3.1 ^c		1.1	Literature
Malacostracans	3.2	3.2 ^d	Mean of 25 species decapods and mysids	1.1	Literature
Cephalopods	4.4	3 ^a , 6.72 ^e , 3.51 ^a , 5.64 ^f , 3.29 ^a , 3.85 ^g , 3.8 ^g , 4.69 ^g , 5.4 ^g	Octopoda, <i>Gonatus fabricii</i> , <i>Loligo opalescens</i> , <i>Moroteuthis ingens</i> , Decapoda, <i>Berryteuthis magister</i> , <i>Berryteuthis</i> sp., <i>Gonatopsis borealis</i> , <i>Onychoteuthis borealijaponica</i>	0.47	Mean of 9 categories of cephalopods
<i>Cololabis saira</i>	7.5	7.92 ^a , 7.0 ^j		1.04	8 % of mean
<i>Engraulis mordax</i>	6.6	6.7 ^a		0.54	8 % of mean
<i>Sardinops sagax</i>	7.3	8.6 ⁿ , 7.4 ^b , 5.9 ^o		0.58	8 % of mean
<i>Sebastes</i> spp.	4.2	3.75 ^a , 3.95 ^a , 4.39 ^a , 3.87 ^a , 3.99 ^a , 4.37 ^a , 4.79 ^a , 4.43 ^a , 3.7 ^a , 5.12 ⁱ , 3.95 ^a , 4.18 ^a , 3.75 ^a , 3.21 ^a , 3.95 ^a , 5.21 ^e , 4.65 ^a	<i>Sebastes alascanus</i> , <i>S. aleutianus</i> , <i>S. crameri</i> , <i>S. elongatus</i> , <i>S. flavidus</i> , <i>S. inermis</i> , <i>S. iracundus</i> , <i>S. matsubarae</i> , <i>S. melanops</i> , <i>S. oculatus</i> , <i>S. paucispinus</i> , <i>S. pinniger</i> , <i>S. rosaceus</i> , <i>S. ruberrimus</i> , <i>S. rubrivinctus</i> , <i>S. spp.</i> , <i>S. goodei</i>	0.34	8 % of mean
<i>Merluccius productus</i>	5.9	5.9 ⁱ	Regression equation: mean ED calculated from hake size-frequency in this diet study	1.3	8 % of mean
<i>Trachurus symmetricus</i>	6.4	6.4 ^h	Value for <i>Trachurus japonicus</i>	0.51	8 % of mean
Myctophidae	7.1	9.8 ^a , 7.6 ^k , 7.6 ^l , 7.3 ^l , 3.5 ^a	<i>Diaphus theta</i> , Lanternfish, <i>Stenobrachius leucopsaurus</i> , <i>Triphoturus mexicanus</i> , <i>Tarletonbeania crenularis</i>	0.57	8 % of mean
Paralepididae	7.1	7.1	Value for Myctophidae	0.57	8 % of mean
<i>Vinciguerria lucetia</i>	5.2	5.2 ^m		0.42	8 % of mean
Fishes (other)		6.6	Mean value of all 9 fish categories here	0.6	Mean of 9 categories of fishes

Citations: ^aSidwell (1981), ^bAbitia-Cardenas et al. (1997), ^cDavis et al. (1998), ^dDonnelly et al. (1993), ^eLawson et al. (1998), ^fEder & Lewis (2005), ^gPerez (1994), ^hOsako et al. (2002), ⁱRiis-Vestergaard et al. (2000), ^jHunt et al. (2000), ^kPayne et al. (1999), ^lChildress & Nygaard (1974), ^mPeterson (1979), ⁿBunce (2001), ^oChildress et al. (1980)

LITERATURE CITED

- Abitia-Cardenas LA, Galvan-Magana F, Rodriguez-Romero J (1997) Food habits and energy values of prey of striped marlin, *Tetrapturus audax*, off the coast of Mexico. Fish Bull 95:360–368
- Bunce A (2001) Prey consumption of Australasian gannets (*Morus serrator*) breeding in Port Phillip Bay, southeast Australia, and potential overlap with commercial fisheries. ICES J Mar Sci 58:904–915
- Childress JJ, Nygaard MH (1974) The chemical composition of midwater fishes as a function of depth of occurrence off Southern California. Deep-Sea Res 20:1093–1109
- Childress JJ, Taylor SM, Cailliet GM, Price MH (1980) Patterns of growth, energy utilization and reproduction in some meso- and bathypelagic fishes off Southern California. Mar Biol 61:27–40
- Davis ND, Myers KW, Ishida Y (1998) Caloric value of high-seas salmon prey organisms and simulated salmon ocean growth and prey consumption. Annu Rep North Pac Anadromous Fish Comm 1:146–162
- Donnelly J, Stickney DG, Torres JJ (1993) Proximate and elemental composition and energy content of mesopelagic crustaceans from the Eastern Gulf of Mexico. Mar Biol 115:469–480
- Eder EB, Lewis MN (2005) Proximate composition and energetic value of demersal and pelagic prey species from the SW Atlantic Ocean. Mar Ecol Prog Ser 291:43–52
- Hunt GL, Jr, Kato H, McKinnell SM (2000) Predation by marine birds and mammals in the subarctic North Pacific Ocean. PICES Scientific Report, 14
- Iversen RTB (1962) Food of albacore tuna, *Thunnus germo* (Lacepede), in the central and northeastern Pacific. Fish Bull 62:459–481
- Lawson JW, Magalhaes AM, Miller EH (1998) Important prey species of marine vertebrate predators in the northwest Atlantic: proximate composition and energy density. Mar Ecol Prog Ser 164:13–20
- McHugh JL (1952) The food of albacore (*Germo alalunga*) off California and Baja California. Bull Scripps Inst Oceanogr 6:161–172
- Osako K, Yamaguchi A, Kurokawa T, Kuwahara K, Saito H, Nozaki Y (2002) Chemical components and body color of horse mackerel caught in different areas. Fish Sci 68: 587–594
- Payne SA, Johnson BA, Otto RS (1999) Proximate composition of some North-Eastern Pacific forage fish species. Fish Oceanogr 8:159–177
- Perez MA (1994) Calorimetry measurements of energy value of some Alaskan fishes and squids. Report No. NTIS No. PB94-152907
- Peterson C (1979) Annual report of the Inter-American Tropical Tuna Commission, 1978. La Jolla, CA
- Pinkas L, Oliphant MS, Iverson ILK (1971) Food habits of albacore, bluefin tuna, and bonito in California waters. Fish Bull 152:2–83
- Riis-Vestergaard J, Velasco F, Hill L, Olaso I (2000) Food consumption of European hake (*Merluccius merluccius*) estimated by application of a bioenergetics model: Is the growth of hake underestimated? ICES theme session Q on trophic dynamics of top predators: foraging strategies and requirements, and consumption models.
- Sidwell VD (1981) Chemical and nutritional composition of finfishes, whales, crustaceans, mollusks, and their products. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Seattle, Washington
- Tirelli V, Borme D, Tulli F, Cigar M, Umani SF, Brandt SB (2006) Energy density of anchovy *Engraulis encrasicolus* L. in the Adriatic Sea. J Fish Biol 68:982–989