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June 1982

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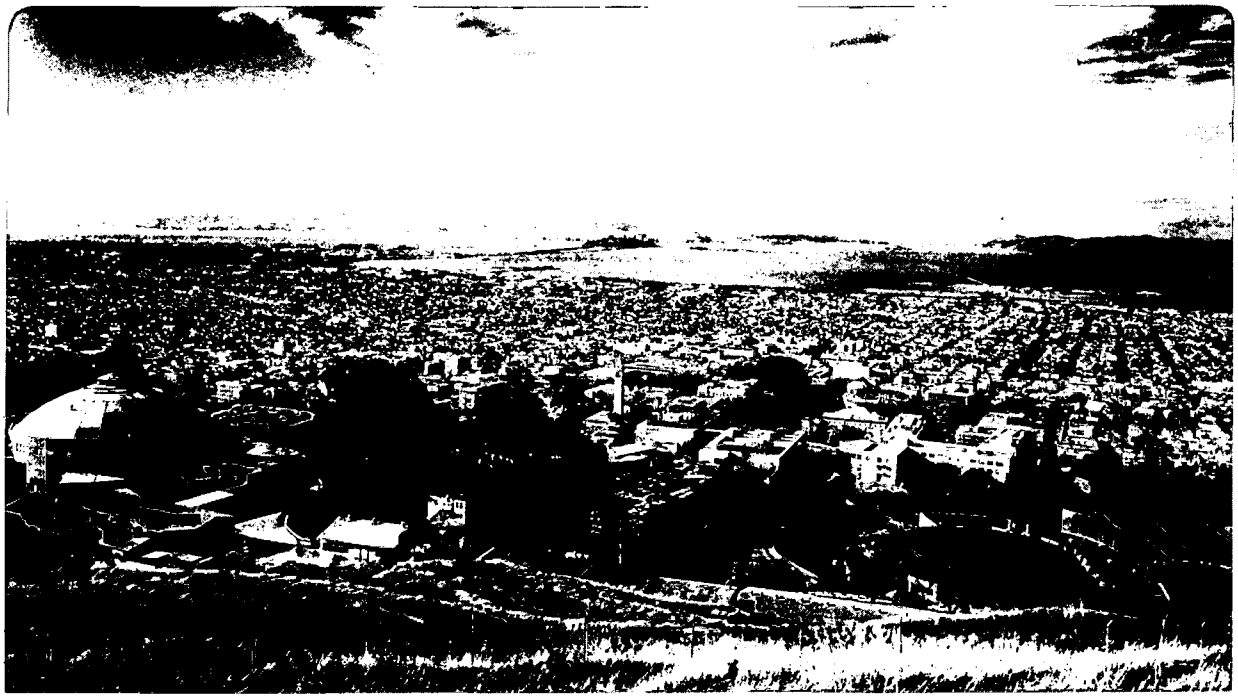

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The Trophic Position of Copepods within the Marine Ecosystem and their Importance to OTEC Operations

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June 1982

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INTRODUCTION

In the marine environment, copepods form the major link in the food chain between plants and the fishes. Coastal waters contain other abundant phytoplankton-grazing organisms (i.e., planktonic stages of bottom living echinoderms, mollusca, decapoda and worms), however, in the seas copepods dominate this group. Marine plankton collections are usually dominated by copepods. They have been found to numerically constitute from 25% to 96% of the total net zooplankton (Wickstead, 1959; Deevey and Brooks, 1977; Hopkins, Bennett and Shuert, 1979; Steen and Gunter, 1980).

Marine copepods, particularly within the low latitudes, are small, rarely exceeding 10 mm in length and generally less than 1 mm. For this reason a knowledge of their feeding habits and the kind and amount of food that they require has been most difficult to detect. Early knowledge on the nutrition of copepods came from gut content studies which usually reflected the composition of the microplankton in the sea at the time. Later work involved the laboratory culture of copepods which led to accurate measurements of food ingested throughout the life cycle. Methods of measuring both feeding and respiration rates have also been improved in recent years. These studies tend to support the theory that oceanic copepods are feeding generalists, with most species feeding on a wide range of sizes and types of food organisms. Both grazers and carnivores appear to take advantage of the most prevalent food source.

In oligotrophic waters of tropical oceans the wide diversity of copepods that appear to be feeding on the same spectrum of food cannot support the theory of niche separation based on the availability of food. Recent speculation on the pressure for resource partitioning and competition for food among copepods is greatly reduced by the effects of heavy predation by other zooplankton and micronekton predators.

In this report we review the body of knowledge on the feeding strategies and diets of copepods, especially those species that frequently occur in tropical and subtropical oceans in regions potentially capable of supporting Ocean Thermal Energy Conversion (OTEC) operations. Conditions that cause mortality among individuals within naturally occurring populations are also addressed. Since copepods are a vital link in the marine food chain the changes that occur in a natural marine copepod population within the area of OTEC operations should assist in determining the overall effect of OTEC on the marine ecosystem.

FEEDING MECHANISMS AMONG COPEPODS

Attempts have been made to categorize copepod feeding strategies according to the structure of feeding and swimming appendages. Anraku and Omori (1963) found that the setation on the copepod second antenna, maxillae and maxilliped along with the dentation on the mandible determines, to a large part, the capabilities that a copepod has in capturing and ingesting different types and sizes of food particles. Other investigators have determined that the distances between setae on the feeding appendages of copepods control the size range of particles that the individual copepod is capable of filtering (Gauld 1964, 1966;

Vyshkvartseva and Guntel'Makher, 1971; Wilson, 1973; Steel and Frost, 1977). Scanning electron migrographs have supported the theories concerning morphological feeding specialization among copepod species (Sullivan, Miller, Peterson, and Soeldner 1975; Nival and Nival, 1978). Grazing copepods generally have maxillae and maxillipeds with numerous long setae that are formed into a "net or scoop", mandibles with many rounded teeth, and swimming appendages that produce strong feeding currents from which food particles are filtered. Carnivorous copepods have feeding appendages with a reduced number of stout setae and a mandible with sharp pointed teeth on the denticulate cutting edge. They are generally capable of strong rapid swimming over relatively short distances. Gauld (1966) has attempted to show possible evolutionary trends within the copepods based on the setal development of feeding appendages. Marshall (1973) has shown in reviewing the literature that there is a definite relationship between the food gathering capacities of calanoid copepod feeding appendages and swimming abilities. Anraku (1963) distinguishes three kinds of feeding mechanisms; filter feeding, encounter feeding and active hunting. It is also recognized that some species incorporate more than one of these mechanisms in their feeding strategy.

COPEPOD FOOD AND ITS DIRECT INFLUENCE ON FEEDING

Diatoms and flagellates are most often the major components within the guts of pelagic calanoid copepods (Marshall and Orr, 1962; Marshall, 1973), however, heterotrophic microorganisms and other crustaceans make up the bulk of the food for deep-sea copepods (Vinogradov, 1962; Harding,

1974; Alvarez and Matthews, 1975). Food preferences, particle selection and ingestion rates are best known for copepods from the genus Calanus (Fuller, 1937; Marshall and Orr, 1955, 1956; Cowey and Corner, 1963; Mullin, 1963; Paffenhöfer, 1970, 1971, 1976a, 1976b; Mullin and Brooks, 1970; Corner, Head and Kilvington, 1972; Frost, 1972a, 1975, 1977; Vidal, 1980a, 1980b, 1980c, 1980d). Although much of the understanding concerning copepod nutrition has been gained from work on temperate and boreal copepod species, investigations concerning the more tropical copepod genus Eucalanus show that factors controlling the feeding process are common among all copepod species (Paffenhöfer and Knowles, 1978b, 1979). A review of the food organisms eaten by tropical and subtropical copepods is given in Table 1.

Mullin (1963) showed that the grazing rates of 4 species of Calanus varied inversely with phytoplankton concentration, and that these calanoids generally removed large cells at a higher rate than small cells when feeding on mixed phytoplankton. Poulet (1978) found that copepods act as opportunistic particle feeders, by being able to shift their grazing pressure from one size to another. No species behaved as a selective grazer with respect to particle size. Paffenhöfer and Knowles (1980) observed that certain calanoid copepods effectively function as omnivores, being able to shift from a more passive particle grazer to a more active carnivorous predator. They suggest that omnivorousness is inherent in most calanoid and possibly many cyclopoid copepod species.

Beers and Stewart (1969) found that the density of marine microzooplankton (<202 μm) was from 10 to 30% of the larger zooplankton density and from 14 to 34% of that of the phytoplankton crop. Oceanic

Table 1. Nutritional information on copepods frequently occurring in tropical and subtropical marine waters.

COPEPOD	FOOD	SIZE RANGE	SOURCE
Acartia clausii	Flagellates and diatoms	<10 μm >10 μm	Marshall and Orr, 1962
	Skeletonema costatum, *Phaeodactylum tricornutum*, *Dunaliella* sp., *Asterionella japonica*, *Lauderia borealis*, *Ditylum brightwellii* and *Artemia* sp. nauplius		Gaudy, 1974
	Tetraselmis succica		Person-le Ruyet, 1975
	Isochrysis galbana, *Dunaliella tertiolecta* and *Peridinium trochiodeum*	4 μm 8-10 μm 10-12 μm	Landry, 1975
	Skeletonema costatum, *Phaedactylum tricornutum*, *Nannochloris oculata* and *Isochrysis* sp.	3-7 μm	Nival and Nival, 1976
	Thalassiosira gravida and *T. nordenskioldii*		O'Connors *et al*., 1976
	Gyrodinium fissum	44x30.6 μm	Piontkovskii and Petipa, 1976
nauplii and copepodids	natural particles	3-19 μm	Allan *et al*., 1977
	naturally occurring algae	4.5-45.3 μm mean diameter	Hargis, 1977

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
	natural phytoplankton, *Skeletonema costatum* and *Procentrum minimum*	16-22 μm	
	Thallasiosira nana, *Colycomonas ovalis*, *Onchromonas nannos*, *Amphidinium* sp. and *Chromonas diplococca*	5-12 μm	Richmond, *et al.*, 1977
	coccolithophores	10 μm	
	Emiliania husley, *Cruciplacotithus neohelis*, *Nitzchia closterium* and *Coscinodiscus* sp.	5-50 μm	Honjo and Roman, 1978
	Exuviella baltica and *Nitzschia closterium*		Moraitou and Verriopoulous, 1978
	Peridinium trochiodeum		Pechen-Finenko, *et al.*, 1978a
	Chaetoceros pseudocurvisetus, *Amphidinium klebsii*, *Procentrum micans* and *Isochrysis galbana*		Tomasini and Mazza, 1978
	Thalassiosira nordenskioldii	8 μm diameter (2-cell chain)	
	T. gravida	30 μm diameter (1-5 cell chain)	Donaghay and Small, 1979a

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
	T. pseudonana and *T. fluviatilis*	8 μm diameter 20 μm diameter	Donaghay and Small, 1979b
A. longiremis (1.16 mm)	immature chaetognath	2.6 mm	Davis, 1977
A. negligens	coral mucus		Richman, *et al.*, 1975
A. tonsa	diatoms	>10 μm	Marshall and Orr, 1962
	Chaetocerous sp., *Chamydomonas reinhardti* and *Isochrysis galbana*		Heinle, 1969
	flagellates	1-10 μm	Hargrave and Geen, 1970
	plastic beads	7-70 μm	Wilson, 1973
	detritus and phytoplankton	5-25 μm	Gerber and Marshall, 1974b
	Skeletonema costatum		Mullin and Evans, 1974
	Gymnodinium lanskaja *Procentrum micans* and *Streptotheca thamensis*	8.8-11.6 μm 30-38 μm 54.6-64.6 μm	Kukina, 1975
nauplii	natural particles	3-19 μm	
copepodids	natural particles	in range of biomass peaks	Allan, *et al.*, 1977
	Gonyaulax tamarensis		Dagg, 1977

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
	Phaeodactylum tricornutum, *Dunaliella* and *Skeletonema* sp.		Reeve and Walter, 1977
	Skeletonema costatum, *Procentrum minimum*, *Thallasiosira nana*, *Colycomonas ovalis*, *Ochromonas nannus*, *Amphidinium* sp. and *Chroomonas diplococca*	5-22 µm	Richman, *et al.*, 1977
	Nitzschia closterium	4-6 µm	
	Fucus vesiculosus detritus	10-24 µm	Roman, 1977
	coccolithophores	10 µm	
	Emiliania huxley, *Cruciplacothithus neohelis*, *Nitzchia closterium* and *Coscinodiscus* sp.	6-50 µm	Honjo and Roman, 1978
	Gonaulax excarvata		White, 1979
Anomalocera patersoni	natural occurring algae and *Artemia* sp. nauplii		Fernández, 1977
Centropages hamatus	*Skeletonema costatum* and *Chlamydomonas* sp.		Gauld, 1951
	flagellates	<10 µm	
	flagellates	>10 µm	
	diatoms	>10 µm	Marshall and Orr, 1962

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
	Tetraselmis suecica		Person-le Ruyet, 1975
	natural phytoplankton	<76 μm	Smith and Hall, 1980
Centropages typicus	*Skeletonema costatum*, *Phaeodactylum tricornutum*, *Lauderia borealis* and *Artemia* sp. nauplius		Gaudy, 1974
	Tetraselmis suecica		Person-le Ruyet, 1975
	Gonyaulax tamarensis		Dagg, 1977, 1978
	Chaetoceros pseudocurvisetus, *Amphidinium klebsii*, *Procentrum micans* and *Isochrysis galbana*		Tomasini and Mazza, 1978, 1979
	natural phytoplankton	<76 μm	Smith and Hall, 1980
Chiridius armatus females	*Dunaliella* sp., mixed microzooplankton and *Chiridius* sp. copepodids	<75 μm	Alvarez and Matthews, 1975
Chirundina indica	microcrustaceans, silicoflagellates, *Artemia* sp. (stage V), *Thalassiosira fluritalis* and *Cyclotella nana*		Mullin, 1966
Clausocalanus arcuicornis	algae and *Artemia salina* (nauplii)		Fernádez, 1977

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
Eucalanus attenuatus	diatoms, radiolarians, silicoflagellates, dinoflagellates, coccolithophorids, microcrustaceans, and foraminiferans		Mullin, 1966
Eucalanus elongatus	*Gymodinium lanskaja*	8.8-11.6 µm	
	Gyrodinium fissum	12.2-36.5 µm	
	Streptotheca thamensis	54.6-64.4 µm	
	Coscinodiscus sp.	29.4-65.8 µm	
	Stephanopixis palmeriana	82.6-84.0 µm	
	Thalassionema bacillaris	12.6-89.6 µm	
	Coscinodiscus sp.	154.0-154.6 µm	
	Rhizosolenia castracanci	93.8-536.7 µm	Kukina, 1975
Eucalanus pileatus			
nauplius III	*Skeletonema costatum*, *Leptocylindrus*		
	Rhizosdenia alata	23 µm	
nauplius IV-V	*Rhizosolenia alata*	68 µm	
adults	fed on all above species at higher rates than juveniles		Paffenhöfer and Knowles, 1978a
adults	Fecal pellets of *E. pileatus* nauplius		Paffenhöfer and Knowles, 1978b
Eucalanus subtenuis	natural phytoplankton		Boyd, Smith and Cowles, 1980
Euchaeta acuta	*Artemia* sp. and silicoflagellates		Mullin, 1966
Euchaeta marina	microcrustaceans		Mullin, 1966

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
Euchirella bella	diatoms, crustaceans, silicoflagellates, foraminiferans and coccolithophorids		Mullin, 1966
Euchirella curticauda	diatoms, silicoflagellates, forminiferans, coccolithophorids and *Artemia* sp.		Mullin, 1966
Euterpina acutifroms	*Platymonas suecica*, *Dicrateria* sp., *Platymonas* sp., *Gymnodinium* sp. and *Phaeodactylum tricornutum*		Nassogne, 1970
Labidocera acutifrons	*Artemia* sp.		Mullin, 1966
Labidocera aestiva	natural phytoplankton	<76 μm	Smith and Hall, 1980
Labidocera trispinosa	*Artemia* sp., *Gymnodinium splendens*, *Acartia tonsa* (nauplius), *A. clausii* (nauplius), *Paracalanus* sp. (nauplius) and *Calanus pacificus* (nauplius)		Landry, 1978b
Lophothrix laticeps	*Artemia* sp. and *Coscinodicus perforatus*		Mullin, 1966
Metridia lucens	diatoms	>10 μm	
	flagellates	>10 μm	Marshall and Orr, 1962
	Artemia sp. (nauplius), *Peridinium* sp., *Thalassiosira nordenskioldii* and *Rhizosolenia* sp.		Hag, 1967

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
Metridia longa	*Artemia* sp. (nauplius), *Dunaliella* sp., *Peridinium* sp., *Thalassiosira nordenskioldii* and *Rhizosolenia* sp.		Hag, 1967
Nannocalanus minor	*Coscinodiscus perforatus*, *Thalassiosira fluvitalis*, *Cyclotella nana*, radiolarians and microcrustaceans		Mullin, 1966
Neocalanus gracilis	*Thalassiosira fluvitalis*, *Cuscinodiscus perforatus*, *Cyclotella nana*, radiolarians, silicoflagellates, crustaceans and coccolithophores		Mullin, 1966
	Coscinodiscus sp., *Thalassiosira fluviatilis*, *Artemia* sp. nauplii		Marshall, 1973
Oithona nana	copepod nauplii	110 μm	Lampitt, 1978
Oithona similis	flagellates	1-10 μm	Hargrave and Geen, 1970
	flagellates	<10 μm and >10 μm	
	diatoms	>10 μm	Marshall and Orr, 1962
Oncaea venusta	bacterial floc		Ogawa, 1977
Paracalanus parvus	diatoms	>10 μm	Marshall and Orr, 1962
	Skeletonema costatum		Mullin and Evans, 1974

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
	bacterial floc		Ogawa, 1977
	Paracalanus parvus eggs, *Thalassiosira fluviatilis*, *Ditylum brightwelli* *Gongaulax polyedra* and *Peridinium trochoideum*		Checkley, 1980
Pleuromamma abdominalis	diatoms, radiolarians, foraminiferans, silicoflagellates and crustaceans		Mullin, 1966
Pleuromamma gracilis	diatoms, radiolarians, foraminiferans, silicoflagellates and crustaceans		Mullin, 1966
Pleuromamma gracilis	natural phytoplankton and *Artemia salina* (nauplii)		Fernández, 1977
Pleuromamma piseki	*Artemia* sp.		Mullin, 1966
Pleuromamma xiphias	diatoms, tintinnids, coccolithophorids, foraminiferans, radiolarians, silicoflagellates and crustaceans		Mullin, 1966
Rhincalanus cornutus	*Thalassiosira fluvitalis* and *Artemia* sp.		Mullin, 1966
Rhincalanus nasutus	diatoms, radiolarians and *Artemia* sp.		Mullin, 1966
nauplius II-III	*Ditylum brightwelli*		
nauplius IV	*D. brightwelli* and *Thalassiosira fluviatilis*		

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
nauplius V	*Coscinodiscus wailessi*, *D. brightwelli* and *T. fluviatilis*		
copepodid I-IV	*C. wailesii*, *D. brightwelli*, *T. fluviatilis* and *Cyclotella nana*		
copepodid V and adults	all above diatoms and *Artemia* sp.		Mullin and Brooks, 1967
Scolecithrix danae	radiolarians and crustaceans		Mullin, 1966
Temora longicornis	*Skeletonema costatum* and *Chlamydomonas* sp.		Gauld, 1951
females	*Skeletonema costatum*	4-5 µm	Berner, 1962
females	flagellates	<10 µm	
	flagellates	>10 µm	
	diatoms	>10 µm	Marshall and Orr, 1962
	flagellates	1-10 µm	Hargrave and Geen, 1970
	Tetraselmis suecica		Person-le Ruyet, 1975
nauplii to adults	*Thalassiosira rotula*		
adults only	*Lauderia borealis*	36 µm	Harris and Paffenhöfer, 1976
	Rhodomonas sp., *Thalassionema nitschiodes*, *Skeletonema costatum*, *Procentrum* sp., *Rhizosolenia delicatula*, *Leptocylindrus danicus*, *Cerataulina pelagica* and *Asterionella japonica*		O'Connors, *et al.*, 1980

Table 1. (continued)

COPEPOD	FOOD	SIZE RANGE	SOURCE
Temora stylifera	*Skeletonema costatum*, *Phaeodactylum tricornutum*, *Dunaliella* sp., *Asterionella japonica*, *Lauderia borealis*, *Ditylum brightwellii* and *Artemia* sp., nauplii		Gaudy, 1974
nauplii	*Peridinium trochoideum*, *Skeletonema costatum* and		
	Leptocylindrus danicus	14-18 µm	Paffenhöfer and
	Rhizosolenia alata	23-68 µm	Knowles, 1978a
females	*Eucalanus pileatus*, nauplius, fecal pellets and		Paffenhöfer and
	Rhizosoelenia alata	30 µm	Knowles, 1978a, 1979
Temora turbinata			
nauplii	*Peridinium trochoideum*		
copepodids and	*Skeletonema costatum* and		
adults	*Leptocylindrus danicus*	14-18 µm	Paffenhöfer and
	Rhizosolenia alata	23-68 µm	Knowles, 1978a
Undinula vulgaris	detritus (95% of gut content)	<239 µm	
	chlorophyll (2% of gut content)	5-30 µm	Gerber and Marshall, 1974b
	Natural suspended particles	<239 µm	Gerber and Gerber, 1979

organic detritus and its associated bacteria and μ flagellates (2-10 μm) populations present other sources of copepod food that are not fully understood at the present time (Parsons and Strickland, 1962; Marshall, 1965; Conover, 1966; Pomeroy and Johannes, 1968). Recently developed techniques in fluorescence analyses of copepod gut contents have enhanced the possibility of separating the phytoplankton component of the copepods gut from other organic matter (Mackas and Bohrer, 1976). The determination of food source, time of feeding and position of feeding within the water column are all important in determining the trophic structure of copepod communities.

PREDATION ON COPEPODS

Predation of copepods on other copepods is a common occurrence, especially among species that do not frequent the euphotic zone through vertical migration. Harding (1974) lists deep-sea copepod species that commonly have copepod remains within their guts. When offered copepod prey of considerable size, Chiridius was unable to ingest it entirely and mastication outside the mouth was necessary; which allowed some of the body contents of the prey to go into solution with the water (Alvarez and Matthews, 1975). Landry (1978) observed Labidocera trispinosa feeding on the developmental stages of other planktonic calanoid copepods. Lampitt (1978) observed Labidocera trispinosa feeding on the developmental stages of other planktonic calanoid copepods and also found that the cyclopoid copepod, Oithona nana fed on copepod nauplii of 100 μm body length. Predatory planktonic copepods may contribute significantly to the mortality of other copepods.

Copepod nauplii may be the major prey of small carnivorous copepods (Hag, 1967; Wickstead, 1962; Hodgkin and Rippingale, 1971; Ambler and Frost, 1974).

Cannibalism has been observed in copepods under culture situations where the adults would often prey on juveniles of their own species (Paffenhöfer and Knowles, 1980), however, Matthews (1964) observed that Chiridius would prey on other smaller and weaker Chiridius adults. Alvarez and Matthews (1975) observed cannibalism among stage V Chiridius kept in a medium of the diatom Dunaliella sp.

Copepods are prey for many pelagic invertebrates. Chaetognaths are often seen in preserved zooplankton samples with copepods in their guts. It has been demonstrated that copepods are the main food organisms for many chaetognaths (Nagasawa and Murumo, 1972; Newbury, 1978; Szyper, 1978). Copepods have been documented as important food items in the diets for many marine macroinvertebrates: i.e., euphausiids (Ponomareva, 1963) and mesopelagic shrimp (Foxton and Roe, 1974; Omori, 1979). In neritic and estuarine waters planktonic medusae (Clifford and Cargo, 1978; Moeller, 1978) and ctenophores (Bishop, 1967; Burrell and Van Engel, 1976; Kremer, 1979) prey heavily on copepods. Ctenophores so dominated the copepods in an enclosed ecosystem, that when they were removed Paracalanus parvus replaced Acartia tonsa as the dominant copepod (Mullin and Evans, 1974). Copepods appear to be subjected to heavy predation pressure throughout their life cycle. Noctiluca, a dinoflagellate, has been observed devouring Acartia tonsa eggs in waters of southern California (Kimor, 1979).

Marine fish which are able to feed directly on copepods are trophically near the base of the marine food chain. Many marine and estuarine larval and juvenile fish feed primarily on copepods (Pálsson, 1973; Jones and Hall, 1974; Kjelson, Peters, Thayer and Johnson, 1975; Paul, Hood and Nevé, 1976; Last, 1978a, 1978b) and copepod eggs were found to constitute 90% of the food items taken by herring larvae (Bjørke, 1978). The adults of commercially important fish such as anchovies and menhaden are planktophagous; feeding largely on adults and juveniles of neritic copepods (Rojas de Mendiola and Ochoa, 1973; Durbin and Durbin, 1975).

Gut analyses of deep-sea fishes indicate that calanoid copepods contribute significantly to the diets of both mesopelagic and bottom species (Bright, 1970; Samyshev and Schetinkin, 1973; Scott, 1973; Tyler and Pearcy, 1975). Thirty-five percent of the deep-sea bottom fish studied by Bright (1970) from the Gulf of Mexico had calanoid copepods in their guts, while the copepods made up approximately 12% of the food items in these fishes diets. In recognition of the importance of copepods in the diet of fishes, small scale commercial fisheries have developed in the northern Atlantic and Pacific for *Calanus finmarchicus* and *C. plumchrus*, which are large species that are seasonally abundant (Omori, 1978). The copepods are deep-frozen and used as food in the culture of salmonids.

COPEPODS AND OTEC OPERATIONS

An operating Ocean Thermal Energy Conversion (OTEC) plant produces a limited upwelling in the marine ecosystem where upwelling does not

normally occur. Due to the inherent nature of OTEC operations, the water which passes through a plant generally has introduced into it, a biocide to prevent fouling in the heat exchangers, and operational accidents that allow potentially harmful substances to escape into the water are always possible. Since copepods are abundant within the base of the marine food pyramid, changes in population levels or community structure should reflect the effects of OTEC operations. Considerable data must, however, be available to the investigator for true changes brought about by OTEC to be distinguished from natural cyclic events within the plankton community.

Feeding response studies from areas of upwelling have shown that different species of marine copepods are adapted to various degrees of change within their environments. Examples of such findings are: Eucalanus were able to withstand lower oxygen levels than either Calanus or Centropages, vertical migration patterns of copepods were altered by phytoplankton food concentrations, and differences in copepod feeding strategies were not as evident during times of food abundance as when food was scarce (Boyd, Smith and Cowles, 1980). Copepods were size selective feeders at high food concentrations, but decreased their selection as total food abundance diminished (Cowles, 1979). Different scales of phytoplankton patchiness appeared to have varying affects on individual copepod species. Dagg (1977) found that Acartia tonsa and Centropages typicus depended on constant food availability and were, therefore, sensitive to small scales of patchiness, whereas Pseudocalanus minutus and Calanus finmarchicus could physiologically remove themselves

from small scale variability. Dagg, Cowles, Whitledge, Smith, Howe and Judkins (1980) compared the feeding rate of large copepods (>102 μm) with the rate of primary production and found that in the Peru upwelling the copepods were harvesting less than 5% of the daily phytoplankton production. Mathisen, Thorne, Trumble and Blackburn (1978) have shown that population densities of pelagic fish in an area of upwelling are more independent from that of the copepods on which they feed, than the copepods are from the population densities of their food.

Many questions remain unanswered concerning possible influences of OTEC on a tropical oceanic ecosystem. Boyd, Smith and Cowles (1980) questions the feasibility of using data from laboratory studies in which copepods are held in unnatural conditions and fed phytoplankton species that are often unknown to them. Much of the present data on copepod nutrition are from species that occur outside the area of OTEC operations. To properly quantify the phytoplankton-zooplankton interactions within the oceans that may result from OTEC operations, measurements should be made on organisms under conditions as close as possible to natural. The quality of field data taken prior to and during OTEC operations becomes extremely important in establishing zooplankton system simulations.

RECOMMENDATIONS

1. Copepod feeding studies should be conducted using copepods and phytoplankton from areas of OTEC operations.
2. In order to assess the effects of OTEC on marine copepods populations, the extent of natural mortality due to predation on copepods must be determined through both field and laboratory studies.

3. Toxicology studies on numerically dominant copepod species within areas of OTEC operations should be conducted using toxicants from OTEC operations.
4. Toxicology studies on the developmental stages of copepods should be conducted in order to assess the effects on delayed development and/ or mortality.
5. The effect of a local OTEC induced upwelling on phytoplankton and copepods should be determined.

Literature Cited

Allan, J. D, S. Richman, D. R. Heinle and R. Huff (1977) Grazing in juvenile stages of some estuarine calanoid copepods. Mar. Biol., 43, 317-332.

Alvarez, V. and J. B. L. Matthews (1975) Experimental studies on the deep water pelagic community of Korsfjorden Norway feeding and assimilation by Chiridius armatus (Crustacea, Copepoda). Sarsia, 58, 67-78.

Ambler, J. W. and B. W. Frost (1974) The feeding behavior of a predatory planktonic copepod Tortanus discaudatus. Limnol. Oceanogr., 19, 446-451.

Anraku, Masateru (1963) Feeding habits of planktonic copepods. Information Bulletin on Planktology in Japan, 9, 10-35.

Anraku, M. and M. Omori (1963) Preliminary survey of the relationship between the feeding habits and the structure of the mouth-parts of marine copepods. Limnol. Oceanogr., 8, 116-126.

Beers, J. R. and G. L. Stewart (1969) Micro-zooplankton and its abundance relative to the larger zooplankton and other seston components. Mar. Biol., 4, 182-189.

Berner, Ågot (1962) Feeding and respiration in the copepod Temora longicornis (Müller). J. mar. biol. Assoc. U.K., 42, 625-640.

Bishop, J. W. (1967) Feeding rates of the ctenophore, Mnemiopsis leidyi. Chesapeake Sci., 8, 259-261.

Bjørke, H. (1978) Food and feeding of young herring larvae of Norwegian spring spawners. Fiskeridir Skr Ser Havunders, 16, 405-421.

Boyd, C. M., S. L. Smith and T. L. Cowles (1980) Grazing patterns of copepods in the upwelling system off Peru. Limnol. Oceanogr., 25, 533-596.

Bright, T. J. (1970) Food of deep-sea bottom fishes. In: Contributions on the Biology of the Gulf of Mexico. W. E. Pequenat and F. A. Chase, Jr., editors, Vol. I. Texas A&M Oceanographic Series. Gulf Publ. Co. Houston, Texas, pp. 245-252.

Burrell, V. G., Jr. and W. A. Van Engel (1976) Predation by and distribution of a ctenophore, Mnemiopsis leidyi A. Agassiz, in the York River Estuary. Estuarine and Coastal Mar. Sci. 4, 235-242.

Checkley, D. M., Jr. (1980) The egg production of a marine planktonic copepod in relation to its food supply: Laboratory studies. Limnol. Oceanogr., 25, 430-446.

Clifford, H. C. and D. G. Cargo (1978) Feeding rates of the sea-nettle Chrysaora quinquecirrha under laboratory conditions. Estuaries, 1, 58-61.

Conover, R. J. (1966) Assimilation of organic matter by zooplankton. Limnol. Oceanogr., 11, 338-345.

Corner, E. D. S., R. N. Head and C. C. Kilvington (1972) On the nutrition and metabolism of zooplankton. Part 8. The grazing of Biddulphia cells by Calanus helgolandicus. J. mar. biol. Assoc. U.K., 52, 847-861.

Cowley, C. B. and E. D. S. Corner (1963) On the nutrition and metabolism of zooplankton. II. The relationship between the marine copepod Calanus helgolandicus and particulate material in Plymouth sea water, in terms of amino acid composition. J. mar. biol. Assoc. U.K., 43, 495-511.

Cowles, T. J. (1979) The feeding response of copepods from the Peru upwelling system: Food size selection. J. Mar. Res. 37, 601-622.

Dagg, M. (1977) Some effects of patchy food environments on copepods. Limnol. Oceanogr., 22, 99-107.

Dagg, M. (1978) Estimated in-situ rates of egg production for the copepod Centropages typicus in the New York bight. J. Exp. Mar. Biol. Ecol., 34, 183-196.

Dagg, M., T. Cowles, T. Whitledge, S. Smith, S. Howe and D. Judkins (1980) Grazing and excretion by zooplankton in the Peru upwelling system during April 1977. Deep-sea Res., 27, 43-60.

Davis, C. C. (1977) Sagitta as food for acartia. Astarte, 10, 1-4.

Deevey, G. B. and A. L. Brooks (1977) Copepods of the Sargasso Sea off Bermuda: Species composition, and vertical and seasonal distribution between the surface and 2000m. Bull. Mar. Sci., 27, 256-291.

Donaghay, P. L. and L. F. Small (1979a) Long-term food modification by Acartia clausi: A preliminary view. Mar. Biol., 52, 129-136.

Donaghay, P. L. and L. F. Small (1979b) Food selection capabilities of the estuarine copepod Acartia clausi. Mar. Biol., 52, 137-146.

Durbin, A. G. and E. G. Durbin (1975) Grazing rates of the Atlantic menhaden Brevoortia tyrannus as a function of particle size and concentration. Mar. Biol., 33, 265-277.

Fernandez, F. (1977) The effect of the intensity of sun light on the metabolic activity and feeding of several species of planktonic copepods. Invest. Pesq., 41 575-602.

Foxton P. and H. S. J. Roe (1974) Observations on the nocturnal feeding of some mesopelagic decapod crustacea. Mar. Biol., 28, 37-49.

Frost, B. W. (1972a) Effects of size and concentration of food particles on the feeding behavior of the marine planktonic copepod Calanus pacificus. Limnol. Oceanogr., 17, 805-815.

Frost, B. W. (1975) A threshold feeding behavior in Calanus pacificus. Limnol. Oceanogr., 20, 263-266.

Frost, B. W. (1977) Feeding behavior of Calanus pacificus in mixtures of food particles. Limnol. Oceanogr., 22, 472-491.

Fuller, J. L. (1937) Feeding rate of Calanus finmarchius in relation to environmental conditions. Biol. Bull., 72, 233-246.

Gaudy, R. (1974) Feeding four species of pelagic copepods under experimental conditions. Mar. Biol., 25, 125-141.

Gauld, D. T. (1951) The grazing rate of planktonic copepods. J. mar. biol. Assoc. U.K., 29, 695-706.

Gauld, D. T. (1964) Feeding in planktonic copepods. In: Grazing in Terrestrial and Marine Environments, pp. 239-245. D. J. Crisp, editor, Blackwell Scientific Publications LTD. Oxford.

Gauld, D. T. (1966) The swimming and feeding of planktonic copepods. In: Some Contemporary Studies in Marine Science, H. Barnes, editor, George Allen and Unwin Ltd., London, pp. 313-334.

Gerber, R. P. and M. B. Gerber (1979) Ingestion of natural particulate organic matter and subsequent assimilation respiration and growth by tropical lagoon zooplankton. Mar. Biol., 52, 33-44.

Gerber, R. P. and N. Marshall (1974) Ingestion of detritus by the lagoon pelagic community at Eniwetok Atoll. Limnol. Oceanogr., 19, 815-824.

Hag, S. M. (1967) Nutritional physiology of Metridia lucens and M. longa from the Gulf of Maine. Limnol. Oceanogr., 12, 40-51.

Harding, G. C. H. (1974) The food and feeding of the deep-sea copepods. J. mar. biol. Assoc. U.K., 54, 141-155.

Hargis, J. R. (1977) Comparison of techniques for the measurement of zooplankton filtration rates. Limnol. Oceanogr., 22, 942-945.

Hargrave, B. T. and G. H. Geen (1970) Effects of copepod grazing on two phytoplankton populations. J. Fish. Res. Board Can., 27, 1395-1403.

Harris, R. P. and G.-A. Paffenhöfer (1976) Feeding growth and reproduction of the marine planktonic copepod Temora longicornis Müller. J. mar. biol. Assoc. U.K., 56, 675-690.

Heinle, D. R. (1969) Culture of calanoid copepods in synthetic seawater. J. Fish. Res. Board Can., 26, 150-153.

Hodgkin, E. P. and R. J. Rippingale (1971) Interspecies conflict in estuarine copepods. Limnol. Oceanogr., 16, 573-575.

Honjo, S. and M. R. Roman (1978) Marine copepod fecal pellets production preservation and sedimentation. J. Mar. Res., 36, 45-58.

Hopkins, T. L., J. L. Bennett and P. G. Shuert (1979) Zooplankton study at the Florida west coast O.T.E.C. site. A final report to the Lawrence Berkeley Laboratory, 41 pp.

Jones, R. and W. B. Hall (1974) Some observations on the population dynamics of the larval stage in the common gadoids. In: The early life history of fish, J. H. S. Blaxter, editor, xii+765 p. Springer-Verlag, New York, pp. 87-102.

Kimor, B. (1979) Predation by Noctiluca miliaris on Acartia tonsa eggs in the inshore waters of southern California. Limnol. Oceanogr., 24, 568-572.

Kjelson, M. A., D. S. Peters, G. W. Thayer and G. N. Johnson. (1975) The general feeding ecology of postlarval fishes in the Newport River Estuary, North Carolina, U.S.A. U.S. Natl. Mar. Fish. Serv. Fish. Bull., 73, 137-144.

Kremer, P. (1979) Predation by the ctenophore Mnemiopsis leidyi in Narragansett Bay. Estuaries, 2, 97-105.

Kukina, I. V. (1975) Experimental studies of the marine copepod consumption of algae of different sizes. Okeanologiya, 15, 514-519.

Lampitt, R. S. (1978) Carnivorous feeding by a small marine copepod. Limnol. Oceanogr., 23, 1228-1231.

Landry, M. R. (1975) The relationship between temperature and the development of life stages of the marine copepod Acartia clausi. Limnol. Oceanogr., 20, 854-857.

Landry, M. R. (1978) Predatory feeding behavior of a marine copepod Labidocera trispinosa. Limnol. Oceanogr., 23, 1103-1113.

Last, J. M. (1978a) The food of four species of pleuronectiform larvae in the eastern English Channel and southern North Sea. Mar. Biol., 45, 359-368.

Last, J. M. (1978b) The food of three species of gadoid larvae in the eastern English Channel and southern North Sea. Mar. Biol., 48, 377-386.

Mackas, D. L. and R. Bohren (1976) Fluorescence analysis of zooplankton gut contents and an investigation of diel feeding patterns. J. Exp. Mar. Biol. Ecol. 25, 77-85.

Marshall, N. (1965) Detritus over the reef and its potential contribution to adjacent waters of Eniwetok Atoll. Ecology, 46, 343-344.

Marshall, S. M. (1973) Respiration and feeding in copepods. Advances in Marine Biology, 11, 57-120.

Marshall, S. M. and A. P. Orr (1955) On the biology of Calanus finmarchieus. VIII. Food uptake, assimilation and excretion in adult and stage V Calanus. J. mar. biol. Assoc. U.K., 34, 495-529.

Marshall, S. M. and A. P. Orr (1956) On the biology of Calanus finmarchius. IX. Feeding and digestion in the young stages. J. mar. biol. Assoc. U.K., 35, 587-603.

Marshall, S. M. and A. P. Orr (1962) Food and feeding in copepods. Rapp. P.-V. Rénu. Cons. perm. int. Explor. mer., 153, 92-98.

Mathisen, O. A., R. E. Thorne, R. J. Trumble and M. Blackburn (1978) Food consumption of pelagic fish in an upwelling area. In: Upwelling Ecosystems, Rolf Boje and Matthias Tomczak, editors, xi+303 p. Springer-Verlag, New York, pp. 111-123.

Matthews, J. B. L. (1964) On the biology of some bottom-living copepods (Aetideidae and Phaennidas) from western Norway. Sarsia, 16, 1-46.

Moeller, H. (1978) Significance of coelenterates in relation to other plankton organisms. Meeresforschung, 27, 1-18.

Moraitou-Apostolopoulou, M. and G. Verriopoulos (1978) Some factors affecting the nutrition of copepods adapted to polluted and eutrophic biotopes. Rev. Int. Oceanogr. Med., 51-52, 89-99.

Mullin, M. M. (1963) Some factors affecting the feeding of marine copepods of the genus Calanus. Limnol. Oceanogr., 8, 239-250.

Mullin, M. M. (1966) Selective feeding by calanoid copepods from the Indian Ocean. In: Some contemporary studies in marine science, H. Barnes, editor, Allen & Unwin. Ltd. London, pp. 545-554.

Mullin, M. M. and E. R. Brooks (1967) Laboratory culture, growth rate and feeding behaviour of a planktonic marine copepod. Limnol. Oceanogr., 12, 657-666.

Mullin, M. M. and E. R. Brooks (1970) The effect of concentration of food on body weight, cumulative ingestion, and rate of growth of the marine copepod Calanus helgolandicus. Limnol. Oceanogr., 15, 748-755.

Mullin, M. M. and P. M. Evans (1974) The use of a deep tank in plankton ecology. Part 2. Efficiency of a planktonic food chain. Limnol. Oceanogr., 19, 902-911.

Nagasawa S. and R. Marumo (1972) Feeding of a pelagic chaetognath Sagitta nagae in Suruga Bay, central Japan. J. Oceanogr. Soc. Jap., 28, 181-186.

Nassogne, A. (1970) Influence of food organisms on the development and culture of pelagic copepods. Helgol. Wiss. Meeresunters, 30, 333-345.

Newbury, T. K. (1978) Consumption and growth rates of chaetognaths and copepods in subtropical oceanic waters. Pac. Sci., 32, 61-78.

Nival P. and S. Nival (1976) Particle retention efficiencies of an herbivorous copepod Acartia clausi (adult and copepodite stages): Effects on grazing. Limnol. Oceanogr., 21, 24-38.

Nival S. and P. Nival (1978) Scanning electron Microscope study of the part played in feeding by the cephalic appendages of two planktonic copepods Temora stylifera and Candacia armata. Arch. Zool. Exp. Gen., 119, 83-94.

O'Connors, H. B., Jr., D. C. Biggs and D. V. Ninivagg (1980) Particle size dependent maximum grazing rates for Temora longicornis fed natural particle assemblages. Mar. Biol., 56, 65-70.

O'Connors, H. B., L. F. Small and P. O. Donaghay (1976) Particle size modification by two size classes of the estuarine copepod Acartia clausi. Limnol. Oceanogr., 21, 300-308.

Ogawa, K. (1977) The role of bacterial floc as food for zooplankton in the sea. Bull. Jpn. Soc. Sci. Fish., 43, 395-407.

Omori, M. (1978) Zooplankton fisheries of the world: A review. Mar. Biol., 48, 199-206.

Omori, M. (1979) Growth feeding and mortality of larval and early post larval stages of the oceanic shrimp Sergestes similis. Limnol. Oceanogr., 24, 273-288.

Paffenhöfer, G.-A. (1970) Cultivation of Calanus helgolandicus under controlled conditions. Helgol. wiss. Meeresunters, 20, 346-359.

Paffenhöfer, G.-A. (1971) Grazing and ingestion rates of nauplii, copepodids and adults of the marine planktonic copepod Calanus helgolandicus. Mar. Biol., 11, 286-298.

Paffenhöfer, G.-A. (1976a) Feeding, growth, and food conversion of the marine planktonic copepod Calanus helgolandicus. Limnol. Oceanogr., 21, 39-50.

Paffenhöfer, G.-A. (1976b) Continuous and nocturnal feeding of the marine planktonic copepodid Calanus helgolandicus. Bul. Mar. Sci., 26, 49-58.

Paffenhöfer, G.-A. and S. C. Knowles (1978a) Feeding of marine planktonic copepods on mixed phytoplankton. Mar. Biol., 48, 143-152.

Paffenhöfer, G.-A. and S. C. Knowles (1978b) Laboratory experiments on feeding, growth, and fecundity of and effects of cadmium on Pseudodiaptomus. Bull. Mar. Sci., 28, 574-580.

Paffenhöfer, G.-A. and S. C. Knowles. (1979) Ecological implications of fecal pellet size, production and consumption by copepods. J. Mar. Res., 37, 35-49.

Paffenhöfer, G.-A. and S. C. Knowles (1980) Omnivorousness in marine marine planktonic copepods. J. Plankton Res., 2, 355-365.

Palsson, O. K. (1973) Investigations on the food of young fish O group in Icelandic waters. Ber. Dtsch. Wiss. Komm. Meeresforsch, 23, 1-32.

Parsons, T. R. and J. D. H. Strickland. (1962) Oceanic detritus. Science, N.Y., 136, 313-314.

Paul, A. J., D. W. Hood and R. A. Neve. (1976) A note on rearing juvenile chum salmon Oncorhynchus keta in an artificial upwelling system. Aquaculture, 9, 387-390.

Pechen-Finenko, G. A., T. V. Pavlovskaya, L. G. Dubilevich and O. V. Kosikhina. (1978a) Experimental study of basic trophic characteristics of planktonic crustaceans. Sov. J. Mar. Biol. (Engl. Transl. Biol. Morya), 4, 754-758.

Person-Le Ruyet, J. (1975) On rearing planktonic Calanoid copepods biology and populations dynamics first results. Ann. Inst. Oceanogr., 51, 203-222.

Piontkovskii, S. A. and T. S. Petipa (1976) Quantitative description of the behavior of the copepod Acartia clausi during its feeding on algae. Biol. Morya. (Vladivost.), 1, 49-56.

Pomeroy, L. R. and R. E. Johnannes (1968) Occurrence and respiration of ultraplankton in the upper 500 meters of the ocean. Deep Sea Res., 15, 381-391.

Ponomareva, L. A. (1963) Euphausiids of the north Pacific: their distribution and ecology. Academy of Sciences of the U.S.S.R. Institute of Oceanology. Translated for U.S. Dept. Interior and NSF. IPST Cat. No. 1368. 154 pp.

Poulet, S. A. (1978) Comparison between five coexisting species of marine copepods feeding on naturally occurring particulate matter. Limnol. Oceanogr., 23, 1126-1143.

Reeve, M. R. and M. A. Walter (1977) Observations on the existence of lower threshold and upper critical food concentrations for the copepod Acartia tonsa. J. Exp. Mar. Biol. Ecol., 29, 211-222.

Richman, S., D. R. Heinle and R. Huff (1977) Grazing by adult estuarine Calanoid copepods of the Chesapeake Bay. Mar. Biol., 42, 69-84.

Richman, S., Y. Loya and L. B. Slobodkin (1975) The rate of mucus production by corals and its assimilation by the coral reef copepod Acartia neglegens. Limnol. Oceanogr., 20, 918-923.

Rojas de Mendiola, B. and L. N-Ochoa (1973) Observations on the food and feeding habits of the anchovy Engraulis ringens Jenyns made during cruise 6908-09. International Sympsoium, Wellington, New Zealand, Feb. 9-15, 1972. New Zealand National Commission for UNESCO, pp. 457-461.

Roman, M. R. (1977) Feeding of the copepod Acartia tonsa on the diatom Nitzschia closterium and brown algae (Fucus vesiculosus) detritus. Mar. Biol., 42, 149-156.

Samyshev, E. Z. and S. V. Schetinkin (1973) Feeding patterns of some species of Myctophidae and Maurolicus muelleri caught in the sound dispersing layers in the northwestern African area. Ann. Biol., 28, 212-215.

Scott, J. S. (1973) Food and inferred feeding behavior of northern sand lance Ammodytes dubius. J. Fish. Res. Board Can., 30, 451-454.

Smith, S. L. and B. K. Hall (1980) Transer of radioactive carbon within the copepod Temora longicornis. Mar. Biol., 55, 277-286.

Steele, J. H. and B. W. Frost (1977) The structure of plankton communities. Philos. Trans. R. Soc. Lond. B. Biol. Sci., 280, 485-534.

Steen, J. P. and G. Gunter (1980) Zooplankton study at the Mobile OTEC site in the northern Gulf of Mexico. Report to the Lawrence Berkeley Laboratory, University of California, Berkeley. 27 pp.

Sullivan, B. K., C. B. Miller, W. T. Peterson and A. H. Soeldner (1975) A scanning electron microscope study of the mandieular morphology of boreal copepods. Mar. Biol., 30, 175-182.

Szyper, James P. (1978) Feeding rate of the chaetognath Sagitta enflata in nature. Estuarine and Coastal Mar. Sci., 7, 567-575.

Tomasini, J. A. and J. Mazza (1978) Dietary behavior of two Calanoid copepods Centropages typicus and Acartia clausi in nutritive media with a single alga. J. cons. cons. Int. Explor. Mer., 38, 154-179.

Tomasini, J. A. and J. Mazza (1979) Feeding behavior of Centropages typicus copepoda Calanoida in nutritive media with two algae and in the presence of nauplii of Artemia sp. J. Cons. Cons. Int. Explor. Mer., 38, 293-307.

Tyler, H. R., Jr. and W. G. Pearcy (1975) The feeding habits of three species of lanterfishes family Myctophidae off Oregon, USA. Mar. Biol., 32, 7-11.

Vidal, J. (1980a) Physioecology of zooplankton. I. Effects of phytoplankton concentrations, temperature, and body size on the growth rate of Calanus pacificus and Pseudocalanus sp. Mar. Biol., 56, 111-134.

Vidal, J. (1980b) Physioecology of zooplankton. II. Effects of phytoplankton concentration, temperature, and body size on the development and molting rates of Calanus pacificus and Pseudocalanus sp. Mar. Biol., 56, 135-146.

Vidal, J. (1980c) Physioecology of zooplankton. III. Effects of phytoplankton concentration, temperature, and body size on the metabolic rate of Calanus pacificus. Mar. Biol., 56, 195-202.

Vidal, J. (1980d) Physioecology of zooplankton. IV. Effects of phytoplankton, temperature, and body size on the net production efficiency of Calanus pacificus. Mar. Biol., 56, 203-211.

Vinogradov, M. E. (1962) Feeding of the deep-sea zooplankton. International Council for the Exploration of the Sea; Symposium on Zooplankton Production, No. 7.

Vyshkvartseva, N. V. and B. L. Gutel Makher (1971) Trapping capacity of the filtration apparatus in some Calanidae. Gidrobiol Zh., 7, 66-72.

White, H. H. (1979) Effects of dinoflagellate bioluminescence on the ingestion rates of herbivorous zooplankton. J. Exp. Mar. Biol. Ecol., 36, 217-224.

Wickstead, J. H. (1959) A predatory copepod. J. Animal Ecol., 28, 69-72.

Wickstead, J. H. (1962) Food and feeding in pelagic copepods. Proceedings of the Zool. Soc. London, 139, 545-555.

Wilson, D. S. (1973) Food size selection among copepods. Ecology, 54, 909-914.

ADDITIONAL REFERENCES ON COPEPOD FOOD AND FEEDING

Abdel-Malek, S. A. (1972) Food and feeding habits of some Egyptian fishes in Lake Quarun. Part 1. Tilapia zillii according to different sexes. Bull. Inst. Oceanogr. Fish., 2, 239-259.

Ackman, R. G, B. A. Linke and J. Hingley (1974) Some details of fatty-acids and alcohols in the lipids of north Atlantic copepods. J. Fish. Res. Board Can., 31, 1812-1818.

Adams, J. A. and J. H. Steele (1966) Shipboard experiments on the feeding of Calanus finmarchius (Gunnerus). In: Some Contemporary Studies in Marine Science, H. Barnes, editor, George Allen and Unwin Ltd., London, pp. 19-35.

Anraku, M. (1964) Some technical problems encountered in quantitative studies of grazing and predation by marine planktonic copepods. J. Oceanographical Soc. Japan, 20, 221-231.

Anraku, M. (1975) Microdistribution of marine copepods in a small inlet. Mar. Biol., 30, 79-88.

Apollonio, S. (1969) Breeding and fecundity of the glass shrimp Pasiphaea multidentata decapoda Caridea in the Gulf of Maine. J. Fish. Res. Board Can., 26, 1969-1983.

Arashkevich, E. G. and V. B. Tseitlin (1978) Dependence of ration on food concentration in phytophagous copepods and their feeding mechanism. Okeanologiya, 18, 530-536.

Arashkevich, Y. G. (1968) The food and feeding of copepods in the northwestern Pacific. Oceanology, 9, 695-709.

Arthur, D. K. (1977) Distribution, size and abundance of micro-copepods in the California current system USA and their possible influence on survival of marine teleost larvae. U.S. Natl. Mar. Fish Serv. Fish. Bull., 75, 601-612.

Bainbridge, V. (1972) The zooplankton of the Gulf of Guinea. Bull. Mar. Ecol., 8, 61-97.

Bainbridge, V. and D. C. T. Forsyth (1972) An ecological survey of a Scottish herring fishery. Part 5. The Plankton of the northwestern North Sea in relation to the physical environment and the distribution of herring. Bull. Mar. Ecol., 8, 21-52.

Bamstedt, U. (1978) Studies on the deep-water pelagic community of Kors Fjord western Norway seasonal variation in weight and biochemical composition of Chiridius armatus Copepoda, Boreomysis arctica Mysidacea and Eukrohnia hamata Chaetognatha in relation to their biology. Sarsia, 63, 145-154.

Bamstedt, U. and M. R. Holt (1978) Experimental studies on the deep water pelagic community of Korsfjorden western Norway prey size preference and feeding of Euchaeta norvegica Copepoda. Sarsia, 63, 225-236.

Barker-Jörgensen, C. (1962) The food of filter feeding organisms. Rapp. P.-v. Rénu. Cons. perm. int. Explor. Mer, 153, 99-107.

Baylor, E. R. and W. A. Sutcliffe, Jr. (1963) Dissolved organic matter in seawater as a source of particulate food. Limnol. Oceanogr., 8, 369-371.

Beklemishev, C. W. (1954) The feeding of some common copepods in the seas of the Far East. Zoologicheskji Zhurnal, 33, 1210.

Beklemishev, K. (1957) Superfluous feeding of zooplankton and the sources of food for bottom animals. Trudy vses. gidrobiol. Obshch. 8, 354-358.

Beklemishev, K. (1959) Anatomy of mouth parts of copepods (masticatory surfaces of the mandibles in some Calanids and Eucalanids). Tr. Inst. Okeanol. 30, 148-155.

Binet, D. (1977) Biological cycles and ontogenic migrations of some pelagic copepods in Ivory-Coast waters. Cah O.R.S.T.O.M. ser Oceanogr., 15, 111-138.

Boyd, D. M. (1976) Selection of particle sizes by filter-feeding copepods: a plea for reason. Limnol. Oceanogr., 21, 175-180.

Bradford, J. M. (1977) Distribution of the pelagic copepod Temora turbinata in New-Zealand coastal waters and possible trans tasman population continuity. N. Z. J. Mar. Freshw. Res., 11, 131-144.

Bradford, J. M. (1978) Summer distribution of the pelagic copepod Centropages aucklandicus in New-Zealand waters. N. Z. J. Mar. Freshw. Res., 12, 287-291.

Braun, J. G. (1974) Preliminary study on the degree of filtration of the zooplankton in canarian waters Canary Islands. Bol. Inst. Esp. Oceanogr., pp. 3-12.

Brenning, U. and K. Fadschild (1979) The Calanoid population (Crustacea Copepoda) at an anchor station of Cape Blanc Spanish Sahara Mauritania northwest Africa in March 1973. Wiss. Z. Wilhelm-Pieck-Univ. Rostock. Math. Naturwiss Reihe, 28, 515-524.

Brooks, J. L. and S. I. Dodson. (1965) Predation, body size and composition of plankton. Science, N.Y. 150, 28-35.

Butler, E. I., E. D. S. Corner and S. M. Marshall (1970) On the nutrition and metabolism of zooplankton. VII. Seasonal survey of nitrogen and phosphorus excretion by Calanus in the Clyde Sea area. J. mar. biol. Assoc. U.K., 50, 525-560.

Cannon, H. G. (1928) On the feeding mechanism of the copepods Calanus finmarchicus and Diaptomus gracilis. Brit. J. exp. Biol., 6, 131-144.

Chindonova, Y. G. (1959) The nutrition of certain groups of abyssal macroplankton in the northwestern area of the Pacific Ocean. Trudy Instituta Okeanologii, 30, 166-189.

Conover, R. J. (1956) Oceanography of Long Island Sound, 1952-1954. VI. Biology of Acartia clausi and A. tonsa. Bull. Bingham oceanogr. Coll., 15, 156-233.

Conover, R. J. (1960) The feeding behavior and respiration of some marine planktonic crustacea. Biol. Bull., 119, 399-415.

Conover, R. J. (1964) Food relations and nutrition of zooplankton. Ooc. Publs. School. Oceanogr. Univ. Rhode I., 2, 81-91.

Conover, R. J. (1962) Metabolism and growth in Calanus hyperboreus in relation to its life cycle Acartia nutrition. Rapp. Proces-Verbauz Reunions Cons. Prema. Int. Explor. Mer, 153, 190-196.

Conover, R. J. (1966a) Feeding on large particles by Calanus hyperboreus (Kröyer). p. 187-194. In: Some contemporary studies in marine science, H. Barnes, editor, Allen and Unwin.

Conover, R. J. (1966b) Factors affecting the assimilation of organic matter by zooplankton and the question of superfluous feeding. Limnol. Oceanogr., 11, 346-354.

Conover, R. J. (1968) Zooplankton - life in a nutritionally dilute environment. American Zool., 8, 107-118.

Corner, E. D. S. (1961) On the nutrition and metabolism of zooplankton. I. Preliminary observation on the feeding of the marine copepod, Calanus helgolandicus (Claus). J. mar. biol. Assoc. U.K., 41, 5-16.

Corner, E. D. S., C. B. Cowey and S. M. Marshall (1965) On the nutrition and metabolism of zooplankton. III. Nitrogen excretion by Calanus. J. mar. biol. Assoc. U.K., 45, 429-442.

Corner, E. D. S., C. B. Cowey and S. M. Marshall (1967) On the nutrition and metabolism of zooplankton. V. Feeding efficiency of Calanus finmarchicus. J. mar. biol. Assoc. U.K., 47, 259-270.

Corner, E. D. S., R. P. Harris, C. C. Kilvington and S. C. M. O'Hara (1976) Petroleum compounds in the marine food web: Short-term experiments on the fate of Naphthalene in Calanus. J. mar. biol. Assoc. U.K., 56, 121-133.

Corner, E. D. S., R. N. Head, C. C. Kilvington and S. M. Marshall (1974) On the nutrition and metabolism of zooplankton. Part 9. Studies relating to the nutrition of over wintering Calanus. J. mar. biol. Assoc. U.K., 54, 319-331.

Corner, E. D. S., R. N. Head, C. C. Kilvington and L. Pennycuick (1976) On the nutrition and metabolism of zooplankton. Part 10. Quantitative aspects of Calanus helgolandicus feeding as a carnivore. J. mar. biol. Assoc. U.K., 56, 345-358.

Cowey, C. B. and E. D. S. Corner (1962) The amino-acid composition of Calanus finmarchicus in relation to that of its food oceanic food chain. Rapp. Proces-Verbauz Reunions Cons. Prema. Int. Explor. Mer. 153, 124-128.

Curl, H. H. and G. C. McLeod (1961) The physiological ecology of a marine diatom, Skeletonema costatum (Grev.) Cleve. J. Mar. Res., 19, 70-88.

Cushing, D. H. (1958) The effect of grazing in reducing the primary production: A review. Rapp. P.-V. Reńu. Cons. perm. int. Explor. Merl, 144, 149-154.

Cushing, D. H. (1968) Grazing by herbivorous copepods in the sea mathematical model Calanus. J. Cons. Cons. Perma. Int. Explor. Mer, 32, 70-82.

Cushing, D. H. (1970) Introduction to pelagic food chains. In: Marine food chains, J. H. Steele, editor, Symposium. viii+552p. Illus. University of California Press: Berkeley, Calif., pp. 69-73.

Cushing, D. H. and T. Vicetic (1963) Studies on a Calanus patch. III. The quantity of food eaten by Calanus finmarchicus. J. mar. biol. Assoc. U.K., 43, 349-371.

Dagg, M. and D. W. Grill (1980) Natural feeding rates of Centropages typicus females in the New York bight USA. Limnol. Oceanogr., 25, 597-609.

deInfante, Aida. (1978) A method for the study of foods of herbivorous zooplankton. Trans. Amer. Micros. Soc., 97, 256-258.

Delano, Y. P. (1961) Preliminary data on the food and feeding of Paracalanus parvas in the Black Sea. Tr. Sevastop. biol. St., p. 12.

Dodson, A. N. and W. H. Thomas (1964) Concentrating plankton in a gentle fashion. Limnol. Oceanogr., 12, 443-450.

Duval, W. S. and G. H. Geen (1976) Diel feeding and respiration rhythms in zooplankton. Limnol. Oceanogr., 21, 823-829.

Easterly, C. O. (1916) The feeding habits and food of pelagic copepods and the question of nutrition by organic substances in solution in the water. Univ. Calif. Publ. Zool., 16, 171-184.

Enright, J. T. and H. W. Honegger (1977) Diurnal vertical migration: Adaptive significance and timing. Part 2. Test of the model: Details of timing. Limnol. Oceanogr., 22, 873-886.

Eriksson, S. (1973) The biology of marine planktonic copepods on the west coast of Sweden. Zoon., 1, 37-68.

Eriksson, S., C. Sellei and K. Wallstrom (1977) The structure of the plankton community of the Oeregrundsgrepen Southwest Bothnian Sea. Helgol. Wiss. Meeresunters, 30, 582-597.

Farmer, L. and M. R. Reeve (1978) Role of the free amino-acid pool of the copepod Acartia tonsa in adjustment to salinity change. Mar. Biol., 48, 311-316.

Fernandez, F. (1978) Metabolism and feeding in planktonic copepods from the Mediterranean the effect of temperature. Invest. Pesq., 42, 97-140.

Fernandez, F. (1979a) Particle selection in the nauplius of Calanus pacificus. J. Plankton Res., 1, 313-328.

Fernandez, F. (1979b) Nutrition studies in the nauplius larva of Calanus pacificus. Mar. Biol., 53, 131-148.

Ferrari, I., G. Gandolfi and A. Stefanini (1978) The zooplankton in a lagoon of the Po River Delta Italy: Its composition and role in the feeding of planktophagous fish. Atti. Soc. Ital. Sci. Nat. Mus. Civ. Stor. Nat. Milano, 119, 211-228.

Frankenberg, C. and K. L. Smith, Jr. (1967) Coprophagy in marine animals. Limnol. Oceanogr., 12, 443-450.

Friedman, M. M. and J. R. Strickler (1975) Chemoreceptors and feeding in calanoid copepods (Arthropoda: Crustacea). Proc. natn. Acad. Sci. U.S.A., 72, 4185-4188.

Frost, B. W. (1972) Feeding processes at lower trophic levels in pelagic communities. In: The biology of the oceanic pacific, C. B. Miller, editor, 33rd Annual Biology Colloquium. Corvalis: Oregon State University Press, pp. 59-77.

Fuller, J. L. and G. L. Clarke (1936) Further experiments on the feeding of Calanus finmarchicus. Biol. Bull., 72, 233-246.

Fulton, J. (1973) Some aspects of the life history of Calanus plumchrus in the Strait of Georgia. J. Fish. Res. Board Can., 30, 811-815.

Gamble, J. C. (1978) Copepod grazing during a declining spring phytoplankton bloom in the northern North Sea. Mar. Biol., 49, 303-315.

Gaudy, R. (1971) Experimental study of egg laying in three neritic copepod species Centropages typicus, Acartia clausi and Temora stylifera. Mar. Biol., 9, 65-70.

Gauld, D. T. (1953) Diurnal variations in the grazing of planktonic copepods. J. mar. biol. Assoc. U.K., 31, 461-474.

Gerinrikh, A. K. (1958) On the nutrition of marine copepods in the tropical region. Dolady Akademiya Nauk. SSSR, 119, 229-233.

Gerber, R. P. and N. Marshall (1974) Reef pseudoplankton in lagoon trophic systems. Proc. of the Second International Symposium on Coral Reefs, Vol. 1. June 22-July 2, 1973. vi+630 p. Illus. Map. The Great Barrier Reef Committee: Brisbane, Australia, pp. 105-107.

Gonzalez, J. G., P. P. Yevich, J. H. Gentile and N. F. Lackie (1975) Problems associated with culture of marine copepods. In: Culture of marine invertebrate animals, Walter L. Smith and Chanley H. Matoira, editors, Conference, Greenport, N.Y., Oct. 1972, viii+ 338 p. Illus. Plenum Press: New York, pp. 199-207.

Greve, W. (1977) Interspecific interaction: The analysis of complex structures in carvivorous zooplankton populations. Helgol. Wiss. Meeresunters, 30, 83-91.

Gruzov, L. N. and G. V. Voloshina (1976) The mechanism regulating food consumption by marine copepods. Okeanologiya, 16, 868-875.

Gueredrat, J. A. (1971) Evolution of a copepod population in the Pacific Ocean equatorial currents system. Zoogeography, ecology and specific diversity. Mar. Biol., 9, 300-314.

Hall, D. J., S. T. Threlkeld, C. W. Burns and P. H. Crowley. (1976) The size efficiency hypothesis and the size structure of zooplankton communities. Annual review of ecology and systematics, 7, 177-208.

Harris, R. P. and G.-A. Paffenhöfer (1976) The effect of food concentration on cumulative ingestion and growth efficiency of two small marine planktonic copepods. J. mar. biol. Assoc. U.K., 56, 875-888.

Heinle, D. R. (1970) Population dynamics of exploited cultures of Calanoid copepods. Helgol. wiss. Meeresunters, 20, 360-372.

Hirakawa, K. (1979) Seasonal change of population structure of a calanoid copepod Calanus pacificus in Funka Bay Hokkaido, Japan. Bull. Plankton Soc. Jpn., 26, 49-58.

Hirche, H. J. (1980) The cultivation of Calanoides carinatus (Copepoda: Calanoida) under different temperature and food conditions with a description of eggs and nauplii. J. mar. biol. Assoc. U.K., 60, 115-126.

Hirota, J. and J. P. Sayper (1976) Standing stocks of zooplankton size classes and trophic levels in Kaneohe Bay, Oahun, Hawaiian Islands. Pacific Sci., 30, 341-361.

Hulsizer, E. E. (1976) Zooplankton of lower Narragansett Bay, Rhode Island, U.S.A. 1972-1973. Chesapeake, Sci., 17, 260-270.

Ikeda, I. (1974) Nutritional ecology of marine zooplankton. Memoirs of the Faculty of Fisheries, Hokkiado University, 22, 1-97.

Ikeda, I. (1976) The effect of laboratory conditions on the extrapolation of experimental measurements to the ecology of marine zooplankton. Part 1. Effect of feeding condition on the respiration rate. Bull. Plankton Soc. Jpn., 23, 1-10.

Ikeda, I. (1977) Feeding rates of planktonic copepods from a tropical sea. J. Exp. Mar. Biol. Ecol., 29, 263-278.

Irie, T., T. Kobayashi and A. Inomata (1979) Herring in the northern Okhotsk Sea USSR 1. Feeding habits. Bull. Hokkaido Reg. Fish. Res. Lab., 44, 25-38.

Itoh, K. (1970) A consideration on feeding habits of planktonic copepods in relation to the structure of their oral parts. Bull. Plankton Soc. Japan, 17, 1-10.

Itoh, K. (1973) Food requirements of copepods estimated from their metabolic rates. Bull. Plankton Soc. Jap., 20, 78-83.

Iwasaki, H., H. Katoh and T. Fujiyama (1977) Cultivation of the marine copepod Acartia clausi. Part 1. Factors affecting generation time and egg production. Bull. Plankton Soc. Jpn., 24, 55-61. (Japanese)

Khailov, K. M. and V. Y. Yerokhin (1971) Utilization of dissolved organic matter by Tigriopus brevicornis and Calanus finmarchicus. Okeanologiya, 11, 117-126.

Koeller, P. A., J. E. Barwell-Clarke, F. Whitney and M. Takahashi (1979) Winter condition of marine plankton populations in Saanich Inlet, British Columbia, Canada. Part 3. Meso-zooplankton. J. Exp. Mar. Biol. Ecol., 37, 161-174.

Kolosova, E. G. (1975) The temperature factor and the distribution of mass species of white sea zooplankton. Okeanologiya, 15, 129-133.

Krough, A. (1931) Dissolved substances as food of aquatic organisms. Biol. Rev., 6, 412-442.

Lam, R. K. and B. W. Frost (1976) Model of copepod filtering response to changes in size and concentration of food. Limnol. Oceanogr., 21, 490-500.

Landry, M. R. (1976) The structure of marine ecosystems: An alternative. Mar. Biol. (Berl.), 35, 1-7.

Landry, M. R. (1978) Population dynamics and production of a planktonic marine copepod Acartia clausii in a small temperate lagoon on San Juan Island, Washington. Int. Rev. Gesamten Hydrobiol., 63, 77-119.

Landry, M. R. (1980) Detection of prey by Calanus pacificus: Implications of the first antennae. Limnol. Oceanogr., 25, 545-549.

Last, J. M. (1979) The food of larval turbot Scophthalmus maximus from the west central North Sea. J. Cons. Cons. Int. Explor. Mer, 38, 308-313.

Lebour, M. V. (1922) The food of plankton organisms. J. mar. biol. Assoc., U.K., 12, 644-677.

Lebour, M. V. (1923) The food of plankton organisms, II. J. mar. Biol., Assoc. U.K., 13, 70-92.

Lebour, M. V. (1925) Young anglers in captivity and some of their enemies. A study in a plunger jar. J. mar. biol. Assoc. U.K., 13, 721-734.

Lee, R. F. (1974) Lipid composition of the copepod Calanus hyperboreus from the Arctic Ocean changes with depth and season. Mar. Biol., 26, 313-318.

Lee, R. F., J. C. Nevenzel and G.-A. Paffenhöfer (1970) Wax esters in in marine copepods. Science, 167, 1510-1511.

Le Ruyet-Person, J., C. Razouls and S. Razouls. (1975) Comparative biology of common and temporarily occurring species of copepods in a neritic ecosystem in the Mediterranean and in the English Channel. Vie Milieu Ser B. Oceanogr., 25, 283-312.

Lewis, A. G. (1967) An enrichment solution for culturing the early developmental stages of the planktonic marine copepod (Euchaeta japonica Marukawa. Limnol. Oceanogr., 12, 147-148.

Lonsdale, D. J., D. R. Heinle, and C. Siegfried. (1979) Carnivorous feeding behavior of the adult calanoid copepod Acartia tonsa. J. Exp. Mar. Biol. Ecol., 36, 235-248.

Lowndes, A. G. (1935) The feeding and swimming of certain calanoid copepods. Proc. Zool. Soc. London, 6, 687-715.

Lyubimova, T. G., A. G. Naumov and L. L. Lagunov (1973) Prospects of the utilization of krill and other nonconventional resources of the world ocean. J. Fish. Res. Board Can., 30, 2196-2201.

McLaren, I. A. (1969) Population and production ecology of zooplankton in Ogac Lake a landlocked fiord on Baffin Island. J. Fish. Res. Board Can., 26, 1485-1559.

Malone, T. C. (1977) Plankton systematics and distribution. Mesa (Mar. Ecosyst. Anal.) N. Y. Bight Atlas Monogr., 13, 1-45.

Marak, R. R. (1960) Food habits of larval cod, haddock and coalfish in the Gulf of Main and Georges Bank area. J. Cons. perm, int, Explor. Mer., 25, 147-157.

Marshall, S. M. (1924) The food of Calanus finmarchicus during 1923. J. mar. biol. Assoc. U.K., 13, 473-479.

Marshall, S. M. and A. P. Orr (1955) The biology of a marine copepod Calanus finmarchicus Gunnèrus. Oliver and Boyd, Edinburg, London, 188 pp.

Marshall, S. M. and A. P. Orr (1961) On the biology of Calanus finmarchius. XII. The phosphorus cycle: excretion, egg production, autolysis. an addendum by R. J. Conover - the turnover of phosphorus by Calanus finmarchius. J. mar. biol. Assoc. U.K., 41, 463-488.

Marshall, S. M. and A. P. Orr (1966) Respiration and feeding in some small copepods. J. mar. biol. Assoc. U.K., 46, 513-530.

Martin, J. H. (1965) Phytoplankton-zooplankton relationships in Narragansett Bay. Limnol. Oceanogr., 10, 185-191.

Mayzaud, P. and S. A. Poulet (1978) The importance of the time factor in the response of zooplankton to varying concentrations of naturally occurring particulate matter. Limnol. Oceanogr., 23, 1144-1154.

Minello, T. J. (1979) The ecological separation of two similar marine calanoid copepods in the coastal waters of the northwestern Gulf of Mexico. Am. Zool., 19, p. 964.

Moore, J. W. and I. A. Moore (1974) Food and growth of Arctic char Salvelinus alpinus in the Cumberland Sound area of Baffin Island. J. Fish. Biol., 6, 79-92.

Moraitou-Apostolopoulou, M. and G. Verriopoulos (1979) Some effects of sublethal concentrations of copper on a marine copepod. Mar. Pollut. Bull., 10, 88-92.

Moraitou-Apostolopoulou, M., G. Verriopoulos and P. Lentzou (1979) Effects of sublethal concentrations of cadmium as possible indicators of cadmium pollution for two populations of Acartia clausi copepoda living at two differently polluted areas. Bull. Environ. Contam. Toxicol., 23, 642-649.

Motoda, S. and T. Minoda (1972) Herbivorous zooplankton food phytoplankton relationships in the western north Pacific Ocean, 142 degrees E. In: The Kuroshio II, K. Sugawara, editor. Saikon Publishing, Co., Tokyo, Japan, pp. 213-217.

Mullin, M. M. (1979) Differential predation by the carnivorous marine copepod Tortanus discaudatus. Limnol. Oceanogr., 24, 774-777.

Mullin, M. M. and E. R. Brooks (1970a) The effect of concentration of food on body weight cumulative ingestion and rate of growth of the marine copepod Calanus helgolandicus. Limnol. Oceanogr., 15, 748-755.

Mullin, M. M. and E. R. Brooks (1970b) Growth and metabolism of two planktonic marine copepods as influenced by temperature and type of food. In: Marine food chains, J. H. Steele, editor, Edinburgh: Oliver & Boyd, pp. 74-95.

Mullin, M. M. and E. R. Brooks (1976) Some consequences of distributional heterogeneity of phytoplankton and zooplankton. Limnol. Oceanogr., 21, 784-796.

Mullin, M. M., E. F. Stewart and F. J. Fuglister (1975) Ingestion by planktonic grazers as a function of concentration of food. Limnol. Oceanogr., 20, 259-262.

Nival, P., G. Malara, R. Charra, I. Palazzoli, and S. Nival (1974) E'tude de la respiration et de l'excrétion de quelques copepodes planctoniques (Crustacea) dans la zone de remontée d'eau profonde des côtes Marocaines. J. exp. mar. Biol. Ecol., 15, 231-260.

Nival P. and S. Nival (1973) Particle filtering efficiency of planktonic copepod. Ann. Inst. Oceanogr., 49, 135-144.

O'Brien, W. J. (1979) The predator-prey interaction of planktivorous fish and zooplankton. Am. Sci., 67, 572-581.

Ondate, K. (1977) On the feeding habits of the Pacific saury Cololabis saira. Bull. Tohoku Reg. Fish. Res. Lab., 38, 75-88.

Ogle, J. (1979) Adaptation of a brown water culture technique to the mass culture of the copepod Acartia tonsa. Gulf Res. Rep., 6, 291-292.

Ojaveer, E. and M. Simm (1975) Effect of zooplankton abundance and temperature on time and place of reproduction of Baltic herring groups. Merentutkimuslaitoksen Julk., 239, 139-145.

Omori, M. (1970) Variations of length weight respiratory rate and chemical composition of Calanus cristatus in relation to its food and feeding. In: Marine Food Chains, J. H. Steele, editor, Symposium, viii+552p. Illus. University of California Press: Berkeley, Calif., U.S.A. pp. 113-126.

Paffenhöfer, G.-A. (1979) Lab-culture of marine holozooplankton and its contribution to its studies of marine planktonic food webs. Ad. Mar. Biol., 16, 211-308.

Paffenhöfer, G.-A. and R. P. Harris (1976) Feeding, growth and reproduction of the marine planktonic copepod Pseudocalanus elongatus Boeck. J. Mar. Biol. Ass. U.K., 56, 327-344.

Paffenhöfer, G.-A. and J. D. H. Strickland. (1970) A note of the feeding of Calanus helgolandicus on detritus. Mar. Biol., 5, 97-99.

Parrish, K. K. and D. F. Wilson. (1978) Fecundity studies on Acartia tonsa (Copepoda: Calanoida) in standardized culture. Mar. Biol., 46, 65-82.

Parsons, T. R. and R. J. LeBrasseur. (1968) The availability of food to different trophic levels in the marine food chain. In: Symposium on marine food chains, Aarhus, J. H. Steele, editor. University of California press.

Parsons, T. R., R. J. LeBrasseur and J. D. Fulton. (1967) Some observations on the dependence of zooplankton grazing on the cell size and concentration of phytoplankton blooms. J. Oceanogr. Soc. Japan, 23, 10-17.

Parsons, T. R., R. J. LeBrasseur, J. D. Fulton and O. D. Kennedy. (1969) Production studies in the Strait of Georgia. II. Secondary production under the Fraser River Plume, February to May, 1967. J. Exp. Mar. Biol. & Ecol., 3, 39-50.

Pavlovskaya, T. V. and G. A. Pechen. (1971) Infusoria as a food for some mass species of marine planktonic animals. Zool. Zh., 50, 633-640.

Pechen-Finenko, G. A. (1973) Effect of food concentration on the efficiency of its assimilation by planktonic crustaceans with different feeding habits. Hydrobiol. J. (Engl. Transl. Gidrobiol. Zh.), 9, 265-271.

Pechen-Finenko, G. A., T. V. Pavlovskaya, L. G. Dubilevich and O. V. Kosikhina (1978) Experimental study on the basic trophic characteristics of two species of planktonic crustaceans. Biol. Morya (Vladivost), 4, 42-47.

Perueva, E. G. (1976) Feeding of copepodid stage IV of Calanus glacialis Jaschnor from the White Sea on the colonial alga Chaetoceros crinitus Schütt. Okeanologiya, 16, 1087-1091.

Perueva, E. G. (1977a) Some experimental information on the feeding of copepodite stage IV of Calanus glacialis qualitative composition of food. Okeanologiya, 17, 890-895.

Perueva, E. G. (1977b) Diurnal feeding rhythm of copepodite stage IV of Calanus glacialis. Okeanologiya, 17, 1085-1089.

Perueva, E. G. and B. Y. Vilenkin (1970) Feeding of Calanus glacialis (Jashnov) under various concentrations of algae. Dokl. Biol. Sci., 194, 547-549.

Petipa, T. S. (1958) The diurnal feeding rhythm of the copepod crustacean Acartia clausi Giesbr. Dokl. Akad. Nauk. SSSR Biol., 120, 435-437.

Petipa, T. S. (1965) The daily consumption of phytoplankton in the Black Sea by the copepod Calanus helgolandicus (Claus). Zoologicheskii. Zhurnal., 44, 844-854.

Poulet, S. A. (1973) Grazing of Pseudocalanus minutus on naturally occurring particulate matter. Limnol. Oceangr., 18, 564-573.

Poulet, S. A. (1974) Seasonal grazing of Pseudocalanus minutus on particles. Marine Biol., 25, 109-123.

Poulet, S. A. and P. Marsot (1978) Chemosensory grazing by marine calanoid copepods (Arthropoda:Crustacea). Science, 200, 1403-1405.

Pütter, A. (1907) Die Ernährung der Wassertiere. Z. allg. Physiol., 7, 283-320.

Raymont, J. E. G. (1963) Plankton and productivity in the oceans. Pergamon Press, New York, 660 pp.

Richman, S. and J. N. Rogers (1969) The feeding of Calanus helgolandicus on synchronously growing populations of the marine diatom Ditylum brightwellii. Limnol. Oceanogr., 14, 701-709.

Riley, G. A. (1963) Organic aggregates in seawater and the dynamics of their formation and utilization. Limnol. Oceanogr., 8, 372-381.

Robertson, S. B. and B. W. Frost (1977) Feeding by an omnivorous planktonic copepod Aetideus divergens. J. Exp. Mar. Biol. Ecol., 29, 231-244.

Rosenberg, G. G. (1980) Filmed observations of filter feeding in the marine planktonic copeod Acartia clausii. Limnol. Oceanogr., 25, 738-742.

Runge, J. A. (1980) Effects of hunger and season on the feeding behavior of Calanus pacificus. Limnol. Oceanogr., 25, 134-145.

Sargent, J. R., R. R. Gatten, E. D. S. Corner and C. C. Kilvington (1977) On the nutrition and metabolism of zooplankton. Part 11. Lipids in Calanus helgolandicus grazing Biddulphia sinensis. J. Mar. Biol. Assoc. U.K., 57, 525-533.

Sekiguchi, H. (1977) Further observation on the feeding habits of planktivorous fish sand eel in Ise Bay. Bull. Jpn. Soc. Sci. Fish., 43, 417-422.

Sekiguchi, H. (1978) Acartia clausi (Copepoda:Calanoida) in the guts of planktivorous sandeels. Bull. Jpn. Soc. Sci. Fish., 44, p. 695.

Sevigny, J. M., M. Sinclair, M. I. El-Sabh, S. Poulet and A. Coote (1979) Summer plankton distributions associated with the physical and nutrient properties of the northwestern Gulf of St. Lawrence, Canada. J. Fish. Res. Board Can., 36, 187-203.

Sheinin, M. S. and E. I. Studenikina (1969) Food requirements of the principal zooplankton of the sea. Ref. Zh. Biol., 1969, No. 12, pp. 151-152.

Shleinik, V. N. (1973) Distribution and age length composition of polar cod of the Barents Sea in 1971. Ann. Biol., 28, 131-132.

Shuman, F. R. and C. J. Lorenzen (1975) Quantitative degradation of chlorophyll by a marine herbivore. Limnol. Oceanogr., 20, 580-586.

Skiver, J. (1980) Seasonal resource partitioning patterns of marine calanoid copepods species intereactions. J. Exp. Mar. Biol. Ecol., 44, 229-246.

Smith, D. F., N. C. Bulleid, R. Campbell, H. W. Higgins F. Rowe, D. J. Tranter and H. Tranter (1979) Marine food web analysis an experimental study of demersal zooplankton using isotopically labeled prey species. Mar. Biol., 54, 49-60.

Sosnowski, S. L., D. J. Germond and J. H. Gentile (1979) The effect of nutrition on the response of field populations of the calanoid copepod Acartia tonsa to copper. Water Res., 13 449-452.

Spooner, M. F. and C. J. Corkett (1979) Effects of Kuwait oils on feeding rates of copepods. Mar. Pollut. Bull., 10, 197-202.

Strickland, J. D. H. (1968) Production of organic matter in the primary stages of the marine food chain. In: Treatise on chemical oceanography, J. P. Riley and G. Skirrow, editors, Academic Press, London, pp. 477-610.

Szyper, J. P., J. Hirota, J. Caperon and D. A. Ziemann (1976) Nutrient regeneration by the larger net zooplankton in the southern basin of Kaneohe Bay Oahu, Hawaiian Islands, USA. Pac. Sci., 30, 363-372.

Turner, J. T. (1978) Scanning electron microscope investigations of feeding habits and mouthpart structure of three species of copepods of the family Pontellidae. Bull. Mar. Sci., 28, 487-500.

Uotani, I, A. Izuha and K. Asai (1978) Foods habits and selective feeding of anchovy larvae Engraulis japonica. Bull. Jpn. Soc. Sci. Fish., 44, 427-434.

Urry, D. L. (1965) Observations on the relationship between the food and survival of Pseudocalanus elongatus in the laboratory. J. mar. biol. Assoc. U.K., 45, 49-58.

Valentin, J. (1972) The oviposition of copepods of the Gulf of Marseille annual cycle and experimental study. Tethys, 4, 349-390.

Vinogradov, M. E. (1973) New data on the quantitative distribution of plankton in the deep layers of the sea of Japan. Okeanologiya, 13, 1093-1097.

Voronina, N. M. and I. N. Sukhanova (1976) Composition of food of massive species of herbivorous Antarctic copepods. Okeanologiya, 16, 1082-1086.

Vyshkvartseva, N. V. (1972a) Phylogenetic interrelations within the genus Calanus on the basis of morphological and functional characteristics of the oral apparatus. Dokl. Akad. Nauk. SSSR Ser. Biol., 202, 1454-1456.

Vyshkvartseva, N. V. (1972b) Structure of the mandibles in the genus Calanus s.l. in relation to latitudinal zonality. Exploration of Marine Fauna, Academy of Sciences of the USSR, Zoological Institute. Trans. Israel Program for Scientific Translations, Jerusalem 1975, pp. 186-199.

Vyshkvartseva, N. V. (1972c) On the phylogenetic interrelationships within the genus Calanus sensu Lato on the basis on morpho-functional differences in the oral apparatus. Transl. Dokl. Akad. Nauk. SSSR Ser. Biol., 202, 151-153.

Watanabe, T., T. Arakawa and S. Fujita (1978) Nutritional evaluation of proteins of living feeds used in seed production of fish. Bull. Jpn. Soc. Sci. Fish., 44, 985-988.

Watanabe T., T. Arakawa, C. Kitajima, K. Fukusho and S. Fujita (1978a) Proximate and mineral compositions of living feeds used in seed production of fish. Bull. Jpn. Soc. Sci. Fish., 44, 979-984.

Watanabe, T., T. Arakawa, C. Kitakima, K. Fukusho and S. Fujita (1978b) Nutritional quality of living feed from the viewpoint of essential fatty-acids for fish. Bull. Jpn. Soc. Sci. Fish., 44, 1223-1228.

Wiborg, K. F. (1976) Fishery and commercial exploitation of Calanus finmarchicus in Norway. J. Cons. Cons. Int. Explor. Mer., 36, 251-258.

Wickstead, J. H. (1961) A quantitative and qualitative study of some Indo-West-Pacific plankton. Fish. Publ., London., 16, 1-200.

Williams, R. and M. A. Wallace (1975) Sampling at ocean weather station India 59 degrees 00 minutes N 19 degrees 00 minutes W in 1975. Ann. Biol., 32, 62-64.

Zagorodnyaya, Y. A. (1974) Feeding habits and migration of the Black Sea copepod Pseudodiaptomus elongatus in winter. Hydrobiol. J., 10, 35-41.

Zalesskikh, L. M. (1978) Feeding habits of juvenile Navaga Eleginus navaga of Pechora Bay in the Barents Sea. Sov. J. Mar. Biol., 4, 937-939.

Zhigalova, N. N. and E. Z. Samyshev (1973) Regularities in the development of zooplankton and correlation between the trophic groups of copepoda in the Bathurst area during the autumn winter period. Ann. Biol., 28, 72-74.

Zhuravlev, V. M. and M. Yu, Neyman (1976) The study of the diurnal rhythm of the vertical migrations and feeding of Parathemisto japonica (Crustacea:Hyperiidae) in the sea of Okhotsk, USSR. Okeanologiya., 16, 346-350.

Zillioux, E. J. (1973) Diver operated vs remote controlled chambers used in under water tracer experiments. Helgol. Wiss. Meeresunters, 24, 112-119.

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