SEASONAL VARIABILITY OF PRISTANE IN MUSSELS (*MYTILUS TROSSULUS*) IN PRINCE WILLIAM SOUND, ALASKA

A

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ABSTRACT

Pristane (2,6,10,14-tetramethylpentadecane) concentrations in mussels (*Mytilus trossulus*) increase abruptly during spring in Prince William Sound (PWS), Alaska. This increase is mainly due to ingestion by mussels of pristane-laden feces produced by near-shore zooplanktivores, especially juvenile pink salmon (*Oncorhynchus gorbuscha*), and I evaluate whether the increase may be used as an index of foraging success, and hence early marine survival, of pink salmon. Pristane is biosynthesized by *Neocalanus* copepods. Examination of the trophic and temporal distribution of pristane found in 3,007 samples implicates *Neocalanus* copepods as the source of pristane in PWS.

Neocalanus copepods often dominate the zooplankton biomass during spring in PWS. Juvenile pink salmon, preying on *Neocalanus*, produce pristane-laden feces that are accumulated by mussels 52 times more efficiently than is dissolved pristane. Releases *en masse* of ~ 100,000,000 juvenile pink salmon from a hatchery at the peak of the *Neocalanus* bloom were immediately followed by increases in pristane concentrations of nearby mussels monitored during 1996 and 1998. Accumulation of dissolved pristane, or of fecal pellets produced by *Neocalanus* copepods, were substantially less important pathways of pristane transfer to mussels. The transfer pathway to mussels via feces produced by zooplanktivores preying on *Neocalanus* is the basis for a potential linkage between pristane accumulation by mussels and survival of juvenile pink salmon, because it reflects indirectly the magnitude of *Neocalanus* prey consumed.

Annual survival values of hatchery pink salmon were weakly correlated ($P = 0.10$) with pristane concentrations monitored in mussels at 25 stations distributed throughout PWS from 1995 through 2001. Although *Neocalanus* copepods are considered important forage for juvenile pink salmon, feeding experiments reported herein confirm previous studies implicating growth inhibition by pristane. Hence, the forage value of *Neocalanus* copepods may be considerably lower than is usually assumed.

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mine alone, and do not reflect any official position of my employer or of any of the constituent agencies of the EVOSTC.

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GENERAL INTRODUCTION

Two species of large calanoid copepods, *Neocalanus plumchrus* and *Neocalanus flemingerii*, often dominate the zooplankton biomass in Prince William Sound (PWS), Alaska during spring, and hence occupy an important niche in the marine food web by connecting primary productivity to a wide variety of predators in upper trophic levels. Their dominance arises from the presence of deep (> 400 m) depressions inside PWS, which are necessary for their diapause and reproduction. *Neocalanus plumchrus* and *N. flemingerii* have a life span of one year and reproduce at depth in winter, after which the adults (i.e. stage VI copepodites) die. The naupliar offspring develop through five naupliar stages as they rise to shallower waters in late winter, metamorphosing to copepodites in time to begin grazing the incipient phytoplankton bloom in early spring. The copepodites develop rapidly from copepodite stage I to stage V by late spring, then seek deep water to begin diapause by the beginning of summer. This strategy allows them to efficiently graze the spring phytoplankton bloom, but it also exposes them to zooplanktivorous predators, often juvenile fish, whose survival depends on growing rapidly during spring to avoid their own predators. Hence, *Neocalanus* copepods, along with copepods in the closely-related genus *Calanus*, are usually considered as important forage for zooplantivores not only in PWS, but also in the pelagic North Pacific and North Atlantic oceans, where their deep-water reproductive habitat is ubiquitous.

Calanus and *Neocalanus* copepods biosynthesize unusually high concentrations of pristane from ingested chlorophyll, and may attain concentrations of ~1% of dry weight in adults or in late-stage copepodites. Pristane (2,6,10,14-tetramethylpentadecane: $(CH_3)_2CH\text{-}(CH_2)_3\text{-}CH(CH_3)\text{-}(CH_2)_3\text{-}CH(CH_3)\text{-}(CH_2)_3\text{-}CH(CH_3)_2$) is an alkane hydrocarbon that is terminally branched and thus relatively resistant to biochemical catabolism via β-oxidation. Hence, pristane is more persistent than un-branched alkanes when released into the environment.

Concentrations of pristane often increase abruptly in mussels (*Mytilus trossulus*) during spring in PWS. Increases of several hundred-fold are common, especially in mussels on shorelines of western PWS adjacent to the deep marine depressions there. These increases typically begin in April, peak during May, and then gradually decline to low values during the fall and winter months by late August.

The primary goal of this research is to elucidate the ecological pathway followed by pristane from *Neocalanus* copepods to mussels. The large sizes of late-stage *N. plumchrus* or of *N. flemingerii* copepodites usually preclude direct ingestion by mussels, so other routes must account for the springtime concentration increases in mussels. Three likely pathways are direct uptake of pristane dissolved into seawater from the copepods, ingestion of fecal pellets produced by them, or ingestion of feces produced by zooplanktivores that prey on *Neocalanus sp.* Objectives of this research include comparative evaluation of the importance of these three pathways in PWS, and assessment of whether interannual variation of pristane accumulation by mussels during spring can be related to interannual variation of marine survival of juvenile pink salmon (*Oncorhynchus gorbuscha*).

Juvenile pink salmon are zooplanktivorous and remain within a few tens of meters of the shoreline during their first few weeks of marine residence in spring to avoid predation. Several hundreds of millions of juvenile pink salmon migrate to the marine waters of PWS, and hence are one of the most common zooplanktivores inhabiting the near shore during spring. Because of their numbers, migration timing, and habitat preference, juvenile pink salmon are likely to be an important intermediary in the transfer of pristane from *Neocalanus sp.* to mussels. Other zooplanktivorous fishes are either much less restricted to the very near shore (such as Pacific herring, *Clupea harengus*), or are usually less abundant (e.g., the *Stichaeidae* such as blennies, pricklebacks and cockscombs).

If mussels accumulate pristane mainly through ingestion of feces produced by near-shore zooplanktivores, the pristane increase in mussels may correspond with the abundance of zooplankton forage available to juvenile pink salmon, and hence the favorability of feeding conditions. If so, pristane accumulation by mussels would reflect concurrent abundances of the juvenile salmon and their prey, and hence might serve as an index of carbon transfer to the juveniles, which may in turn provide a particularly sensitive proxy index for early marine survival. Because marine mortality is thought to be greatest and most variable during the initial period of marine residence, such a proxy index might have predictive value that could be used to improve management of the fishery on pink salmon.

The seasonal pattern of increases of pristane in mussels is evident in the results of hydrocarbon analyses conducted for the 1989 *Exxon Valdez* oil spill (EVOS). This event stimulated the most comprehensive hydrocarbon analysis of a marine food web in history, and pristane was among the hydrocarbons analyzed because of its presence in crude oil. The hydrocarbon data engendered by the spill provide an opportunity to examine how a moderately persistent organic compound that is introduced at the level of secondary production permeates a marine food web. The first chapter of this dissertation is devoted to summarizing these results with the aim of determining if the distribution and temporal variation of pristane in this food web are consistent with *Neocalanus* copepods as the pristane source.

The ecological pathway traversed by pristane from *Neocalanus* to mussels is the subject of a series of laboratory and field experiments that are presented in chapters 2 and 3, respectively. The laboratory experiments involved monitoring the dynamics of pristane uptake and depuration by mussels exposed to dissolved pristane, or to pristane-laden feces produced by juvenile pink salmon fed a natural zooplankton assemblage that was collected from PWS during spring, which consisted almost entirely of *Neocalanus sp.* The growth of these juvenile pink salmon was also monitored, and compared to growth of cohorts fed nearly equivalent rations of brine shrimp (*Artemia sp.*) as a control treatment. These experiments established the ability of mussels to bioconcentrate pristane, and the characteristic time scales of accumulation and of depuration. They also established the nutritive value relative to brine shrimp of the natural zooplankton assemblage present in PWS during the peak of the juvenile pink salmon outmigration period.

The field experiments reported in chapter 3 focus on the ecological response to release *en masse* of ~ 100,000,000 juvenile pink salmon from a hatchery in PWS near the peak of the springtime zooplankton bloom in 1996 and again in 1998. Pristane concentrations in mussels were monitored at stations near the release point for several days prior to the releases through several days afterward. Concentrations of pristane dissolved in seawater and of pristane associated with particulate matter in seawater were also monitored, as were zooplankton abundances. Fecal pellets produced mainly by *N. plumchrus* or *N. flemingerii* were collected and analyzed for pristane which, combined with zooplankton concentrations and their fecal production rates, allowed assessment of the importance of these fecal pellets as a vector of pristane transfer to mussels. When combined with the results of the laboratory experiments (which used zooplankton collected during the 1998 field experiments), the relative importance of the three alternative pathways of pristane accumulation by mussels can be clearly established.

The final chapter (chapter 4) is devoted to an assessment of whether the results of long-term monitoring of pristane concentrations in PWS mussels during spring and summer bear any relation to variation in the marine survival of hatchery-released pink salmon. Mussels were collected biweekly during spring and biweekly or monthly during summer from a network of 27 sampling stations distributed throughout PWS from 1995 through 2001. Pristane concentration increases were determined for each station sampled, and results were examined for spatial and temporal patterns. An index summarizing the overall springtime increase and subsequent decline was developed for comparison with the annual marine survival values of the hatchery pink salmon. Four hatcheries in PWS release ~ 500,000,000 juvenile pink salmon annually during spring, and the returns of adults to these hatcheries provides an especially firm basis for estimating marine survival.

Chapter 1

DISTRIBUTION OF PRISTANE IN THE NERITIC ECOSYSTEM OF THE NORTHERN GULF OF ALASKA

Short, JW (In prep) Distribution of pristane in the neritic ecosystem of the northern Gulf of Alaska. Prepared for submission to Marine Ecology Progress Series

Abstract

Biosynthesis of pristane, a terminally-branched alkane hydrocarbon, by *Calanus* copepods in the Atlantic Ocean produces up to 1% of the dry mass of stage V copepodites and adults. I confirm here that similar concentrations are attained in Pacific Ocean species of *Calanus* and *Neocalanus,* but concentrations in other GOA zooplankton genera are at least an order of magnitude lower. Late-stage *Calanus* and *Neocalanus* copepodites account for half or more of the biomass of the spring zooplankton bloom in the neritic waters of the northern GOA and contain ~50% lipid on a dry weight basis. Pristane is lipophilic and is somewhat recalcitrant, so it is moderately persistent in the marine food web, and serves as a natural chemical label for a substantial proportion of the lipid produced at the secondary level of trophic production in this ecosystem.

Results from hydrocarbon analyses of 49 species comprising 3,007 samples collected during damage assessment studies for the 1989 *Exxon Valdez* oil spill, including birds, fishes, molluscs, crustaceans, plants, mammals and an echinoderm, demonstrate that the pristane introduced into the food web by *Calanus* and *Neocalanus* copepodites during spring gradually dissipates as it passes through successive consumer species and with time. Pristane concentrations in zooplanktivorous species during spring are usually about an order of magnitude below concentrations in the copepodites. Roughly tenfold or greater reductions occur with each successive trophic transfer. Pristane concentrations are highest in adipose tissues, and are lowest in brains and blood, of species for which multiple tissues were collected. Pristane is probably introduced into intertidal and subtidal benthic food webs by feces produced by *Calanus* and *Neocalanus* copepodites, or by zooplanktivores preying on these copepodites. Seasonal comparisons indicate that pristane concentrations in species dwelling in the intertidal, the subtidal benthos, the mid-water column, and in birds are nearly always higher during spring, consistent with production during the spring zooplankton bloom.

Introduction

Chemical methods are often used to investigate marine food web dynamics. This approach typically involves the analysis of relatively persistent compounds that serve to label prey organisms, such as unusual aliphatic hydrocarbons and fatty acids (Blumer et al. 1964, Blumer et al. 1969, Paradis and Ackman 1977, Sargent and Whittle 1981, Parrish et al. 2000, Iverson et al. 1997, 2002, 2004, Stübing et al. 2003), or the analysis of stable isotopes of carbon and nitrogen as an indicator of relative trophic position (Lajtha and Michener 1994). Pristane (2,6,10,14-tetramethylpentadecane) was the first aliphatic hydrocarbon proposed for this purpose (Blumer et al. 1964), in part because it is terminally branched and thus recalcitrant to biodegradation (Pirnik 1977, Schaeffer et al. 1979), conferring persistence (Blumer et al. 1969). Pristane is readily analyzed in marine tissues by gas chromatography, with detection limits on the order of 10 ng g^{-1} (Short et al. 1996). Despite these advantages, pristane analysis has not often been used for food web studies, in part because foundation studies to identify the species that produce pristane biochemically, as well as studies to determine the distribution and persistence of pristane in tissues of their predators, are required to provide context for the interpretation of new data.

The major biogenic source of pristane identified is copepods in the genus *Calanus*. These copepods introduce large quantities of pristane annually to mid- and high-latitude marine food webs at the secondary trophic level. Pristane is biosynthesized in these copepods from ingested chlorophyll (Avigan and Blumer 1968), and approaches 1% dry weight in adults or late copepodite stages of *C. finmarchicus, C. glacialis*, and *C. hyperboreus* (Blumer et al. 1964). These high concentrations have only been found in *Calanus* among the zooplankton genera examined. Pristane concentrations in other zooplankton collected from the Atlantic Ocean, including other calanoid copepod genera, were lower by factors of at least 10 and usually more than 100 (Blumer et al. 1964), and only traces are found in phytoplankton (Blumer et al. 1971). *Calanus* copepods are mostly herbivorous, and are an important link in marine food webs between primary production and consumers at higher trophic levels, especially during spring phytoplankton blooms at subarctic latitudes where they may account for most of the spring zooplankton biomass near the sea surface (Parsons and Lalli 1988). Hydrocarbons are highly lipophilic, so pristane strongly associates with lipids of consumers that ultimately depend on *Calanus* copepods. The relatively high concentration of pristane produced annually by a large biomass of secondary producers, its lipophilicity, and its environmental persistence led to its proposal as a natural tracer molecule of predation relationships (Blumer et al. 1964).

Pristane is nearly ubiquitous in marine organisms at widely varying concentrations that usually depend on trophic distance from marine zooplankton, especially *Calanus spp.* Concentrations in lipids of zooplanktivores approach or exceed those found in *Calanus spp.*, including basking and other planktivorous sharks (Kayama et al. 1969), herring (*Clupea harengus*) and sand lance (*Ammodytes americanus*; Ackman 1971), as do concentrations in stomach oils of procellariiform birds (Clarke and Prince 1976). Concentrations in lipid-rich tissues of pelagic fishes that do not feed directly on zooplankton are usually substantially lower, such as livers of Atlantic cod (*Gadus morhua*), Greenland cod (*Gadus ogac*), Greenland halibut (*Reinhardtius hippoglossoides*), American plaice (*Hippoglossoides platessoides*), wolffish (*Anarhichas spp.*) and redfish (*Sebastes marinus*), in which pristane concentrations range from 1.86 – 99 $\mu g\ g^{-1}$ wet weight (Johansen et al. 1977). However sperm whales (*Physeter macrocephalus*), which feed mainly on squid, contained as much as 240 $\mu g\ g^{-1}$ in their blubber (Sano 1968), while sockeye salmon (*Oncorhynchus nerka*), which are facultative zooplanktivores, contained only 0.380 $\mu g\ g^{-1}$ in their livers and 2.4 $\mu g\ g^{-1}$ in their viscera (Sasaki et al. 1991). Pristane in oil from herring in the Baltic Sea contained less than 1% of the pristane concentration found in oil from herring in the Atlantic Ocean (Linko and Kaitaranta 1976), consistent with the low abundance of *Calanus* copepods in the Baltic Sea (Hernroth and Ackefors 1979). Tissues of benthic invertebrates consistently contain pristane concentrations below about 2 $\mu g\ g^{-1}$ (Johansen et al. 1977, Mackie et al. 1978, Mackie et al. 1974), as does the blubber of the Pacific walrus (*Odobenus rosmarus divergens*), which feed primarily on these invertebrates (Seagars and Garlich-Miller 2001). Pristane was not detected in any of four species of benthic epiphytes collected from a Carribean lagoon (Botello and Mandelli 1978). Concentrations in lipid-rich tissues of freshwater fishes or in carcasses of birds that depend on terrestrial food webs were also uniformly near or below the detection limits of the analyses (Ackman 1971, Custer et al. 2001, Lopez-Leitón et al. 2001).

Although the distribution of pristane in marine organisms as reported in the literature is broadly consistent with *Calanus* copepods as the primary source, other sources may exist, and comparisons of these studies must account for sampling from different parts of the world and decades apart. In contrast, samples of biota that were analyzed for hydrocarbons to assess the impacts of the 1989 *Exxon Valdez* oil spill (EVOS) in Prince William Sound (PWS), Alaska, provide an opportunity to evaluate the distribution of pristane in a regional subarctic marine food web during a period of a few consecutive years. Over 3,900 samples of biota were collected by government agencies from the affected part of the northern Gulf of Alaska (GOA) during the years immediately following the incident. The sampled biota included several species of birds, fish, molluscs, crustaceans, marine and terrestrial mammals and one echinoderm, and several different tissues were sampled from some of these species. The samples were analyzed by the same gas-chromatography (GC) method for a suite of aliphatic and aromatic hydrocarbons characteristic of crude oil, including pristane (Short et al. 1996), making this the largest data set of its kind that is internally consistent with respect to sampling and chemical analysis methods. Most of the analyzed samples were collected to evaluate the extent of pollution in environmental compartments where oil impacts were not obvious, hence the need for sensitive GC analyses. Hydrocarbons characteristic of the spilled oil were often not detected in these samples (Short and Heintz 1997), but pristane was, especially in mussels (*Mytilus trossulus*) collected both before and after the spill (Short and Babcock 1996, Karinen et al. 1993).

Copepods of the genus *Neocalanus* often dominate the near-surface zooplankton biomass during spring in the northern GOA (Cooney et al. 2001, Cooney 1986a, 1986b, Mackas et al. 1993, Miller et al. 1988), and this genus is closely related to *Calanus* (Bradford and Jillett 1974). If the concentrations of pristane in *Neocalanus* and *Calanus* copepods are similar, then this ecosystem presents an instance of an extensively sampled food web receiving a large annual input of pristane from secondary production during spring.

I present here the results of pristane analyses of Pacific Ocean species of the genera *Calanus* and *Neocalanus*, and in other zooplankton sampled during spring in the northern GOA, to determine whether the high pristane concentrations found in Atlantic Ocean *Calanus* species also occur in Pacific Ocean species of this and other copepod genera. I then present a summary of the seasonal distributions of pristane among the biota sampled for government-sponsored EVOS damage assessment studies, to evaluate whether distributions of pristane among species at different trophic levels are consistent with *Calanus* and *Neocalanus* copepods as sources.

Study Area

Nearly all of the samples were collected from the vicinity of the path traversed by oil spilled from the T/V *Exxon Valdez,* including PWS in the northern GOA and extending along the Kenai and Alaska peninsulas to Chignik (Fig. 1.1). Most of these samples (83%) were collected from PWS, and the remainder from the spill-impacted region west of PWS (Fig. 1.1).

Prince William Sound is a complex fjord-type ecosystem with a sea surface area of about 8,800 km^2 (Schmidt 1977). Depths exceed 700 m in the northwestern part of the sound. Direct deep-water exchange with the GOA is limited by a 180 m barrier sill on the continental shelf just outside PWS. The surface waters of PWS are flushed by the Alaska Coastal Current (ACC) that usually enters through Hinchinbrook Entrance and exits through Montague Strait (Niebauer et al. 1994, Vaughan et al. 2001) (Fig. 1.1). This flushing action is strongest in the fall and winter when wind-stress forcing by storms in the GOA is greatest (Niebauer et al. 1994, Vaughan et al. 2001), and freshwater runoff, which drives the ACC, is also greatest (Royer 1979). Surface-water from the GOA regularly introduces pelagic plankton communities into PWS, including *Neocalanus* copepods (Cooney 1986a, Cooney 1986b, Cooney 1993, Cooney et al. 2001, Vaughan et al. 2001).

The annual cycle of marine production follows a pattern typical of subarctic marine waters. Increased light and heat during spring together with calmer winds permit development of a stratified euphotic surface layer that leads to a strong spring phytoplankton bloom. This bloom peaks in April inside PWS and somewhat later in the coastal GOA, and is followed by a strong zooplankton bloom (Eslinger et al. 2001, Cooney et al. 2001). The zooplankton bloom biomass consists mainly of *Neocalanus cristatus, N. plumchrus* (and *N. flemingerii* [Miller 1988], a species that has recently been distinguished from *N. plumchrus*), *Calanus marshallae, Metridia okhotensis* and *Pseudocalanus spp.* in PWS (Cooney 1986b, Cooney et al. 2001), and *N. cristatus, N. plumchrus, N. flemingerii*, and *E. bungii* in the open GOA (Mackas et al. 1993).

The coastal waters of the northwestern GOA are very productive, and have supported numerous important commercial fisheries, including five species of Pacific salmon (*Oncoryhnchus spp.*), Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*), Pacific herring (*Clupea harengus pallasi*) and walleye pollock (*Theragra chalcogramma*), as well as a diverse fauna of marine mammals and birds, both resident and migratory. Primary productivity is estimated at 100-225 g C m^{-2} yr^{-1} (Goering et al. 1973, Sambrotto and Lorenzen 1986), and most of the annual primary production occurs during the spring bloom (Goering et al. 1973). The biomass dominance of *Calanus* and *Neocalanus* copepods in the ensuing zooplankton bloom (~50% of biomass during May [Cooney et al. 2001]), together with the high lipid content of these copepods (~50% dry weight, [Båmstedt 1986, Duesterloh 2002]) implies that a substantial proportion of the annual energy budget for this coastal marine ecosystem flows through these genera.

Methods

Zooplankton Samples

Three groups of copepods were collected for pristane analysis. The three groups are distinguished in Table 1.1 by their collection locations and seasons. The first group was collected from Lynn Canal and Chatham Strait in southeastern Alaska. These samples were preserved in 5% buffered formalin seawater immediately following collection during late June 1991, and analyzed December 1994 following species sorting of the preserved samples. The sorted species consisted mostly of stage V copepodites and adult females. The second and third groups were collected from PWS during July 1998 and May 2000 respectively. These samples were sorted and identified immediately after collection and were stored frozen at -20 °C until analysis in December 1999 (second group) and May 2000 (third group). Discrete copepodite stages of *C. marshallae*, *N. cristatus*, and *N. plumchrus* were analyzed separately from the third group. Species and copepodite stages were determined following criteria given by Gardner and Szabo (1982). *Neocalanus plumchrus* was distinguished from *N. flemingeri* in the third group based on examination of the mandibular gnathobase and the ratio of cephalosome to prosome lengths following Miller (1988). These species were not distinguished in the first group, so identification of *N. plumchrus* in this group is presumptive.

Exxon Valdez Oil Spill Samples

Comparison of hydrocarbon analysis results among the samples collected for the EVOS requires caution, because these samples were collected for a variety of assessment objectives by multiple government agencies and personnel. Samplers all followed the same collection, storage and documentation procedures, which involved use of dichloromethane-rinsed surfaces of collection and dissection tools, and storage in pre-cleaned glass environmental sample jars at -20 °C as soon as possible after collection.

Close geographical or temporal coordination of sample collection among different species was impossible because of biological constraints on species availability and conflicting sampling objectives. Sampling effort was therefore unevenly distributed among species, among tissues within species, among geographical locations and at different sampling times. The common and scientific names of the species considered herein, along with their foraging mode, are given in Table 1.2.

All of the hydrocarbon data generated from government studies of the EVOS are archived in the *Exxon Valdez* Oil spill of 1989 State/Federal Trustee Council Hydrocarbon Database (EVTHD) at the Auke Bay Laboratory, and are available from the author. Details of the sample collection methods are contained in the final reports of the principal investigators of the studies funded by the *Exxon Valdez* Trustee Council, and are available from the Council in Anchorage, Alaska. These studies are identified in the EVTHD for each sample contained therein.

To facilitate comparisons among samples, the most broadly sampled tissues are emphasized in the presentation of the results. These include livers and eggs of birds, whole bodies and eggs of fish, whole bodies of molluscs and plants, hepatopancreas and eggs of crustaceans, and blubber and livers of mammals. Relevant results for other less frequently sampled tissues or for stomach contents are also presented when these serve to corroborate or qualify the main body of results. I categorically excluded samples from consideration when they failed to meet any of the following criteria: the sampling location was outside the spill area (see Fig. 1.1) or was not recorded in the database, the collection date was not recorded, the dry weight of the sample was not recorded, the sampled animal was not identified to species, the sampled matrix was feathers or an egg or mollusc shell, or the sample was likely contaminated by crude oil or refined petroleum products. I considered contamination likely if the ratio phytane to pristane was greater than 10%. Phytane (2,6,10,14-tetramethylhexadecane) is a branched hydrocarbon that is rarely found apart from petroleum sources (Dean and Whithehead 1961, Blumer and

Snyder 1965, Ackman and Zhou 2003), is about as persistent as pristane in the environment, and is present in *Exxon Valdez* cargo oil at nearly the same concentration as pristane (Wang et al. 2003). Application of these selection criteria reduced the number of samples considered to 3,007.

Most (57.7%) of the samples reported were collected within PWS during 1989 and 1990, and 22.7% were collected inside PWS during 1991 through 1995. Another 15.5% of samples were collected from outside PWS (but within the spill area, Fig. 1.1) during 1989 and 1990, and 4.5% were collected during 1991 through 1995. All but 2 of the samples collected after 1990 are molluscs, and of these 98.5% are bivalves.

Pristane Analysis

The chemical analysis of aliphatic hydrocarbons in the oil spill samples involved dichloromethane extraction of macerated tissues spiked initially with a suite of perdeuterated alkane internal standards, solvent concentration and exchange into hexane over steam, purification by silica gel/alumina column chromatography eluted with pentane, and solvent re-concentration followed by alkane resolution with gas chromatography (GC) with measurement by flame ionization (Short et al. 1996). Identification of pristane is based on GC elution time, with occasional confirmation by GC-mass spectrometry. The method for the zooplankton samples involved no alumina and less silica gel, because of the small tissue mass aliquots analyzed (< 0.1 g).

The accuracy of the pristane analyses were generally within ± 15% based on comparison with authentic hydrocarbon standards prepared by the National Institute of Standards and Technology (NIST), and the coefficient of variation was generally less than ± 20%. The method detection limit (MDL), defined as the estimated concentration associated with a 1% probability of type I detection error, was 0.0617 to 0.210 μg depending on the analytical laboratory. The corresponding MDL estimate for individual samples is the ratio of these values and the mass of the sample analyzed.

Dry Weight Determination

Zooplankton samples were air-dried at room temperature to constant weight. The ratio of wet and dry weights of *Neocalanus plumchrus* CV copepodites collected from Prince William Sound was 6.1. Samples collected for the *Exxon Valdez* oil spill were heated overnight at 60 °C for dry weight determination.

Data Analysis

Pristane concentrations are presented as μg pristane per gram dry tissue weight. Results are aggregated seasonally to evaluate seasonal variability and comparability. Pristane concentrations within each season, species, and tissue type are summarized by box plots indicating the median, 10%, 25%, 75% and 90% of the data for large sample sizes ($n > 5$), or the range ($n \leq 5$) in Figures 1.2 – 1.8.

The significance of differences between two samples is determined by the nonparametric Mann-Whitney U test (Mann and Whitney 1947).

Results

Zooplankton

Neocalanus and *Calanus* copepods contained the highest concentrations of pristane among the species surveyed (Table 1.1). Median pristane concentrations ranged from 2,440 to 8,020 μg g^{-1} in the CIV and CV copepodite stages of these species. The median was significantly lower in the CIV copepodite stage compared with the CV stage ($P = 0.024$) of *C. marshallae*, but not of *N. plumchrus* ($P = 0.15$). However, the pristane concentration of one sample of CIII *N. plumchrus* was only 731 μg g^{-1}, substantially lower than the lowest concentration in CIV copepodites (2,440 μg g^{-1}). Pristane concentrations in the formalin-preserved samples of *C. marshallae, N. cristatus*, and *N. plumchrus* from southeastern Alaska were not significantly different than frozen samples collected from PWS ($P > 0.142$).

Pristane concentrations were consistently less than 700 µg g^{-1} in the other zooplankton species analyzed, and were usually much less (Table 1.1). The median concentration in *M. okhotensis* was 660 µg g^{-1}, compared with concentrations less than 125 µg g^{-1} in the two other species of *Metridia*. *Euchaeta elongata* from southeastern Alaska contained 455 µg g^{-1} compared with 23.8 µg g^{-1} from PWS. The remaining species surveyed contained less than 125 µg g^{-1}, including *Pseudocalanus spp.* and the three euphausid species (*Thysanoessa spp.*)

Exxon Valdez Oil Spill Samples

Birds

The highest pristane concentrations in birds were found in the two zooplanktivorous species. One shearwater liver contained 1,960 µg g^{-1} (Fig. 1.2), and the stomach contents of the same animal contained 1,460 µg g^{-1}. The median concentration of 19 fork-tailed storm petrel eggs was 519 µg g^{-1}.

Substantial pristane concentrations were found in the five piscivorous bird species. Median pristane concentrations in livers of black kittiwakes, marbled murrelets, and pigeon guillemots were 137 µg g^{-1}, 46.1 µg g^{-1} and 1.15 µg g^{-1} (Fig. 1.2). The liver of one common loon sampled during spring 1989 contained 229 µg g^{-1}. Median pristane concentrations in eggs of bald eagles and black kittiwakes were similar, with ranges of 1.17 µg g^{-1} to 62.2 µg g^{-1} for bald eagles and 1.51 µg g^{-1} to 61.7 µg g^{-1} for black kittiwakes (Fig. 1.2.). Median pristane concentrations were higher in bald eagle eggs sampled during spring compared with summer 1989 and 1990, but the significance of these differences was marginal ($P < 0.10$). Twenty-two blood samples from bald eagles were analyzed, but pristane was usually not detected.

Birds feeding primarily nearshore or on intertidal invertebrates contained lower concentrations of pristane than did the piscivorous birds. The invertebrate feeders include three shorebirds (black turnstone, rock sandpiper, and surfbird) and five sea ducks (Barrow's and common goldeneye, harlequin duck, surf scoter, and white-winged scoter). Among these 8 species, median pristane concentrations in livers were highest in black turnstones and surfbirds sampled during winter, at 5.11 $\mu g\ g^{-1}$ and 12.9 $\mu g\ g^{-1}$ respectively. The median for black turnstone livers was 1.05 $\mu g\ g^{-1}$ in summer 1989 compared with 5.11 $\mu g\ g^{-1}$ in winter 1990, but the difference is not significant ($P = 0.5$). In contrast, pristane concentrations in livers of rock sandpipers and of all the sea ducks were lower, ranging from below MDL to 2.68 $\mu g\ g^{-1}$ across all 39 liver samples of these species. Although no seasonal trends were evident in these shorebird and sea duck samples, they were usually collected during fall or early winter, rather than the spring and summer collections typical of most other species in this survey, so comparisons among these species requires allowance for for the possibility of seasonal trends.

The only samples collected from an obligate avivore were peregrine falcon eggs. Median pristane concentrations in eggs collected during spring or summer 1990 were less than 1 $\mu g\ g^{-1}$, but ranged to 12.2 $\mu g\ g^{-1}$ in the 12 samples analyzed (Fig. 1.2).

Fish

Pristane concentrations were highest in Pacific herring and juvenile pink salmon. Muscle and viscera of Pacific herring had median concentrations near 100 $\mu g\ g^{-1}$, compared with 11.6 $\mu g\ g^{-1}$ to 21.6 $\mu g\ g^{-1}$ in reproductive tissues and eggs (Fig. 1.3). Pristane concentrations in pink salmon increased substantially following migration to seawater. The median concentration in alevins just prior to emergence from gravels of incubation streams was 4.57 $\mu g\ g^{-1}$, compared with median concentrations in seawater-resident fry during spring and summer of 57.9 $\mu g\ g^{-1}$ and 142 $\mu g\ g^{-1}$, which are significant increases (alevins vs spring juveniles, $P < 0.001$; spring vs summer juveniles, $P < 0.004$).

Pristane concentrations were generally lower in the other fishes. The median pristane concentration in whole juvenile dusky rockfish sampled during fall 1989 was 34.6 $\mu g\ g^{-1}$, compared with median concentrations of 7.10 μg g^{-1} to 13.3 μg g^{-1} in whole prickleback species sampled during spring or summer. During spring, one juvenile Pacific cod contained 8.09 μg g^{-1}, but three others contained less than 0.090 μg g^{-1} (Fig. 1.3). Pollock (*Theragra chalcogramma*), which are commercially important in PWS and the GOA, were unfortunately not sampled, because their pelagic habitat was considered to be at low risk of contamination from the oil spill.

Molluscs

The highest pristane concentrations among molluscs occurred in some of the suspension-feeders sampled during spring. The suspension-feeders sampled include bay mussels, butter clams, Kennerley's venus clams, littleneck clams, Pacific oysters, sunset clams, weathervane scallops and razor clams (Table 1.2). Bay mussels contained the highest median concentrations among these suspension-feeders at 2.34 μg g^{-1} to 3.51 μg g^{-1} during spring, compared with 0.179 μg g^{-1} to 0.234 μg g^{-1} during summer, and this seasonal difference was highly significant ($P < 0.001$; Fig. 1.4). Some bay mussels contained concentrations greater than 50 μg g^{-1} during spring, comparable with concentrations of some piscivorous fish. Pristane concentrations during spring were significantly greater than summer for all the other suspension-feeders where data are available for comparison ($P < 0.01$) except for razor clams, which had greater concentrations in summer compared with spring (Fig. 1.4).

Increased concentrations of pristane in bay mussels during spring compared with summer is a consistent pattern evident each year from 1989 through 1995 (Fig. 1.5). The differences between spring and summer concentrations are significant in each of these years ($P < 0.001$) except 1991 ($P = 0.065$).

Pristane concentrations attained seasonally maximum values in bay mussels, butter clams, and littleneck clams during May (Figs. 1.4 and 1.5). In 1989, pristane concentrations increased from less than 0.5 μg g^{-1} in March and early April to over 63 μg g^{-1} in early May, then gradually subsided to concentrations generally less than 1 μg g^{-1} by August, and this pattern repeated each subsequent year through 1995. The available data for butter clams and littleneck clams are consistent with the trends evident for bay mussels, but maximum pristane concentrations did not exceed 10 μg g^{-1}.

Pristane concentrations in periwinkle snails, intertidal algal and detrital grazers, were comparable with the suspension-feeding bivalves. Median concentrations were 1.51 μg g^{-1} in spring 1989 and 0.504 μg g^{-1} in summer 1990 (Fig. 1.4). Pristane concentrations were usually below MDL in the deposit-feeding *Macoma* clams (Fig. 1.4).

Crustaceans, Echinoderm and Plants

Substantial but variable pristane concentrations occurred in the hepatopancreas of all three crab species sampled. Median concentrations were 39.1 μg g^{-1} in king crab hepatopancreas, and ranged from 3.26 μg g^{-1} to 27.1 μg g^{-1} in Tanner crab and from 0.261 μg g^{-1} to 4.53 μg g^{-1} in Dungeness crab (Fig. 1.6). Maximum pristane concentrations near 100 μg g^{-1} to more than 400 μg g^{-1} were evident in all three species.

Concentrations in crab eggs or ovaries were generally lower than in the hepatopancreas, with median concentrations of eggs ranging from below MDL to 15.1 μg g^{-1} across the three crab species and the sampling seasons. Maximum concentrations were also lower, the highest value being 33.2 μg g^{-1} (Fig. 1.6).

Spot shrimp eggs contained somewhat higher pristane concentrations than the crab eggs. Median concentrations of shrimp eggs were 7.90 μg g^{-1}, and the maximum value was 223 μg g^{-1} (Fig. 1.6).

The median pristane concentration in the suspension-feeding barnacle during spring was 1.74 μg g^{-1}, comparable with concentrations in suspension-feeding molluscs (Figs. 1.3 and 1.6). Barnacles were not sampled during other seasons.

Concentrations of pristane in green sea urchin gonads were low compared with the crustacean tissues, with a median of 0.257 μg g^{-1} and a maximum of 2.26 μg g^{-1} (Fig. 1.6).

The median concentration of pristane in rockweed collected during spring from Montague Island was 5.68 μg g^{-1}, and ranged from 4.53 μg g^{-1} to 9.02 μg g^{-1} (Fig. 1.6). One eelgrass sample concurrently collected from the same location contained 5.04 μg g^{-1}. Pristane concentrations were below detection limits in six samples of rockweed collected in late summer/early fall from sites along the Alaska Peninsula.

Mammals

Substantial concentrations of pristane were found in some tissues of the piscivorous harbor seal, harbor porpoise and sea lion. The large number of tissue types sampled from harbor seals provides an indication of the distribution of pristane within this animal. The highest median pristane concentrations occurred in the mammary, followed by blubber, milk, kidney, heart, ovary, liver, blood, and brain in descending order. Median concentrations in the mammary were 294 μg g^{-1} in the spring and 52.9 μg g^{-1} in the summer, and were between 2.82 μg g^{-1} and 50.9 μg g^{-1} in blubber, milk, kidney, and heart (Fig. 1.7). Maximum concentrations ranged to several hundred μg g^{-1} in the mammary and ranged to 50 – 150 μg g^{-1} in blubber, milk, kidney and liver, while minimum concentrations were near or below MDL in blubber, kidney and liver. The median concentration in liver was 0.590 μg g^{-1} but exceeded 10 μg g^{-1} in 2 samples. Comparatively low concentrations (< 9 μg g^{-1}) were consistently found in the blood, brain, heart, lung and ovary.

The distribution of pristane in the harbor porpoise and sea lion were consistent with the pattern evident in harbor seals. The two blubber samples from harbor porpoise had pristane concentrations of 0.234 μg g^{-1} and 175 μg g^{-1}, similar to the values that range from 0.333 μg g^{-1} to 138 μg g^{-1} in six samples of sea lion blubber (Fig. 1.8). Liver concentrations ranged from below MDL to 679 μg g^{-1} in harbor porpoise and sea lion, encompassing the range found in harbor seal livers (Fig. 1.8). Concentrations in sea lion brains were consistently low (< 1.29 μg g^{-1}), similar to harbor seal brains.

Pristane concentrations ranged from 37.3 μg g^{-1} to 628 μg g^{-1} in killer whale blubber, but were only 5.26 μg g^{-1} in the single sample of liver (Fig. 1.8). Blubber contained 8.97 μg g^{-1} and 8.02 μg g^{-1} in single samples from grey and minke whales, and liver concentrations ranged from 0.136 μg g^{-1} to 3.58 μg g^{-1} in these two whales.

Pristane concentrations were consistently low in sea otter blood, fat, and livers compared with the piscivorous marine mammals. Pristane was less than 14 μg g^{-1} in fat or liver (Fig. 1.8), and was detected only once in 55 sea otter blood samples at 0.179 μg g^{-1}.

Pristane concentrations were 1.03 μg g^{-1} or less in 45 samples of feces from brown bears collected from the Alaska Peninsula during spring, and was 0.684 μg g^{-1} in a single liver sample collected (Fig. 1.8). Concentrations of pristane were below MDL in five samples of Sitka black-tailed deer livers (Fig. 1.8).

Discussion

Analogous Role of Pristane in Pacific and Atlantic Ocean Members of Calanus and Neocalanus

The high concentrations of pristane reported here for Pacific Ocean species of *Calanus* and *Neocalanus* are comparable with concentrations reported previously for Atlantic Ocean *Calanus* species (Blumer et al. 1964), indicating that Pacific Ocean species of both *Calanus* and *Neocalanus* possess the ability to biosynthesize pristane from ingested chlorophyll. Pristane concentrations in stage V copepodites of Atlantic Ocean species *C. finmarchichus*, *C. glacialis*, and *C. hyperboreus* ranged from 4,500 – 9,200 μg g^{-1}, and did not appear to vary significantly from April through August, or geographically within a geographic range of > 300 km (Blumer et al. 1964). Pristane concentrations in stage V copepodites of the Pacific Ocean species *C. marshallae, N. cristatus,* and *N. plumchrus* reported here range from 1,960 – 8,850 μg g^{-1}, and also do not vary seasonally from spring through summer nor geographically from southeast Alaska to PWS, a distance of ~ 500 km (Table 1.1). Although the sample sizes of copepods used to characterize the pristane concentrations in these species are small, the concentrations are probably typical of the respective populations in the regions sampled, at least for the Pacific Ocean species. The mean pristane concentration of mixed stages IV and V *C. marshallae, N. flemingerii,* and *N. plumchrus* collected from PWS during spring with a 505 μm-mesh plankton net was 7,490 ± 3,250 μg g^{-1}. This mean concentration was derived from twelve plankton net tows, each containing several thousands of these copepods (Short in prep). The general agreement of the mean pristane concentration of the zooplankton tows and the results for the constituent individual zooplankters indicates the concentrations measured in the individual zooplankters are not anomalous, but typical of the populations sampled. Also, note that the insignificant differences between pristane concentrations in formalin-preserved compared with frozen samples of *C. marshallae* or *N. cristatus* indicates that prolonged contact with formaldehyde has little effect on pristane concentration, which is not surprising given the chemical resistance of alkanes to weak oxidizers such as formaldehyde.

Members of both *Neocalanus* and *Calanus* inhabiting high latitudes of the northern hemisphere accumulate substantial lipid reserves for sustenance during prolonged periods of diapause and for subsequent reproduction (Conover 1988). Their phylogenetic and life-history similarities suggest that *Neocalanus* copepods may share with *Calanus* copepods the ability to biosynthesize pristane from chlorophyll. Avigan and Blumer (1968) were unable to resolve whether this biosynthetic competence is associated with the copepod's anabolic metabolism or with the microbial community inhabiting their gut, but in either case the increasing pristane concentration with copepodite life stage in *N. plumchrus* and *C. marshallae* (Table 1.1) suggests pristane production parallels oil droplet formation. Analysis of tropical and Antarctic members of these genera may provide additional insight regarding the role of pristane in the life histories of these copepods.

Zooplankton genera other than *Calanus* and *Neocalanus* may acquire pristane through similar pathways of anabolic synthesis, or through predation. *Pseudocalanus spp.* are herbivorous (Mauchline 1998), so the lower pristane concentrations found in these zooplankters may have been acquired through a less active biosynthetic pathway compared with *Calanus* or *Neocalanus* species. The other zooplankton analyzed here or by Blumer et al. (1964) are either omnivorous or carnivorous, and pristane in these species may be acquired through ingestion of the younger copepodite stages of *Calanus* or *Neocalanus*, or of later copepodite stages or adults of, for example, *Pseudocalanus spp*.

Dominance of Calanus and Neocalanus as Sources of Pristane in the Northern Gulf of Alaska

Evidence supporting the identification of *Calanus* and *Neocalanus* copepods as the major source of pristane in the northern GOA includes: (1) the fact that, of all the biota and tissue types sampled, pristane concentrations are highest in these copepods, (2) *Calanus* and *Neocalanus* copepods account for a large proportion of the zooplankton biomass in the spring zooplankton bloom, (3) pristane concentrations in other species decline with increasing trophic transfers from these copepods, and (4) patterns of seasonal variability are generally coherent with the production of pristane by *Calanus* and *Neocalanus* copepods. *Calanus* and *Neocalanus* copepods may account for ~ 50% of the zooplankton biomass during May (Cooney et al. 2001), and pristane concentrations exceed those of other potential zooplankton producers of pristane by a factor of ~ 50, implying ~98% of the pristane produced during spring is produced by *Calanus* and *Neocalanus* copepods. The combined wet weight biomass of *Calanus* and *Neocalanus* copepods in the uppermost 50 m of seawater is ~ 0.15 g m^{-3} in May (Cooney et al. 2001), equivalent to ~ 7 mg pristane m^{-2} sea surface (assuming a wet:dry weight ratio of 6.1 and a pristane concentration of 0.6%: $0.15 \text{ g m}^{-3} \times 50 \text{ m} \times (6.1)^{-1} \times 0.006 = 7.4$ mg pristane m^{-2}). Averaged over the 8,800 km^2 surface area of PWS, this implies production on the order of at least 65 tons of pristane annually by these copepods. In comparison, this about the same as the amount of pristane introduced into PWS by the crude oil spilled from the T/V *Exxon Valdez* (assuming a spill volume of 43,000 m^3 (Wolfe et al. 1994), an oil density of 0.87 kg l^{-1}, and a pristane concentration of 1.89 g kg^{-1} oil (Wang et al. 2003) leads to $43{,}000{,}000 \text{ l} \times 0.87 \text{ kg l}^{-1} \times 1.89 \text{ g kg}^{-1} = 71$ tons). That other annual inputs of anthropogenic petroleum products to PWS are much smaller than the amount introduced by the EVOS is confirmed by the very low concentrations of petroleum hydrocarbons in mussels analyzed for monitoring seawater quality there (Payne et al. 2003). Hence, neglecting catastrophic oil spills, PWS is inoculated annually with a substantial dose of pristane generated almost entirely by *Calanus* and *Neocalanus* copepods, which then permeates the marine food web through trophic transfers involving predation, and by fecal production associated with these transfers or with the copepods themselves.

Distribution of Pristane in the Marine Food Web of the Northern Gulf of Alaska

The large number of species, tissues and samples analyzed for hydrocarbons following the EVOS is by far the most comprehensive chemical survey of a marine ecosystem for the distribution of hydrocarbons among the constituent biota. Other oil spills before or since the EVOS (e.g. the Amoco Cadiz, CNEXO 1981), or pre-development surveys of marine biota potentially at risk from offshore oil and gas exploration (e.g. Johansen et al. 1977) have had far fewer resources available for the chemical analysis of affected biota, and large-scale monitoring programs for hydrocarbons in marine biota (e.g. the US benthic surveillance program, Lauenstein et al. 1993) are limited to one or a few species. The exceptional breadth of sampling for the EVOS has the potential of providing an especially detailed portrayal of the distribution of pristane in the food web, provided that proper allowance is made for certain problems regarding sample comparability and interpretation. Comparison of the results from the EVOS is problematic because of the sampling inconsistencies among the species, tissues and seasons. None of these samples were collected randomly, so the results are probably biased from multiple sources, and the magnitude and direction of these biases are unknown. Also, the sample sizes were very small (< 5) for many of the species and tissues examined. Nonetheless, even a non-random survey of the distribution of pristane can provide a useful indication of the approximate variability of the biota and the tissues sampled, of the most dominant trends regarding biomagnification or dissipation across trophic levels, and might also provide evidence suggestive of unexpected distribution pathways.

Equilibrium thermodynamics provides a basis for deriving expected distributions of lipophilic organic contaminants such as hydrocarbons among components of food webs (e.g. Clark et al. 1990). In this approach, contaminant concentrations in all the discrete chemical phases of the ecosystem, including the lipid and aqueous compartments of the biota, and the respired media (i.e. water and air) are assumed to be at a state of chemical equilibrium, implying no inherent tendency of these concentrations to change with time. Observed deviations of concentrations from these expected values are then taken as evidence of (1) non-equilibrium conditions, which may result from kinetic limitation of contaminant transport among phases, (2) active transport, where biologically mediated processes may enhance or suppress rates of contaminant transport, or (3) metabolic transformation of the contaminant, which usually involves biochemical detoxification pathways to promote the removal of the contaminant from an organism. All three of these must be considered in the distribution of pristane among biota of the northern GOA.

The basic thermodynamic parameter used to describe the distribution of a contaminant among immiscible phases is the partition coefficient. The partition coefficient is the ratio of fugacity capacities of a contaminant in two phases (fugacity capacity is the ratio of a volatile solute's concentration in a solvent and its vapor pressure; Kelly et al. 2004), and ideally is determined in the all of the phases of interest. Such determinations are often difficult in practice, and an approximate measure of the partition coefficient, the octanol-water distribution coefficient, K_{ow}, is often used as a proxy (Kelly et al. 2004). The octanol-water distribution coefficient for a contaminant is the ratio of the contaminant concentration in *n*-octanol and water (i.e. $K_{ow} = [X]_{octanol}/[X]_{water}$; $[X]$ = contaminant concentration). This coefficient may then be used to predict the approximate distribution of a contaminant within an organism or among organisms within a contaminated environment, and is usually discussed in terms of its common logarithm (i.e. log K_{ow}). In particular, the log K_{ow} provides a convenient and standardized measure of the tendency of a contaminant to bioaccumulate, and to biomagnify within a food web. Bioaccumulation refers to the increased contaminant concentration within an organism that results from the passive partitioning of the contaminant between the aqueous phase comprising the water compartment and the respired medium of an organism (where concentrations are assumed equal), and the lipid compartment of the organism. Hence, the log K_{ow} provides a measure of the expected contaminant concentration in the lipid compartment of the organism for a given aqueous concentration, which may be compared with observed concentrations when expressed on a lipid mass basis (i.e. lipid-normalized concentrations). For example, a contaminant with a log K_{ow} value of five would be expected to attain a lipid concentration 100,000-fold greater than the ambient aqueous concentration, and if the lipid content is 1% of the organism wet weight, then the whole-body concentration of the contaminant would be reduced to 1,000-fold greater than the ambient aqueous concentration.

Biomagnification may occur when an organism accumulates a contaminant through its diet, and the affinity of the contaminant for the lipid phase is sufficiently great that diffusion losses of the contaminant back to the ambient aqueous phase are outweighed by the rate of accumulation. Biomagnification also implies that the rate of metabolic transformation of the contaminant by the organism is negligible, and that the organism is able to somehow concentrate the contaminant above the lipid-normalized concentrations present in its prey, the details of which remain unclear (Kelly et al. 2004). It has been found empirically that non-metabolizable contaminants having log K_{ow} values exceeding five tend to biomagnify in food webs (Kelly et al. 2004).

The log K_{ow} value of pristane has not been reported, but an approximate value may be inferred from uptake experiments by marine mussels, which have little capacity to metabolize hydrocarbons (Lee et al. 1972, Mironov and Shchekaturina 1979). The whole-body bioaccumulation factor of pristane (i.e. the ratio of the somatic concentration and the dissolved aqueous concentration) in mussels (*Mytilus trossulus*) is about 2,000 (Murray et al. 1991, Short in prep.). Assuming a lipid concentration of 1% of wet weight (Kluytmans et al. 1975), the lipid-normalized partition coefficient would be on the order of 200,000, approximately equivalent to a log K_{ow} value of 5.3. This value is near the threshold for biomagnification, provided metabolic transformation is negligible. This implies that pristane incorporated by an organism would eventually become distributed among its constituent tissues at approximately equal concentrations per unit lipid. However, the ability to metabolize pristane has been demonstrated in fish (Cravedi et al. 1985, Le Bon et al. 1987, 1988a) and in the rat (Tulliez and Bories 1975, Le Bon et al. 1988b), so it is likely this capability is widespread among vertebrates, and might be present among some invertebrates also. Hence, pristane would not be expected to biomagnify appreciably in a marine food web, because of its low inherent tendency based on its partition coefficient value, and because of the ability of most organisms occupying the upper trophic levels (i.e. the vertebrates) to metabolize it.

The foregoing discussion provides a framework for interpreting the observed distribution of pristane among the biota analyzed for the EVOS. Clearly, the expected distribution of pristane among tissues within an organism, or among different organisms should account especially for variation in the lipid content of the sampled tissues, the metabolic capability of the organism to transform pristane, and kinetic limitations on the transport of pristane among the sampled compartments. The breadth of sampling conducted after the EVOS provides an opportunity to examine whether the results are consistent with expectations based on equilibrium thermodynamics at both the organism and the ecosystem levels, and the extent to which processes such as transport rate limitation and metabolic degradation must be invoked to explain discrepancies from those expectations.

At the organism level, the distribution of pristane in harbor seal tissues provides an example of how the variability of pristane concentrations may be considerable among different tissues and among the individuals sampled. Among individuals, the more than 500-fold variation in pristane concentrations in blubber (Fig. 1.7), which is almost entirely lipid, is probably the result of differences in diet, and the time elapsed since ingestion of pristane-laden prey. Although harbor seals may prey on a wide spectrum of fish, cephalopods and crustaceans, especially pollock and octopus (*Octopus sp.*), with smaller but substantial reliance on capelin (*Mallotus villosus*), eulachon (*Thaleichthys pacificus*) and Pacific herring (Pitcher 1980), they tend to forage site-specifically, taking prey that are readily available within a home range of a few tens of km (Iverson et al. 1997). Seals that prey on species that are more closely connected trophically to *Neocalanus* or *Calanus* zooplankton would be expected to consume a higher ration of pristane, and these seals would tend to have higher concentrations of pristane in their lipid tissues, just as Atlantic Ocean herring contain much more pristane than Baltic Sea herring (Linko and Kaitaranta 1976) owing to the scarcity of *Calanus* copepods in the Baltic Sea (Hernroth and Ackefors 1979). Once incorporated into storage lipids or into lipid-rich cell membranes, pristane may remain unavailable to metabolic degradation if the rate of lipid or cell turnover is low. For example, somatic tissues of rats and of rainbow trout fed single doses retain traces of pristane for weeks, despite metabolic transformation and elimination of up to 99% of the absorbed pristane (Tulliez and Bories 1975, Cravedi and Tulliez 1982, Le Bon et al. 1988b), almost entirely by liver enzymes (Cravedi et al. 1989). Some of the variability of pristane concentrations among comparable tissues of different individuals may be attributed to differences in the efficiency of pristane-degrading activity among individuals, but coefficients of variation on the order of 25% in radioisotope studies of the pristane degradation rate in rainbow trout (Le Bon et al. 1987) and the rat (Le Bon et al. 1988b) indicate this is a relatively minor source of variability in comparison with dietary variability and differences in lipid content. Metabolic competence to degrade pristane therefore does not preclude retention at slowly-declining concentrations in lipid-rich tissues on a time scale of weeks.

Much of the additional variation of pristane concentrations across different tissues of the harbor seal may be the result of differences in lipid content. Whereas adipose tissue is almost entirely composed of lipid, the (dry weight) lipid content of the heart and liver of harbor seals is on the order of 10 – 30% (Ackman and Hooper 1974). Expression of pristane concentrations in the lipid of these tissues would likely reduce the variability within each tissue type, and make concentrations among different tissue types more similar, with the noteworthy exception of the brain. The low concentrations of pristane in the blood of harbor seals (as well as of bald eagles) is likely the result of the ready availability of pristane in blood to pristane-degrading enzymes in the liver and the low lipid content of the dry matter of blood. The even lower concentrations of pristane in harbor seal brain (Fig. 1.7) is probably the result of exclusion by the blood-brain barrier, which limits diffusion of molecules larger than glucose from the blood to brain tissues (Newsholme and Leech 1983), effectively excluding fatty acids and pristane. This is noteworthy because brain tissue contains about 10% lipid on a wet weight basis (Folch et al. 1951), equivalent to about 40% lipid on a dry weight basis given that the ratio of dry and wet weights of harbor seal brain tissues sampled averaged 0.24. Despite the substantially greater proportion of lipid in brain compared with blood on a dry weight basis, the blood-brain barrier effectively excludes pristane from brain tissue.

Although the variability in the distribution of pristane among harbor seal tissues and individuals may be quite large (Fig. 1.7), detection of pristane in lipid-rich tissues of an organism may still be taken as evidence of a trophic relation to *Neocalanus* or *Calanus* copepods in marine ecosystems such as the northern GOA, where other sources of pristane are probably negligible. The converse may not necessarily be true, however, because of this large variability. Low concentrations in an individual may be the result of especially active metabolism for pristane degradation, or a diet that has weak trophic connection to *Neocalanus* or *Calanus* copepods. Variation in the lipid content among tissues sampled is also an important factor to consider (e.g. Fig. 1.7). Across species, lipid content may vary by a factor of 20 among whole-body samples of fish and shellfish in this region (Iverson et al. 2002). But giving these caveats due consideration, pristane concentrations would be expected to generally decrease in species that can metabolize it, and be relatively low in species or tissues that have low lipid content, but otherwise should remain about the same following a trophic transfer. The pristane distribution patterns depicted in Figures 1.2 – 1.8 broadly reflect these expected trends.

The collective results from the EVOS samples shows that the trend of generally declining pristane concentrations with trophic transfers in the marine-dependent food web extends from the neritic components to the intertidal and the benthos. Pristane concentrations in the neritic predators of *Calanus* and *Neocalanus* copepods are generally higher than any of the other species sampled, but are lower than the concentrations in the copepods themselves. These neritic predators include the fork-tailed storm petrel and shearwaters among the birds (Fig. 1.2), herring and juvenile pink salmon among the fish (Fig. 1.3), and *Euchaeta elongata* and *Metridia spp.* among the zooplankton (Table 1.1). These species may all prey directly on *Calanus* and *Neocalanus* copepodite stages, and all had pristane concentrations of several hundred $\mu g\ g^{-1}$. Pristane concentrations are lower by an order of magnitude or more in species that prey on these neritic copepod consumers, including the bald eagle, black kittiwake, common loon, marbled murrelet and pigeon guillemot among the birds (Fig. 1.2), and the piscivorous marine mammals (Fig. 1.8). In contrast with these neritic species, pristane concentrations are usually much lower in species associated with the intertidal.

Part of the decline of pristane concentrations in the direct consumers of *Calanus* and *Neocalanus* copepods is because of their lower lipid content. For example, lipid accounts for ~ 1% of the wet weight of juvenile pink salmon and 3 – 10% of Pacific herring in PWS (Iverson et al. 2002). Assuming 80% water content, these wet weight proportions would be equivalent to corresponding dry weight proportions of ~ 5 – 50% for these two species, compared with lipid proportions of the copepods of 50% or more (Båmstedt 1986, Duesterloh 2002). Hence reduction by factors of up to ~ 5 in wet weight pristane concentrations in these two consumer species may be attributed to their lower lipid content, and the remainder of the reduction is probably the result of metabolic degradation. Corrections for differences in lipid content among the other species and tissues sampled are comparable in magnitude because of similar ranges of lipid and water contents, suggesting that metabolic degradation by vertebrate consumers may be the most important factor accounting for the progressive declines of pristane concentrations in the higher-order consumer groups depicted in the pelagic/neritic compartment in Fig. 1.9.

The route by which pristane enters the intertidal is not entirely clear. None of the species associated with the intertidal have pristane concentrations as high as the neritic predators of *Calanus* or *Neocalanus* copepods, but they often contain concentrations approaching 10 $\mu g\ g^{-1}$. Pricklebacks and black pricklebacks in the intertidal may opportunistically prey on *Calanus* or *Neocalanus* when available, and juvenile dusky rockfish definitely do (Yang 1993) (Fig. 1.2). The fact that pristane concentrations are generally higher in suspension-feeding compared with deposit-feeding molluscs in the intertidal suggests that the acquired pristane may be associated with dispersed organic particulate material in the water column. This material could be *Calanus* or *Neocalanus* copepodites, or dispersed fecal material produced by the neritic predators of *Calanus* or *Neocalanus* copepods, or feces of the copepods themselves.

Although plausible, direct predation by mussels on *Calanus* or *Neocalanus* copepodites is not likely to be a major pathway of pristane accumulation by mussels. While mussels may effectively prey on some smaller (~ 0.25 mm length) mesozooplankton (Wong et al. 2003) and may occasionally capture mobile zooplankton as large as 3 – 6 mm length

(Davenport et al. 2000), escape responses of even the naupliar stages of copepods are usually adequate to avoid capture by mussels (Green et al. 2003).

Incorporation of fecal material produced by efficient predators of *Calanus* or *Neocalanus* copepodites is probably a more important pathway of pristane accumulation by mussels. Although feeding experiments using *Calanus finmarchichus* have shown that lipid assimilation by herring and rainbow trout (*Salmo gairdneri*) is very efficient, with less than 5% of total ingested lipid excreted in feces (Sargent et al. 1979), the high concentration of pristane in these copepods means that the feces produced would still contain pristane concentrations on the order of 500 $\mu g\ g^{-1}$. This is much higher than tissue concentrations found in mussels during spring (Fig. 1.5). Juvenile pink salmon prey heavily on *Neocalanus* copepodites during spring in PWS (Cooney et al. 1981, Sturdevant et al. 1996, Willette 1996, Willette et al. 2001), where they remain close to the shoreline during the first few weeks of their marine residence (Healey 1980, Cooney et al. 1981, Willette 2001). Dispersion of feces produced by nearshore piscine predators of *Neocalanus* might provide a pristane-laden form of organic material that could be readily ingested by mussels. However, this route of incorporation is hypothetical. So is the possibility that mussels may incorporate pristane-laden feces produced directly by *Neocalanus* copepodites, because the concentration of pristane in feces from these copepodites has not been measured.

Feces produced by birds preying on nearshore zooplanktivores such as juvenile pink salmon which in turn prey directly on *Neocalanus* copepodites is another plausible but probably minor route for pristane incorporation by mussels. The highest pristane concentrations in juvenile pink salmon (Fig. 1.3) were more than an order of magnitude lower than concentrations in *Neocalanus* copepodites (Table 1.1), and concentrations in feces produced by birds preying on these juveniles would be lower by another one or two orders of magnitude because most of the pristane ingested by birds would be assimilated along with the ingested lipids. Hence, fecal concentrations of pristane produced by birds would likely be 10% or less compared with pristane concentrations in feces of zooplanktivorous fishes, but this route might still be important in some instances if aggregations of nearshore fish feeding on *Neocalanus* copepodites are attacked by aggregations of piscivorous birds.

Regardless of the pristane transport pathway, intertidal deposit-feeders and herbivores have consistently low concentrations of pristane, as do most of their predators, including sea otters, the sea ducks, and rock sandpipers (Figs. 1.2, 1.4, 1.6 and 1.8). The somewhat elevated (~ 1 – 10 $\mu g\ g^{-1}$) pristane concentrations associated with the eelgrass, rockweed and periwinkle snails sampled during spring are probably the result of herring eggs deposited on these plants. The samples of these three species that contained the higher concentrations were all from Montague Island and were collected during a herring spawning event which was particularly extensive in 1989. Herring eggs contain pristane at concentrations above 10 $\mu g\ g^{-1}$, so these may have been the vector for pristane transmission to these plants and the periwinkle snail. Pristane is below MDL in rockweed collected later in the year (Fig. 1.6). Hence, egg deposition is another route by which pristane may be introduced to the intertidal.

The very variable concentrations of pristane in benthic foragers (crabs and shrimp) may reflect occasional opportunities to prey on *Calanus* and *Neocalanus* copepods directly. Pristane concentrations in spot shrimp eggs and Dungeness crab hepatopancreas were substantial in the fall (Fig. 1.6), when *Calanus* and *Neocalanus* copepods descend to deep (> 300 m) waters during diapause (Fulton 1973, Damkaer 1977, Conover 1988, Miller and Clemons 1988, Miller 1993). The continental shelf and most of PWS is shallower than 300 m, so these copepods may encounter the benthic interface instead, where they may be vulnerable to predation by benthic foragers. Whatever the cause, pristane concentrations were also found to be highly variable in pink shrimp (*Pandalus borealis*) compared with the other species sampled during the most extensive survey of pristane in marine biota before this one (Johansen et al. 1977). The pristane concentrations in king and in Tanner crabs, as well as in some of the spot shrimp and Dungeness crab samples, may arise mostly through predation or scavaging on first- and second-level consumers of *Calanus* and *Neocalanus* copepods. In contrast, pristane concentrations are uniformly low in the green sea urchin, which grazes epibenthic algae, and in the terrestrial mammals, consistent with an absence of autochthonous sources of pristane in the nearshore benthic or the terrestrial communities.

The timing of the annual spring increase of pristane in suspension-feeding molluscs (Fig. 1.5) provides additional evidence that *Calanus* and *Neocalanus* copepods are the dominant source of pristane in the region sampled. Pristane concentrations consistently increase sharply just following the spring zooplankton bloom every year, and begin to decline in June just as *Calanus* and *Neocalanus* copepods begin their ontogenetic migration to deeper water. Mussels depurate half their burden of accumulated hydrocarbons in ~1 – 4 weeks, with the longer periods following longer exposures (Pruell et al. 1986, Mason 1988a, 1988b), so the decline of pristane concentrations in mussels throughout the summer reflects the decline of pristane production by *Calanus* and *Neocalanus* copepods, lagged by a few weeks. The absence of increases in pristane concentrations in suspension-feeding molluscs later in the summer provides strong evidence against the presence of another important source of pristane available to this food web, at least during summer, given the ability of these organisms to concentrate hydrocarbons from seawater into their tissues by more than a thousand-fold (Murray et al. 1991, Short in prep.).

The annual increases of pristane concentrations in mussels during spring were associated with a concurrent pulse of pristane-laden particulate material to the benthos in PWS. Pristane concentrations in sediments collected by sediment traps deployed at 10 – 20 m depths were much higher during spring, when concentrations ranged as high as 1.1 mg pristane g^{-1} dry sediment, and these concentrations were also concurrent with increases found in benthic sediments adjacent to the traps (Sale et al. 1995). Traps deployed during other seasons, including winter, had much lower pristane concentrations in the collected sediments, which further corroborates the spring production of pristane by *Calanus* and *Neocalanus* copepods as the major source.

Although nearly all the evidence regarding the distribution and seasonal variability of pristane implicates *Calanus* and *Neocalanus* copepods as the dominant natural source, two exceptions stand out. Pristane concentrations in livers of black turnstones and in surfbirds were higher than expected in winter compared with other birds that forage in the intertidal (Fig. 1.2), with concentrations more comparable with piscivorous birds. The source and route of pristane to livers of these two bird species during winter is unclear.

The dissipation of pristane in biota following production during spring is consistent with expectations based on its relatively low log K_{ow} value and its biochemical transformation by organisms that are metabolicly competent to degrade it, with time scales for its dispersion and removal from the food web of weeks to months. Pristane dissolved into seawater may be photo-oxidized (Rontani and Giusti 1987), or may be degraded by the microbial community (Pirnik 1977, Schaeffer et al. 1979, Alvarez 2003). Pristane in fecal material exported to the benthos may also be vulnerable to microbial degradation, although pristane incorporated into carbonate oozes of the deep seafloor may persist for several millenia (Ohkouchi et al. 1997).

The nearshore food web of the northern GOA may be roughly represented by springtime pristane concentrations in the sampled biota (Fig. 1.9). This representation is consistent with documented trophic relationships (Table 1.2). Pristane concentrations decline about tenfold with each trophic level beginning with the *Calanus* and *Neocalanus* copepod producers through their first, second and third level predators. The decline at each trophic transfer may be attributed to (1) metabolic degradation in the livers of these predators, and (2) dilution by consumption of other prey that have less dependence on carbon derived from *Calanus* or *Neocalanus* copepods. Transport of pristane to the benthos and to the intertidal is probably mediated by fecal production from *Calanus* and *Neocalanus* copepods or their predators, and perhaps augmented by ontogenetic migration of these copepods to the benthos.

Uses of Pristane as a Tracer Molecule

The trophic distance from *Calanus* or *Neocalanus* copepods as depicted in Fig. 1.9 is not the same as the absolute trophic level of a species in the food web. For example, both Pacific herring and sea otters occupy almost identical trophic levels (3.1 and 3.2 respectively, Okey and Pauly 1998) in the northern GOA, but these two species have very different trophic distances from *Neocalanus* copepods (Fig. 1.9). This is because these two species rely most heavily on different parts of the food web. Pacific herring are zooplanktivorous, and prey directly on *Neocalanus* copepods which are at trophic level 2, whereas sea otters rely most heavily on inter- and subtidal shellfish, especially suspension-feeding clams, which are also at trophic level 2 (Okey and Pauly 1998). Hence, the scheme depicted in Fig. 1.9 may serve to complement analysis of trophic level based on mass-balance considerations (Okey and Pauly 1998) or stable nitrogen isotopes (Lajtha and Michener 1994, Kline and Pauly 1998) by providing an indication of the food-web branch occupied by a species, but cannot be used as an alternative method for determining the absolute trophic level.

Despite the various factors that contribute to the variability of pristane in these biota, the coherence of the distribution of pristane in the sampled biota of the northern GOA as depicted in Fig. 1.9 suggests that detection of pristane may serve as a reasonably reliable indicator of trophic distance from *Calanus* or *Neocalanus* copepods in this region, provided confounding anthropogenic sources of pristane can be confidently discounted. Obviously, further work will be necessary to establish the magnitude of these linkages and their ecological importance more clearly, including at minimum better assessments of variability of pristane concentrations among individuals on a lipid-normalized basis, better estimates of the persistence of pristane in adipose tissues of species that can metabolize it in their livers, and elucidation of the details of the fecal transport pathways depicted in Fig. 1.9.

Inclusion of pristane might lead to substantial improvements in current methods based on lipid analysis for elucidating dietary dependencies of marine predators, for separating breeding stocks of marine fishes, and as a proxy measure of marine carbon imported with anadromous fishes to terrestrial food webs. Provided the variability of metabolic activity for pristane degradation is comparable to variability in the transformation of ingested fatty acids, pristane may be a useful addition to the lipids analyzed for inferring the dietary dependencies of harbor seals (Iverson et al. 1997, 2002) and other marine vertebrates (Iverson et al. 2004), at least in food webs where *Calanus* or *Neocalanus* copepods are important.

To the extent that the variability of pristane in the blubber of harbor seals reported here (Fig. 1.7) is due to differences in diet among the individuals sampled, inclusion of pristane may enhance the power of such efforts to distinguish actual dietary differences. Elucidation of these dietary dependencies may in turn help to identify habitat dependencies that are important for the viability of the populations studied. The large difference in pristane concentrations of herring oils from the Baltic and North Seas (Linko and Kaitaranta 1976) indicates that pristane analysis may be helpful in distinguishing stocks of herring and perhaps other fishes, which may be of considerable use in the management of commercially exploited species. Available evidence indicates that natural terrestrial sources of pristane may be negligible in comparison with pristane imported with anadromous salmonids to riparian systems (Ackman 1971), where pristane may serve as an independent proxy for carbon from marine lipids. For example, pristane analysis of depot lipid or of feces from brown bears might distinguish bears that prey mainly on fish from those preying on mammals, and a similar approach might find useful application to other terrestrial mammals associated with anadromous streams.

Pristane might also serve as a useful proxy of carbon subsidy from fecal material to marine benthic communities in regions where *Neocalanus* or *Calanus* copepods are important in the pelagic food web. In addition, pristane could also be useful in physiological studies, including studies on assimilation efficiency of ingested lipids, and studies on lipid turnover rates. Finally, pristane analyses may serve to elucidate suspected contaminant pathways in ecosystems. The pattern of pristane dispersion in the ecosystem comprising the biota surveyed here suggests that these contaminant pathways may often be subtle and unexpected.

Conclusions

As in Atlantic Ocean *Calanus* species, biosynthesis of pristane occurs in Pacific Ocean species of copepods in the genera *Calanus* and *Neocalanus*, producing concentrations that increase with copepodite development to near 1% dry mass in stage V copepodites. Pristane biosynthesis may occur in other herbivorous calanoid copepods such as *Pseudocalanus spp.*, but concentrations in these species are lower by factors of ~ 100, and these species are considerably smaller than late-stage copepodites of *Calanus* or *Neocalanus* (e.g., 2 mm total length vs 4 – 8 mm). The large size and high concentrations of pristane in stage V copepodites of the *Calanus* and *Neocalanus* species that dominate the biomass of the annual spring zooplankton bloom implies these copepodites are by far the major source of pristane for the neritic ecosystem of the northern Gulf of Alaska.

The pristane introduced with the spring pulse of secondary production serves as a natural chemical label for the associated lipid produced by *Calanus* and *Neocalanus* copepodites, and these pristane-labeled lipids permeate the food web at least through fall, initially through direct predation on these copepods by zooplanktivorous birds and fishes. Pristane resists degradation but it is not as refractory as halogenated organic pollutants, and does not magnify through the food chain. Fish and rats are capable of transforming pristane to more excretable metabolites, which suggests that other vertebrates are also.

Despite this capability, pristane accumulates in lipid storage compartments of vertebrates and may persist at least for weeks. Pristane concentrations tend to decline with the number of trophic transfers among subsequent consumer species, because of its low inherent tendency for food-chain biomagnification, metabolic degradation by vertebrate predators, and dilution by alternate prey that are more weakly dependent on carbon derived from *Calanus* or *Neocalanus* copepods. Defecation of pristane-labeled lipids that are not assimilated by consumers, especially the zooplanktivores, may provide a pathway for pristane to the intertidal and the subtidal benthos, but fecal material produced by the *Calanus* and *Neocalanus* copepodites might also be important, and requires further study for resolution.

The distribution of pristane incorporated by birds and mammals suggests that measurement of pristane per unit lipid may provide additional insight into the way pristane is transferred trophically, and that blood sample analysis for pristane is a very insensitive indicator of lipid concentrations of pristane. These attributes make pristane a candidate as a tracer compound for food web analysis, for physiological studies, and as an adjunct for studying the permeation of food webs by lipophilic organic pollutants. The results of this survey of pristane in the neritic food web of the GOA confirm an earlier suggestion by Blumer et al. (1964) that pristane may be a useful label for probing marine food webs.

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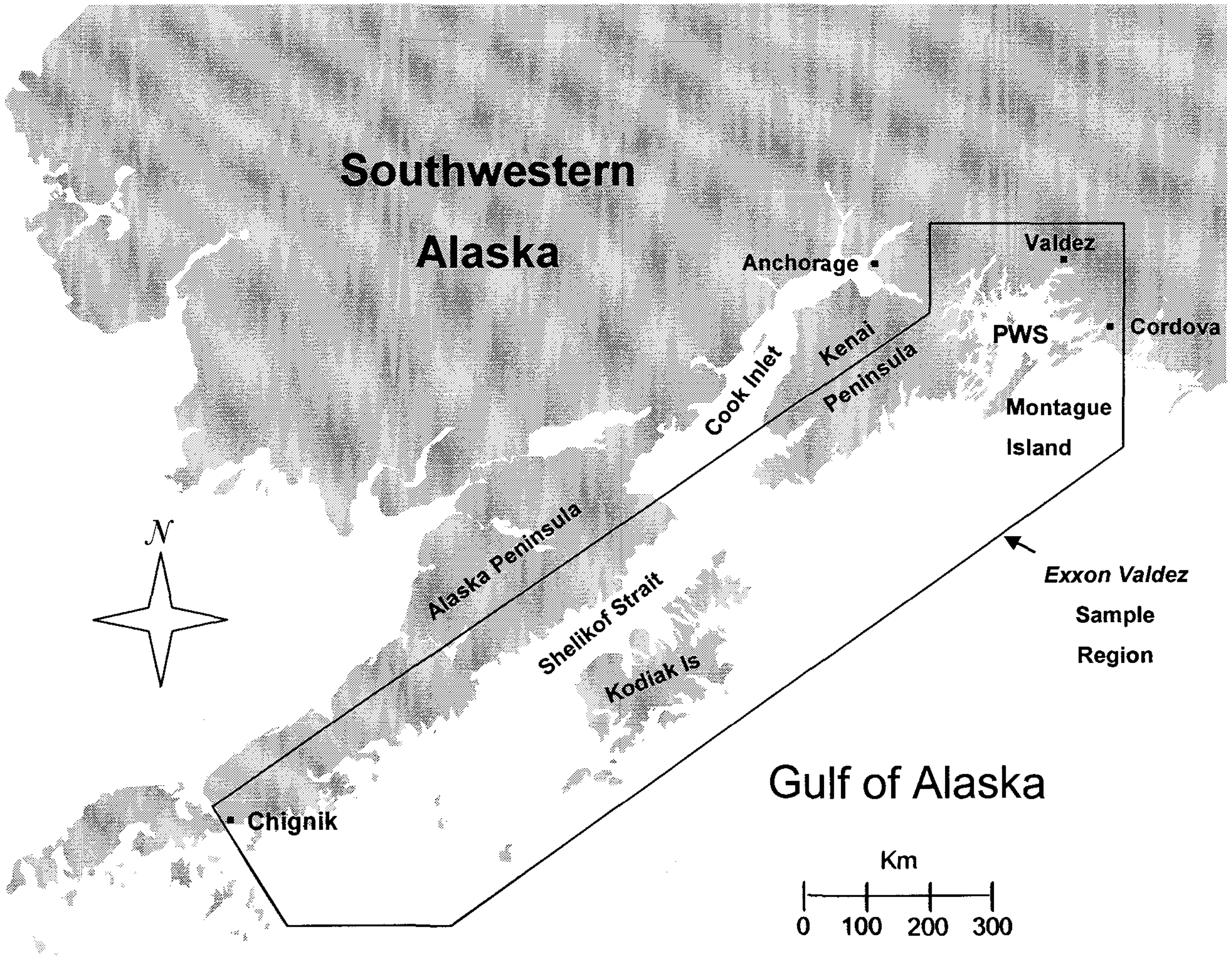

Figure 1.1. Region of the northwestern Gulf of Alaska where biota samples were collected.

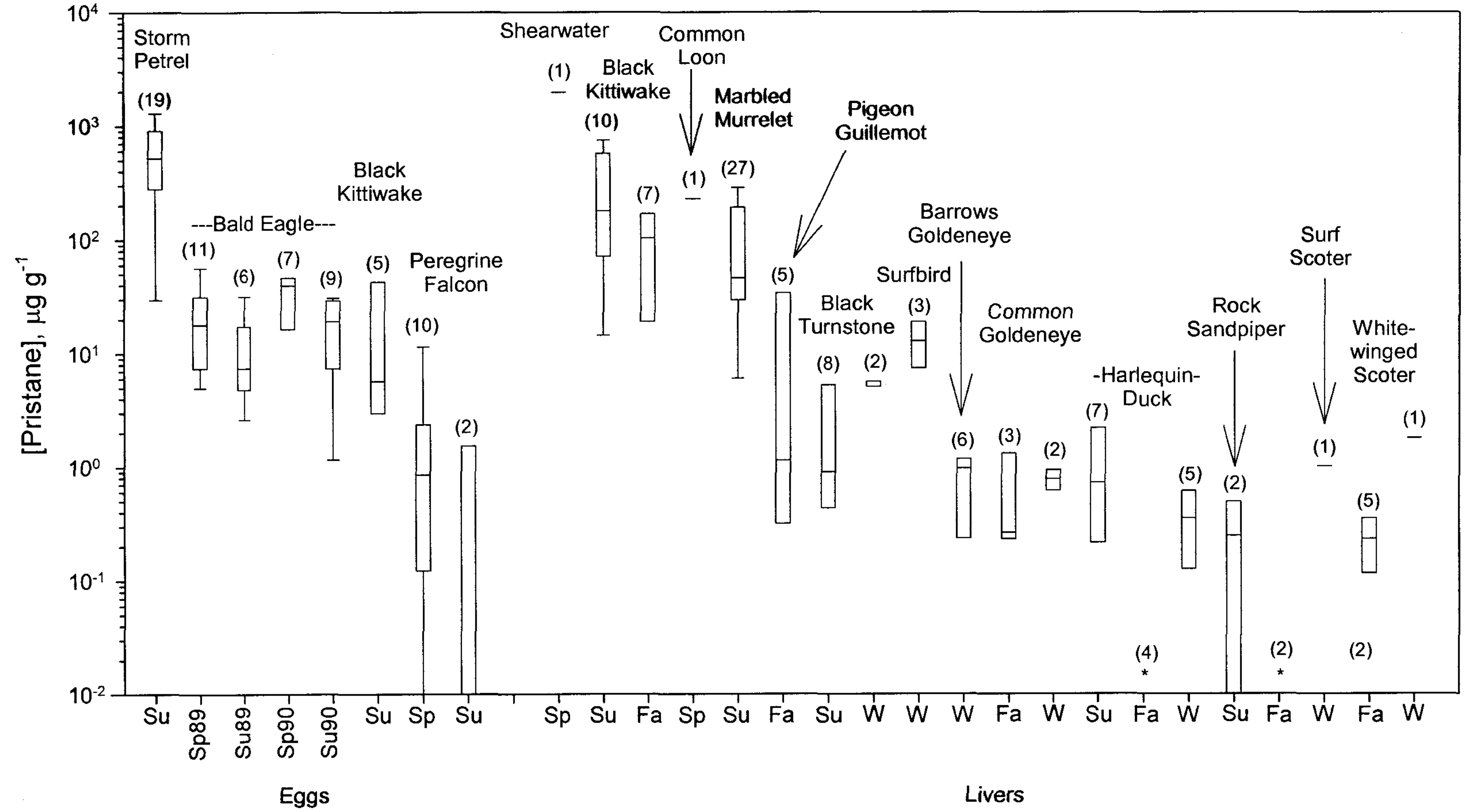

Figure 1.2. **Pristane concentrations in eggs and in livers of birds. Number of samples analyzed in parentheses. The horizontal** lines indicate the 10th, 25th, median, 75th and 90th percentiles of the distributions. Asterisks indicate concentrations below method detection limits. Sp = spring, Su = summer, Fa = fall, W = winter sampling; "89" = 1989, "90" = 1990.

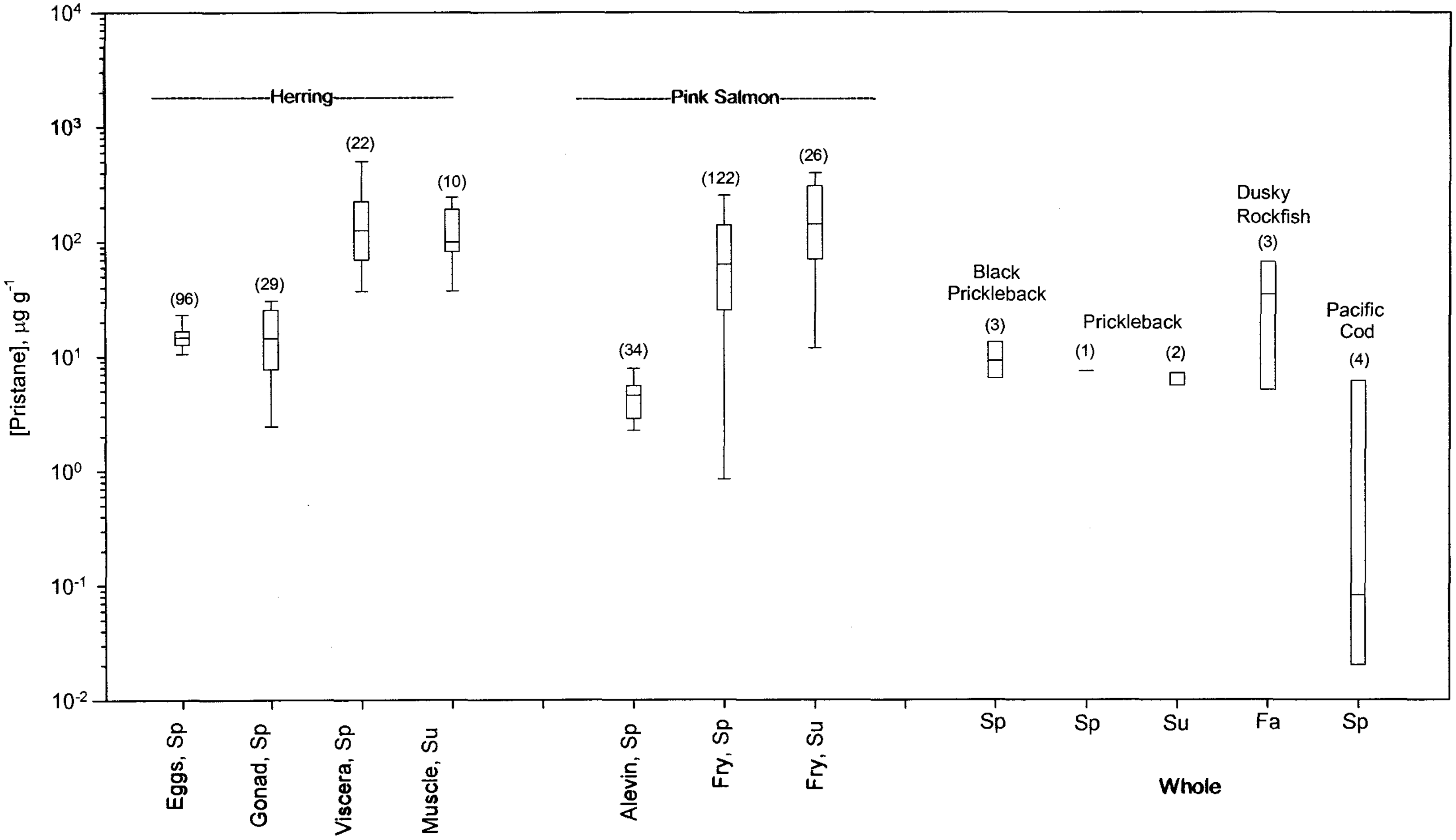

Figure 1.3. Pristane concentrations in tissues of fish. Symbols and abbreviations as in Figure 1.2.

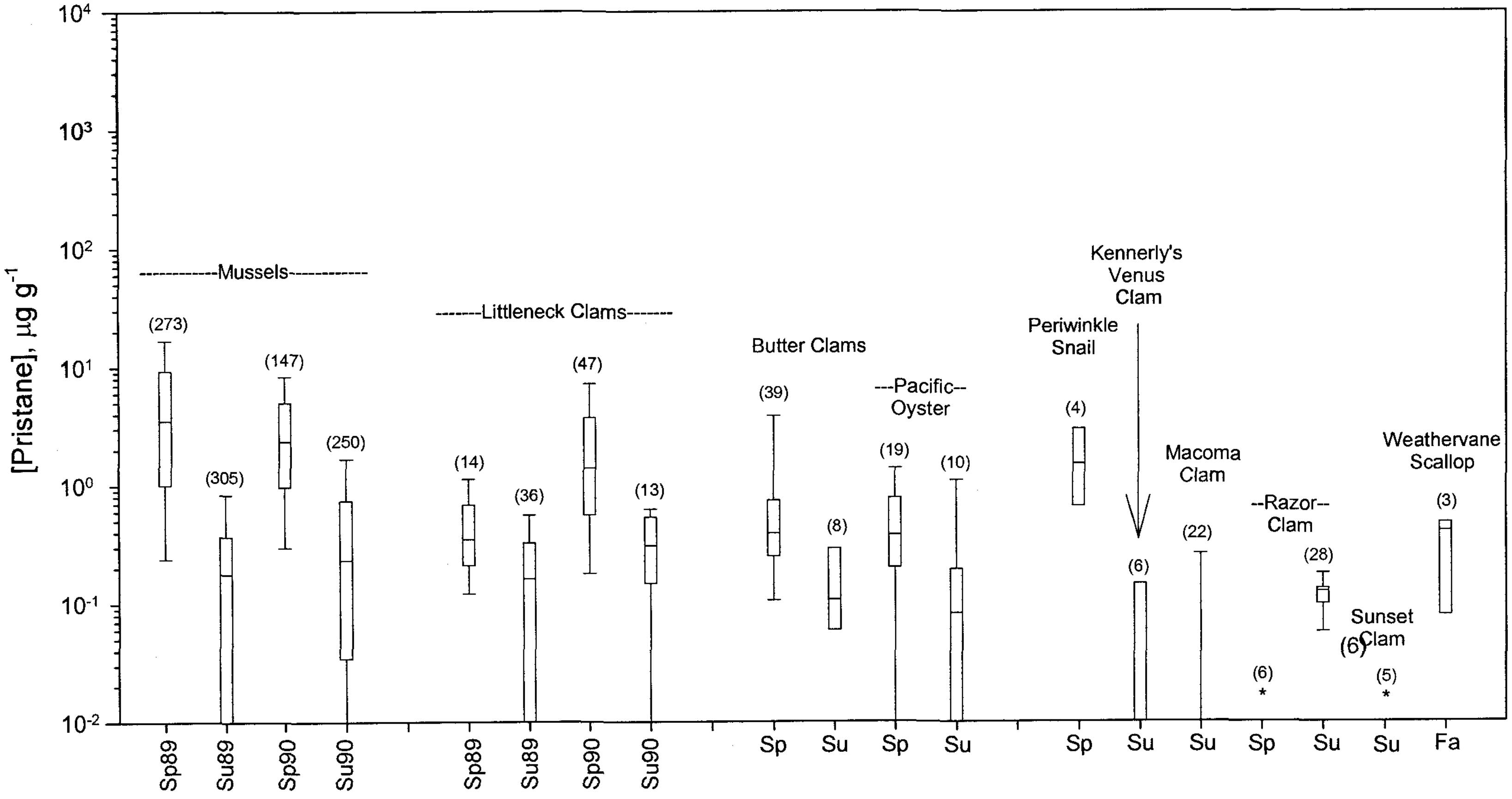

Figure 1.4. Pristane concentrations in molluscs. Symbols and abbreviations as in Figure 1.2.

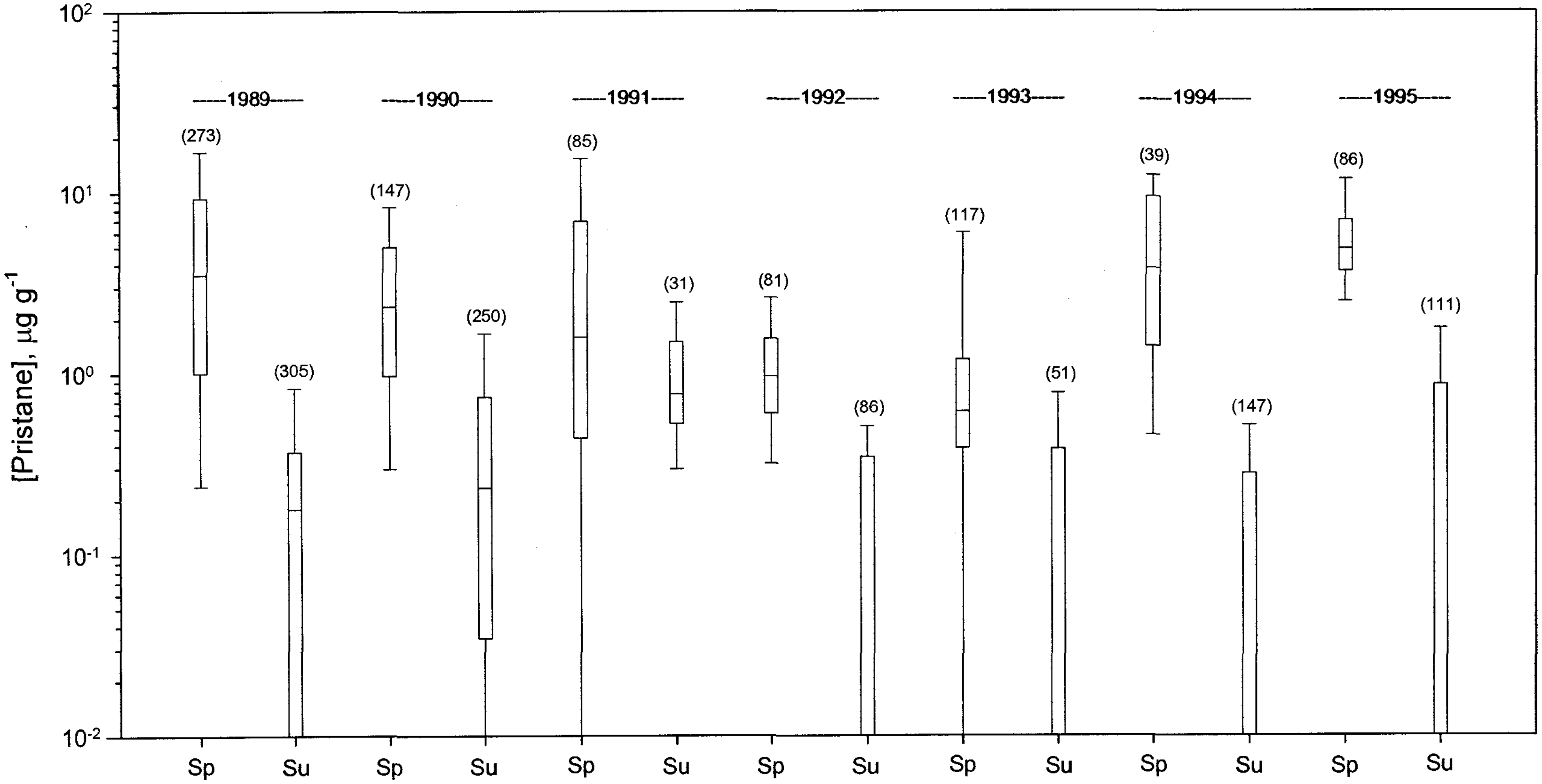

Figure 1.5. Pristane concentrations in bay mussels (*Mytilus trossulus*). Symbols and abbreviations as in Figure 1.2.

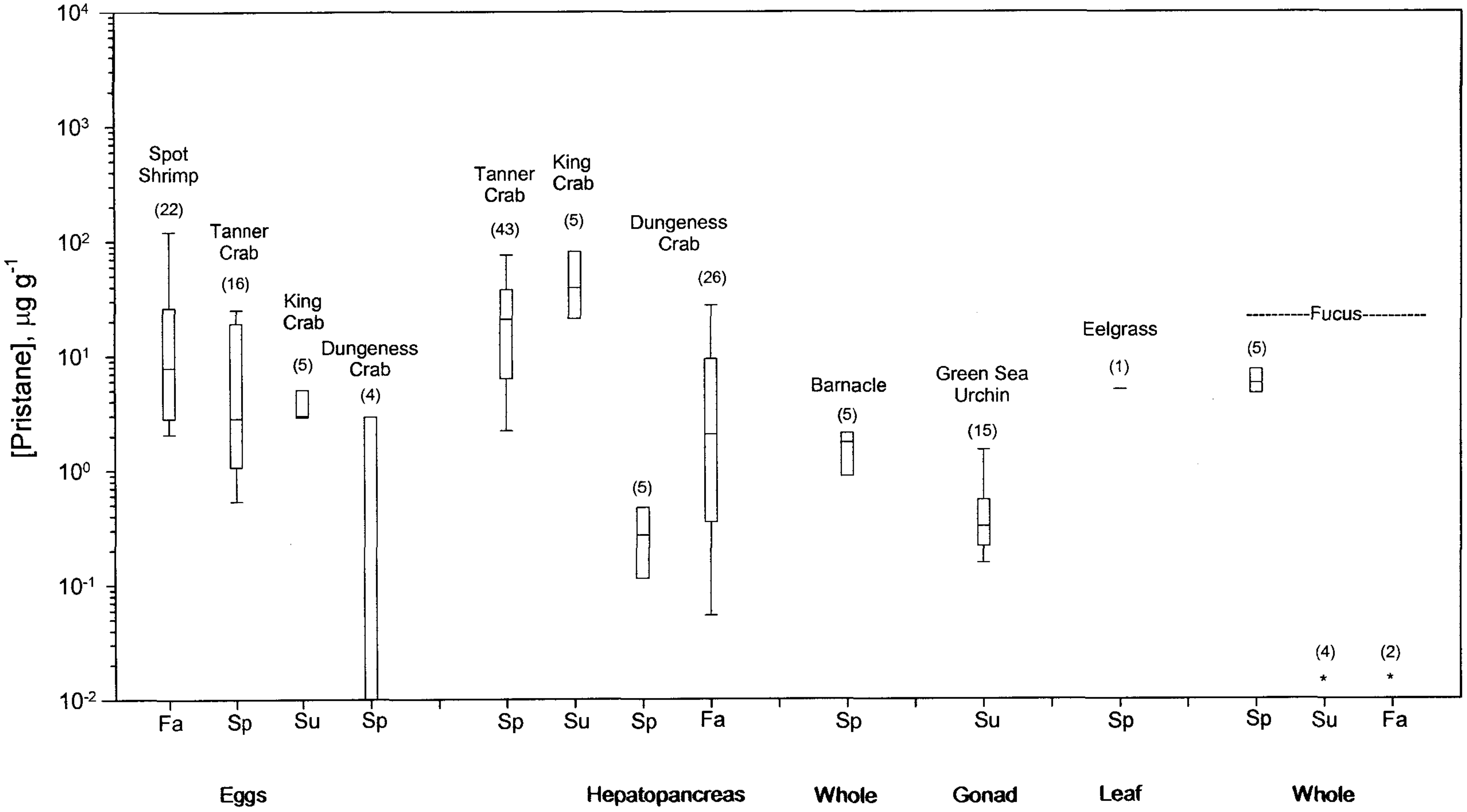

Figure 1.6. Pristane concentrations in crustaceans, sea urchin and plants. Symbols and abbreviations as in Figure 1.2.

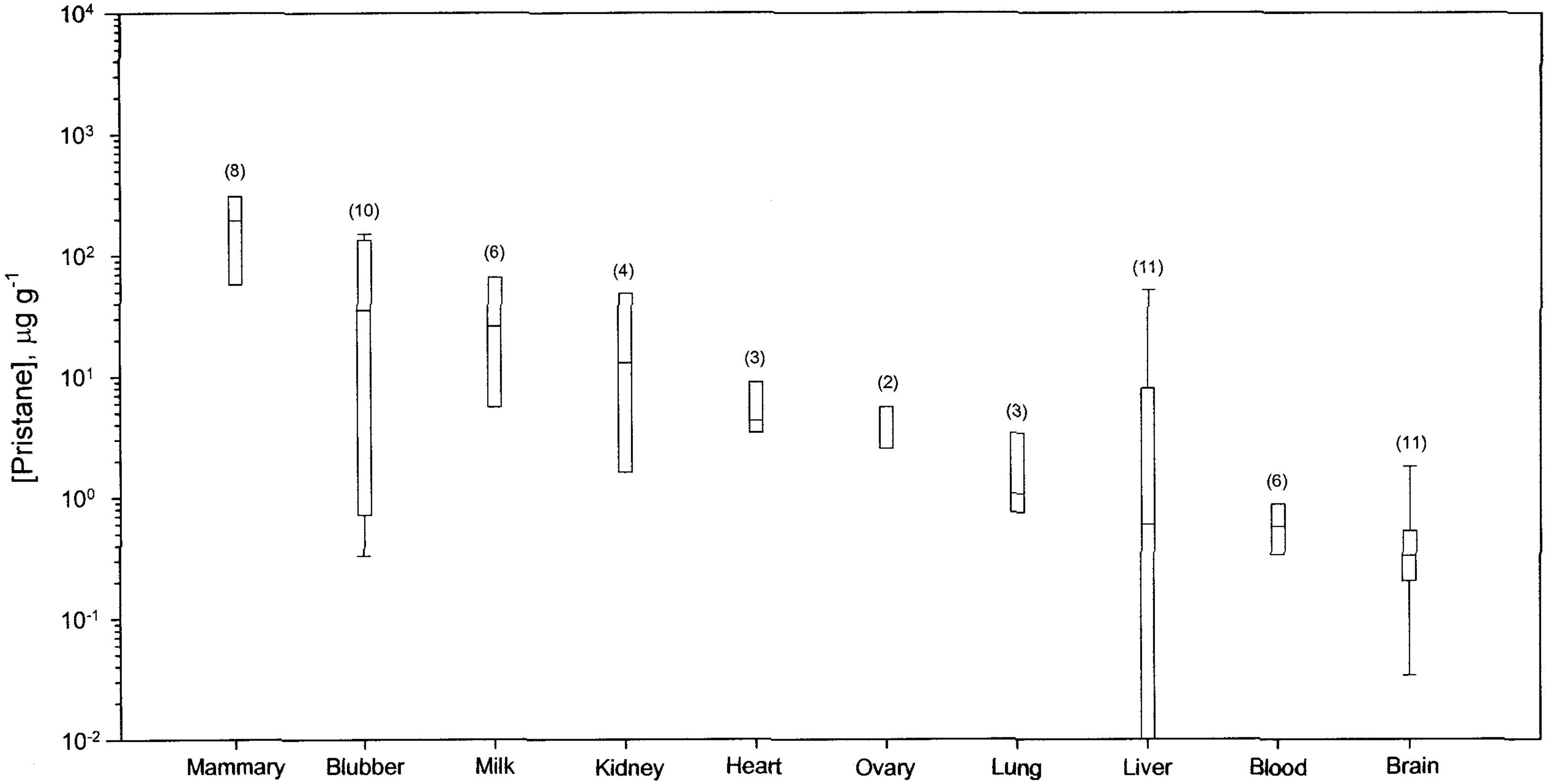

Figure 1.7. Pristane concentrations in harbor seal (*Phoca vitulina*) tissues. Symbols and abbreviations as in Figure 1.2.

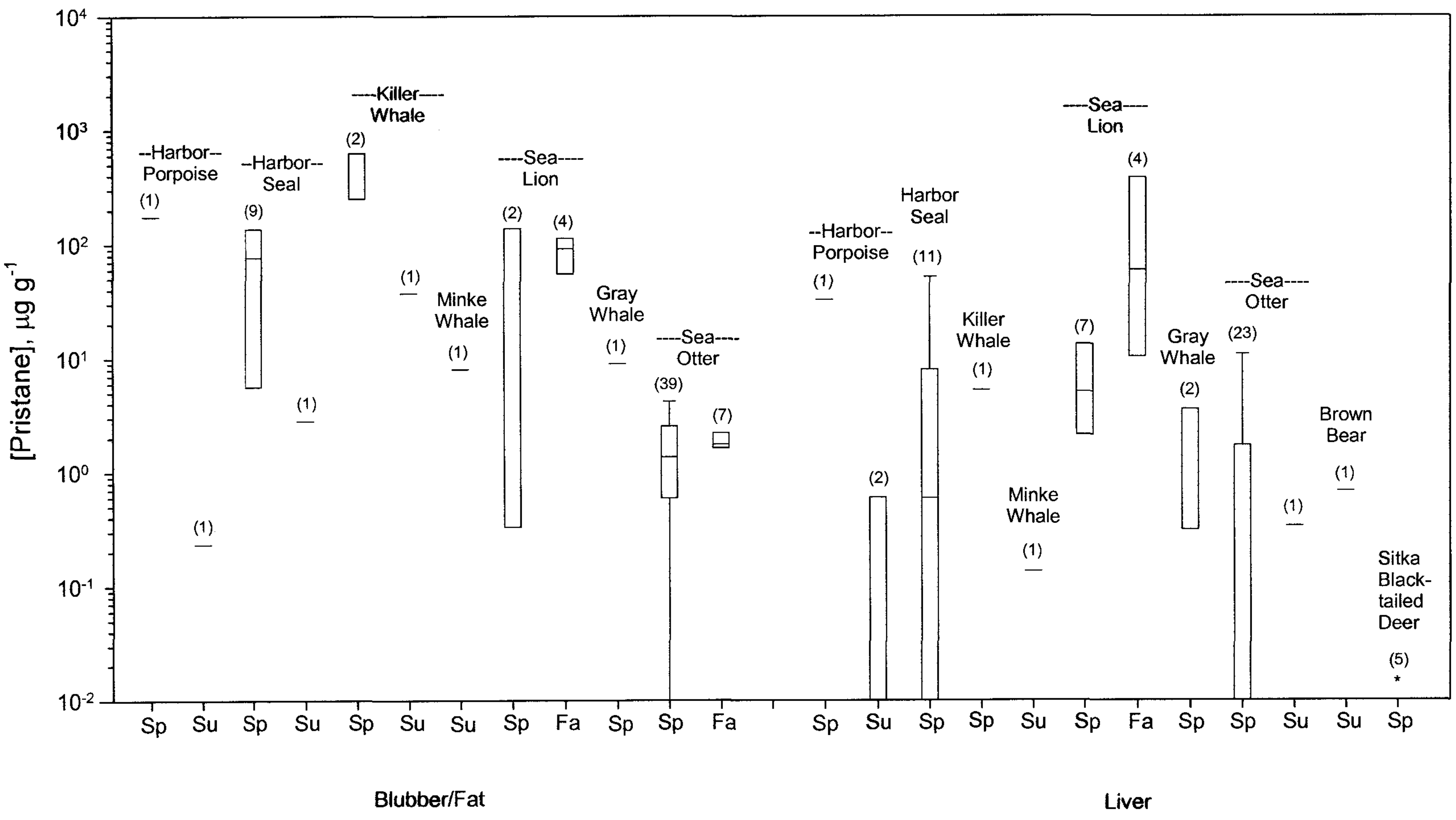

Figure 1.8. Pristane concentrations in mammal blubber and liver. Symbols and abbreviations as in Figure 1.2.

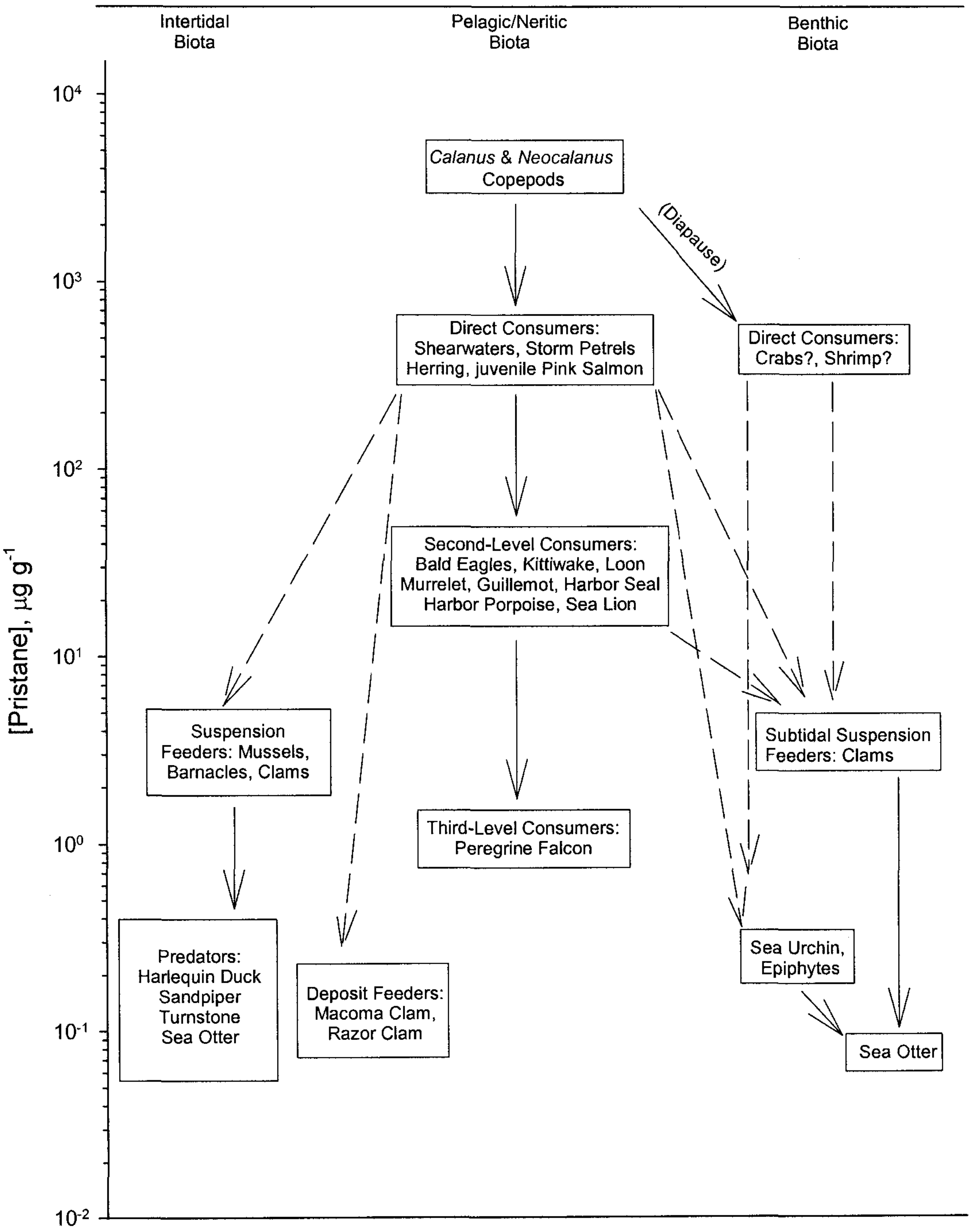

Figure 1.9. Generalized trophic relationships based on pristane concentrations. Solid arrows indicate ingestion of pristane from predation, dashed arrows indicate hypothesized ingestion of pristane associated with fecal material.

Tables

Table 1.1. Concentrations of pristane in zooplankton. PWS = Prince William Sound, SEAK = Southeastern Alaska; Sp = Spring, Su = Summer.

Species	Region	Season	Median [Pristane] (μg g^{-1})	Range (μg g^{-1})	Samples Analyzed n	Individuals/ Sample n
Chiridius spp.	PWS	Su	15.6		1	25
Calanus marshallae – CV and adult female	SEAK	Su	6240	5630-6390	3	1
Calanus marshallae - CV	PWS	Sp	6520	5450-7300	6	1
Calanus marshallae - CIV	PWS	Sp	1030	606-1620	3	1
Eucalanus bungii – CV and adult female	SEAK	Su	107	61.6-205	3	1
Euchaeta elongata – CV and adult female	SEAK	Su	455	388-600	3	1
	PWS	Su	23.8	23.6-24.0	2	2
Metridia pacifica - female	PWS	Su	30.8		1	28
Metridia okhotensis – CV and adult female	SEAK	Su	660	509-672	3	1
Metridia lucens – CV and adult female	SEAK	Su	86.6	74.8-121	3	1
Neocalanus cristatus - CV	SEAK	Su	4460	3960-6070	3	1
Neocalanus cristatus - CV	PWS	Sp	2440	1960-5190	5	1
Neocalanus plumchrus - CV	SEAK	Su	7890	6980-11300	3	1
Neocalanus plumchrus - CV	PWS	Sp	8020	4010-8850	5	1
Neocalanus plumchrus - CIV	PWS	Sp	4430	2660-6700	5	1
Neocalanus plumchrus - CIII	PWS	Sp	731		1	4
Pseudocalanus spp	PWS	Sp	117		1	16
Thysanoessa inermis	PWS	Su	39.0	34.8-43.2	2	1
Thysanoessa raschii	PWS	Su	9.09		1	1
Thysanoessa spinifera	PWS	Su	3.42	1.84-5.00	2	1

Table 1.2. Common and scientific names and foraging modes of species. Species compared in this study were sampled during the Natural Resources Damage Assessment effort for the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska. Foraging modes: AE = algal epiphytes, AV = avivore, BI = benthic invertebrates, DF = deposit feeder, II = intertidal invertebrates, PP = primary producer, PV = piscivore, SF = suspension feeder, TH = terrestrial herbivore, TM = predator of terrestrial mammals, TO = terrestrial omnivore, ZV = zooplanktivore.

Species Name	**Foraging Mode**	**Reference**
I. Birds		
Bald Eagle, *Haliaeetus leucocephalus*	PV, AV,TM	Ehrlich et al. 1988
Barrow's Goldeneye, *Bucephala islandica*	BI, II	DeGange and Sanger 1986
Black-Legged Kittiwake, *Rissa tridactyla*	PV, BI	DeGange and Sanger 1986
Black Turnstone, *Arenaria melanocephala*	II	Ehrlich et al. 1988
Common Goldeneye, *Bucephala clangula*	BI	Ehrlich et al. 1988
Common Loon, *Gavia immer*	PV, BI	Ehrlich et al. 1988
Fork-tailed Storm Petrel, *Oceanodroma furcata*	PV, ZV	DeGange and Sanger 1986
Harlequin Duck, *Histrionicus histrionicus*	BI, II	DeGange and Sanger 1986
Marbled Murrelet, *Brachyramphus marmoratus*	PV, BI	DeGange and Sanger 1986
Peregrine Falcon, *Falco peregrinus*	AV	Ehrlich et al. 1988
Pigeon Guillemot, *Cepphus columba*	PV, BI	DeGange and Sanger 1986
Rock Sandpiper, *Calidris ptilocnemis*	II	Ehrlich et al. 1988
Shearwater, *Puffinus spp.*	PV, ZV	DeGange and Sanger 1986
Surfbird, *Aphriza virgata*	II	Ehrlich et al. 1988

Surf Scoter, *Melanitta perspicillata*	BI	Ehrlich et al. 1988
White-winged Scoter, *Melanitta fusca*	BI	DeGange and Sanger 1986
II. Fish		
Black Prickleback, *Xiphister atropurpureus*	ZV	Hart 1973
Dusky Rockfish (juvenile), *Sebastes ciliatus*	BI, ZV	Yang 1993
Pacific Herring, *Clupea harengus*	ZV	Hart 1973
Pacific Cod (juvenile), *Gadus macrocephalus*	BI, ZV, PV	Yang 1993
Pink Salmon (juvenile), *Oncorhynchus gorbuscha*	ZV	Rogers et al. 1979
Prickleback, *Anoplarchus purpurescens*	ZV, BI, AE	Hart 1973
III. Molluscs		
Bay Mussel, *Mytilus trossulus*	SF	O'Clair and O'Clair 1998
Butter Clam, *Saxidomus giganteus*	SF	O'Clair and O'Clair 1998
Kennerley's Venus, *Humilaria kennerleyi*	SF	Abbott 1954
Littleneck Clam, *Protothaca staminea*	SF	O'Clair and O'Clair 1998
Macoma Clam, *Macoma balthica*	DF	O'Clair and O'Clair 1998
Pacific Oyster, *Crassostrea gigas*	SF	Abbott 1954
Periwinkle Snail, *Littorina sp.*	AE	O'Clair and O'Clair 1998
Razor Clam, *Siliqua patula*	SF	Abbott 1954
Sunset Clam, *Gari californica*	SF	Abbott 1954
Weathervane Scallop, *Patinopecten caurinus*	SF	Abbott 1954
IV. Crustaceans		
Barnacle, *Balanus cariosus*	SF	O'Clair and O'Clair 1998
Dungeness Crab, *Cancer magister*	BI, PV	O'Clair and O'Clair 1998
King Crab, *Paralithodes camtschaticus*	BI, PV	Cunningham 1969

Spot Shrimp, *Pandalus platyceros*	BI	Butler 1980
Tanner Crab, *Chionoecetes bairdi*	BI	Brethes et al. 1982
V. Echinoderm		
Sea Urchin, *Strongylocentrotus droebachiensis*	AE	O'Clair and O'Clair 1998
VI. Mammals		
Brown Bear, *Ursus arctos*	TO	McCarthy 1989
Gray Whale, *Eschrichtius robustus*	BI, PV	Calkins 1988
Harbor Porpoise, *Phocoena phocoena*	PV	Calkins 1988
Harbor Seal, *Phoca vitulina*	PV	Calkins 1988
Killer Whale, *Orcinus orca*	PV, MM	Calkins 1988
Minke Whale, *Balaenoptera acutorostrata*	ZV, PV	Calkins 1988
Sitka Black-Tailed Deer, *Odocoileus hermionus*	TH	O'Clair and O'Clair 1998
Sea Lion, *Eumetopias jubatus*	PV	Calkins 1988
Sea Otter, *Enhydra lutris*	BI	Calkins 1988
VII. Plants		
Eelgrass, *Zostera marina*	PP	
Rockweed, *Fucus spp.*	PP	

Chapter 2

ACCUMULATION OF PRISTANE BY MUSSELS (*MYTILUS TROSSULUS*) MEDIATED BY JUVENILE PINK SALMON (*ONCORHYNCHUS GORBUSCHA*) PREDATION ON *NEOCALANUS* COPEPODS I: LABORATORY STUDY

Short, JW (In prep) Accumulation of pristane by mussels (*Mytilus trossulus*) mediated by juvenile pink salmon (*Oncorhynchus gorbuscha*) predation on *Neocalanus* copepods I: laboratory study. Prepared for submission to Marine Ecology Progress Series

Abstract

Juvenile pink salmon (*Oncorhynchus gorbuscha*) were fed zooplankton from Prince William Sound (PWS), Alaska, to evaluate the role played by their feces in transferring pristane from *Calanus* and *Neocalanus* copepods to bay mussels (*Mytilus trossulus*), and to compare growth of these pink salmon with growth of their cohorts fed similar rations of brine shrimp (*Artemia sp.*). The PWS zooplankton used as food contained 7,450 ± 3,250 $\mu g\ g^{-1}$ pristane (95% CI; dry mass basis), and feces derived from them contained 383 ± 72.8 $\mu g\ g^{-1}$ pristane. The absorption efficiencies of tissue mass and of pristane by pink salmon fed PWS zooplankton were 74.6 ± 8.49% and 98.7 ± 0.108%. In comparison, *Artemia sp.* used as a control diet contained 1.24 ± 0.597 $\mu g\ g^{-1}$ pristane, and pristane was usually not detectable in feces derived from them. The efficiency of tissue mass absorption of *Artemia* was 88.4 ± 0.731%. Pink salmon fed *Artemia* grew about four times faster than those fed PWS zooplankton, and gross growth efficiencies of the *Artemia*-fed fish were about three times greater. The difference in growth between the two diets is attributed mainly to growth inhibition by pristane in the PWS zooplankton-fed fish. Mussels accumulated pristane about 52 times faster from dispersed feces than from dissolved pristane. The bioaccumulation factor for dissolved pristane was 2,000, compared with 175,000 for pristane accumulated from feces. Mussels exposed to partially dispersed feces accumulated pristane less rapidly than did mussels exposed to completely dispersed feces. Mussels exposed to dispersed feces derived from *Artemia*-fed fish accumulated readily detectable pristane concentrations from exposure concentrations less than ~ 0.020 $\mu g\ l^{-1}$ (parts per trillion). These results indicate that predation by nearshore zooplanktivores on *Calanus* and *Neocalanus* copepodites in PWS, exemplified by juvenile pink salmon, is an important route by which pristane is transferred from these copepodites to mussels.

Introduction

Chemical analysis of lipids may provide useful insights into aquatic food-web dynamics. Biosynthesis of unusual and environmentally persistent compounds may serve as labels for tracing nutrient transport among environmental compartments (Corner et al. 1986). Comparative analyses of food and resulting feces are necessary to determine digestibility and absorption efficiency (e.g., Sargent et al. 1979). One of the first lipids proposed for such purposes is pristane (2,6,10,14-tetramethylpentadecane; Blumer et al. 1964), a branched alkane hydrocarbon biosynthesized by marine copepods in the genera *Calanus* and *Neocalanus*. Late-stage copepodites of these genera biosynthesize pristane from ingested chlorophyll (Avigan and Blumer 1968), attaining concentrations that may approach 1% dry body mass (Blumer et al. 1964, Short in prep [a]). Pristane is relatively persistent in the environment because it is terminally branched, and hence relatively resistant to β-oxidation.

Every spring, bay mussels (*Mytilus trossulus*) in Prince William Sound (PWS), Alaska rapidly accumulate pristane, with concentrations subsiding to background levels by late summer (Short in prep [a]). *Neocalanus plumchrus* and *N. flemingerii* have a life span of one year and reproduce at depth in winter, after which the adults (i.e. stage VI copepodites) die. The naupliar offspring develop through five naupliar stages as they rise to shallower waters in late winter, metamorphosing to copepodites in time to begin grazing the incipient phytoplankton bloom in early spring. The copepodites develop rapidly from copepodite stage I to stage V by late spring, then seek deep water to begin diapause by the beginning of summer. In the surface waters of PWS during spring these copepodites may dominate the zooplankton biomass (Cooney 1986a, Cooney 1986b, Kirsch et al. 2000, Cooney et al. 2001). The pristane content of these copepodites increases with each development stage, and the appearance of CIV and CV copepodites in PWS surface waters is directly followed by accumulation of pristane by mussels (Short in prep [a]). Concentrations of pristane in mussels may increase up to several thousand fold over two to three weeks beginning mid-April, but the ecological pathway followed by pristane from *Calanus* and *Neocalanus* copepodites is not clear.

Although mussels may occasionally ingest mesozooplankton as large as late-stage *Calanus* and *Neocalanus* copepodites (Davenport et al. 2000), their ingestion rate is probably too low to account for the rapid increases of pristane concentrations during spring in PWS. Escape responses of naupliar stages of calanoid copepods in the flow field of blue mussels (*M. edulis*) are often effective (Green et al. 2003), and the escape responses of late-stage *Calanus* copepodites are considerably more effective (Landry 1978, Ohman 1988). Also, the internal diameter of the intake siphon of mussels is ~ 0.5 mm, similar to the diameter of stage IV or V *Neocalanus* copepodites, so successful capture of these copepodites by mussels implies relatively precise (and hence unlikely) geometric alignment of the major axis of the copepodite with that of the intake siphon of the mussel. These two factors insure that successful capture of *Neocalanus* copepodites by mussels is rare.

Other potentially significant pathways of pristane transfer from *Neocalanus* copepodites to mussels include accumulation of pristane dissolved into seawater from the copepodites, or ingestion of feces produced by the copepodites. Pristane may diffuse from the lipid compartment of copepodites into the ambient seawater. The uptake of pristane dissolved in seawater may be assessed by measuring ambient concentrations during the spring zooplankton bloom, along with the bioaccumulation factor of pristane in mussels. The bioaccumulation factor may be determined from comparison of the uptake and depuration rates of pristane in mussels exposed to a constant ambient concentration of pristane. Pristane was undetected in feces of stage CV copepodites of *Calanus helgolandicus*, but the concentration of pristane in these copepods is lower by factors of several hundred compared with other species of *Calanus* or *Neocalanus* (Prahl et al. 1984, Blumer et al. 1964, Short in prep [a]). The pristane content of *Neocalanus* copepodite feces has not been reported, but this concentration, when combined with production and sinking rates of copepodite feces, would permit an assessment of the importance of this route of pristane incorporation by mussels. Because of the difficulty of collecting sufficient copepod feces for direct experimental determination of pristane bioaccumulation by mussels, the importance of this route will be evaluated on the basis of a field observations reported elsewhere (Short in prep [b]).

Another less direct but possibly important route of pristane incorporation by mussels may be through ingestion of dispersed feces produced by predators of *Neocalanus* copepodites. Feces of fish fed *Calanus helgolandicus* stage V copepodites contained significant amounts of pristane, although absolute concentrations were not reported (Prahl et al. 1985). Juvenile pink salmon (*Oncorhynchus gorbuscha*) are an abundant zooplanktivore in PWS during spring, although their biomass is less than 1% that of some other zooplanktivores such as juvenile Pacific herring (*Clupea pallasi*) or pollock (*Theragra chalcogramma*) (Okey and Pauly 1998). Wild stocks and hatcheries combined produce over a half-billion juvenile pink salmon annually (Johnson et al. 2002) that migrate to marine waters during April and May (Kirkwood 1972, Olsen 1991), coincident with the spring zooplankton bloom (Cooney et al. 1995). Juvenile pink salmon generally remain close to shore during their initial marine residence to avoid predation (Healey 1980, Cooney et al. 1981, Willette 2001), and this behavior may place them immediately above mussel beds during high tides. Juvenile pink salmon prey heavily on copepods, especially *Neocalanus* and *Calanus* in PWS (Cooney et al. 1981, Sturdevant et al. 1996, Willette 1996, Willette et al. 2001). Although feeding experiments using *Calanus finmarchichus* have shown that lipid assimilation by rainbow trout (*Salmo gairdneri*) is very efficient, with less than 5% of total ingested lipid excreted in feces (Sargent et al. 1979), the high concentration of pristane in these copepods implies the feces produced would still contain concentrations of pristane on the order of 500 $\mu g\ g^{-1}$. This is much higher than tissue concentrations found in mussels during spring, which are usually less than 20 $\mu g\ g^{-1}$ (Short in prep [a]). Their feeding habits, nearshore residence, and numbers suggest that juvenile pink salmon may provide an important ecological pathway for transferring pristane produced by *Neocalanus* copepodites to suspension-feeders such as mussels via fecal material produced through predation.

Knowledge of the ecological pathway followed by pristane from *Neocalanus* copepods to mussels would facilitate interpretation of the annual spring increase of pristane concentrations in mussels, which might prove useful for indirectly monitoring *Calanus* and *Neocalanus* zooplankton abundances, and perhaps the early marine survival of zooplanktivorous fishes such as pink salmon and herring. Marine survival of pink salmon is thought to be determined during the initial period of marine residence (Parker 1962, Parker 1968, Ricker 1976, Hartt 1980, Peterman 1987, Karpenko 1998, Willette et al. 2001), and if mussels accumulate pristane primarily from feces produced by nearshore zooplankton predators, then monitoring pristane increases in mussels during spring may provide an index of forage conditions for these predators. Abundant forage may promote rapid growth, reducing the period of maximum vulnerability to predation and thus increasing population survival (Parker 1971, Healey 1982a, West and Larkin 1987, Willette et al. 1999, Willette 2001, Willette et al. 2001). Abundant forage has also been proposed to enhance survival of juvenile pink salmon by providing alterative prey to their predators (Willette et al. 2001), reducing predation pressure.

The primary objective of this study is to compare two of the pathways by which pristane can be accumulated by mussels that are amenable to laboratory manipulation. These two pathways are ingestion of pristane-laden feces produced by juvenile pink salmon fed *Neocalanus* copepods, and absorption of pristane dissolved in seawater. Comparison with a third pathway, involving ingestion by mussels of fecal pellets produced by *Neocalanus* copepods, will be based on a companion field study conducted in PWS during spring (Short in prep [b]). In the present study, I determined the concentration of pristane in feces produced by juvenile pink salmon fed zooplankton collected during the annual spring bloom from PWS, and then measured the uptake and depuration dynamics of pristane in mussels exposed to these feces or to pristane dissolved in seawater. These measurements supply constraints on the relative importance of dissolved vs fecal-associated pristane as sources of pristane for mussels in PWS. The companion field study will incorporate these results into an overall comparison of the importance of dissolved pristane, pristane associated with feces produced by *Neocalanus* copepodites, and pristane associated with feces produced by predators of these copepodites as routes of pristane accumulation into mussels.

The secondary objective is to evaluate the growth efficiency of juvenile pink salmon reared on *Neocalanus* copepodites. Gross growth efficiencies as high as 45% have been assumed for evaluations of the impact of juvenile pink salmon on their zooplankton forage base in PWS (Cooney 1993, Cooney and Brodeur 1998, Boldt and Haldorson 2002), but these may be too high in view of the inhibitory effect of pristane on fish growth reported previously (Luquet et al. 1983, 1984). The feeding experiments reported here provided an opportunity for direct measurement. A more precise estimate of growth efficiency permits a more accurate assessment of the potential impact of juvenile pink salmon on their *Neocalanus* prey, and the amount of fecal material produced per unit growth, and may also provide insight into the growth dynamics of the juveniles relying on a natural diet.

Methods

Laboratory experiments were conducted by feeding juvenile pink salmon a diet of frozen zooplankton collected from PWS during spring, and exposing mussels to the fecal material produced. The mass of zooplankton consumed and of feces produced by the pink salmon, and their pristane concentrations were monitored throughout the feeding period, along with pink salmon growth. Mussels were exposed to whole feces or to homogenized feces dispersed in seawater, or to homogenized feces produced by pink salmon fed frozen brine shrimp (*Artemia sp.*) as a control comparison. Mussels were also exposed to pristane dissolved in seawater, to compare the uptake and depuration rates of ingested pristane with those of pristane absorbed passively from seawater. These were all compared with mussels exposed to the same ambient seawater but without addition of any pristane. Pristane accumulation was measured at approximately equal interval ratios in mussels throughout their two week exposure, and during a four week depuration period following exposure.

Experimental Animal Collection

Zooplankters were collected in PWS during 23 – 30 April 1998 over a series of 12 samplings. At each sampling a 505 µm-mesh plankton net with a 0.5 m diameter opening and 1 l jar at the cod-end (to reduce compaction) was towed for 10 min at a depth of ~ 5 m during daylight. Captured zooplankton were rinsed from the net into a polypropylene tray, and then poured into a 0.5 mm-mesh circular metal sieve partially immersed in seawater and left covered with tinfoil to exclude light for 3 – 6 h to allow evacuation of zooplankton intestinal tracts. At the end of the zooplankton defecation period the sieve was removed from the seawater, allowed to drain for a few min, and the zooplankton were transferred to ~ 20 cm^3 compartments of polypropylene ice cube trays with a metal spatula and stored frozen at -20 °C. About 1 g of the drained zooplankton from each sampling was preserved in 5% formalin-seawater for determination of species composition.

Juvenile pink salmon were collected from the inner bay at Little Port Walter on Baranof Island in Southeast Alaska, and were transported to the Auke Bay Laboratory by air in early July 1998. Several hundred of the smallest individuals were selected for the feeding experiments, and these had a mean initial weight of 1.81 ± 0.0859 g wet wt. (95% CI, n = 9; sample sizes were usually at least the minimum necessary to achieve meaningful statistical power here and following). Small fish were selected because of the limited amount of zooplankton collected from PWS available for the feeding experiments. These fish were fed a commercial diet formulated for salmon hatcheries (Biodiet), were offered food twice daily and were allowed to feed to satiation. On 16 July, fish selected opportunistically for the feeding experiments were fed twice daily on the zooplankton collected earlier from PWS, or on a frozen commercial *Artemia sp.* fish-food product (Sally's Frozen Brine Shrimp, San Francisco Bay Brand, containing minima of 5.02% crude protein, 0.24% crude fat, 0.29% crude fiber, and 92.5% moisture, and packaged as a 5 mm thick sheet of frozen copepods wrapped in polyethylene packaging material).

About 900 mussels (*Mytilus trossulus*) were collected from Tee Harbor, ~ 12 km north of the Auke Bay Laboratory in Southeast Alaska, on 13 July 1998. For the fecal exposure experiments, 600 individuals ranging from 2 – 4 cm shell length were selected opportunistically from the 900 mussels collected, and were distributed sequentially among each of 12 glass pans, resulting in 50 mussels in each pan. Each pan was then placed inside a 38 l polypropylene tray filled with seawater and fitted with an air stone. The trays were placed in tanks of flowing seawater at 7.4 °C, and the seawater in the trays was replaced once daily until the fecal exposures began on 20 July. The remaining ~ 300 mussels were held in flowing seawater until 24 August, when 56 individuals within the same size range were placed into each of 6 glass trays for the dissolved pristane exposure experiment. The 31 ‰ seawater used for these experiments was pumped from a depth of 15 m in Auke Bay, with particles larger than ~ 100 µm removed by filtration through sand, allowing passage of most phytoplankton and small zooplankton.

Zooplankton Consumption and Fecal Production by Pink Salmon

Juvenile pink salmon were sorted into three groups according to their zooplankton diet and treatment of their resulting feces. Groups 1 and 2 were fed the zooplankton collected from PWS, and group 3 was fed *Artemia sp.* Feces produced by groups 2 and 3 were macerated prior to dispersion in the seawater aliquots used for the mussel exposures, while those of group 1 were left whole. These groups are denoted as "whole feces – pristane" (WF-P), "homogenized feces – pristane" (HF-P) and "homogenized feces – *Artemia*" (HF-A). Each treatment comprised triplicate feeding and fecal collection containers with separate groups of 20 juvenile pink salmon in each replicate. Each group of fish was kept in a 38 l polypropylene tray fitted with an air stone, and the tray was kept in a flowing seawater bath at temperatures ranging from 7.3 – 8.5 °C. Treatment trays were placed within and among the seawater bath containers in a sequence determined using the random number generator on a Hewlett-Packard model 32S II handheld calculator.

Fish in each replicate were offered 7 g (wet wt) of frozen zooplankton from PWS or frozen *Artemia sp.*, depending on treatment, at 8 am and again at 8 pm daily, and allowed to feed for 1 h, beginning 20 July through 4 August 1998. The daylength is approximately 17 h at this latitude and time of year. Just prior to feeding, each group of 20 fish was transferred together by dip net to a separate tray for feeding. After feeding, each group was again transferred by dip net to another tray, where they remained until the next feeding period. The fecal material defecated during the previous 11 h was collected from the first tray by filtering the seawater through 202 μm-mesh plankton netting after fish had been removed. Fecal material from the feeding period was collected by pipette and stored in a polypropylene container at -20 °C for pristane analysis and for determination of the ratio of wet and dry weight of the feces. The weight of this material was included with the weight produced during the previous defecation period for measurement of total fecal weight produced, but was not included in material used for the mussel exposures because of the possibility of contamination by the zooplankton food. After removal of feces, unconsumed zooplankters were collected by filtration through a 202 μm-mesh net and weighed.

Two reserve pools of 25 and 12 juvenile pink salmon were offered rations of zooplankton from PWS or *Artemia sp.*, respectively, that were identical (on a wet weight basis) with the rations offered fish in the experimental replicates. The reserve pool fish were used to replace dead or moribund fish in the treatment groups. When feeding the fish in the reserve pools, zooplankton were first thawed in seawater and then collected with a 202 μm-mesh net to determine the ratio of frozen weight to zooplankton weight recovered.

This ratio was used to adjust the tissue weight of frozen zooplankton for water losses caused by freezing and thawing, because this water mass was not available for consumption by fish. The mass of food consumed by fish in the treatment groups was estimated as the difference in the tissue weight of zooplankton offered (adjusted for water losses on thawing), and the tissue weight of zooplankton recovered by dip net at the end of each feeding period.

Pink Salmon Growth and Feeding

For estimating growth rates, juvenile pink salmon were weighed near the middle and again at the end of the experiment by transferring all 20 of the fish in a treatment replicate to a bucket containing seawater on a scale with a dip net, and noting the increase in weight. Consumption of food altered fish weight significantly, so weighings were conducted at least 6 h after the morning feeding period but before the evening feeding period. I estimated the instantaneous growth rate as $k = t^{-1} \ln(W_f\ W_i^{-1})$, where t is the number of days between weighings, and W_f and W_i are the final and initial masses. Two fish died during the interval between weighings, which were replaced from the reserve pools, and the weight of fish in the treatment was corrected for the difference in weights between the dead and replacement fish. Fish from two of the HF-A replicates were inadvertently mixed on the fifth day of the experiment, so weighings for growth rate determination of these two treatment replicates were based on observations from this day and end of the feeding period, whereas the initial weighings for the other treatment groups occurred on the fourth day of the experiment (Table 2.1).

Food consumption rations were determined for each feeding period and treatment group replicate as the ratio of food consumed and the estimated weight of fish. Food consumed was calculated as the difference between the mass of food offered at the beginning of each 12-h feeding period, and the mass that remained unconsumed at the end. The weight of fish at the beginning of each feeding period was calculated on the assumption of exponential growth between measurements of fish weights, with $W_{t'} = W_i \exp(kt')$, where $W_{t'}$ is the weight of fish in a treatment group replicate at time t', and k is the instantaneous growth rate calculated as described above.

Mussel Exposures to Pristane

The 38 l polypropylene trays containing mussels exposed to pink salmon feces were also located at random in larger containers of flowing seawater that served to maintain temperature in the range 7.3 – 8.5 °C. Mussels were marked initially with red nailpolish, and were replaced with un-marked mussels when removed for pristane analysis to maintain an approximately constant ratio of tissue mass to exposure water volume. Each experimental treatment comprised three groups as replicates, with each replicate containing 50 mussels. Feces collected for the HF-P and HF-A treatment groups were macerated in ~ 1 ml seawater with a Potter-Elvehjem tissue grinder, then mixed with 38 l of seawater containing 50 mussels. Feces collected for the WF-P treatment were left to soak for 24 h in a separate 38 l polypropylene tray to allow time for the fecal material to disperse and for pristane to dissolve, and were then used for the WF-P exposures. A fourth treatment group consisted of 50 mussels per replicate exposed to seawater but no feces as a control. Seawater of all the treatment groups was replaced once every 12 h with freshly and independently prepared seawater containing feces appropriate for each group replicate. Five mussels were removed from each treatment replicate at 0, 2, 4, 7, and 14 d during the exposure period for pristane analysis, and again at 2, 4, 7, 14, and 28 d following the exposure period when the mussels were kept in flowing seawater with no fecal material added to monitor depuration of the accumulated pristane.

Another experiment involved exposure of mussels to a nominal 0.5 $\mu g\ l^{-1}$ solution of pristane in seawater. This concentration is near the upper limit of concentrations that might be found in natural seawater (Blumer et al. 1964), and was chosen to mimic an environmentally relevant exposure condition. Three replicates were exposed to this pristane solution, and another three replicates were exposed to ambient seawater as a control treatment. Each treatment replicate consisted of 50 mussels in a glass tray, and the three trays of the 0.5 μg pristane l^{-1} seawater exposure were placed in a fiberglass tank containing 475 l seawater to which 0.222 mg pristane dissolved into 1.0 ml acetone was added. The control treatment replicates were placed in a similar tank, and both tanks were equipped with circulation pumps and air stones. Seawater in the two tanks was replaced twice daily throughout the 14-day exposure period. Five marked mussels were removed (with replacement from the reserve pool of un-marked mussels) from each treatment replicate at 0, 2, 4, 8, and 14 d during the exposure period, and again at 2, 4, 8, 14, and 32 d following the exposure period when the mussels were kept in flowing seawater with no pristane added to monitor depuration. Four-liter aliquots of seawater were sampled for pristane analysis at the beginning of three and again at the end of two 12 h exposure episodes to verify exposure concentration.

Two mussels died during the first (fecal-exposure) experiment and none during the second (dissolved pristane) exposure. Mussels attached themselves to the glass pan with byssal threads and their shells remained slightly opened throughout the exposure and depuration periods of both experiments, indicating active seawater pumping.

Dry Weight Determination

The ratio of dry and wet weights of tissue and of fecal samples was determined by drying a weighed sample aliquot at 60 °C for 24 h. This ratio varied considerably among different batches of zooplankton collected from PWS, ranging from 0.0625 to 0.267 (mean 0.134 ± 0.0352, n = 12). The wide variability of this ratio for PWS zooplankton is likely the result of differences in zooplankton composition (especially the proportion of small gelatinous zooplankters), differences in the extent of seawater drainage during collection and differences in rupturing caused by freezing the zooplankton. Because of this variability, conversions involving zooplankton from PWS were batch-specific. Ratios for other sample types were less variable as follows: *Artemia sp.,* 0.0903 ± 0.00360 (n = 6); feces from PWS zooplankton, 0.105 ± 0.00571 (n = 29); feces from

Artemia sp., 0.0718 ± 0.0114 (n = 24); mussels, 0.112 ± 0.00149 (n = 180). These mean values were used for these respective samples in calculations.

Pristane concentrations are expressed on a dry weight basis, except in calculations involving the kinetic constants that characterize pristane uptake and depuration in mussels, and growth and assimilation efficiencies of juvenile pink salmon, which are on a wet weight basis.

Pristane Analysis

The chemical analysis of tissue samples for pristane involved pentane extraction of macerated tissues spiked initially with perdeuterated *n*-hexadecane as an internal standard, solvent concentration and exchange into hexane over steam, purification by silica gel/alumina column chromatography eluted with pentane, solvent re-concentration, resolution of alkanes by gas chromatography (GC) and measurement by flame ionization (Short et al. 1996). Identification of pristane is based on GC elution time. The method for the zooplankton samples involved no alumina and less silica gel, because of the small tissue mass aliquots analyzed (< 0.05 g dry mass vs ~ 0.5 g for mussels).

The seawater samples were spiked with an acetone solution containing the same perdeuterated internal standard used for the tissue analyses, then extracted twice into 100 ml aliquots of dichloromethane. The dichloromethane extracts were combined and exchanged into 1 ml hexane over steam, and then analysed by the GC analysis used for the tissue samples.

The accuracy of the pristane analyses were generally within ± 15% based on comparison with an authentic hydrocarbon standard prepared by the National Institute of Standards and Technology, and the coefficient of variation was generally less than ± 20%. The method detection limit (MDL), defined as the estimated concentration associated with a 1% probability of type I detection error, is 0.162 μg for tissue samples. The corresponding MDL estimate for individual samples is the ratio of this value and the weight of the sample analyzed. No comparable MDL estimate is available for pristane in seawater, so the ratio of the tissue MDL and the seawater aliquot volume (4 l) is assumed, resulting in a MDL of 0.041 μg l^{-1}.

Data Analysis

Except for the kinetic constants characterizing pristane uptake and depuration by mussels, Student's t-test was used to calculate confidence intervals and for tests of significance between pairs of treatments.

I assumed that mussels accumulate and depurate pristane according to the following first-order kinetic process:

$$\frac{dP}{dt} = k_1 P_{ex} - k_2 P \qquad \text{(eq 1)}$$

where P_{ex} in the external concentration of pristane in the exposure seawater (assumed constant), P is the concentration in mussel tissue, and k_1 and k_2 are rate constants for uptake and depuration, respectively. The solution to this equation is:

$$P = \frac{P_{ex} k_1}{k_2}\left(1 - e^{-k_2 t}\right) \qquad \text{(eq 2)}$$

During depuration, P_{ex} is zero, and eq 1 simplifies to $P = P_{int}\, e^{-k_2(t-14)}$ (eq 3), where P_{int} is the concentration at the end of the 14 day exposure period. I fitted the pristane concentration measurements in mussels simultaneously to eqs 2 and 3 for the uptake and depuration phases of exposure, using the pristane concentration estimated at the end of the exposure period as the value for P_{int} in eq 3 for depuration, and using least-squares error minimization to find simultaneous best-fit estimates for k_1, k_2 and P_{int}.

I used a non-linear bootstrap method to estimate 95% confidence intervals for k_1 and k_2. This involved randomly associating (with replacement) the observed data errors to the estimated value of P at each sampling time in place of each actual data point (subject to the constraint that the result be non-negative), and re-estimating k_1 and k_2, the process repeated 1,000 times. The 95% confidence interval is estimated as the bounds of upper and lower 2.5% of values in the tails of this distribution. This method preserves the error distribution without making assumptions about it (Efron and Tibshirani 1993), and permits simultaneous estimation of k_1 and k_2 while making full use of the available data.

I also used a bootstrap method to estimate the significance of differences between pairs of depuration constants k_1 or k_2. I calculated the difference between each of the 1,000 iterated estimates of the two k's compared, in the order of the smaller subtracted from the larger of the two k's estimated initially, and counted the proportion that were negative or zero. This proportion is taken as the probability of Type I error (i.e., the significance level).

The bioaccumulation factor (BAF) for pristane in mussels is the ratio of the tissue and exposure concentrations at equilibrium, with the tissue concentration expressed on a wet weight basis (Barron 1994), and may be calculated directly from eq 1 when equated with zero as the ratio of the kinetic constants k_1 and k_2.

Results

Pristane in Zooplankton and Feces

Pristane concentrations in the thawed batches of zooplankton collected from PWS were variable, ranging from 1,590 – 16,000 $\mu g\ g^{-1}$ (mean 7,490 ± 3,250 $\mu g\ g^{-1}$, n = 12). This was not the result of variable species composition among the batches, because all contained more than 95% Stages IV and V *Neocalanus plumchrus*, *N. flemingeri* or *Calanus marshallae* (mass basis). This variability may instead have been caused by differences in losses during thawing. The ratio of wet PWS zooplankton weight recovered after thawing in the reserve trays and the initial frozen weight was surprisingly low and variable, ranging from 0.245 – 0.392 (mean 0.306 ± 0.0376, n = 9). Freezing likely disrupted cell membranes allowing loss of cellular contents, which may have included variable amounts of the lipid droplets of *Calanus* and *Neocalanus* copepods. Similar losses of mass on thawing occurred with frozen *Artemia sp.*, where ratios ranged from 0.339 – 0.640 (mean 0.490 ± 0.0507, n = 15). The mean pristane concentration of frozen *Artemia sp.* was 1.24 ± 0.597 μg g^{-1} (n = 3).

Concentrations of pristane in feces derived from PWS zooplankton ranged from 137 – 660 μg g^{-1} (mean 383 ± 72.8 μg g^{-1}, n = 21). Concentrations in feces derived from *Artemia sp.* ranged from < MDL to 30.8 μg g^{-1}, the latter being less than three times the MDL for that sample. These samples had relatively high values of the MDL because of the small sample aliquot sizes (< 20 mg) available for analysis. The mean MDL for these samples was 21.9 μg g^{-1}, and ranged from 9.02 – 81.2 μg g^{-1}.

Juvenile Pink Salmon Feeding and Growth

Juvenile pink salmon grew significantly faster when fed *Artemia sp.* compared with zooplankton from PWS. The mean instantaneous growth rate for the *Artemia*-fed fish was $k = 0.0209 \pm 0.00368$ d^{-1} (n = 3), more than four times faster than fish fed zooplankton from PWS ($k = 0.00502 \pm 0.00251$ d^{-1}, n = 6; $P < 0.001$) (Table 2.1). Gross growth efficiencies (i.e., the ratio of body growth and wet mass of zooplankton consumed, or K_1) were correspondingly greater for the *Artemia*- compared with the PWS zooplankton-fed fish, with $K_1 = 0.185 \pm 0.0418$ (n = 3) and 0.0657 ± 0.0340 (n = 6), respectively. These differences were not the result of differing rations. Fish fed *Artemia sp.* consumed a mean of 10.9 ± 0.561% (n = 3) of their wet weight in (wet) *Artemia sp.* per day, equivalent to 0.988 ± 0.0559% of dry *Artemia sp.* per day (Table 2.1). In comparison, fish fed PWS-zooplankton consumed a mean of 7.66 ± 0.554% (n = 6) of their wet weight in (wet) PWS-zooplankton per day, equivalent to 0.931 ± 0.0943% of dry PWS-zooplankton per day (Table 2.1). Hence, on a dry weight basis of food consumed, the ingestion rates of *Artemia sp.* and of PWS-zooplankton were nearly identical.

Fish absorbed a greater proportion of *Artemia* than PWS zooplankton. Fish absorbed 88.4 ± 0.731% (n = 3) of the *Artemia sp.* ingested compared with 74.6 ± 8.49% (n = 6) for the PWS zooplankton-fed fish, a significant ($P < 0.001$) difference. Hence, the *Artemia*-fed fish grew faster in part because they consumed about 5% more food and absorbed it more completely (88.4% vs 74.6%) compared with fish fed zooplankton from PWS, but these differences are not sufficiently great to account for the fourfold increase in growth rate.

Pristane was very efficiently absorbed by the PWS zooplankton-fed fish, with 98.7 ± 0.108% (n = 6) of ingested pristane absorbed. The absorption of pristane was significantly ($P < 0.001$) greater than the absorption of PWS zooplankton biomass by these fish. The absorption efficiency of pristane in *Artemia sp.* could not be accurately estimated because fecal concentrations were too frequently below MDL.

Uptake and Depuration of Pristane in Mussels

The assumed uptake and depuration functions (eqs 2 and 3) provide a reasonably good approximation of the measured concentrations in mussels exposed to dissolved pristane or to pristane contained in feces (Figs. 2.1 – 2.4). The variability of the measured pristane concentrations increases substantially with concentration in all exposure treatments, and is greatest at the end of the exposure period and near the beginning of the depuration period.

Mussels rapidly accumulated dissolved pristane (Fig. 2.1). The measured exposure concentration was 0.558 ± 0.817 $\mu g\ l^{-1}$ (n = 4; the large confidence interval was caused by one sample containing 1.73 $\mu g\ l^{-1}$, which may have been caused by inadequate mixing before sampling). For calculation of the kinetic constants and BAF, I assume the nominal value of 0.5 μg l^{-1} based on the mass of pristane added. The estimates of the uptake and depuration constants are $k_1 = 339$ d^{-1} (95% CI: 263 – 417 d^{-1}) and $k_2 = 0.169$ d^{-1} (95% CI: 0.122 – 0.202 d^{-1}), giving a BAF estimate of 2,000. The depuration constant implies a half-life of ln 2 $k_2^{-1} = 4.1$ d for accumulated pristane. The concentration of pristane in mussels exposed to seawater with no pristane added was consistently less than 0.060 μg g^{-1} (wet weight basis; see Fig. 2.1 for dry weight basis), implying seawater concentrations near 0.030 μg l^{-1} during the exposure and depuration periods.

Mussels exposed to homogenized feces produced by pink salmon that were fed zooplankton from PWS (HF-P treatment) accumulated pristane to much higher concentrations than when exposed to the dissolved pristane, despite nearly equivalent exposure concentrations (Figs. 2.1 and 2.2). The mean concentration of pristane added to the seawater as homogenized feces in the HF-P treatment was 0.317 ± 0.0163 μg l^{-1} (n = 84), slightly less than the 0.5 μg l^{-1} exposure to dissolved pristane. The rate constant for pristane uptake in mussels of the HF-P treatment was 17,600 d^{-1} (95% CI: 12,600 – 22,900 d^{-1}), which is 52 times faster than dissolved pristane was accumulated. Depuration of pristane accumulated by mussels in the HF-P treatment was significantly slower ($P = 0.012$) than depuration of pristane accumulated from the dissolved form. The depuration constant k_2 for the HF-P treatment was 0.101 d^{-1} (95% CI: 0.0571 – 0.135 d^{-1}), implying a pristane half life of 6.9 d. The BAF implied by the ratio of the kinetic constants is 175,000, far higher than the BAF for dissolved pristane.

Mussels exposed to whole feces produced by pink salmon that were fed zooplankton from PWS (WF-P treatment) accumulated pristane more slowly than mussels in the HF-P treatment (Figs. 2.2 and 2.3). The mean concentration of pristane added to the seawater was nearly the same as that of the HF-P treatment, but the rate constant for pristane uptake in the WF-P treatment was about a third as rapid ($k_1 = 6{,}360$ d^{-1}, 95% CI: 4,830 – 7,660 d^{-1}). The depuration constant k_2 for the WF-P treatment was 0.0992 d^{-1} (95% CI: 0.0668 – 0.127 d^{-1}), implying a pristane half-life of 7.0 d, which was not significantly different ($P = 0.533$) than the depuration constant for the HF-P treatment, but was significantly slower ($P = 0.007$) than the depuration rate of mussels that accumulated dissolved pristane. The BAF implied by the ratio of the kinetic constants is 64,200.

Mussels exposed to feces produced by the *Artemia*-fed pink salmon (HF-A treatment) accumulated readily detectable concentrations of pristane (Fig. 2.4), despite exposure concentrations near the limits of detectability (implying exposure concentrations < ~ 0.020 $\mu g\ l^{-1}$). The uptake rate constant could not be accurately estimated because the exposure concentration was too often below the MDL, but the depuration rate constant was not significantly lower ($P > 0.23$) than those of the other exposures to fecal material ($k_2 = 0.0766\ d^{-1}$, 95% CI: $0.0372 - 0.126\ d^{-1}$), implying a pristane half-life of 9.1 d.

Discussion

The relative importance of pristane accumulation from the dissolved state compared with ingestion of food particles containing pristane can be roughly determined by the octanol-water partition coefficient (K_{ow}) of pristane (Kelly et al. 2004). The octanol-water distribution coefficient for a contaminant is the ratio of the contaminant concentration in *n*-octanol and water (i.e. $K_{ow} = [X]_{octanol}/[X]_{water}$; [X] = contaminant concentration). This coefficient is a measure of the tendency of a low-polarity chemical such as pristane to accumulate into a low-polarity solvent such as *n*-octanol or lipid in biological tissues. Empirically, organic compounds that have values of K_{ow} exceeding about 100,000 may biomagnify in biota, provided the accumulating organism has a negligible capability to metabolizing the compound (Kelly et al. 2004). Biomagnification may occur when an organism accumulates a contaminant through its diet, and the affinity of the contaminant for the lipid phase is sufficiently great that diffusion losses of the contaminant back to the ambient aqueous phase are outweighed by the rate of accumulation through ingestion.

The K_{ow} value of pristane has not been reported, but an approximate value may be inferred from the BAF result of ~ 2,000 reported here. Marine mussels have little capacity to metabolize hydrocarbons (Lee et al. 1972, Mironov and Shchekaturina 1979). Assuming a lipid concentration of 1% of wet weight (Kluytmans et al. 1975), and that all of the accumulated pristane was contained within the lipid compartment of the mussels, the lipid-normalized partition coefficient would be on the order of 200,000. This BAF value implies that pristane is near the threshold for food-chain biomagnification. The pristane accumulation and depuration results from the mussels exposed to pristane incorporated within fecal material support this conclusion. The 175,000-fold increase (at equilbrium) of pristane accumulated by mussels exposed to 0.317 $\mu g\ l^{-1}$ of pristane in dispersed feces of the HF-P treatment implies an equilibrium concentration of 55.5 $\mu g\ g^{-1}$ in the mussels on a wet weight basis. The wet weight concentration of pristane in the feces is (383 $\mu g\ g^{-1}$) x (0.105) = 40.2 $\mu g\ g^{-1}$. The ratio of these values is near one, the value indicative of the biomagnification threshold. Expression of pristane concentrations per unit lipid would have little effect on this comparison. Assuming wet mussel tissue contains 1% lipid, a wet weight concentration of pristane of 55.5 $\mu g\ g^{-1}$ in mussels implies a pristane concentration of (0.0000555 g g^{-1}) x $(0.01)^{-1}$ x 100% = 0.56% of lipid. The concentration of pristane stage V copepodites of *Neocalanus plumchrus* is ~ 0.8% (Short in prep[a]), and these copepodites usually contain 50% or more of their dry weight as lipid (Båmstedt 1986, Duesterloh 2002). Assuming the relation of pristane and lipid is unaltered by passage through the intestinal tract, the concentration of pristane per unit lipid in the fecal material produced by the juvenile pink salmon would be on the order of 0.4%, comparable with the equilibrium concentration (0.55%) estimated for pristane in the lipids of mussels ingesting these feces. These results indicate mussels have little tendency to biomagnify pristane through ingestion of fecal material produced by juvenile pink salmon preying on *Neocalanus plumchrus*, which is consistent with the empirical findings based on the estimated K_{ow} of pristane (Kelley et al. 2004).

The results from the mussel uptake experiments indicate that pristane associated with feces produced by juvenile pink salmon is a substantially more available form of this hydrocarbon for mussels than is dissolved pristane. The 52-fold increase in the rate of pristane accumulation by mussels exposed to dispersed, pristane-laden feces (HF-P treatment) compared with exposure to dissolved pristane (cf. Figs. 2.1 and 2.2) reflects the greater efficiency of particle-capture by these suspension-feeders compared with passive absorption of dissolved pristane. This greater efficiency is a consequence of the lower entropy of pristane associated with feces compared with the dissolved state. In a unit volume of seawater, pristane in fecal material is concentrated in a relatively few particles compared with the molecular scale of dissolved pristane. Suspension-feeders such as mussels are adapted to collect these particles efficiently by filtration, capturing particles as small as 1 μm (Vahl 1972). The accumulation rate of pristane from the dissolved state is limited by the diffusion rate across the seawater boundary layer adjacent to mussel tissues, an inherently slow process compared with particle filtration. Mussels thus incorporate a much higher proportion of pristane from a unit volume of inspired seawater when concentrated in fecal particles compared to dissolved form. A similar result has been reported for the suspension-feeding copepod *Calanus helgolandicus*, which required exposure to much higher concentrations of dissolved naphthalene than of naphthalene bound to food particles to achieve equivalent internal concentrations (Corner et al. 1976).

The high efficiency of particle-capture by mussels is also evident in the other two experimental treatments. Mussels exposed to the whole feces derived from PWS zooplankton, which were allowed to partially disintegrate in seawater for 24 h prior to introduction to the mussels, still accumulated pristane nearly twenty times faster than did mussels exposed to dissolved pristane. The slower accumulation rate of pristane by mussels exposed to whole feces compared with the accumulation rate of homogenized feces is because only a fraction of the whole feces disintegrated to particle sizes available to the mussels. Dissolution of pristane prior to incorporation by mussels was clearly a negligible process, because even if all the pristane in the feces dissolved, comparison with the results for the dissolved pristane uptake experiment show that this would have accounted for less than ~ 5% of the pristane burden accumulated by the mussels exposed to the whole feces (compare Figs. 2.1 and 2.3).

Mussels exposed to feces derived from *Artemia sp.* accumulated pristane to higher concentrations than mussels exposed to dissolved pristane (cf. Figs. 2.1 and 2.4), despite the much lower seawater concentration of pristane associated with the *Artemia sp.*-derived feces. In fact, the likely exposure concentration of this treatment of ~ 0.020 μg l^{-1} would be difficult to detect by direct analysis of 4 l aliquots of seawater, as would the resulting tissue concentrations of mussels exposed to this concentration of dissolved pristane. By assuming a BAF of 2,000 for the accumulation of dissolved pristane into mussels, an exposure concentration of 0.020 μg l^{-1} and a ratio of dry and wet weights of 0.1, the equilibrium concentration of pristane in dry mussel tissue is 0.40 μg g^{-1}, very near the tissue MDL for a 0.5 g dry weight tissue aliquot of 0.326 μg g^{-1}. Comparison with observed mussel tissue concentrations exceeding 10 μg g^{-1} (Fig. 2.4) that resulted from exposure to pristane associated with *Artemia*-derived feces illustrates the ability of mussels to bioconcentrate fecal-associated pristane from very low ambient exposures.

The slower depuration rate of pristane from mussels exposed to pristane-laden feces compared with those exposed to dissolved pristane is probably because of the additional time required for ingested pristane to migrate to the externally-exposed tissues of mussels. Pristane absorbed from seawater solution accumulates initially on the externally-exposed tissue surfaces (especially the gills, which account for most of the externally-exposed surface area), where the reverse process of depuration occurs readily. Pristane ingested with fecal material is transported directly to the innermost tissues, and additional time is required for it to migrate to the gills and other external tissue surfaces where depuration occurs. This additional time is reflected in the longer half-lives of ingested pristane (7 – 9 d) compared with pristane absorbed from solution (~ 4 d). These half-lives are comparable with those reported previously for mussels briefly exposed to dissolved hydrocarbons (Mason 1988). The same rationale was used to explain the slower depuration of naphthalene accumulated through the diet compared with accumulation from the dissolved state for *Calanus helgolandicus* (Corner et al. 1976).

Ingestion of pristane-laden feces may account for the increased concentrations of pristane often found in mussels of PWS during spring. Feces derived from fish fed zooplankton from PWS remain a relatively concentrated source of pristane. The mean concentration of pristane in feces produced by the PWS zooplankton-fed fish was 383 $\mu g\ g^{-1}$, which would make these feces the second most concentrated form of pristane in PWS during spring (cf. Short in prep [a]). Although direct measurements have not been reported, the solubility of pristane in seawater is almost certainly less than 1 $\mu g\ l^{-1}$, based on comparison with solubilities of *n*-alkanes that have comparable molecular mass (Sutton and Calder 1974). The BAF derived from the mussels exposed to dissolved pristane reported herein is 2,000, implying a maximum pristane concentration of 2 $\mu g\ g^{-1}$ wet weight, or about 20 $\mu g\ g^{-1}$ dry weight, when mussels are exposed to seawater saturated with pristane. In PWS, concentrations in mussels during spring may exceed 50 $\mu g\ g^{-1}$ dry mass (Short in prep [a]), when ambient seawater concentrations are ~ 0.1 $\mu g\ l^{-1}$ or less (Short and Harris 1996), limiting mussel tissue concentrations to < 2 $\mu g\ g^{-1}$ dry weight when accumulated from dissolved pristane only. Uptake of dissolved pristane clearly cannot account for the higher concentrations observed in these mussels during spring, but ingestion of fecal material produced by nearshore zooplanktivores such as juvenile pink salmon could. Ingestion of fecal material produced by *Calanus* or *Neocalanus* copepods might also be a significant uptake pathway for mussels, if the concentration of pristane and the particle density of fecal pellets are sufficiently great. The importance of this pathway will be evaluated in a companion field study (Short in prep [b]).

My estimate of absorption efficiency for tissue mass of PWS zooplankton is substantially lower than that reported for rainbow trout (*Salmo gairdnerii*) fed frozen zooplankton consisting mainly of *Calanus hyperboreus*, where the estimated absorption efficiency was 94% for tissue mass (Sargent et al 1979). This may be a consequence of the correction I used for water loss on thawing. Without this correction, the assimilation efficiencies reported here would be nearly identical with those reported by Sargent et al. (1979), but it is not clear whether a similar correction was used by Sargent et al. (1979).

In contrast with the PWS zooplankton, nearly all of the pristane contained in *Artemia sp.* was probably defecated by the juvenile pink salmon. The concentration of pristane in feces derived from *Artemia sp.* was probably ~ 10 $\mu g\ g^{-1}$, well above the concentration estimated in the *Artemia sp.* food (1.24 ± 0.597 $\mu g\ g^{-1}$). The absorption efficiency of ingested *Artemia sp.* tissue mass was 88.4%, suggesting that little of the ingested pristane was assimilated. This might be the result of the much lower lipid content of the *Artemia sp.*, which is near ~ 2.7% (dry weight basis) according to the supplier. The lipid content of late stage *Calanus* and *Neocalanus* copepodites is much higher, usually 50% or more (Båmstedt 1986, Duesterloh 2002), so it may be that the lipid content of *Artemia sp.* is too low to stimulate sufficient bile salts for efficient absorption of lipids and associated pristane.

The daily rations ingested by the pink salmon in the experiments reported here are comparable with rations of wild juveniles. Wild pink salmon typically consume 5 – 30% of their body weight per day in wet weight of prey (Simenstad et al. 1980, Godin 1981, Healey 1982b). The experimental pink salmon consumed 7.7% of their body weight of PWS zooplankton, and 11% of *Artemia sp.* daily (Table 2.1). The experimental pink salmon were therefore not stressed on account of food availability.

The growth rate of the juvenile pink salmon fed *Artemia sp.* is somewhat lower than that typical of wild juveniles, and may have been a consequence of the selection of small fish and handling stress. Wild juvenile pink salmon typically have daily growth rates of about 3% of body weight per day during the initial phase of their marine residence (Cooney et al. 1981, Willette 2001). Selection of the smallest fish available for these experiments in mid-July led to an average individual weight of 1.8 g, and these fish would have weighed

~ 0.3 g during when entering seawater some 90 days earlier. This amount of growth implies an instantaneous growth rate of ~ 2% d^{-1}, consistent with the continued growth of the fish that were fed *Artemia sp.* Selection of the smallest fish means their measured growth performance is probably an underestimate of the growth rate of the population sampled, hence inferences regarding the sampled population growth under the experimental conditions used here must be done with caution. Also, the considerable daily handling stress of all treatment groups may have reduced growth somewhat, but this affected all the treatment groups equally, and hence cannot account for the low growth rate of the pink salmon that were fed zooplankton from PWS compared with those that were fed *Artemia sp.* Despite these caveats, the differences in the growth of fish that were fed zooplankton from PWS compared with fish that were fed *Artemia sp.* were so great that differences of approximately similar magnitude would probably be found in larger, faster-growing fish as well.

The low growth rate of juvenile pink salmon that were fed zooplankton from PWS is most likely due to the pristane content, because pristane inhibits growth of fish. Juvenile rainbow trout (*Salmo gairdnerii*, 13 g initial wet weight) ingesting a daily ration of ~ 1.5 g dry artificial food per g wet body weight that contained 1% pristane for 45 weeks had a mean instantaneous growth rate $k = 0.00748$ d^{-1}, compared with a control diet where $k = 0.0141$ d^{-1}, and the fish fed pristane required 67% more food to achieve equivalent weight gain (Luquet et al. 1983). Similar results were found during a follow-up experiment with larger rainbow trout (121 g), where fish ingesting identical rations (~ 2 g dry food per g wet body weight) containing either 1% pristane or no pristane had $k = 0.00349$ d^{-1} compared with $k = 0.00817$ d^{-1}, and the pristane-fed fish required nearly three times the food ingested by control fish to achieve equivalent growth (Luquet et al. 1984). These instantaneous growth rates are not very different than those reported here, as are the food conversion efficiencies (the ratio of K_1 for the PWS zooplankton- and *Artemia*-fed fish is 2.8, implying the PWS zooplankton-fed fish must ingest 2.8 times more food than the *Artemia*-fed fish to achieve equivalent growth). The results presented here for juvenile pink salmon and by Luquet et al. (1983, 1984) indicate that pristane inhibits fish growth substantially, and is the primary reason why pink salmon grew so poorly on a diet of zooplankton from PWS.

The feeding experiments with pristane added to artificial fish food conducted by Luquet et al. (1983, 1984) suggest that pristane reduced growth by interfering with lipid metabolism. These experiments demonstrated that pristane (as well as other saturated hydrocarbons) depressed appetite of fish, that pristane depressed growth when ingested rations fed with and without pristane were identical, and that the appetite depression did not appear until about 2 weeks after feeding on pristane-laden food began. This last observation argues against a palatability effect of pristane causing appetite depression. Instead, Luquet et al. (1984) suggest that appetite depression results from slower growth, not *vice versa*. These authors also noted lower liver mass, lower liver lipid content and liver hepatosomatic index (i.e., the ratio of liver and body masses) of fish ingesting pristane-contaminated food compared with those ingesting equivalent rations of uncontaminated food. These results imply that pristane inhibits fish growth through an unknown metabolic effect.

The growth inhibition of pristane on the juvenile pink salmon that were fed zooplankton from PWS may have been exacerbated by two other factors. First, *Calanus* and *Neocalanus* copepodites may not be as balanced a diet for juvenile pink salmon as *Artemia sp*. Although rich in lipid, *Calanus* and *Neocalanus* copepodites may be deficient in other nutrients essential for rapid growth. Juvenile pink salmon in PWS would have access to a broader spectrum of prey than those captured and frozen for my feeding experiments, such as zooplankton too small to be efficiently captured by the 505 μm-mesh plankton net, or prey found in other habitats accessible to pink salmon such as harpacticoid copepods in benthic sediments or insects at the seasurface. These other prey may supply the nutrients necessary for rapid growth that may be lacking in *Calanus* and *Neocalanus* copepodites. Second, nutrients essential for rapid growth may have been lost from the *Calanus* and *Neocalanus* copepodites captured from PWS during thawing. The ~ 70% reduction in mass on thawing suggests considerable losses of water-soluble nutrients, and perhaps some of these were essential for juvenile pink salmon growth, although similar losses also affected the *Artemia* treatment, which supported the better fish growth nonetheless. Hence, it is unlikely that these losses would be sufficient to account for the large differences in growth observed between these two diets.

Calanus and *Neocalanus* copepods are an important link in marine food webs between primary production and consumers at higher trophic levels, especially during spring phytoplankton blooms at sub-arctic latitudes where they may account for most of the spring zooplankton biomass near the seasurface (Parsons and Lalli 1988). The value placed by researchers on these copepods as prey items to their consumers has heretofore been based mainly on their high lipid, and hence caloric content. The countervailing effect of growth inhibition caused by pristane suggests that the energetic value based only on caloric content assigned to these copepods in models of marine food webs requires revision. In fact, it may be that the relatively high concentrations of pristane biosynthesized by these copepods act as a chemical defense against predation, by prolonging the period of greatest vulnerability of their predators to size-dependent predation. Size-dependent mortality from predation has been implicated as an important factor for the survival of juvenile pink salmon (Parker 1971, Healey 1982a, West and Larkin 1987, Willette et al. 1999, Willette 2001, Willette et al. 2001).

Pristane was initially suggested to play a role in buoyancy regulation, allowing copepods to expend less energy to maintain position in the water column during diapause, and thereby conserve lipid stores (Blumer et al. 1964), but this hypothesis is problematic. The hypothesized advantage of pristane in buoyancy regulation was based in part on lipid utilization rates of active but starving copepods, which use lipid stores more rapidly than quiescent copepods in diapause (Hirche 1983, Campbell et al. 2004), leading to an exaggeration of the benefits of pristane as an agent to decrease buoyancy. *Calanus* and

Neocalanus copepods are actually close to neutral buoyancy and consume only a small proportion of their storage lipids during diapause (Jónasdóttir 1999, Campbell and Dower 2003, Campbell et al. 2004), with the greater proportion of the lipids being used for gamete production (Jónasdóttir 1999). Also, if pristane concentrations on the order of 1% dry mass interacts somehow with lipids to reduce lipid utilization during dormant periods, it is not clear why nearly the same concentration would be produced by, for example, *Calanus marshallae*, which may have multiple generations annually and therefore relatively brief periods of diapause, and *Neocalanus spp.*, which have only one generation annually and a correspondingly longer period of diapause (Conover 1988).

In contrast to the buoyancy regulation hypothesis, the inhibitory effect of pristane on growth of copepod predators would have a clear and direct benefit on the population fitness of copepods. By exposing their predators to increased risk of mortality, copepods reduce predation on themselves in two respects: there are fewer predators, and the remaining predators are smaller than they would otherwise be and hence less able to capture prey, because the search volume of predators varies directly with their size. This situation is analogous to the adverse effects certain phytoplankton may have on the reproductive capacity of their copepod predators (Ban et al. 1997, Ianora et al 1999, Paffenhöfer 2002). In both cases, the reproductive potential of the predator population is reduced when chemically defended prey are consumed, by reduced fecundity of predators in the case of diatoms, and by outright mortality of fish in the case of *Calanus* and *Neocalanus* copepods. And in both cases, the damage inflicted on the predators involves death of the prey.

The inhibitory effect of pristane on juvenile pink salmon growth has serious implications for growth models and estimates of prey impacts of juvenile pink salmon in PWS. *Calanus* and *Neocalanus* copepods may account for half or more of the ingested biomass of juvenile pink salmon in PWS during spring (Cooney et al. 1981, Sturdevant et al. 1996, Willette 1996, Willette et al. 2001). Gross growth efficiency assumptions of 25% -

45% are possibly high by factors of 3 – 6, implying that juvenile pink salmon may need to consume a correspondingly greater proportion of prey to achieve estimated growth rates in the field. Growth inhibition by pristane may also prolong the period of maximum vulnerability to size-dependent predation, and models of population trajectories in PWS (e.g. Willette et al. 2001) may be improved by recognition of this inhibitory effect. At a larger scale, the growth inhibition caused by pristane may lead to lower assessments of the carrying capacity of the North Atlantic and North Pacific Oceans for trophic levels above *Calanus* and *Neocalanus* copepods, as a consequence of the lower gross growth efficiency associated with predators of these abundant and widely distributed prey. Finally, the low gross growth efficiency for PWS zooplankton indicates that pink salmon produce considerably more abundant feces than would be estimated on the assumption of a value of ~ 25%, making fecal production by nearshore zooplanktivorous fishes an even more important pathway followed by pristane to mussels than would be otherwise assumed.

Conclusions

Feces produced by nearshore zooplanktivorous fishes, exemplified by juvenile pink salmon, feeding on *Calanus* and *Neocalanus* copepodites is an important pathway followed by pristane from the copepodite sources to mussels during spring in PWS. Five factors contribute to the importance of this pathway: (1) juvenile pink salmon remain close to shorelines during early marine residence, in close proximity to mussel beds in PWS, (2) pristane inhibits fish growth, so zooplanktivorous fishes must consume inordinately large rations of *Calanus* and *Neocalanus* copepodites to sustain growth, (3) *Calanus* and *Neocalanus* copepodites often account for the greatest prey biomass available to these fishes during spring, (4) pristane ingested with *Calanus* and *Neocalanus* copepodites is incompletely absorbed by juvenile pink salmon and their feces remain a relatively concentrated source of pristane, and (5) mussels are more efficient, by factors ranging to ~ 50, at accumulating pristane from fish feces than from pristane dissolved in seawater.

The hatcheries operated by Prince William Sound Aquaculture Corporation provide a unique opportunity to evaluate the importance of juvenile pink salmon as a conduit for pristane from *Calanus* and *Neocalanus* copepodites to mussels in the field. These hatcheries often release on the order of 10^8 juvenile pink salmon *en masse* at the height of the zooplankton bloom during spring, flooding the adjacent shorelines with these fish when *Calanus* and *Neocalanus* copepodites are most abundant. Monitoring pristane in seawater, mussels, and in fecal pellets produced by *Calanus* and *Neocalanus* copepodites would permit assessment of the importance of fecal material produced by juvenile pink salmon as a vehicle for pristane transfer to mussels, and is the focus of the sequel to this paper (Short in prep [b]).

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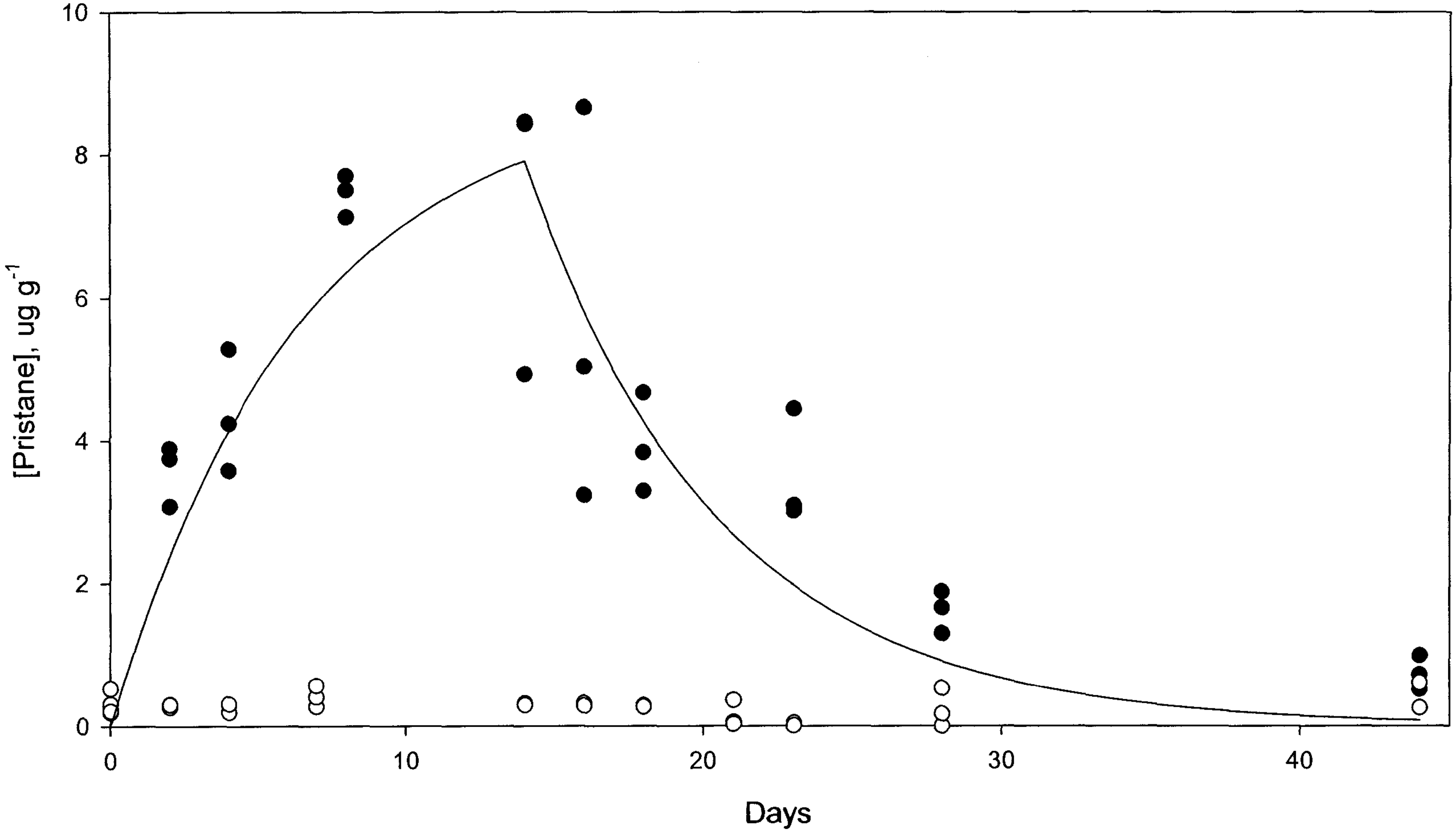

Figure 2.1. Accumulation and depuration of dissolved pristane by mussels. Mussels exposed to 0.5 mg l^{-1} dissolved pristane for 14 d, followed by a 30 d depuration period (filled circles), or to ambient laboratory seawater (open circles). Solid line indicates non-linear least-squares fit of accumulation and depuration functions assuming first-order kinetics for both processes (see Methods).

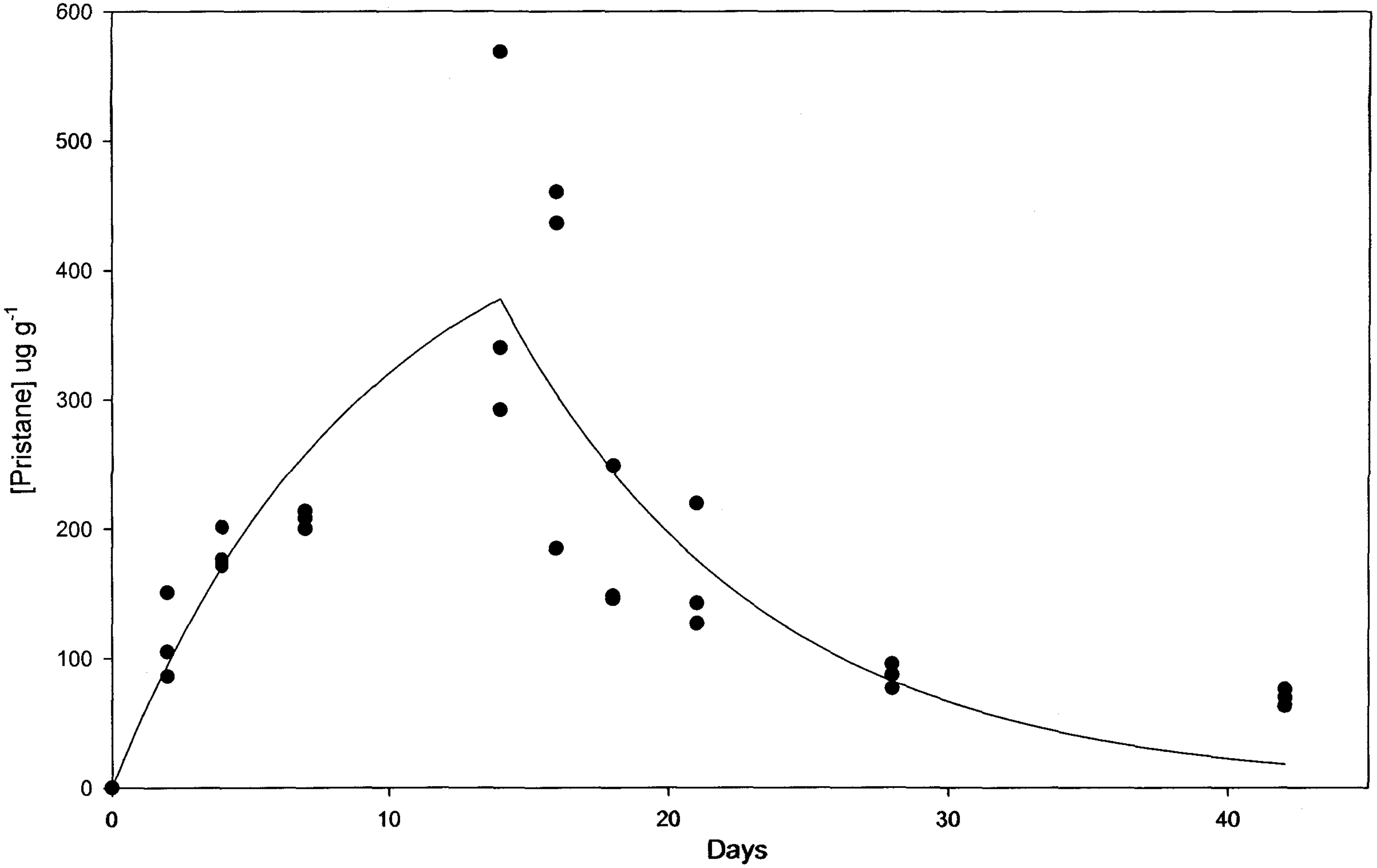

Figure 2.2. Accumulation and depuration of pristane from homogenized feces derived from PWS zooplankton by mussels. Mussels exposed to pristane for 14 d, followed by a 28 d depuration period. Solid line indicates non-linear least-squares fit of accumulation and depuration functions assuming first-order kinetics for both processes (see Methods).

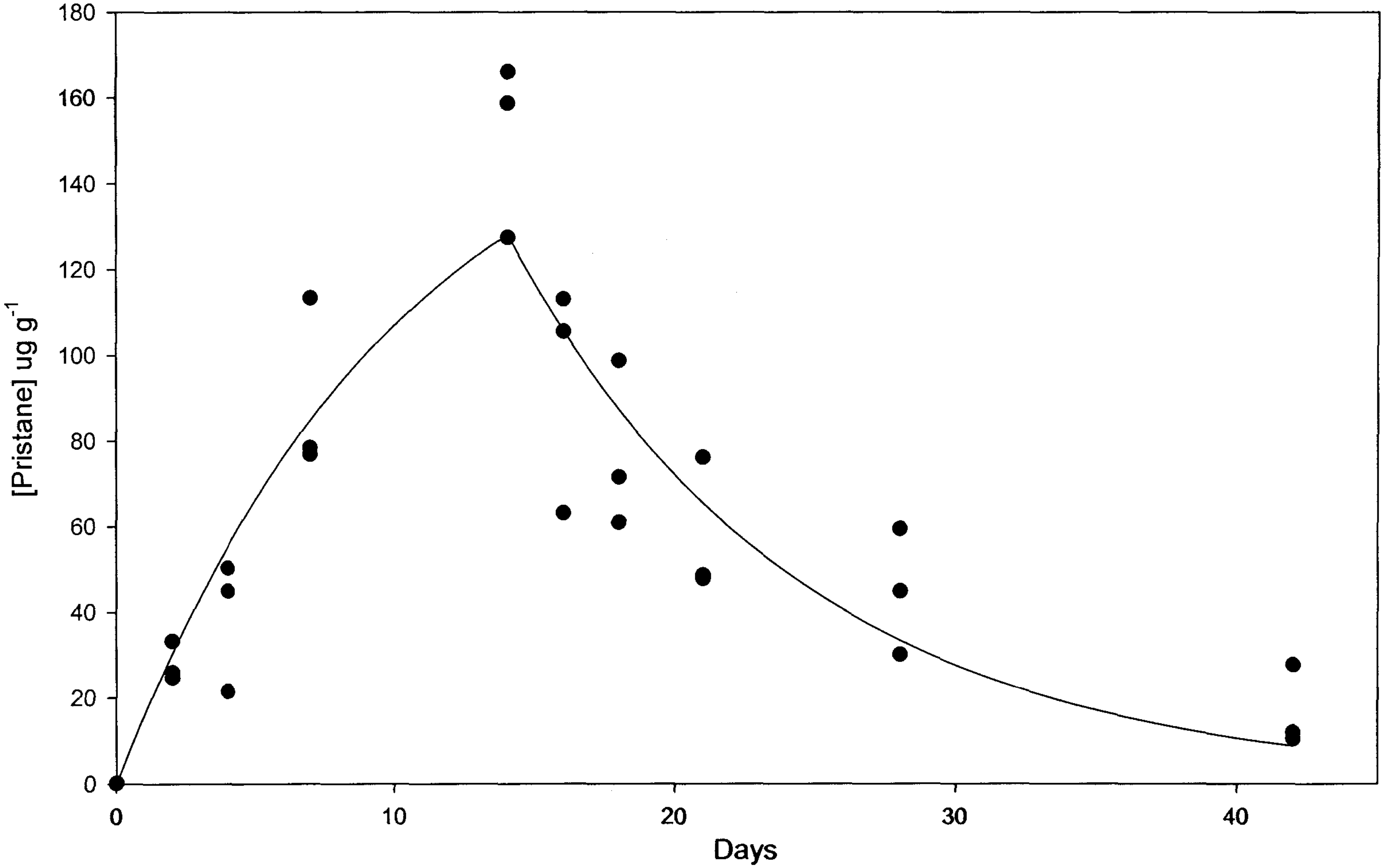

Figure 2.3. Accumulation and depuration of pristane from whole feces derived from PWS zooplankton by mussels. Mussels exposed to pristane for 14 d, followed by a 28 d depuration period. Solid line indicates non-linear least-squares fit of accumulation and depuration functions assuming first-order kinetics for both processes (see Methods).

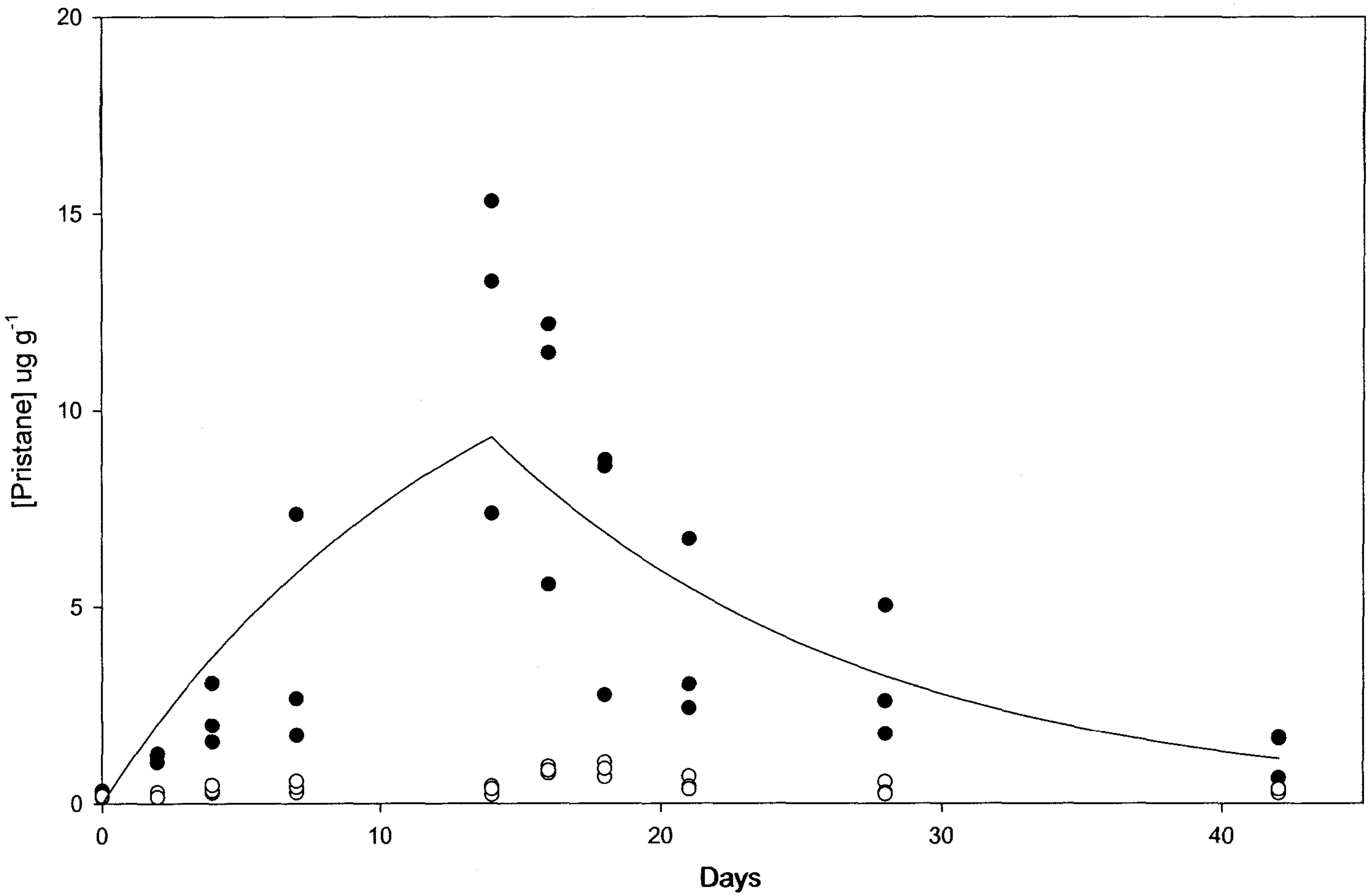

Figure 2.4. Accumulation and depuration of pristane from homogenized feces derived from *Artemia sp.* by mussels. Mussels exposed to pristane for14 d, followed by a 28 d depuration period (filled circles), or exposed to ambient laboratory seawater (open circles). Solid line indicates non-linear least-squares fit of accumulation and depuration functions assuming first-order kinetics for both processes (see Methods).

Tables

Table 2.1. Growth of juvenile pink salmon. Weights of 20 juvenile pink salmon in each of the treatment group replicates (see Methods) are given for the beginning and end of the growth determination interval. See Methods section for calculation of growth rate constants. Food consumption is based on the number of successive measurements of food consumed per unit estimated total wet body weight indicated in parentheses.

Zooplankton Type:	PWS-Zooplankton						*Artemia sp.*		
Treatment Group:	HF-P			WF-P			HF-A		
Replicate:	1	2	3	1	2	3	1	2	3
Total weights (g), initial:	37.2	40.3	38.6	38.3	38.1	33.5	40.9	40.5	42.5
final:	39.1	41.6	39.2	41.4	39.7	35.4	48.1	47.1	52.0
Days between weighings:	9	9	9	9	9	9	7.76	7.76	9
Growth Rate ($k \times 10^2$):	0.554	0.353	0.171	0.865	0.457	0.613	2.09	1.95	2.24
Mean Food Consumption: (Wet Food/Wet Body Wt., x 100%)	8.21 ±0.823 (n = 18)	7.23 ±0.736 (n = 18)	7.54 ±0.881 (n = 18)	7.25 ±0.692 (n = 18)	7.30 ±0.775 (n = 18)	8.43 ±0.788 (n = 18)	11.0 ±1.09 (n = 15)	10.7 ±1.36 (n = 15)	11.1 ±1.03 (n = 18)
(Dry Food/Wet Body Wt., x 100%)	1.03 ±0.213	0.868 ±0.192	0.891 ±0.223	0.850 ±0.207	0.889 ±0.207	1.06 ±0.223	0.989 ±0.0988	0.965 ±0.123	1.01 ±0.0932

Chapter 3

ACCUMULATION OF PRISTANE BY MUSSELS (*MYTILUS TROSSULUS*) MEDIATED BY JUVENILE PINK SALMON (*ONCORHYNCHUS GORBUSCHA*) PREDATION ON *NEOCALANUS* COPEPODS II: FIELD STUDY

Short, JW (In prep) Accumulation of pristane by mussels (*Mytilus trossulus*) mediated by juvenile pink salmon (*Oncorhynchus gorbuscha*) predation on *Neocalanus* copepods II: field study. Prepared for submission to Marine Ecology Progress Series

Abstract

This field study investigated the role of juvenile pink salmon (*Oncorhynchus gorbuscha*) in the transfer of pristane from copepods to bay mussels (*Mytilus trossulus*) during spring in Prince William Sound (PWS), Alaska. Pristane is a branched, saturated aliphatic hydrocarbon produced by copepods in the genera *Neocalanus* and *Calanus*, and these copepods dominate the springtime zooplankton biomass in PWS. Mussels may accumulate dissolved pristane, pristane associated with copepod fecal pellets and with feces produced by fish preying on copepods. Pristane concentrations were monitored in mussels and in the dissolved and particulate phases of seawater at three stations one week before through one week after releases of ~ 10^8 juvenile pink salmon from a hatchery in PWS in 1996 and again in 1998, along with zooplankton composition and abundances.

Pristane concentrations increased up to ~ 10 $\mu g\ g^{-1}$ (dry weight) in mussels after releases of juvenile pink salmon. Pristane concentrations in seawater were usually below detection limits (0.041 $\mu g\ l^{-1}$), limiting the contribution to pristane burdens of mussels to ~ 2 $\mu g\ g^{-1}$ from dissolved pristane. The pristane concentration of fecal pellets produced by *Neocalanus* was 80.2 $\mu g\ g^{-1}$, which limited the contribution to mussels from this source to no more than ~ 3 $\mu g\ g^{-1}$. Analysis of stomach contents and visual observations of behavior confirmed the fecal pathway mediated by fish as the primary cause of the concentration increase of pristane in mussels following release of the fish.

Zooplankton sampling indicated that *Neocalanus* abundance declined by more than half the week following the release, and is attributed to consumption by released fish. Decline of *Neocalanus* apparently released smaller copepods including *Pseudocalanus*, the other major component of zooplankton biomass, and *Acartia* from competition for food, and the population of late-stage *Pseudocalanus* and *Acartia* copepods doubled as the *Neocalanus* population declined.

Introduction

Investigations of marine food webs must often rely on indirect methods to infer trophic relationships. The feeding habits of marine fauna are frequently difficult to determine by direct observation, and for many species (e.g. starfish) analysis of stomach contents is impractical. In such cases chemical analysis of marker compounds may be necessary to gain insight into dietary dependencies. Analysis of lipids has gained increasing attention over the last two decades (Iverson et al. 2004, Howell et al. 2003, Walton et al. 2000, Graeve et al. 1997, Grahl-Nielsen and Mjaavatten 1991, Fraser et al. 1989), because some lower-trophic level species biosynthsize unusual (and often essential) fatty acids that may serve as chemical tracers, and because of the introduction of capillary gas chromatography for the analysis of these compounds, which has tremendously increased the ease of isolating and identifying closely-related lipids.

One of the first lipids proposed as a chemical marker compound for food-web investigations is pristane (2,6,10,14-tetramethylentadecane; Blumer et al. 1964), a branched alkane hydrocarbon biosynthesized by marine copepods in the genera *Calanus* and *Neocalanus*. Late-stage copepodites of these genera biosynthesize pristane from ingested chlorophyll (Avigan and Blumer 1968), attaining concentrations that may approach 1% dry body mass (Blumer et al. 1964, Short in prep [a]). Pristane is relatively persistent in the environment because it is terminally branched, and hence is more resistant to β-oxidation. *Calanus* and *Neocalanus* copepods are an important link in marine food webs between primary production and consumers at higher trophic levels, especially during spring phytoplankton blooms at sub-arctic latitudes where they may account for most of the spring zooplankton biomass near the seasurface (Parsons and Lalli 1988). Despite these advantages, pristane analysis has not often been used for food web studies, in part because little is known about the ecological pathways followed by it.

One ecological pathway followed by pristane that is not clear is from *Neocalanus* and *Calanus* copepods to suspension-feeding organisms such as clams and mussels. In Prince

William Sound (PWS), Alaska, pristane concentrations in bay mussels (*Mytilus trossulus*) often increase dramatically during spring to concentrations as high as ~ 50 μg g^{-1} (dry weight basis), returning to low concentrations by late summer (Short in prep [a]). The source of pristane is mainly stage IV and V *Neocalanus plumchrus*, *Neocalanus flemingerii* and *Calanus marshallae* copepodites (Short in prep [a]). Bay mussels may accumulate pristane through direct ingestion of *Neocalanus* and *Calanus* copepodites, through absorption of pristane dissolved into seawater from *Neocalanus* and *Calanus* copepodites, from ingestion of fecal pellets produced by these copepodites, or from ingestion of fecal pellets produced by predators of these copepodites.

Direct ingestion of late stage *Neocalanus* or *Calanus* copepodites by mussels is possible but unlikely, because these copepodites are nearly as large as the diameter of the intake siphon of bay mussels, and are usually able to escape the incurrent stream of mussels (Green et al. 2003). Accumulation of dissolved pristane by mussels is limited by the ambient concentration of pristane in seawater in PWS, and by the bioaccumulation factor (BAF, i.e. the ratio at equilibrium of the wet weight concentration of pristane in mussels and the concentration of pristane dissolved in ambient seawater). Concentrations of dissolved pristane as high as ~ 0.2 μg l^{-1} have been measured in PWS during spring (Short and Harris 1996), and the BAF of pristane in mussels is ~ 2,000 (Short in prep [b]), which implies maximum concentrations in mussels accumulated from dissolved pristane would be ~ 0.4 μg g^{-1} wet tissue weight, or ~ 4 μg g^{-1} dry tissue weight. This suggests uptake by mussels of dissolved pristane may be significant. Pristane was undetected in feces of stage CV copepodites of *Calanus helgolandicus*, but the concentration of pristane in these copepods is lower by factors of several hundred compared with other species of *Calanus* or *Neocalanus* (Prahl et al. 1984, Blumer et al. 1964, Short in prep [a]), so the importance of this pathway as a route of pristane accumulation by PWS mussels is unclear. However, the laboratory study accompanying the field study presented here indicated that fecal matter produced by fish preying on

Neocalanus and *Calanus* copepods may be a very important route of pristane from these copepods to mussels (Short in prep [b]).

Prince William Sound is a nearly ideal setting for evaluating the relative importance of the alternative transfer pathways of pristane from *Neocalanus* and *Calanus* copepods to mussels. The zooplankton biomass is dominated by these genera during spring, (Cooney et al. 2001, Cooney 1986a, Cooney 1986b), facilitating evaluation of pristane in zooplankton feces and of pristane dissolved from these copepods into seawater. Five large salmon hatcheries are located within PWS, each releasing up to ~ 10^8 juvenile salmon (mainly pink salmon, *Oncorhynchus gorbuscha*, from four of the hatcheries) during spring (Johnson et al. 2002). Three of the pink salmon hatcheries are located in areas remote from population centers, and pink salmon are usually released *en masse* at the peak of the zooplankton bloom, which effectively floods the vicinity with fish. Juvenile pink salmon are zooplanktivorous, and *Neocalanus* and *Calanus* copepods are important prey in PWS (Willette et al. 2001, Sturdevant et al. 1996, Willette 1996, Cooney et al. 1981). The concurrent release of large numbers of juvenile pink salmon from a discrete source in a remote area, when *Neocalanus* and *Calanus* copepods dominate their zooplankton prey, provides an especially favorable opportunity to evaluate the influence of feces produced by the released fish on pristane transfer from copepods to mussels.

Objectives of this study are to evaluate the relative importance of pristane dissolved in seawater, pristane in fecal pellets produced by *Neocalanus* and *Calanus* copepods, and pristane in fecal material produced by juvenile pink salmon as proximal sources of pristane accumulated by bay mussels in PWS. Knowledge of the ecological pathway followed by pristane from copepods to mussels may permit a more detailed interpretation of the annual spring increase of pristane concentrations in mussels. This might prove useful for indirectly monitoring *Calanus* and *Neocalanus* zooplankton abundances, and possibly the intensity of consumption of these copepods by their near-shore predators.

Marine survivals of pink salmon populations are thought to be determined during the initial period of marine residence (Parker 1962, Parker 1968, Ricker 1976, Hartt 1980, Peterman 1987, Karpenko 1998, Willette et al. 2001), and if mussels accumulate pristane primarily from feces produced by near-shore zooplankton predators, then monitoring pristane increases in mussels during spring might provide an index of forage conditions for these predators and the relative success of their feeding, both geographically and inter-annually.

Methods

Field data were collected during spring, 1996 and again during spring, 1998 near the Wally H. Noerenberg salmon hatchery (WHN), operated by the Prince William Sound Aquaculture Corporation (PWSAC). This hatchery is located on the north shore of Lake Bay, a small embayment on the southern coast of Esther Island in northwestern PWS (Figure 3.1). Juvenile pink salmon are reared in marine net pens a few weeks prior to their release into PWS. The mean mass of a released juvenile was 0.30 g in 1996 and 0.485 g in 1998. About 1.3×10^8 and $\sim 7.0 \times 10^7$ juvenile pink salmon were released the evenings of 3 May 1996 and of 1 May 1998, respectively, on falling tides to aid dispersal of the released fish. Sea surface temperatures ranged 4.5 – 6.9 °C during both years of the study.

During both years I monitored daily concentrations of pristane dissolved in seawater and of pristane accumulated by bay mussels, beginning about one week prior through about one week following the release date, at each of three monitoring stations established within 3 km of the release point (Figure 3.1). I also captured juvenile pink salmon just prior to release and a few days afterward to examine their stomach contents and, in 1996, to determine their whole-body concentrations of pristane. In 1996, I collected bulk zooplankton for species composition and for collecting zooplankton fecal pellets for pristane analysis and for sinking rate determination. In 1998, I collected zooplankton from each of the three monitoring stations to determine species composition, relative abundance, variability among stations and collection times, and to compare with standardized zooplankton collections made by the WHN staff at two stations in the area (Figure 3.1). I also collected zooplankton fecal pellets for determination of the wet and dry weight ratio. Following are details of these collections and the analyses performed on them.

Sampling Stations and Mussel Collection

The three monitoring stations are denoted as Lake Bay (LB), Esther Light (EL) and Hodgkin's Point (HP). The LB station is located near the mouth of Lake Bay, 2.12 km to the east of the pink salmon release area, and the other two stations are located 1.11 km to the west (EL) and 2.53 km to the east (HP) from the LB station, with another small embayment about the size of Lake Bay between the LB and HP stations (Figure 3.1). The shore at the LB station is a small, protected indentation of the coastline, mostly bedrock with mussels present in scattered clumps at a beach slope of about 15°. The EL station had a dense horizontal band of mussels attached to a steep (> 50°) bedrock face where an access ladder to a navigational light is located. The HP station is a small, irregular reef extending seaward from Esther Island that descended abruptly to deep (200 m) water on the seaward face. Mussels were collected from the scattered bands near the top of the reef. At each station and collection event, at least 20 mussels with shell lengths ranging from 2 – 4 cm were collected *ad libitum* as near as possible to the center of the vertical tidal range of the mussel bed, with at least 1 m separating each mussel collected. Collected mussels were stored in polyethylene bags at -20 °C until analysis for pristane. Mussel samples were collected daily, weather permitting.

Seawater Sampling

In 1996, seawater samples were collected in duplicate at the PWSAC plankton sampling station 2 in the mouth of Lake Bay (Figure 3.1). One of the duplicates was filtered through a 1.5 μm glass fiber filter to distinguish dissolved pristane from pristane associated with particles, and these are compared with analysis of the other un-filtered duplicate. Single samples were collected within 100 m of each of the three mussel sample stations in 1998, and each was filtered as in 1996. Samples were collected daily, weather permitting.

Seawater samples were collected by submerging a 4-l glass jar to a depth of ~ 10 cm and removing the lid. Unfiltered samples and sample filtrates were spiked with perdeuterated *n*-hexadecane and sequentially extracted twice with 100-ml aliquots of dichloromethane within 2 h of collection. The glass fiber filter containing the filtered material was wrapped in aluminum foil and stored at -20 °C until analysis for pristane.

Zooplankton Sampling and Species Composition Determination

In 1996, zooplankters were collected near the PWSAC plankton sampling station 2 in the mouth of Lake Bay (Figure 3.1). At each sampling a 1.75 m long, 505 μm-mesh plankton net with a 0.5-m diameter circular opening and 1 l jar at the cod-end (to reduce compaction) was towed obliquely for 10 min at a depth of ~ 5 m during daylight. The captured zooplankters were concentrated by filtration with a 0.5 mm-mesh sieve, and about 1 g was transferred to a 5% solution of formalin in seawater for determination of species composition. Fecal pellets defecated by the remaining zooplankton were collected for pristane analysis (see below).

In 1998, zooplankters were collected along with seawater samples near each of the three mussel collection stations, where seawater depths were ~ 50 m (LB) or ~ 100 m (EL and HP) and the seafloor slope was > 30°. Two collections were made at each station, one with a 202 μm-mesh plankton net and another with a 505 μm-mesh net, both having the same shape and size of the net used in 1996. Both nets were hauled vertically from 30 m depth to the surface at ~ 1 m s^{-1}, sweeping a calculated seawater volume of 5.89 m^3. The aspect ratio of these nets exceeded 5.4, and hence were more than 90% efficient (Tranter and Smith 1968), so the calculated seawater volume swept during the vertical tows is presumed accurate for calculation of zooplankton abundances. Zooplankters were collected at ~ 0800 h – 0900 h each day the weather allowed sample collection. Additional samples were collected ~1500 h on 29 April, ~2200 h on 30 April, and near midnight on 7 May to evaluate whether the composition or abundances varied diurnally. A total of 36 vertical tows were collected with each mesh size. Captured zooplankters were stored in 5% formalin in seawater for determination of species composition. The 202 µm-mesh samples were used for determination of species abundance, biomass, and variability among stations, and the 505 µm-mesh samples were treated as duplicates for the large zooplankton captured to evaluate sampling variability within stations.

Zooplankters were identified to genus and usually to species. *Neocalanus plumchrus* was not distinguished from *N. flemingerii*, which are hereafter denoted as *N. plumchrus/flemingerii*. Copepodite stages of *N. plumchrus/flemingerii*, *N. cristatus* and *Calanus marshallae* were also identified. Samples were split before sorting with a plankton splitter. Split samples contained at least 100 individuals. Species and copepodite stages were determined following criteria given by Gardner and Szabo (1982). Zooplankton biomass was calculated from abundances assuming wet tissue weights of 12 mg ind^{-1} for combined stages of *N. cristatus*, 1 for combined stage IV and V of *N. plumchrus/flemingerii* or *C. marshallae*, 0.1745 for *Limacina*, 0.142 for *Pseudocalanus*, 0.121 for *Oithona*, 0.0519 for *Acartia*, 0.0333 for *Oikopleura*, and 0.02 for bryozoan larvae (from M. Sturdevant, NMFS, Auke Bay Laboratory, personal communication). A value of 0.1 mg ind^{-1} was arbitrarily assumed for the other species encountered, which probably overestimates their contribution to biomass but they were encountered so rarely that this bias is likely negligible.

Samples of zooplankton were collected twice weekly by PWSAC staff as part of their plankton watch program at two locations, one within Lake Bay and the other at the mouth of the bay (Figure 3.1). These collections involved three vertical tows from 20 m depth to the surface of a 0.5 m diameter, 243 µm-mesh plankton net at each station. The settled volume of phytoplankton and zooplankton in the combined tows was determined by allowing plankton to settle in a graduated conical flask for 24 h. Results of this program are used in part to determine juvenile salmon release dates at PWSAC hatcheries.

Collection of Zooplankton Fecal Pellets

Zooplankton captured in 1996 were rinsed from the net into a polypropylene tray, and then poured into a 0.5 mm-mesh circular metal sieve partially immersed in seawater and left covered with tinfoil to exclude light for 3 – 6 h to allow evacuation of zooplankton intestinal tracts. The sieve rested in a stainless steel bowl with 202 μm-mesh plankton netting attached to the bottom of the sieve to exclude small zooplankton that may have passed through the metal sieve from the bottom of the bowl. The sieve and plankton mesh were carefully removed from the bowl after the zooplankton defecation period, leaving a layer of green zooplankton fecal pellets visible on the bottom of the bowl. Most of the seawater was removed from the bowl by siphon, and any remaining material other than fecal pellets was removed by pipette or with zooplankton forceps. The accumulated fecal pellets were transferred with seawater to a conical glass vial, and most of the seawater was removed by pipette after the pellets had settled. The pellets were rinsed three times with distilled water to remove salt, with most of the water removed by pipette each time after the pellets had settled. After the last rinse the fecal pellets were transferred to an aluminum dish and allowed to dry overnight at ~ 50 °C, and then were transferred to a small vial and stored at -20 °C for pristane analysis.

Determination of Zooplankton Fecal Pellet Sinking Rate

The sinking rate of one sample of zooplankton fecal pellets was determined by measuring the range of times required for individual pellets to fall through a 22.5 cm column of ambient seawater (salinity 31‰, temperature 6 °C).

Juvenile Pink Salmon Collection and Stomach Content Analysis

Released and un-released juvenile pink salmon were collected to compare stomach contents and pristane concentrations. Schools of released fish were located by visual inspection from a skiff, and individuals were captured by dip-net two days after release in 1996, and 1 – 3 days after in 1998. Stomach contents of captured fish that were preserved in 5% formalin in seawater were examined by dissecting out then incising the stomach, and rinsing the exposed contents onto a zooplankton counting plate. Zooplankton in pink salmon stomachs were identified to genus, and unusual items (e.g. dipterans) were also noted. Pristane analysis was performed on whole fish stored frozen at -20 °C.

Dry Weight Determination

The ratio of dry and wet weights of tissue was determined by drying weighed sample aliquots at 65 °C for 24 h. This ratio was 0.113 ± 0.00907 ($n = 27$) for mussels collected in 1996, and 0.0962 ± 0.00399 ($n = 42$) in 1998. The ratio was 0.541 ± 0.167 ($n = 4$) for zooplankton fecal pellets. Pristane concentrations are expressed on a dry weight basis.

Pristane Analysis

Pristane analysis of whole organisms and of particulate material filtered from seawater involved pentane or dichloromethane extraction of macerated tissues or of filters spiked initially with perdeuterated *n*-hexadecane as an internal standard, solvent concentration and exchange into hexane over steam, purification by silica gel/alumina column chromatography eluted with pentane, solvent re-concentration, resolution of alkanes by gas chromatography (GC) and measurement by flame ionization (Short et al. 1996). Identification of pristane is based on GC elution time. The dichloromethane extracts of seawater samples were combined and exchanged into 1 ml hexane over steam, and then analysed by the GC analysis used for the tissue samples.

The accuracy of the pristane analyses were generally within ± 15% based on comparison with an authentic hydrocarbon standard prepared by the National Institute of Standards and Technology, and the coefficient of variation was generally less than ± 20%. The method detection limit (MDL), defined as the estimated concentration associated with a

1% probability of type I detection error, is 0.162 μg for tissue samples. The corresponding MDL estimate for individual samples is the ratio of this value and the mass of the sample analyzed. No comparable MDL estimate is available for pristane in seawater, so the ratio of the tissue MDL and the seawater aliquot volume (4 l) is assumed, resulting in a MDL of 0.041 μg l^{-1}.

Data Analysis

The significance of differences between daylight and night-time abundances of *Neocalanus plumchrus/flemingerii* and of *Pseudocalanus sp.* were evaluated by the paired t-test. Samples collected at 2200 h on 30 April and near midnight on 7 May 1998 were pooled for this test. For *Neocalanus plumchrus/flemingerii*, morning and night-time samples collected from each station with the 505 μm-mesh nets were paired, as were samples collected with the 202 μm-mesh nets, and the t-test was applied to the sum of these samples to increase the power of the test. For *Pseudocalanus sp.*, the t-test was applied only to samples collected with the 202 μm-mesh net.

The significance of changes in the pristane concentrations of mussels and in the abundances of zooplankton during the monitoring period was evaluated with a one-way repeated measures analysis of variance (RM-ANOVA). The measurements were repeated at each of the sampling stations on each of the days sampled, and the sampling days are considered as the treatments in this analysis. Pristane concentration data in mussels, and zooplankton abundance data were log-transformed prior to the RM-ANOVA, which then satisfied assumptions of normality (determined by the Kolmogorov-Smirnoff test) and equality of variance (determined by the Levene median test).

Results

General Observations

Most of the juvenile pink salmon in the 1996 release dispersed rapidly from the inner bay. The following day it appeared the majority of released fish were migrating along the western shore of Esther Island, although groups including thousands of juveniles could be found in the vicinity of the mussel monitoring stations for several days, and were observed defecating above mussel beds at high tides. Cursory examination of the PWSAC plankton watch samples collected after the release revealed few large copepods such as *Neocalanus* or *Calanus* at the station within Lake Bay, and the pink-colored fecal casts characteristic of juvenile pink salmon preying on these copepods were rarely evident. *Neocalanus* and *Calanus* were somewhat more abundant at the PWSAC station in the mouth of Lake Bay. Weather conditions were generally calm during the weeks before and after the pink salmon release.

In contrast with 1996, a substantial proportion of the juvenile pink salmon released in 1998 remained within the inner part of Lake Bay for several days. Pink-colored fecal casts were abundant within the inner bay by the third day following the release, floating on the seasurface or suspended in the upper few m of the water column, and were readily evident in the PWSAC plankton watch samples. These casts apparently attracted over a thousand gulls (*Larus sp.*) and kittiwakes (*Rissa tridactyla*) on the seventh day after the release, when they could be seen floating on the sea surface and pecking the surface for the casts. Juvenile pink salmon were visually evident near the EL and LB stations the day following the release and again two days later, but could not be found in the vicinity of the HP station on either of these days. Weather conditions before and after the release were considerably less calm compared with those of 1996, with gales on 28 April, 3 May and 8 May 1998.

Pristane in Mussels

Pristane concentrations generally increased in mussels beginning at least 2 days after the juvenile pink salmon were released in both 1996 and 1998 (Figures 3.2 and 3.3), and the RM-ANOVA indicated that overall these changes were highly significant ($P \leq 0.005$). The median mussel concentrations increased nearly seven-fold in 1996 and nearly four-fold in 1998, and remained elevated beginning 2 – 3 days after the release.

Pristane in Seawater

Nearly all of the pristane concentration measurements were below detection limits (0.041 $\mu g\ l^{-1}$). Four samples contained detectable pristane concentrations associated with particulate material in 1996, the highest being 0.083 $\mu g\ l^{-1}$. Three samples (of 27) contained detectable dissolved pristane in 1998, the highest being 0.107 $\mu g\ l^{-1}$, and three contained particulate-pristane (maximum 0.066 $\mu g\ l^{-1}$). These concentrations are too low to resolve contributions from dissolved pristane and pristane associated with particulate matter, or to evaluate temporal trends.

Pristane in Fecal Pellets

The mean pristane concentration in fecal pellets produced by the zooplankton collected in 1996 was 80.2 ± 35.7 $\mu g\ g^{-1}$ (95% CI, n = 8). These pellets were ~ 500 μm in length and ~ 80 μm in diameter. The sinking rate of the pellets ranged from 2.1 – 3.0 $m\ h^{-1}$.

Zooplankton Abundance and Species Composition

Comparison of *Neocalanus plumchrus/flemingerii* abundances in the 202 and the 505 μm-mesh collection pairs at each station in 1998 usually agreed within a factor of two (i.e. the ratio of the higher and lower abundance at each station and sampling). Of the 36 collection pairs, 21 were within a factor of 1.5, 31 were within a factor of two and all were within a factor of three. Among pairs, the relative frequency of higher abundances in the smaller mesh net was 58%, suggesting that these copepods did not avoid the smaller mesh net.

Neocalanus plumchrus/flemingerii and *Pseudocalanus sp.* were by far the most abundant zooplankton collected. In 1996, *N. plumchrus/flemingerii* stages IV and V copepodites usually accounted for 85% of the individuals and 98% of the biomass. *Pseudocalanus sp.* usually accounted for less than 5% of the individuals, but these small (< 2 mm TL) copepods are not efficiently captured by the 505 µm-mesh net used. *Calanus marshallae* stages IV and V copepodites accounted for 2 – 15% of the individuals and of the biomass. Hence, nearly all of the zooplankton fecal pellet mass collected from these copepods was produced by either *N. plumchrus/flemingerii* or *Calanus marshallae.*

In 1998, the median abundances of *Neocalanus plumchrus/flemingerii* and *Pseudocalanus sp.* were 418 and 1,500 individuals m^{-3} (Table 3.1). These two genera nearly always accounted for more than half the numbers of zooplankton, and consistently accounted for more than 80% of the biomass. Total biomass of zooplankton ranged from 0.276 – 2.81 g m^{-3} (median 0.783 g m^{-3}, $n = 36$). Other important contributors to the zooplankton in 1998 included *Acartia sp.*, bryozoan larvae, *Calanus marshallae*, *Oithona sp.*, and *Oikopleura sp.* Small (< 2 mm TL) hyperiid amphipods and pteropods (*Limacina helicina*), and chaetognaths (*Sagitta elegans*, < 10 mm TL) were also often present.

Abundances of *Neocalanus plumchrus/flemingerii* declined substantially at all three stations following release of the juvenile pink salmon in 1998 (Figure 3.4). Abundances declined simultaneously to between a half to less than a third at the three monitoring stations, and this decline was highly significant (RM-ANOVA, $P = 0.007$). Before the release, the median abundance of *N. plumchrus/flemingerii* was 710 individuals m^{-3}, declining to 261 m^{-3} afterwards. These declines in abundance are reflected by corresponding declines in biomass (Figure 3.5). In concert with the decline of *N. plumchrus/flemingerii*, abundances and biomass of *Acartia sp.* and of *Pseudocalanus sp.*

increased by factors of three and two, respectively, (Figures 3.4, 3.6 and 3.7), and these increases were highly significant (RM-ANOVA, $P \leq 0.002$).

The species composition of zooplankton collected in the afternoon and night samples were not notably different than the morning samples (Figures 3.4 – 3.7). Abundances of *Neocalanus plumchrus/flemingerii* or of *Pseudocalanus sp.* were not significantly different in the morning compared with the night-time samples (paired t-test; $P = 0.132$, $df = 11$ for N. plumchrus/flemingerii, and $P = 0.547$, $df = 5$ for *Pseudocalanus sp.*), and these two generic groups accounted for at least 83% of the zooplankton biomass sampled on 30 April or on 7 May 1998, regardless of the hour of sampling. This indicates little diurnal variation of the zooplankton community during the two weeks of this study.

Zooplankton and Pristane in Juvenile Pink Salmon

Neocalanus and *Pseudocalanus* accounted for nearly all of the prey found in the stomachs of juvenile pink salmon captured within three days of release from the hatchery (Table 3.2). These two genera comprised over 96% of individuals and 99% of the biomass. Other prey infrequently found include, in decreasing order, harpacticoid copepods, small insects, barnacle larvae, *Acartia sp.*, juvenile pteropods, hyperiid amphipods, immature euphausiids, and one each of a decapod larvae, *Cumacea sp.*, *Colembola sp.*, and *Oithona sp.*

Individual pink salmon displayed considerable variability in their stomach contents (Table 3.2). Whereas *Neocalanus* usually accounted for most of the biomass, some individuals contained none of these but numerous *Pseudocalanus sp.* instead (Appendix 12). Differences in prey selection may have resulted from differences in sizes of the juvenile pink salmon captured, because the individuals that targeted *Pseudocalanus sp.* were invariably smaller than the median size of the unreleased fish. Also, in 1998, smaller pink salmon were captured at the EL station both 25 h and 65 h following release, but the small numbers of captured animals and the opportunistic sampling method precludes inference about the pink salmon population at the EL station in 1998.

The juvenile pink salmon collected from all three sampling stations in 1996 contained considerable concentrations of pristane. Pristane concentrations ranged from 255 – 424 μg g^{-1}, and most of this was because of the *Neocalanus* in the stomachs of these fish. Unreleased fish at the hatchery contained 2.38 μg g^{-1} pristane in 1996, and did not contain any zooplankton in 1996 or in 1998.

Discussion

Dispersion of fecal material produced by nearshore predators of *Neocalanus plumchrus/flemingerii* is clearly the dominant pathway followed by pristane from these copepods to mussels in PWS during spring. The importance of this pathway is strongly supported by the responses of pristane in the ecological compartments monitored, and by the numerical responses of zooplankton in the immediate vicinity to the hatchery releases of juvenile pink salmon. The following discussion begins with consideration of two plausible alternative pathways, accumulation by mussels of pristane dissolved in seawater or of pristane associated with fecal pellets produced by copepods, which are shown to be small in comparison with the pathway involving fecal material produced by predators of these copepods discussed subsequently.

Accumulation of Dissolved Pristane by Mussels

Accumulation of dissolved pristane by mussels is a significant but minor pathway because of the low ambient seawater concentrations, the bioaccumulation factor of mussels for pristane, and the fact that pristane concentrations increased considerably in mussels following the hatchery releases of pink salmon (Figures 3.2 and 3.3) but concentrations of pristane in seawater did not. The highest concentration of pristane measured in seawater during this study was 0.107 μg l^{-1}, which implies a wet weight tissue concentration of pristane in mussels of 0.215 μg g^{-1} at equilibrium. Assuming a ratio of dry and wet tissue weights of 0.1, this is equivalent to 2.15 μg g^{-1} dry weight. This upper limit is comparable with concentrations observed in mussels prior to release of the hatchery pink salmon (Figures 3.2 and 3.3), but is lower than concentrations in mussels at the LB station after the release by a factor of ~ 10. Hence, accumulation of dissolved pristane by mussels may account for a portion of the pristane burden when abundances of copepod predators are low, but cannot account for the higher concentrations found after the hatchery releases.

Accumulation of Pristane in Copepod Fecal Pellets by Mussels

Accumulation by mussels of pristane associated with fecal pellets produced by *Neocalanus* and *Calanus* is comparable to accumulation of dissolved pristane. The contribution from pristane in copepod fecal pellets may be estimated from the concentration of pristane in the pellets, the concentration of pellets in seawater, and the BAF of mussels for particulate-bound pristane. The concentration of pristane in fecal pellets produced by *Neocalanus plumchrus/flemingerii* from PWS is reported here as 80.2 ± 35.7 μg g^{-1}. The BAF of pristane associated with organic particulate material (dispersed pink salmon feces) in mussels was measured in the accompanying laboratory study at 175,000 (Short in prep [b]).

The equilibrium concentration (denoted here as C_p) of fecal pellets in seawater produced by *Neocalanus plumchrus/flemingerii* may be estimated by equating the generation rate of the pellets with their loss rate from sinking. The result derived by Bienfang (1980) for a well-mixed column of seawater of depth z containing an homogenous distribution of identical copepods is $C_p = p\, B\, z\, \psi_p^{-1}$, where p is the pellet production rate per organism per unit time, B is the standing stock of organisms per unit volume producing pellets, and ψ_p is the sinking rate of the pellets produced. Well-fed *Calanus* copepods rarely produce more than about 4 pellets h^{-1} (Raymont and Gross 1942, Marshall and Orr 1955a, 1955b, 1956, Corner et al. 1972, Gaudy 1974). Seawater rarely contained more than one *N. plumchrus/flemingerii* l^{-1} in the zooplankton samples of the uppermost 30 m from 1998

(Table 1), giving a pellet generation rate (*p B*) of 4 pellets l^{-1} h^{-1}. Assuming the minimum observed sinking rate of ~ 2 m h^{-1}, the concentration of pellets at 5 m depth would therefore be 10 pellets l^{-1}, and this depth corresponds with maximum thickness of seawater that would be above mussels at high tide in PWS. The volume of a pellet produced by *N. plumchrus/flemingerii* in this study is ~ 2.5 x 10^{-6} ml (calculated from the volume of a cylinder having the length and diameter of the fecal pellets). The volume and sinking rate estimates reported here for fecal pellets from *N. plumchrus/flemingerii* are comparable with values reported by Bienfang (1980) for *Calanus spp.*, who also reported a density of 1.17 g ml^{-1} for these copepods feeding on diatoms. The ratio of wet and dry weights of the fecal pellets produced by *N. plumchrus/flemingerii* was 0.541. Using these values an upper limit to the concentration of pristane associated with copepod fecal pellets in seawater in PWS may be estimated as (10 pellets l^{-1}) x (2.5 x 10^{-6} ml $pellet^{-1}$) x (1.17 g ml^{-1}) x (80.2 μg pristane g^{-1} dry weight) x (0.541) = 0.00127 μg l^{-1}. At equilibrium the corresponding concentration of pristane in mussels would be 175,000 x 0.00127 μg l^{-1} x 0.001 l g^{-1} wet tissue = 0.222 μg g^{-1} wet tissue, or about 2.22 μg g^{-1} dry tissue. Hence, pristane associated with fecal pellets produced by *N. plumchrus/flemingerii* could measurably contribute to the pristane burden found in PWS mussels, but alone cannot account for the large increases in the concentrations observed during spring.

Accumulation of Pristane in Pink Salmon Feces by Mussels

The critical role played by the hatchery-released juvenile pink salmon in the transfer of pristane from *Neocalanus* copepods to mussels near the hatchery is supported by several lines of evidence. Because of their high abundances relative to other potential prey, *Neocalanus* and *Pseudocalanus* copepods are the most readily encountered prey for zooplanktivorous fishes in PWS (Table 3.1). Consumption of *Neocalanus* and *Pseudocalanus* copepods was confirmed by the stomach content analysis in both 1996 and 1998, with *Neocalanus* the main prey taken on a biomass basis (Table 3.2). Observation of these pink salmon defecating directly above the monitored mussel beds confirms the validity of this pathway, and the quantitative importance of this pathway may also be assessed.

Estimates are available for the feeding rate of juvenile pink salmon on *Neocalanus* copepods, the efficiency of absorption of *Neocalanus* ingested by pink salmon, and the pristane content of the feces produced, which permit a rough assessment of the rate at which pristane is introduced into ambient seawater. A minimum feeding rate is directly available from the stomach content analysis of salmon caught 25 h after release from the hatchery in 1998 (Table 3.2). The median consumption rate of pink salmon caught at the LB station was 0.83 *Neocalanus* h^{-1} and was 0.375 h^{-1} at the EL station. Using the average of these multiplied by the number of fish released implies consumption of about 10^9 *Neocalanus* per day. This is probably an underestimate, because it does not account for the gastric turnover rate, which may be as fast as two to three times a day (Healey 1982). Assuming an average wet tissue weight of 1 mg $copepod^{-1}$ for a mixture consisting of equal proportions of stage IV and stage V *Neocalanus plumchrus/flemingerii*, this is equivalent to daily consumption of ~ 1000 kg of these copepods. The absorption efficiency of pink salmon fed a copepod assemblage identical to that collected here in the 505 μm-mesh tows was 75%, the ratio of dry and wet fecal weight was 0.117, and the concentration of pristane in the feces produced was 383 μg g^{-1} (dry mass basis; Short in prep. [b]). This implies daily introduction of ~ 11 g pristane associated with feces into the seawater near the hatchery by the released pink salmon. Assuming the cruising speed of the released pink salmon is 1 body length s^{-1}, these fish would travel a maximum of 3.3 km in each of two directions the first day, covering 6.6 km of shoreline. Assuming also these fish remain within 50 m of the shoreline and an average seawater depth of 25 m leads to an approximate volume of seawater receiving the feces produced by the pink salmon of 8.3×10^6 m^3, and a corresponding concentration of pristane associated with feces of ~ 0.0013 μg l^{-1}. The BAF of pristane associated with these feces when completely dispersed was estimated at 175,000 (Short in prep [b]), so a pristane concentration of 0.0013 μg l^{-1} associated with dispersed feces could result in a daily increase in the mussel tissue concentration of ~ 0.24 μg g^{-1} on a wet tissue weight basis, or ~ 2.4 μg g^{-1} on a dry tissue mass basis (assuming a ratio of dry to wet mussel tissue weight of 0.1). This is broadly consistent with the increase of the pristane concentration observed in mussels at the LB station in 1998.

The intensity of predation by hatchery-released pink salmon on *Neocalanus plumchrus/flemingerii* may also be inferred from the population changes of these copepods following the 1998 release. The decline in the median value of *N. plumchrus/flemingerii* abundance from 710 to 261 individuals m^{-3} over a 4-day period following release indicates a loss of ~ 0.5 individuals l^{-1}, or ~ 0.5 mg wet tissue mass l^{-1}. If all this were consumed by juvenile pink salmon, it would lead to (0.5 mg l^{-1}) x (0.25) x (0.117) x (0.383 μg mg^{-1}) = 0.0056 μg pristane l^{-1}, which is comparable with the estimate of 0.0027 μg l^{-1} d^{-1} based on the feeding rate of the pink salmon, and if completely dispersed would cause an increase of the pristane concentration in mussels of ~ 9.4 μg g^{-1} at equilibrium.

The foregoing estimates of fecal-associated pristane available for uptake by mussels may be overestimated because feces produced by pink salmon may not fully disperse immediately, so some (possibly large) fraction of the feces produced may be present in fecal masses too large for mussels to ingest. However, volume of seawater occupied by pink salmon feces may also be overestimated, first because pink salmon cannot spend all their time cruising, but must stop to feed if feces are to be produced at all, and second because unlike other marine fish (Prahl et al. 1985), the feces produced by pink salmon preying on *Neocalanus* are nearly neutrally buoyant, as indicated by the floating fecal material inside Lake Bay in 1998, and so may be effectively retained within seawater depths less than 25 m within a day of production. Also, onshore winds may concentrate feces on or near shorelines, increasing their concentration near mussel beds, possibly considerably. Pristane-laden feces of pink salmon preying on *Neocalanus* is thus the most likely pathway to mussels, and is broadly consistent with the magnitude of pristane concentration increases observed in mussels immediately following releases of the hatchery pink salmon.

Accumulation of Pristane by Mussels in Prince William Sound

Each of the three ecological pathways considered here contribute to the magnitude of pristane increases in mussels during spring in PWS. Increasing populations of late-stage copepodites of *Neocalanus* and of *Calanus* may introduce pristane into the surface seawater by dissolution and by production of pristane-laden fecal pellets, which may then be accumulated by mussels. These two pathways would account for gradual increases during April to mussel concentrations of 4 – 5 $\mu g\ g^{-1}$ at most. Abundances of these copepods are lower most years compared to 1998, so peak concentrations of pristane in mussels from these two pathways would be correspondingly lower. The more dramatic increase in pristane concentrations during late April – early May is caused by feces produced from predation by zooplanktivorous fishes on these copepods, which may cause pristane concentrations in mussels to increase on the order of ~ 2.4 $\mu g\ g^{-1}$ per day. If increases of this magnitude were sustained over several days, this pathway may account for pristane concentration increases of tens of $\mu g\ g^{-1}$ in mussels.

Factors contributing to the springtime increases of pristane in PWS mussels include simultaneously high abundances of *Neocalanus* or *Calanus* copepods and their predators, and favorable winds and currents that would concentrate and trap feces produced by the predators along shorelines containing mussel beds. The responses of pristane concentrations in mussels at the three stations monitored during this study reflect these requirements.

Neocalanus and *Pseudocalanus* biomasses were unusually high at all three stations monitored near the hatchery in 1998. The average biomass of *Neocalanus* and of *Pseudocalanus* from 1994 through 1997 in PWS was 0.16 $g\ m^{-3}$ and 0.08 $g\ m^{-3}$, respectively, in the upper 50 m of the water column in early May (Cooney et al. 2001).

In 1998, the biomass of *Neocalanus* in the upper 30 m sampled here was typically greater by a factor of three or more prior to release of the hatchery pink salmon, and the biomass of *Pseudocalanus* was also considerably higher, especially after the release (Figure 3.6). In 1996, hatchery records indicate that substantial abundances of zooplankton were present at the stations monitored by PWSAC staff (Figure 3.1), and visual inspection of these samples showed they contained mostly *Neocalanus* and *Pseudocalanus*.

The results of the night-time sampling indicate that the zooplankton prey field biomass remained dominated by *Neocalanus* and *Pseudocalanus sp.* throughout the day and night, so the juvenile pink salmon released from the hatchery did not have access to a substantially different zooplankton prey field at night. The absence of a substantial shift in the zooplankton composition may have been a result of sampling within 50 m of the shoreline in seawater depths of ~ 100 m or less. These shallow depths may have been too distant horizontally to be reached in substantial numbers by zooplankton predators residing at deeper depths during daylight hours.

The hatchery releases of juvenile pink salmon in 1996 and in 1998 insured high abundances of these fish near the monitoring stations. Differences in the responses of pristane concentrations in mussels among the stations may in part reflect differences in the time required for the released fish to arrive at them. Large increases in mussel burdens of pristane first occurred at the station (LB) nearest the hatchery in both years, and in 1996 was followed by increases at the next nearest station (EL) and finally the most distant station (HP; Figure 3.2). This pattern is consistent with observations of fish leaving Lake Bay and migrating along the coast the day after the release, with an additional 1 – 2 days of travel needed for fish to reach the EL and HP stations, respectively. In 1998, when a large portion of the released fish remained within Lake Bay feeding on the abundant zooplankton there, fish took longer to disperse to the outlying monitoring stations, which may partially account for the delayed or absent increases of pristane in mussels at the EL and HP stations, respectively.

Surface currents may also have influenced the pattern of pristane increases observed in mussels following the hatchery releases of pink salmon. In 1996, the weather was mild, so feces deposited on or near mussel beds were less apt to be advected. In 1998 the weather was much less calm, and the EL and HP stations are more exposed to wind-driven currents, which may also account in part for the delayed or absent increases of pristane in mussels at those stations (Figure 3.3). The LB station is in a more protected location, which may have contributed to the more pronounced pristane increase in mussels there.

Effects of Released Pink Salmon on Zooplankton Biomass

The abrupt decline of the *Neocalanus* population immediately following release of the hatchery pink salmon (Figures 3.4 and 3.6) was probably caused by the predation of the salmon on the copepods. *Neocalanus* copepods have completed about a quarter of their year-long life cycle by May, so natural mortality due to senescence is likely to be negligible. It is of course possible that the coincident changes in the species composition of the zooplankton with the release of the juvenile pink salmon from the hatchery was simply the result of advection of a different water mass containing different proportions of these species, but three observations suggest predation by the released salmon on *Neocalanus* is a more likely cause. First, the reduction of the *Neocalanus* population abundance near the hatchery measured immediately following the pink salmon release agrees closely with the estimated predation impact of the pink salmon on the copepods, based on the stomach contents of the released fish the day following the release. Consumption of ~ 10^9 *Neocalanus* per day following the release as estimated above would reduce the copepod population abundance by 450 individuals m^{-3} over four days (Figure 3.4) in 8.9×10^6 m^3 of seawater, which volume is equivalent to a shoreline distance of 3.6 km seasurface at a depth of 25 m and a distance from shore of 50 m. This distance is consistent with the distances of the zooplankton sampling stations from the point where the juvenile salmon were released. Second, the abrupt decline in the abundance of *Neocalanus* was observed qualitatively in 1996, and it seems unlikely that such an abrupt change in zooplankton composition so precisely coincident with the hatchery releases would occur by advection twice. Third, previous sampling of PWS suggests that a zooplankton community dominated by *Pseudocalanus* biomass would be unusual in early May, the period of maximum *Neocalanus* biomass (Cooney et al. 2001).

Reduction of the *Neocalanus plumchrus/flemingerii* population apparently allowed a corresponding rapid increase in the populations of *Acartia sp.* and of *Pseudocalanus sp.* These three copepod genera are all mainly herbivores (Mauchline 1998) that are actively growing during spring, and hence compete for phytoplankton production. When food is abundant copepodites of both *Acartia sp.* and *Pseudocalanus sp.* develop isochronally (Klein Breteler et al. 1994, Miller et al. 1977, Landry 1975), and can pass through a copepodite stage in a week or less, even at relatively cold temperatures (Klein Breteler and Schogt 1994). Early copepodite stages of these two genera are too small to be captured in the 202 μm-mesh net, but must be present at abundances comparable with the later stages that were captured, given the relatively rapid time scale of their development. Because isochronal development implies exponential growth (Miller et al. 1977), these species are able to respond rapidly to release from competition for food, with early copepodite stages rapidly recruiting to later stages. The abrupt reduction of *Neocalanus* abundance through predation by the released pink salmon would have left a considerable proportion of phytoplankton production available to surviving *Acartia sp.* and *Pseudocalanus sp.*, allowing their corresponding numerical response. Note that the total zooplankton biomass changed little despite the abrupt loss of *Neocalanus* biomass, owing to the rapid response mainly by *Pseudocalanus sp.*

Implications for Monitoring Pristane in Mussels

Juvenile pink salmon and other zooplanktivorous fishes in PWS face an interesting foraging problem in early spring. Only two kinds of prey are readily available in the pelagic food web: large copepods dominated by *Neocalanus*, and small copepods dominated by *Pseudocalanus*. Preying on large copepods is inherently more efficient, especially in light of their very high lipid content (~ 50% dry weight; Båmstedt 1986, Duesterloh 2002), but their high pristane content (4 – 8 mg g^{-1} dry body mass for stage IV – V copepodites, Short in prep [a]) seriously impairs growth of juvenile salmonids, including pink salmon (Short in prep [b], Luquet et al. 1983, 1984). Because of their substantially smaller size, *Pseudocalanus* require more search effort to capture but they contain much less pristane (~ 0.1 mg g^{-1} dry tissue mass). In the laboratory study that accompanies this field study, juvenile pink salmon had gross growth efficiencies of only 6.6% when fed the zooplankton assemblage caught in the 505 μm-mesh nets of this study. This implies that juvenile salmon would have to consume about 45% of their body weight daily to support growth of 3% wet body weight d^{-1} reported for juvenile pink salmon in PWS (Cooney et al. 1981, Willette 1996, Willette et al. 2001) and this exceeds the estimated ration for the first day following release of the juveniles caught at the LB station by a factor of ten. Although pink salmon have been found to consume as much as 37% of their body mass daily in a laboratory study (Mortensen 1983), such a high forage rate is probably impossible for most juveniles to sustain in the wild, even in 1998 when zooplankton abundances were relatively high. But if juveniles preying entirely on *Neocalanus* attain much lower ingestion rates, they will grow much more slowly than 3% d^{-1}, which would in turn expose them to greater risk of mortality from their own predators. Hence, a foraging strategy to maximize growth would probably require predation on *Pseudocalanus*, which a few juvenile pink salmon apparently did, judging from the large numbers of these copepods in their stomachs and the absence of any *Neocalanus*, or to search for alternative prey in other habitats, such as harpacticoid copepods in the benthos (Cooney et al. 1981, Sturdevant et al. 1996).

Field evidence from other studies of hatchery-released pink salmon supports the hypothesis that releases *en masse* may deplete zooplankton abundances in the immediate vicinity, leading to slower growth (Willette et al. 1999) and lower energy density of the released pink salmon (Paul and Willette 1997). Growth of juvenile pink salmon was especially slow during April to mid-May, when abundances of *Neocalanus* were greatest (Figures 9 and 10 in Cooney et al. 1981, Figure 6 in Willette et al. 2001). These latter two observations are also consistent with growth inhibition from the pristane content of *Neocalanus* copepods. Although estimates of the carrying-capacity of PWS for juvenile pink salmon indicate depletion of zooplankton abundances is unlikely except perhaps on small, localized spatial scales, such as the immediate vicinity of hatcheries just after a mass-release of juveniles (Cooney 1983, Cooney and Brodeur 1998, Boldt and Haldorson 2002), these estimates did not account for growth inhibition by pristane. The growth efficiencies assumed or implied by these estimates exceed 25%, whereas if growth is inhibited through ingestion of pristane, depletion of zooplankton abundances may be considerably greater than these estimates have indicated.

Understanding the trophic interactions among predators of *Neocalanus* and their prey is crucial for interpreting the annual increase of pristane concentrations in mussels during spring in PWS. The results of this study indicate these increases are mostly due to feces produced by zooplanktivorous fishes such as pink salmon inhabiting the near shore during spring, implying that mussel beds where increases are especially large are near relatively high concurrent abundances of *Neocalanus* copepods and their predators. Hence, a systematic survey of mussel beds for pristane increases during spring might indicate favorable feeding habitats for these predators. Comparison of the magnitude of these increases interannually might serve as a proxy indicator of interannual differences in the intersection of concurrent abundances of *Neocalanus* copepods and their predators. These spatial and temporal variations of pristane increases in mussels during spring might also bear some relation to the early marine survival of juvenile pink salmon, but the details of any such relationship are unclear at present. High pristane concentrations in mussels may indicate abundant *Neocalanus* prey and nearshore zooplanktivorous fishes during spring, but these conditions may not translate directly to increased survival of fish. Because of the growth-inhibiting property of pristane, areas where pristane is abundant in mussels may also indicate particularly favorable opportunities for the predators of the zooplanktivorous fishes there. Indeed, growth inhibition by pristane in *Neocalanus* makes the abundances of zooplantivorous fishes in PWS especially sensitive to abundances of higher trophic level predators.

Conclusions

Each of three distinct ecological pathways may be followed by pristane from its source in *Neocalanus* and *Calanus* copepods to suspension-feeding mussels in PWS. When these copepods are abundant during spring, pristane dissolved into seawater from them, or pristane associated with fecal pellets produced by them may be accumulated by mussels to concentrations of a few $\mu g\ g^{-1}$ dry tissue weight. Substantially higher concentrations may be attained when zooplanktivorous fishes such as juvenile pink salmon are present, through ingestion by mussels of pristane-laden feces produced by these fishes preying on the copepods.

The large hatchery releases of juvenile pink salmon caused a detectable shift in the zooplankton community near the hatchery. Predation of the released fish on *Neocalanus* released the smaller *Pseudocalanus* and *Acartia* from competition for food, and these smaller species largely replaced the zooplankton biomass lost through consumption of *Neocalanus* by the released fish.

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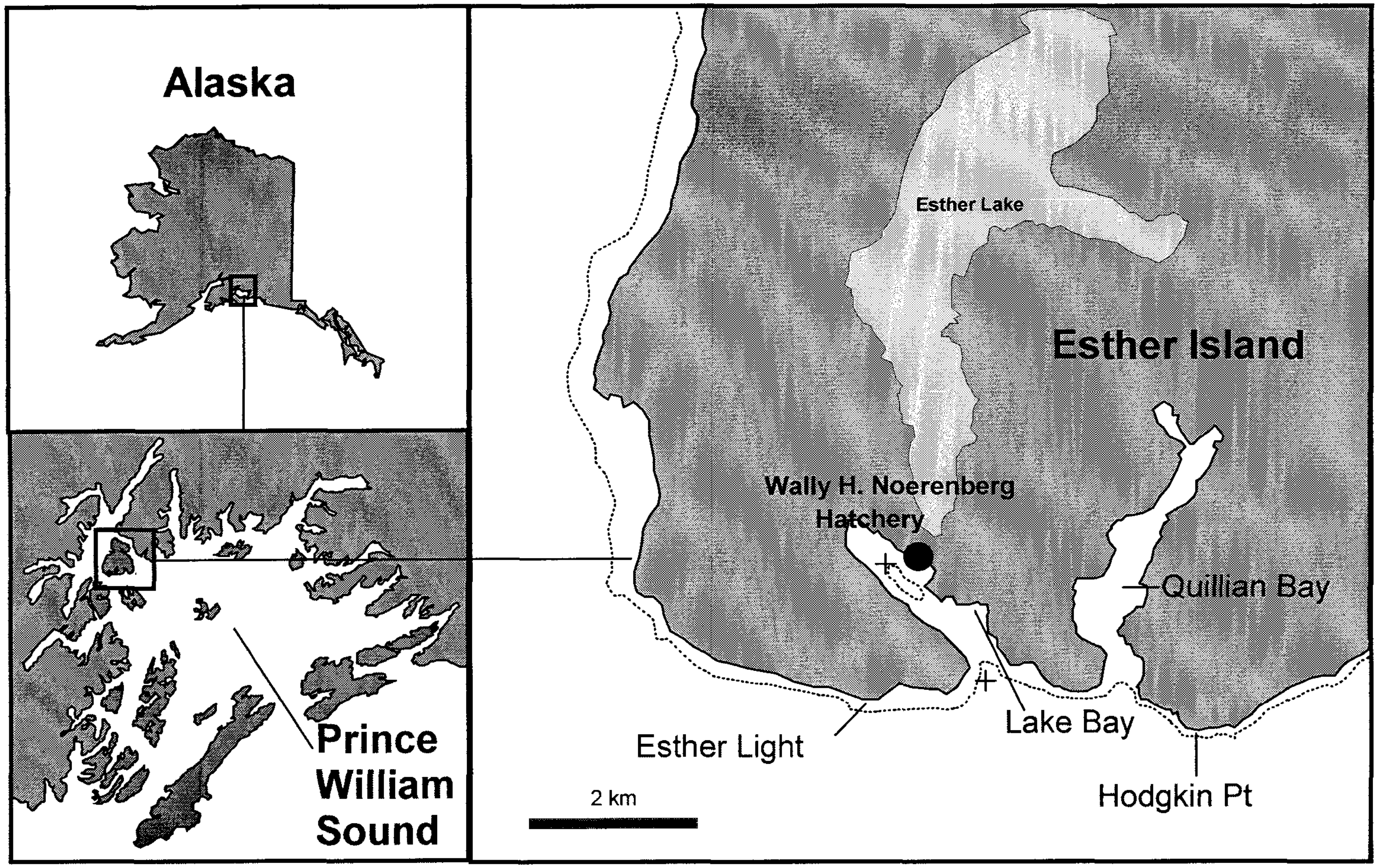

Figure 3.1. Map of study area. Lines indicate the mussel monitoring stations, and crosses the zooplankton sampling stations monitored by the Prince William Sound Aquaculture Corporation in relation to the W. H. Noerenberg hatchery. The dashed line along the coast indicates the approximate 50 m depth contour.

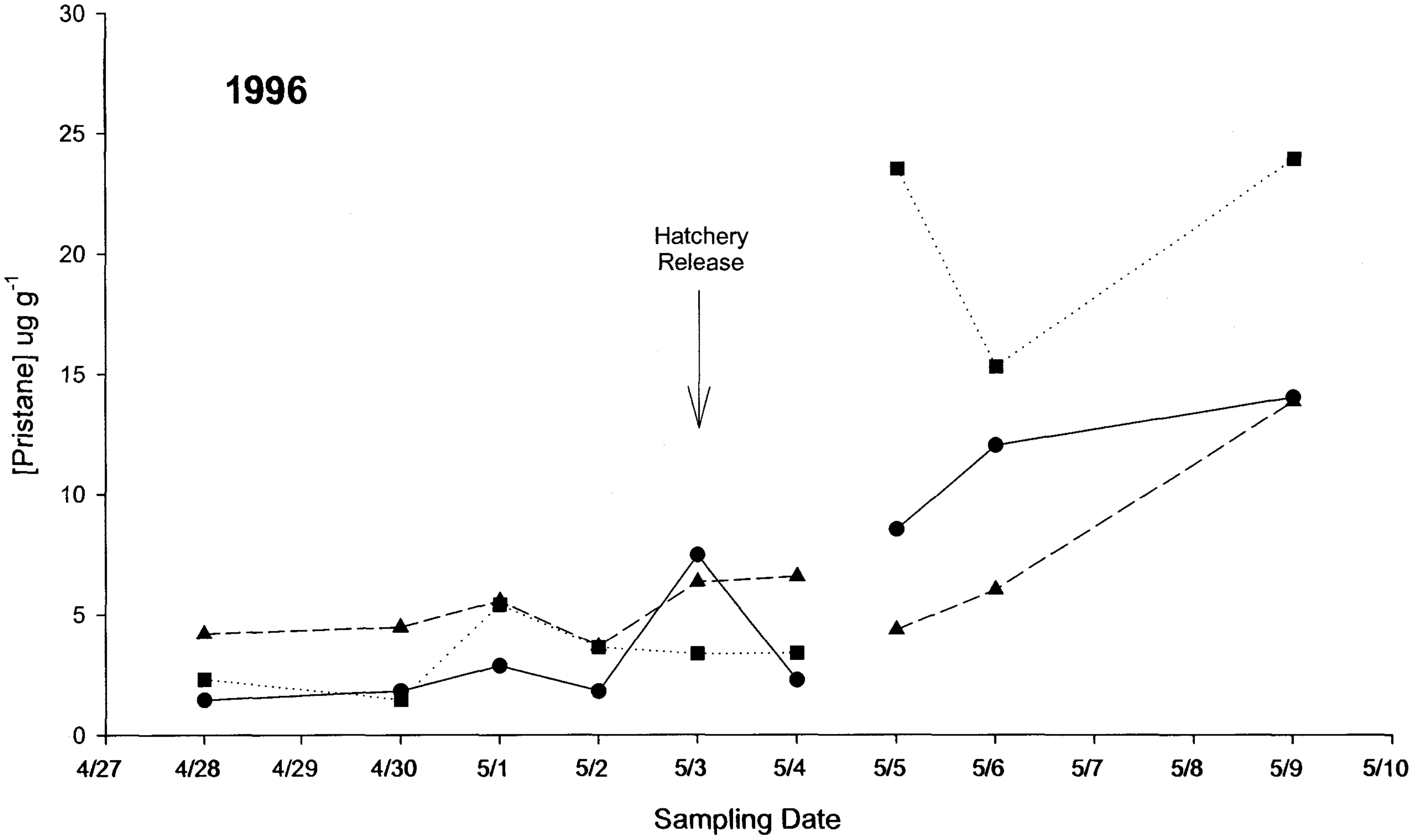

Figure 3.2. Pristane in mussels near W. H. Noerenberg hatchery, 1996. Stations: circle = Esther Light, square = Lake Bay, triangle = Hodgkins Point. Release date of 1.3 x 10^8 juvenile pink salmon from the hatchery is indicated by the vertical arrow.

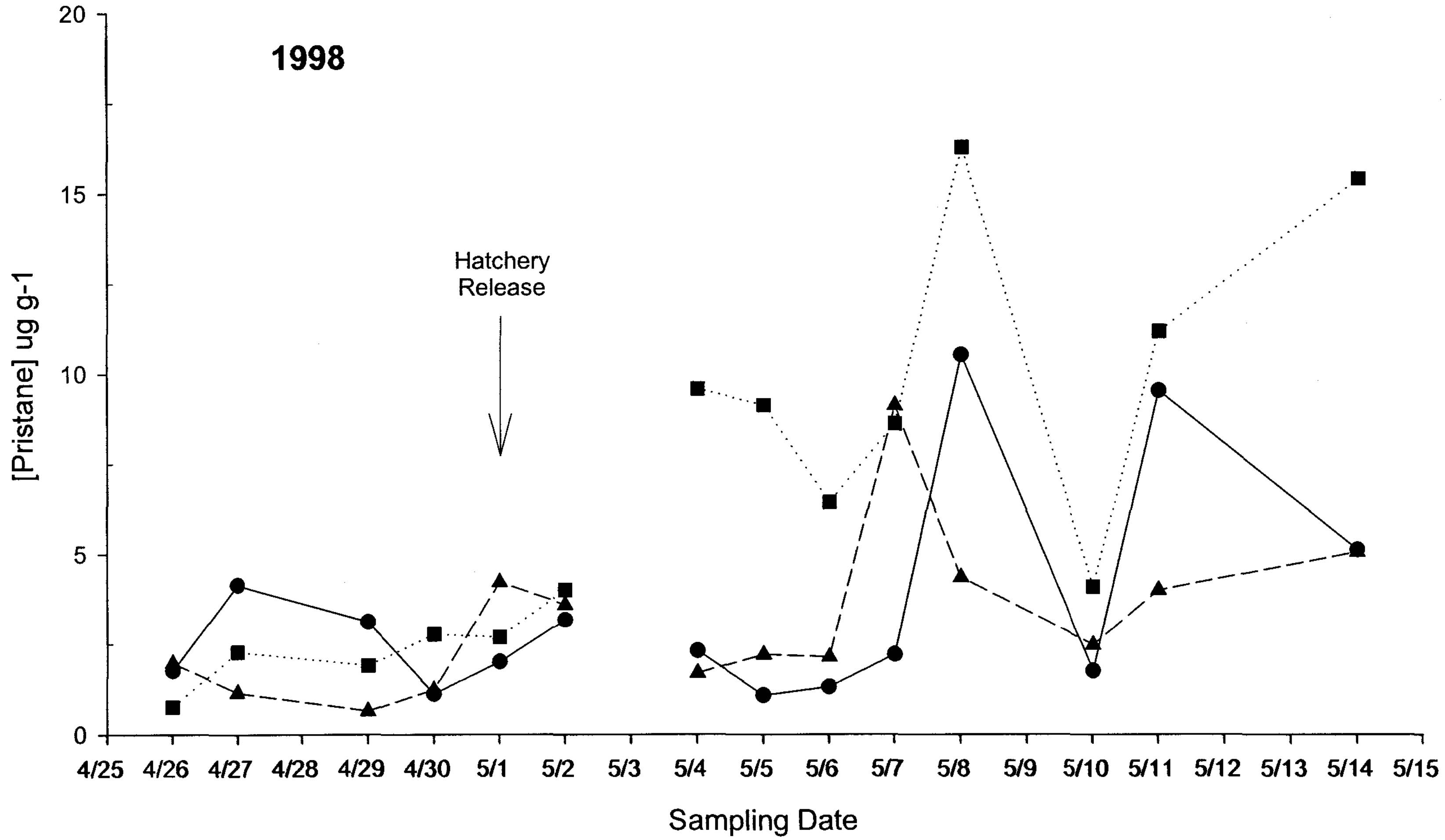

Figure 3.3. Pristane in mussels near W. H. Noerenberg hatchery, 1998. Stations: circle = Esther Light, square = Lake Bay, triangle = Hodgkins Point. Release date of 7.0 x 10^7 juvenile pink salmon from the hatchery is indicated by the vertical arrow.

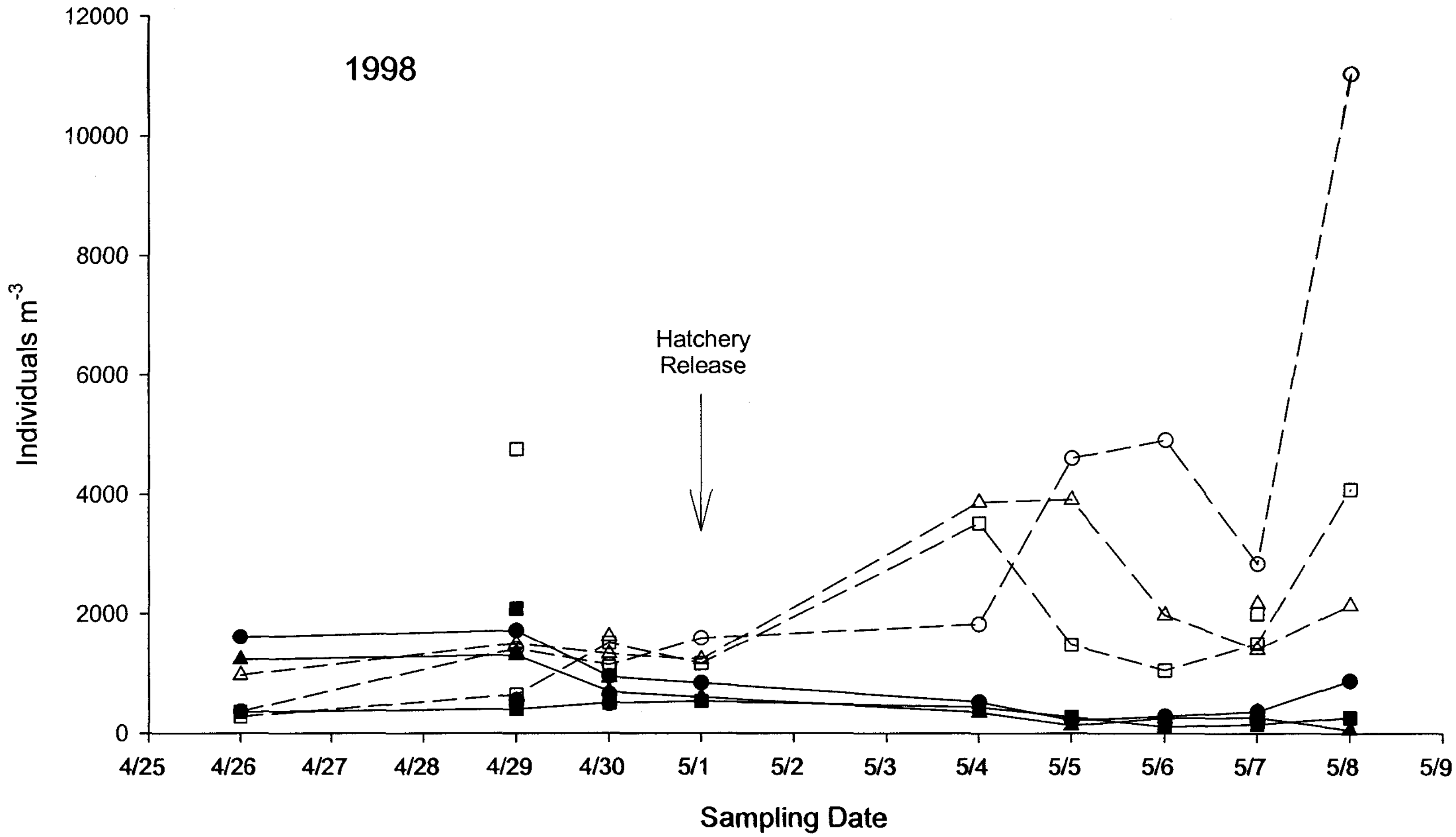

Figure 3.4. *Neocalanus* and *Pseudocalanus* copepod abundance. Stations: circle = Esther Light,square = Lake Bay, triangle = Hodgkins Point. *Neocalanus* = solid symbols and lines, *Pseudocalanus* = open symbols and dashed lines. Afternoon (4/29), late evening (4/30) and midnight (5/7) samples unconnected by lines, otherwise morning samples.

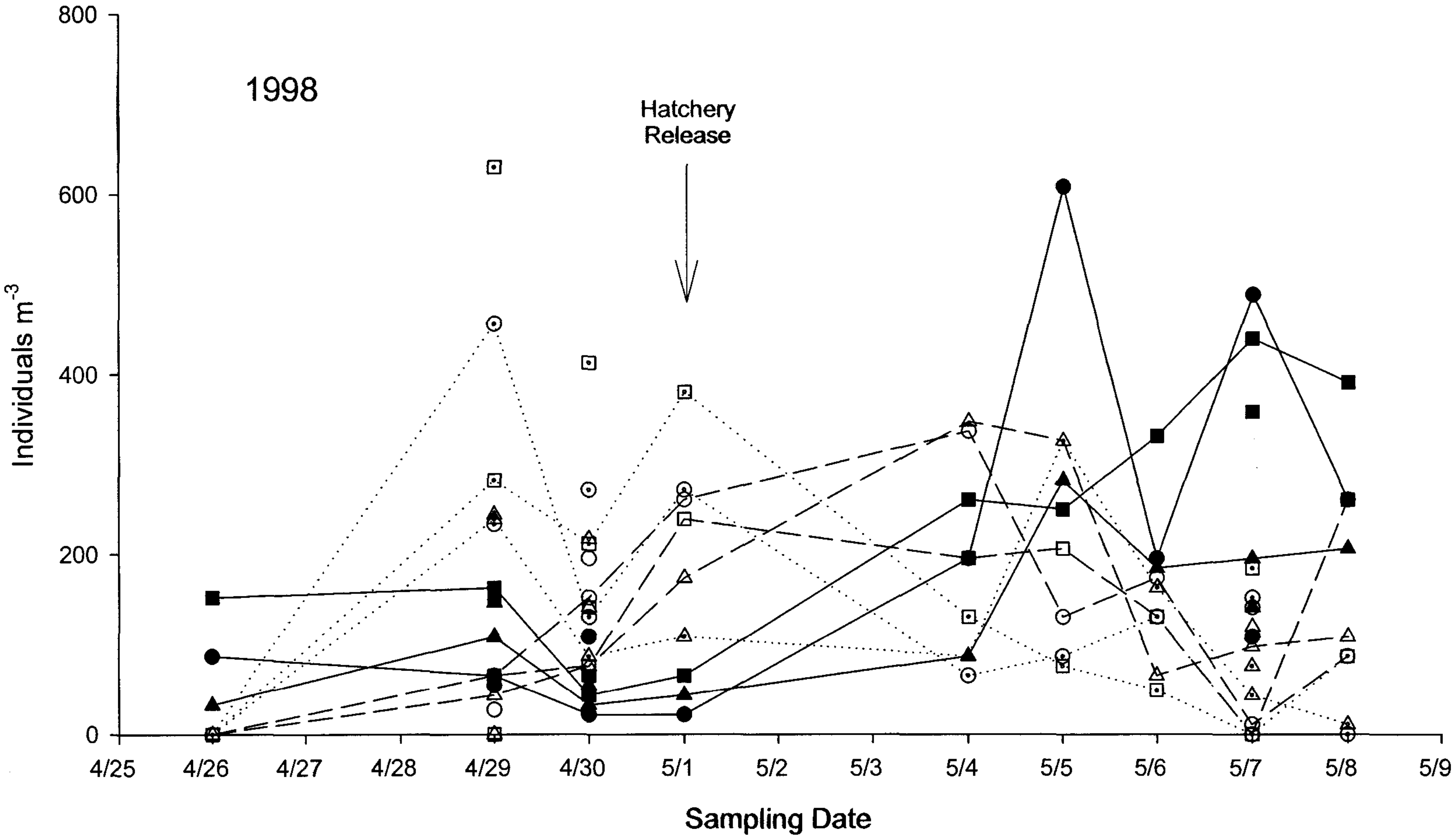

Figure 3.5. ***Acartia*, and bryozoan larvae and *Oikopleura* abundance. Stations: circle = Esther Light, square = Lake Bay,** triangle = Hodgkins Point. *Acartia* = solid symbols and lines, bryozoan larvae = open symbols and dashed lines, *Oikopleura* = dotted open symbols with dotted lines. Afternoon (4/29), late evening (4/30) and midnight (5/7) samples unconnected by lines, otherwise morning samples.

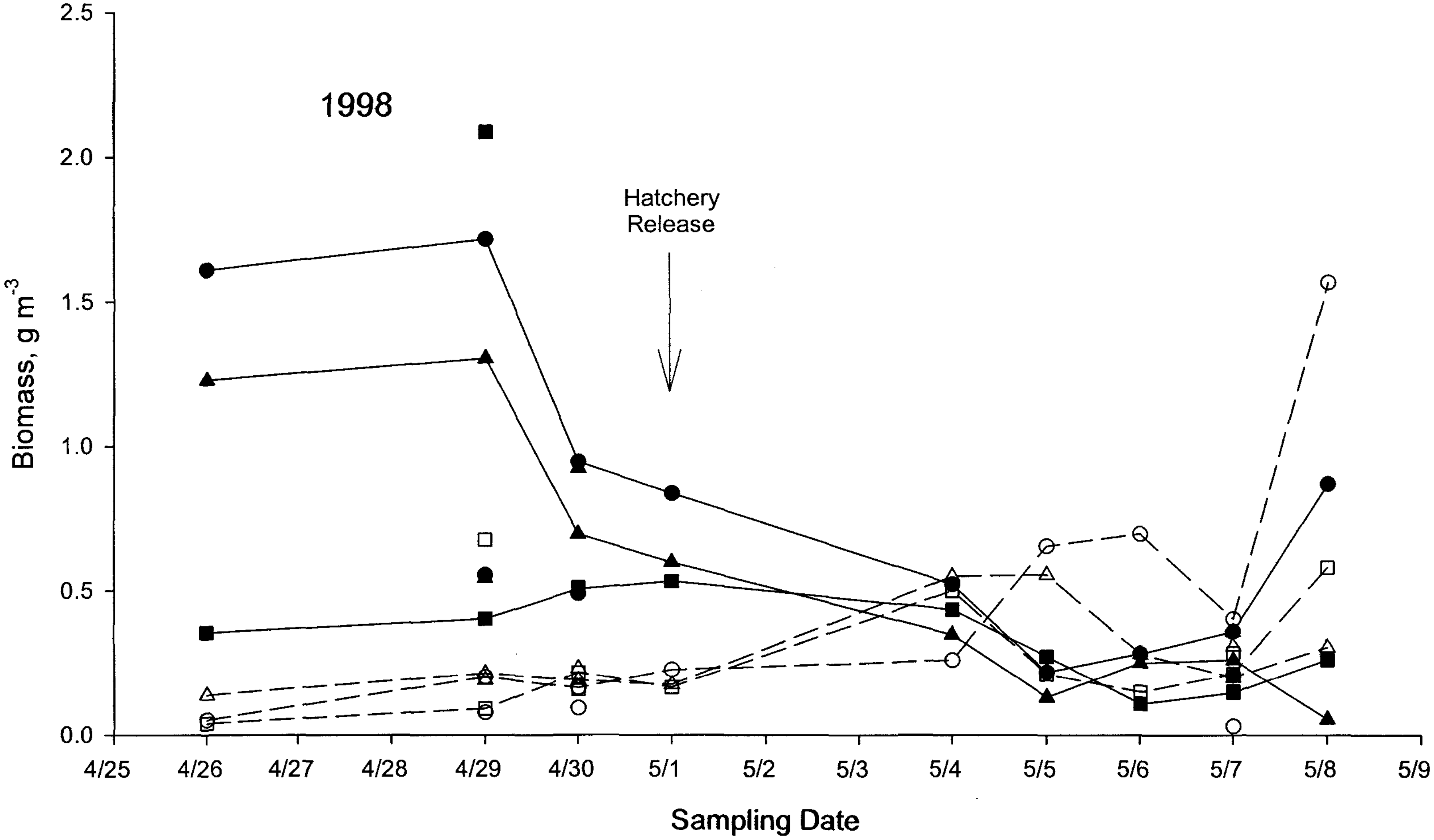

Figure 3.6. *Neocalanus* and *Pseudocalanus* biomass. Stations: circle = Esther Light, square = Lake Bay, triangle = Hodgkins Point. *Neocalanus* = solid symbols and lines, *Pseudocalanus* = open symbols and dashed lines. Afternoon (4/29), late evening (4/30) and midnight (5/7) samples unconnected by lines, otherwise morning samples.

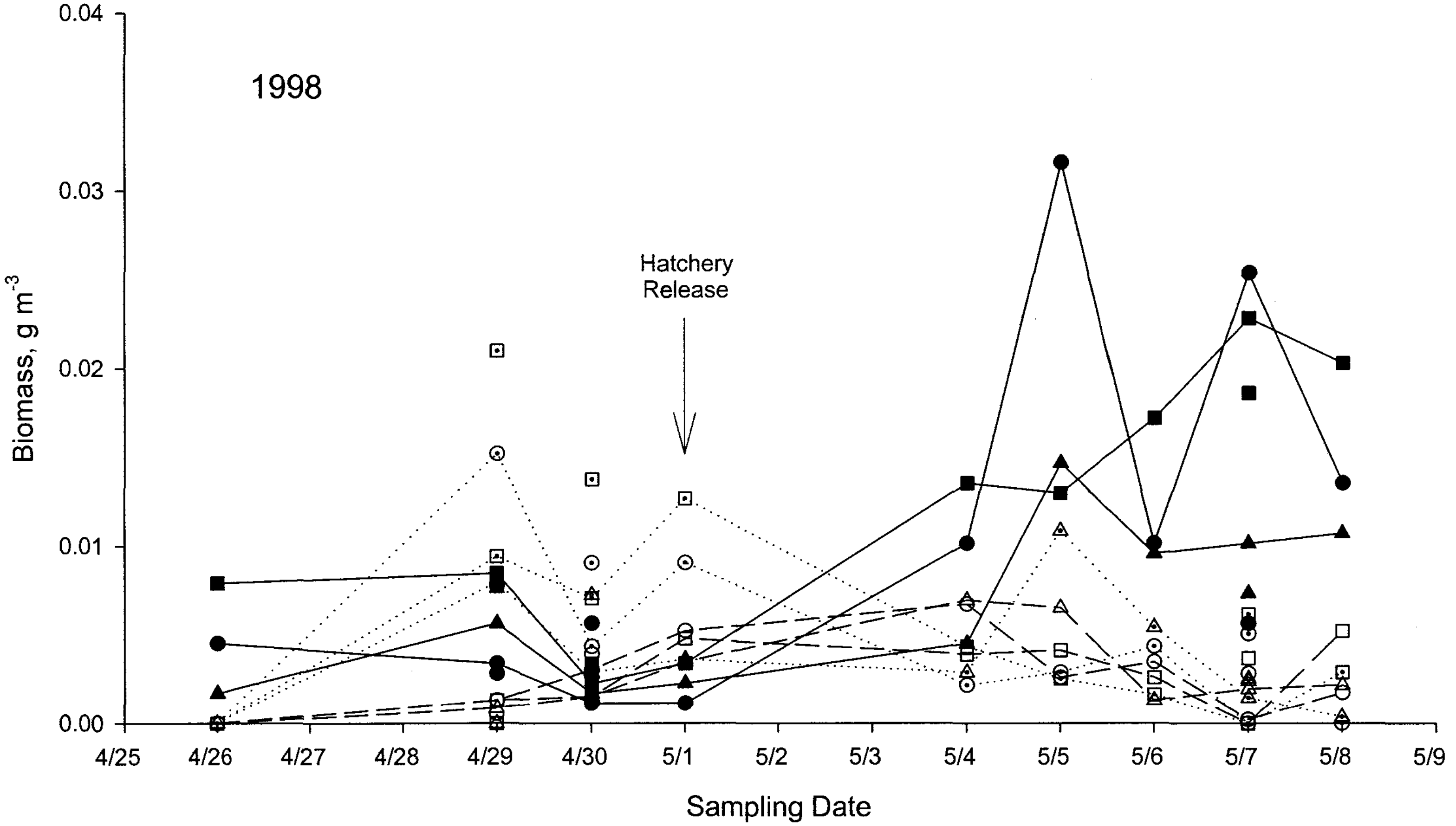

Figure 3.7. *Acartia*, bryozoan larvae and *Oikopleura* biomass. Stations: circle = Esther Light, square = Lake Bay, triangle = Hodgkins Point. *Acartia* = solid symbols and lines, bryozoan larvae = open symbols and dashed lines, *Oikopleura* = dotted open symbols with dotted lines. Afternoon (4/29), late evening (4/30) and midnight (5/7) samples unconnected by lines, otherwise morning samples.

Table 3.1. Zooplankton composition near W. H. Noerenberg hatchery, spring, 1998. Summary of 36 vertical zooplankton tows from 30 m depth at three sampling station (EL, LB and HP; see Methods), from 26 April 1998 through 8 May 1998. Abbreviations of zooplankton are: AC = *Acartia sp.*, BL = bryozoan larvae, CM = *Calanus marshallae*, NFP = *Neocalanus plumchrus/flemingerii*, OIT = *Oithona sp.*, OKP = *Oikopleura sp.*, PSC = *Pseudocalanus sp.* Zooplankton abundance is individuals m^{-3}, and biomass is g m^{-3}.

	AC	BL	CM	NPF	OIT	OKP	PSC	Other	Total
Abundance									
Median	144	114	10.9	418	21.7	130	1500	27.2	2,620
Range	0.68 – 608	0 – 348	0 – 304	54.3 – 2031	0 – 261	0 - 630	217 – 11,000	4.58 – 94.9	815 – 12,600
Biomass									
Median	0.00747	0.00228	0.0109	0.418	0.00263	0.00434	0.213	0.00489	0.783
Range	3.52×10^{-5} – 0.0316	0 – 0.00695	0 – 0.304	0.0543 – 2.09	0 – 0.0316	0 – 0.0210	0.0309 – 1.57	7.63×10^{-4} – 0.0259	0.276 – 2.81

Table 3.2. Stomach contents of juvenile pink salmon near W. H. Noerenberg hatchery. Median (range) of pink salmon fork length (FL), and number of individuals and biomass (mg) of *Neocalanus sp.* and of *Pseudocalanus sp.* in stomachs of seven juvenile pink salmon following release from the hatchery in 1996 and 1998. The number of hours after the juveniles were released from hatchery net pens is indicated. "Unreleased" indicates results for cohorts retained within net pens.

Year	Hours After Release	Station	Pink Salmon FL (mm)	*Neocalanus sp.* Individuals	*Neocalanus sp.* Biomass	*Pseudocalanus sp.* Individuals	*Pseudocalanus sp.* Biomass
1996	0	Unreleased	38	0	0	0	0
			(33–40)				
	42	EL	35	6	6.00	34	4.83
			(32–36)	(2–10)	(2.00–10.0)	(0–82)	(0–11.6)
	42	LB	35	7	7.00	81	11.5
			(32–38)	(0–13)	(0–13.0)	(38–203)	(5.40–28.8)
	42	HP	35	9	9.00	29	4.12
			(33–38)	(0–12)	(0–12.0)	(19–129)	(2.70–18.3)
1998	0	Unreleased	38	0	0	0	0
			(35–40)				
	25	EL	32	9	9.00	51	7.24
			(30–36)	(0–28)	(0–28.0)	(2–59)	(0.284–8.38)
	25	LB	37	20	20.0	12	1.70
			(35–39)	(18–33)	(18.0–33.0)	(0–38)	(0–5.40)
	65	EL	32	5	5.00	13	1.85
			(30–33)	(3–11)	(3.00–11.0)	(5–17)	(0.710–2.41)
	65	LB	35	8	8.00	22	3.12
			(30–35)	(0–17)	(0–17.0)	(2–56)	(0.284–7.95)
	65	HP	38	5	5.00	12	1.70
			(37–39)	(3–7)	(3–7)	(3–49)	(0.426–6.96)

Chapter 4

RELATIONSHIP BETWEEN PRISTANE ACCUMULATION BY MUSSELS (*MYTILUS TROSSULUS*) AND MARINE SURVIVAL OF PINK SALMON (*ONCORHYNCHUS GORBUSCHA*) IN PRINCE WILLIAM SOUND, ALASKA

Short, JW (In prep) Relationship between pristane accumulation by mussels (*Mytilus trossulus*) and marine survival of pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska. Prepared for submission to Marine Ecology Progress Series

Abstract

Pristane concentrations were monitored in bay mussels (*Mytilus trossulus*) from early spring through mid-summer each year of 1995 through 2001 at 27 stations in Prince William Sound (PWS), Alaska, to evaluate whether increases of pristane are related to the marine survival of pink salmon reared by PWS hatcheries. Mussels accumulate pristane through ingestion of feces produced by near-shore zooplanktivores such as juvenile pink salmon that prey on *Neocalanus* or *Calanus* copepods during spring, and large increases reflect high consumption of these copepods near shore.

Pristane increases were consistently greatest at stations on the western portion of PWS adjacent to the deepest seawater depths where *Neocalanus* copepods reproduce during winter. Pristane increases varied inconsistently among the stations monitored in western PWS from year to year, probably because of random components of factors affecting the distribution of copepod and zooplanktivore abundances rather than site-specific factors such as beach habitat type or proximity to a hatchery. Pristane accumulation by mussels at one of the monitored stations reflected accumulations by other mussels in the vicinity within about 2 km. Pristane accumulation by mussels throughout PWS remained at intermediate levels from 1995 through 1997, increased by ~ 50% during 1998 – 1999, then fell by factors of ~ 3 – 4 during 2000 – 2001, reflecting substantial interannual variability in the nearshore production of pristane at the stations monitored. Indexes of pristane accumulation by mussels were weakly correlated ($r = 0.667$, $P = 0.10$) with survival of hatchery pink salmon considered in aggregate, but were usually not correlated with survivals from individual hatcheries. Marine survival of pink salmon was not correlated among the four pink salmon hatcheries in PWS. A monitoring program that includes pristane concentrations in mussels during spring, augmented by data on zooplankton community composition and on predator abundances, holds promise for improving forecasts of pink salmon recruitment in PWS.

Introduction

In Prince William Sound (PWS), Alaska, foraging by nearshore zooplanktivorous fishes can be recorded by increases of pristane concentrations in mussels (*Mytilus trossulus*), which might provide an indirect and relatively inexpensive index of foraging conditions for these fishes (Short in prep [a]). Copepods in the genera *Neocalanus* and *Calanus* often dominate the springtime zooplankton biomass in PWS (Cooney 1986a, Cooney 1986b, Kirsch et al. 2000, Cooney et al. 2001), and stage V copepodites or adults contain substantial concentrations (~1% of dry mass) of pristane (2,6,10,14-tetramethyl-hexadecane; Blumer 1964, Short in prep [b]). Pristane is biosynthesized by these copepods from chlorophyll (Avigan and Blumer 1968), and it is relatively persistent when released into the environment. Zooplanktivorous fishes preying on these copepod species produce feces containing traces of pristane, which can be efficiently accumulated by mussels after dispersion of the fecal matter in seawater (Short in prep [c]).

Pristane concentrations in mussels often increase sharply in early spring by factors ranging to several thousand, mainly from accumulation of fecal material produced by near-shore zooplanktivorous fishes, and then decline during late spring and summer (Short in prep [b]). Because a large increase in the concentration of pristane accumulated by mussels requires the simultaneous presence of *Neocalanus* and *Calanus* copepods and of their zooplanktivorous predators, the magnitude of the increase of pristane concentration in mussels may reflect the magnitude of carbon transfer from these copepods to their predators in immediately adjacent waters. Hence, monitoring the magnitude of pristane accumulation by mussels during spring may have some utility as an index of forage conditions for nearshore zooplantivorous fishes.

Favorable conditions for foraging on *Neocalanus* do not necessarily imply rapid growth of juvenile salmonids, however, because pristane inhibits their growth. Laboratory experiments show that ingestion of ~1% pristane in the (dry) diet, whether artificial fish food or in *Neocalanus* copepods, reduces food conversion efficiency by a factor of ~ 3 (Luquet et al. 1983, Luquet et al. 1984, Short in prep [c]). Hence, fish that target *Neocalanus* or *Calanus* copepods must consume nearly three times the food compared with fish that do not to achieve equivalent growth, and they would produce three times the fecal material if equivalent growth were attained. During spring, the biomass of *Neocalanus* is roughly the same as the biomass of all other pelagic zooplankton combined (mostly *Pseudocalanus spp.*; Cooney et al. 2001, Short in prep [a]), but the *Neocalanus* are larger by a factor of ~ 5 or more. Preying on *Neocalanus* is thus efficient because of the relatively large ration presented by individuals of these copepods, but this advantage is partially offset by growth inhibition from the ingested pristane. As a result, juvenile fish that prey on zooplankton other than *Neocalanus* or *Calanus* may grow faster than fish that prey on these copepods, so the implication of large increases of pristane in mussels for the survival of juvenile zooplanktivorous fishes foraging nearby is not clear.

Prince William Sound is an especially favorable setting for investigating how the springtime increase of pristane in mussels may be related to the survival of juvenile pink salmon (*Oncorhynchus gorbuscha*). Juvenile pink salmon are often the dominant nearshore zooplanktivore during spring, especially following their release from hatcheries (Cooney et al. 1981). Pink salmon have a fixed two-year life span, are anadromous, and have high fidelity for their natal stream, characteristics which make them very attractive for study in the field. In Alaska, pink salmon typically spawn during summer, spend the fall and winter within freshwater-irrigated gravels of streams or intertidal beaches, and emerge during early spring to migrate to the sea (Heard 1991). After ~ 16 months at sea they return to their natal habitat to spawn and then die. Because most surviving cohorts concurrently return to and concentrate at their natal stream, and are not interspersed among conspecifics of other year classes, it is relatively simple to monitor their marine survival. In PWS, pink salmon are reared at four large hatcheries, which may each release up to ~ 10^8 juveniles *en masse* (Johnson et al. 2002) bearing a thermally-induced otolith mark unique to the hatchery of origin (Willette 1996). This hatchery marking permits estimation of the contribution from the fishery to the marine mortality of the hatchery fish, permitting an especially accurate assessment of marine mortality prior to the fishery. The year-class strength of hatchery pink salmon is thought to be established during the initial phase of their marine residence, when mortality rates are greatest (Parker 1962, Parker 1968, Ricker 1976, Hartt 1980, Peterman 1987, Karpenko 1998, Willette et al. 2001). This combination of circumstances make hatchery reared pink salmon in PWS especially suitable for studying the relation between their marine survival and their foraging success during their initial marine residence, as reflected by the accumulation by mussels of fecal-borne pristane produced by the juvenile salmon.

The primary objective of the seven-year program monitoring pristane concentrations in mussels during spring in PWS is to provide a basis for evaluating whether increases of pristane could be related to the marine survival of pink salmon. Secondary objectives include characterization of the geographic pattern of these increases and their interannual variability, to determine whether portions of PWS had consistently higher increases than others.

Methods

Study Area

Prince William Sound is a small semi-enclosed sea adjacent to the northern Gulf of Alaska with a heavily indented shoreline, and containing numerous islands in the west (Figure 4.1). The sound was recently deglaciated (< 10,000 yr bp), and much of the shoreline consists of steep, rocky headlands and boulder-strewn beaches. Fine-particle beaches are not common, and are often found in "pocket beaches" of a few tens to hundreds of m length bracketed by rocky outcrops of similar lengths or longer. The maximum range of tidal excursion in PWS ~ 4.6 m, with a semi-diurnal tide typical of the Pacific coast of northwesthern North America.

A series of marine depressions at seawater depths below 400 m provide overwintering reproductive habitat for *Neocalanus* in PWS (Figure 4.1). Reproduction occurs during January and February in waters deeper than ~ 300 m during winter, followed by death of the adults, and the offspring develop while rising to the surface and grazing on the spring phytoplankton bloom (Fulton 1973, Damkaer 1977, Conover 1988, Miller and Clemons 1988, Miller 1993). This life-history strategy allows *Neocalanus* copepodites to efficiently incorporate the springtime maximum in primary production (Eslinger et al. 2001).

Mussels are common in the lower half of the intertidal of PWS, and are usually present on beaches or rock outcrops that are sufficiently protected from high-energy waves that would otherwise scour the substrate of epifauna. Winter storms may generate sustained wind speeds of 35 m s^{-1} or more, generating waves of several m height along exposed shorelines. The frequency of these storms declines with the approach of spring, although violent storms may occur during any season in PWS.

Three of the pink salmon hatcheries in PWS are operated by the Prince William Sound Aquaculture Corporation (PWSAC) and include the Armin F. Koernig (AFK) hatchery, the Wally H. Noerenburg (WHN) hatchery, and the Cannery Creek (CCH) hatchery. Another pink salmon hatchery is located in the Port of Valdez and is operated by the Valdez Fisheries Development Association (VFDA). The locations of these four hatcheries are shown in Figure 4.1. Outmigrating juvenile pink salmon tend to travel west along the northern margin of PWS and then south along the corridors formed by the islands in the western part of the sound. Returning adults follow the same path in reverse (Templin et al. 1996).

Mussel Collection

Mussels were collected from a network of 25 stations in PWS during each of the seven years of the monitoring period (Figure 4.1). Station names, locations and abbreviations are listed in Table 4.1. Each year, samples were collected during 7 – 9 synoptic collections beginning in March and ending in July or August. The rationale used to establish the locations of these stations required balancing broad geographic coverage with accessibility. Some of the stations were established near hatcheries operated by the Prince William Sound Aquaculture Corporation (PWSAC), and were sampled by hatchery staff. The remaining stations were visited by small aircraft equipped with floats to enable landing on the sea surface near remote beaches, and then moving the airplane to the beach to permit sample collection. The primary constraint on beach selection was the judgment of professional pilots regarding the likelihood that a plane could get to a beach under poor weather conditions. Despite these precautions, some stations occasionally could not be sampled because of weather.

Mussels were collected at two additional stations (Foxfarm 2 and Foxfarm 3) located ~ 2 km east and west of one of the 25 monitoring stations (Foxfarm 1) for all but the first year monitored, to assess the variability of results over km distances. At Point Pakenham in 2000, mussels were collected at each of 5 tidal elevations spanning the lower half of the intertidal to assess the effect of elevation on pristane content in mussels.

At each beach where mussels were collected, ten mussels were collected from selected mussel beds and placed into a polyethylene bag together with collection documentation. Selected mussels ranged 20 - 45 mm total length. Mussels were collected *ad libitum* within sampled mussel beds, with ~ 1 m separating each mussel collected. Mussels were frozen at – 20 °C within 8 h of collection until analysis for pristane.

Dry Weight Determination

The ratio of dry and wet weight of tissue was determined by drying weighed sample aliquots at 65 °C for 24 h. This ratio was 0.110 ± 0.00160 (n = 1,975) for mussels collected during the seven years of the monitoring program.

Marine Survivals of Hatchery Pink Salmon

Marine survivals of hatchery pink salmon are estimated as the ratio of returning adults and the number of juveniles released. Estimates of the numbers of released juveniles are based on measurements of the numbers of eggs collected and estimates of mortality during rearing at the hatchery, and these mortality rates are usually small. Estimates of the numbers of adults returning to a hatchery are derived from two sources. First, all adult pink salmon caught within ~ 5 km of a hatchery during the period of the returning migration are assumed to have originated from the hatchery. Second, released juveniles received a hatchery identification mark, which was either a nearly microscopic wire bearing a binary code that was injected into the fish's snout, or was imprinted as variations in the daily circuli of otoliths by brief changes in water temperature. Wire tags or otoliths of adult pink salmon captured during the mixed-stock fishery within PWS are sampled and decoded by the Alaska Department of Fish and Game, and the proportion of the catch bearing a hatchery's mark is estimated based on the ratio of number of marked individuals among the sampled adults and the enumerated size of the landed catch.

Pristane Analysis

The chemical analysis of mussels for pristane involved pentane extraction of macerated tissues spiked initially with perdeuterated *n*-hexadecane as an internal standard, solvent concentration and exchange into hexane over steam, purification by silica gel/alumina column chromatography eluted with pentane, solvent re-concentration, resolution of alkanes by gas chromatography (GC) and measurement by flame ionization (Short et al. 1996). Identification of pristane is based on GC elution time.

The accuracy of the pristane analyses was generally within ±15% based on comparison with an authentic hydrocarbon standard prepared by the National Institute of Standards and Technology, and the coefficient of variation was generally less than ±20%. The method detection limit (MDL), defined as the estimated concentration associated with a 1% probability of type I detection error, is 0.162 μg. The corresponding MDL estimate for individual samples is the ratio of this value and the mass of the sample analyzed. The mean MDL was 0.278 ± 0.00153 $\mu g\ g^{-1}$ on a dry tissue mass basis (n = 1,975), and ranged from 0.0577 – 5.23 $\mu g\ g^{-1}$.

Data Analysis

The integrated accumulation of pristane by mussels at each site throughout the spring and summer is summarized by a pristane accumulation index (PAI), which is a step-wise approximation of the integral of pristane concentration in mussels over time:

$$PAI = (t_2 - t_1)\ [P]_1 + \sum_{i=2}^{I-1} \frac{(t_{i+1} - t_{i-1})\ [P]_i}{2} + (t_I - t_{I-1})\ [P]_I \approx \int_{t_1}^{t_I} [P]\ dt \qquad \text{eq 1}$$

where $[P]_i$ is the pristane concentration measured in mussels collected at time t_i ($i = 1,\ldots,I$), for mussels collected on I successive samplings throughout the collection season from the same site. This approximation method is used because it does not require equally spaced sampling intervals, or that sampling begin and end on exactly the same dates among different sites, and missed samplings are readily accommodated. These are considerable advantages of practicality for a long-term sampling program involving many stations that may not always be accessible due to poor weather. It is, however, necessary that $[P]$ at t_1 and at t_I be near the annual minimum concentration, and that the number of samplings (I) be sufficiently numerous to adequately describe the shape of the accumulation profile in mussels. These requirements were fulfilled for the results reported herein.

Interannual differences of overall pristane accumulation by mussels across all of PWS are compared using two measures. The first is simply the sum of the PAI's across the 25 stations sampled during each of the years monitored (ΣPAI). The second is the magnitude of the first principal component (PC1) of the matrix of correlations among

PAI's of the 25 sampling stations (i.e. principal component analysis, or PCA). This PC1 is the linear combination of PAI's from the 25 stations that account for the greatest proportion of interannual PAI variability. The weighting factors for each station that define PC1 reflect the extent to which station PAI's are intercorrelated, hence PC1 has the effect of suppressing contributions from stations that are anomalous. The weighting factors that define PC1 are listed in Table 4.1.

Differences among pairs of pristane concentrations in mussels are evaluated statistically using least-significant difference (LSD) criteria based on an extensive sampling of the error distribution for these measurements. An error distribution for log-transformed pristane concentrations in mussels was generated from 178 triplicate and 79 duplicate samples analyzed for the *Exxon Valdez* oil spill, which are contained in the *Exxon Valdez* Oil spill of 1989 State/Federal Trustee Council Hydrocarbon Database (EVTHD) at the Auke Bay Laboratory, and are available from the author. These replicated samples were collected and analyzed by similar methods, and they all contained pristane concentrations above method detection limits. The variances of these replicates were homoscedastic after log transformation. A distribution for differences of two random samples of the error distribution can be generated by Monte Carlo simulation. Based on this distribution of differences, the LSD at $\alpha = 0.05$ type I error rate is about 1.015, which corresponds to a ratio of about 2.75 for un-transformed data. Thus, mussels from two different samples are judged significantly different if the ratio of the larger pristane concentration to the smaller is more than 2.75. The power of this test to detect an actual increase of 3 is about 58%, again derived from Monte Carlo simulation of the error distribution.

Propagation of errors for derived indices indicates that 66% changes in the PAI (eq 1) are significant at the $\alpha = 0.05$ type I error rate. The power of these criteria to detect an actual doubling of the PAI is about 80%, estimated by Monte Carlo simulation. The power to detect ΣPAI differences among years is greater, due to the larger number of measurements involved: differences of 22% are significant, and the power to detect such increases when they occur is about 50%.

The marine survival of juvenile pink salmon released by hatcheries in PWS is examined by correlation and by PCA to assess whether these survivals are intercorrelated among the four hatcheries across years. To evaluate the significance of the dominant eigenvector (PC1) of the correlation matrix of annual survivals among hatcheries, I randomly re-assigned the observed survivals (with replacement) and calculated the PC1 eigenvalue 1,000 times, and then I took the proportion of eigenvalues that were greater than the eigenvalue calculated for the original data as the estimate of the significance level (type I error rate). I used this same method to evaluate the significance of the PC1 associated with PCA of pristane concentrations in mussels from the three Foxfarm stations.

I used the Pearson correlation coefficient to evaluate whether a significant relationship exists between the results for pristane accumulation by mussels in PWS and the marine survival of juvenile pink salmon. I evaluated this relationship at two spatial scales. For PWS as a whole, I calculated the correlation coefficient of either the ΣPAI or the PC1 value (derived from the PCA of the pristane concentrations in mussels) and the survival of pink salmon released by all four hatcheries combined. I performed a similar comparison with survivals from individual hatcheries, to examine whether survivals from each hatchery were correlated with either of these two indices of pristane accumulation by mussels throughout PWS. At a smaller spatial scale, I calculated correlations using a reduced ΣPAI index (ΣPAI^r), which only included data on pristane in mussels from stations within ~ 50 km of a hatchery, and survivals from the hatchery. Results from each of the hatcheries were also combined to determine whether the aggregated indexes were correlated with respective hatchery survivals. Because spurious correlations may result from autocorrelation within the time series of the indices of pristane accumulation by PWS mussels or the survivals of pink salmon, I evaluated the significance of autocorrelation by linearly regressing each time series with itself lagged by one year, and calculating the probability of type I error for the slope of the regression.

Results

Spatial and Temporal Variability of Pristane in Mussels

Pristane concentrations in mussels increased during spring, often sharply, especially at stations on the western side of PWS. Results for 1995 are depicted in Figures 4.2 and 4.3, and the same seasonal pattern was repeated each succeeding year (Figures 4.4 – 4.5). Pristane increases were consistently greatest and most persistent at stations to the west of a line from Valdez Narrows through Montague Strait (Figure 4.1).

Pristane concentrations were consistently above annual station averages only at Point Eleanor during the period 1995 through 2001 (Figures 4.4 – 4.5). The Foxfarm 1, Esther Island and Herring Point stations were above their annual averages during 4 of the 7 years. Five stations were variable, above the annual average during 3 or 4 of the last 7 years, including the AFK hatchery, Applegate Island, Fairmont Island, Perry Island and Point Pakenham.

In contrast, 7 stations were consistently below annual averages, and another 9 stations were below for all but 1 or 2 of the 7 years. These stations include all 7 of the stations eastward of a line running from Montague Strait to Valdez Narrows, 3 stations in distal fjords (Cannery Creek, Decision Point, and Division Point), 3 stations along the western coastline of Knight Island Passage (Main Bay, Chenega Island, and Fleming Island), 2 stations on the Naked Island complex (Naked Island and Storey Island), and the station on the east coast of Knight Island (see Figure 4.1).

The ΣPAI index varied considerably during the seven-year study period (Table 4.2). The ΣPAI index had intermediate values ranging from 8,670 – 9,200 μg g^{-1} d during 1995-1997 that did not differ significantly using the LSD criterion (see Methods). The index was significantly higher in 1998 and 1999 at ~ 12,600 $\mu g\ g^{-1}$ d, and was significantly lower in 2000 and 2001 at 3,000 – 5,000 $\mu g\ g^{-1}$ d.

Pristane concentrations in mussels at the three Foxfarm stations were moderately correlated. Correlation coefficients among station pairs ranged from 0.57 to 0.89, and were very highly significant ($P < 0.001$, df = 45). The dominant eigenvalue of the PCA of these results accounted for 83% of the variation in the pristane concentrations among mussels, and was very highly significant ($P < 0.001$) based on comparison with dominant eigenvalues generated by PCA of randomly assigned concentrations among stations and years (see Methods).

Pristane concentrations in mussels varied little with vertical tide height within the mussel bed sampled a Point Pakenham in 2000. These concentrations ranged from 1,450 $\mu g\ g^{-1}$ – 2,790 $\mu g\ g^{-1}$ except for the sample from the lower edge of the mussel bed, where the concentration was 748 $\mu g\ g^{-1}$.

Coherence of Marine Survival of Hatchery Pink Salmon

The marine survivals of pink salmon released by the hatcheries in PWS were not significantly inter-correlated. The strongest correlation coefficient was $r = 0.68$ ($P = 0.10$, df = 5) between the AFK and WHN hatcheries. Other correlations were considerably weaker ($r < 0.47$) and sometimes negative. The eigenvalue of the dominant eigenvector of the correlation matrix accounted for 49% of the variation in the survivals among hatcheries, and was not significant ($P = 0.48$). The marine survivals varied considerably among hatcheries, with no one hatchery consistently accounting for a disproportionate share of the aggregate survival of hatchery pink salmon in PWS (Figure 4.6).

Relation of Interannual Variability of Pristane in Mussels and Marine Survival of Pink Salmon

Taken across PWS as a whole, the marine survivals of hatchery pink salmon were only weakly related to springtime increases of pristane in mussels. Correlation of the marine survivals from the hatcheries combined against the ΣPAI index was not significant ($r = 0.667$, $P = 0.10$, df = 5; Figure 4.7), but nonsignificance may be due to the relatively low statistical power present. The correlation of survivals and the PC1 from the PCA of pristane concentrations in mussels produced similar results ($r = 0.584$, $P = 0.17$, Figure 4.8). The PC1 accounted for 35% of the variation in the concentrations of pristane in the mussels, and the weighting factors that define this PC1 indicate that contributions from the individual stations to the eigenvalue are broadly similar except at the CCH hatchery and the Foxfarm station (Table 4.1).

Marine survivals of pink salmon released from the CCH were strongly correlated with the ΣPAI index ($r = 0.894$, $P = 0.0066$) and with the PC1 from the PCA of pristane concentrations in mussels ($r = 0.923$, $P = 0.0031$), in contrast with correlations associated with the other hatcheries ($|r| < 0.529$, $P > 0.22$), where correlation coefficients were sometimes negative (Figures 4.7 and 4.8).

Correlations derived from analysis at smaller spatial scales were variable. Coefficients of regression of survivals with the ($\Sigma\mathrm{PAI}^{r}$) index for each hatchery considered individually ranged from $r = -0.361$ to $r = 0.830$ (Figure 4.9), only the largest of which was significant (for CCH: $P = 0.021$). When the survival-($\Sigma\mathrm{PAI}^{r}$) data from the hatcheries were combined, the regression coefficient was $r = 0.127$, which was not significant ($P = 0.51$, df = 26; Figure 4.9).

Neither the marine survivals of hatchery pink salmon nor the ΣPAI index were significantly autocorrelated. The regression coefficients for the slopes of the autocorrelation regressions were $r = 0.341$ ($P = 0.51$, df = 4) and $r = 0.400$ ($P = 0.432$) for survival and for the ΣPAI index, respectively. Although these time series are too brief to permit a statistically powerful assessment of autocorrelation, these results suggest that contributions from autocorrelation to the correlations noted above between survivals and indices of pristane accumulation by mussels are likely negligible.

Discussion

The two most important pathways followed by pristane from its source in *Neocalanus* and *Calanus* copepods to mussels are feces produced by their predators, followed by feces produced by the copepods themselves (Short in prep [a]). Increases of pristane concentrations derived from copepod feces are probably limited to less than ~ 3 μg g^{-1} (Short in prep [a]), but this may account for an appreciable portion of the pristane accumulated by mussels in late March (Figure 4.2). Feces produced through predation on these copepods contain higher concentrations of pristane and may be more readily transported to mussel beds (Short in prep [a]), and the greater part of the pristane in mussels is probably accumulated through this pathway. The predators involved are likely zooplanktivores that reside close to shore such as sand-lance (*Ammodytes hexapterus*), gunnels (*e.g. Pholis laeta*), cockscombs (*Anoplarchus spp.*) and other Stichaeidae, and perhaps juvenile herring (*Clupea harengus*) (Mecklenburg et al. 2002). Outmigration of wild juvenile pink salmon usually does not begin until mid-April (Cooney et al. 1995), and hence is not likely a substantial contributor of pristane-laden fecal material for accumulation by mussels in late March.

The association of the largest increases of pristane concentrations in mussels during spring with proximity to the deepest seawater depths (Figures 4.2 – 4.3) suggests that the population of *Neocalanus spp.* that overwinters and reproduces within PWS may be the source of most of the pristane accumulated by the mussels. Thermohaline stratification conditions conducive to the spring phytoplankton bloom are first established during early to mid-March in the more protected embayments of PWS, especially in the northwestern portion of the sound, becoming more widespread throughout PWS during the ensuing 1 –

2 weeks (Eslinger et al. 2001, Wang et al. 2001, Gay and Vaughan 2001). Developing *Neocalanus* copepodites originating from the deepest parts of PWS are ideally situated to graze on the developing phytoplankton bloom (Figure 4.1). While evidence from stable carbon and nitrogen isotopes indicates that considerable proportions of adult *Neocalanus* overwintering in the marine depressions of PWS originate from the Gulf of Alaska, presumably entering PWS during summer or fall by advection (Kline 1999), it seems likely that much of the carbon incorporated in their offspring is derived from local phytoplankton production. Production of pristane-laden feces in this region would be greatly facilitated by releases of juvenile pink salmon from hatcheries, because the migration path followed by these fish generally coincides with the overwintering habitat of *Neocalanus spp.* (Figure 4.1). However, concurrent outmigration of wild juvenile pink salmon would also increase the abundance of near-shore zooplanktivores in eastern PWS, yet pristane increases in mussels there were substantially lower than western PWS, corroborating the importance of the local overwintering habitat for production of *Neocalanus* copepodites in spring.

The main reason pristane accumulation was so inconsistent across years at most of the monitoring stations is probably the result of random variation in the co-occurrence of *Neocalanus* copepods and their predators (especially juvenile pink salmon), rather than site-specific factors such as beach slope and aspect, beach particle size distribution, proximity to hatcheries or major pink salmon-producing streams, tidal elevation at sampling etc. The opportunistic selection of station locations did not permit much consideration of site-specific factors beyond mussel availability, hence the beaches at these stations span a variety of morphological characteristics. Despite these differences, most mussels on beaches on the western side of PWS accumulated substantial concentrations of pristane during some, but rarely every year. This suggests that oceanographic factors that concentrate zooplankton and the foraging behavior that leads juvenile pink salmon to search for these concentrations often override the importance of site-specific factors associated with the selected monitoring-station location. Variable wind- and tidally-driven currents change the locations of these zooplankton concentrations on time scales of days to weeks, hence considerable interannual variability in the locations of these concentrations during spring is to be expected. Because of this, the fact that the monitoring stations were chosen opportunistically rather than randomly is less problematic than might otherwise be the case: the complex interaction of local winds and tidal currents with the heavily indented shorelines typical of PWS leads to a sampling environment that is characterized by a considerable degree of sampling isotropism. This conclusion is further corroborated by the degree of intercorrelation of pristane concentrations in mussels over distances of several km at the Foxfarm stations, and by the general absence of differences among mussels sampled across the vertical excursion of tidal heights within mussel beds. This last is important because often only the upper portion of a mussel bed was available for sampling owing to the constraints imposed by sampling areas accessibly by aircraft.

The four-fold interannual range spanned by the ΣPAI index (Table 4.2) reflects substantial variation in the availability of *Neocalanus* copepods as prey for near-shore zooplanktivores, especially juvenile pink salmon. Hatchery production of pink salmon insures a large and fairly constant abundance of juvenile pink salmon introduced into PWS during the seven-year study period (Table 4.2), and these juveniles remain very close to shorelines during the initial phase of their marine residence (Healey 1980, Cooney et al. 1981, Willette 2001). The interannual variability of pristane in mussels therefore probably reflects variation in the abundance of *Neocalanus* and *Calanus* copepods rather than variation in the abundance of near-shore zooplanktivores. The variation in the abundance of *Neocalanus* and *Calanus* copepods may reflect variation in contemporaneous primary production, or variation in the composition in the springtime zooplankton community, with *Neocalanus* and *Calanus* copepods accounting for a smaller proportion of the community in 2000 or 2001 compared with 1998 or 1999. Whatever the reason, the lower pristane accumulation by mussels in 2000 and 2001 probably reflects a substantial change in the nature of the zooplankton prey field compared with prior years.

The lack of intercorrelation among the marine survivals of hatchery pink salmon indicates that any relation between these survivals and pristane in mussels should at least be considered at two spatial scales. Conditions favorable for pink salmon clearly fluctuate from year to year in PWS, and these changes are related to interannual variation in environmental conditions such as sea surface temperature that affect PWS as a whole (Wertheimer et al. 2004). The absence of intercorrelation among the marine survivals of hatchery pink salmon indicates that effects on survivals associated with localized conditions within the sound are comparable with effects that affect PWS as a whole, for otherwise the hatchery survivals would be intercorrelated. Thus, the survival of pink salmon released from individual hatcheries may have a large random component, comparable with the variability of the combined survival. Field sampling indicates that juvenile pink salmon released from hatcheries remain poorly mixed within PWS, and that the condition of these juveniles remains strongly dependent on sampling location, during their first three months of marine residence (Boldt and Haldorson 2004). The survival performance of individual hatcheries should therefore also be evaluated to determine the importance of conditions in their vicinities. The absence of correlation of marine survivals among the four hatcheries suggests that the marine survival may in large part be determined by events initially following release of the pink salmon, before these hatchery fish have time to mix within PWS.

The nonsignificant but suggestive correlation between the aggregate marine survival of hatchery pink salmon and either the ΣPAI index or the PC1 from the PCA of pristane concentrations in mussels suggests that it may yet be possible to construct a monitoring program that would have some value for predicting the marine survival of these fish for PWS as a whole. If the low significance is merely the result of inadequate statistical power resulting from too few years monitored, the strength of the correlation might improve if the monitoring were extended to include more years, but it is also possible that the correlation might become even less significant. In comparison, the lower correlations observed between marine survivals for a specific hatchery and the ΣPAI^{r} index for stations adjacent to it (CCH excepted) suggests that while the ΣPAI index may have some questionable potential to reflect favorable conditions for recruitment in PWS as a whole, it may be inadequate at smaller spatial scales. Note that the broadly similar correlations between marine survivals and either the ΣPAI index or the PC1 follow from the fact that contributions from most stations to PC1 are similar. Hence, inclusion of results that are occasionally anomalous from some stations does not have a large effect on the ΣPAI index because they are averaged over the more numerous remaining stations, which tend to vary coherently.

Two advantages of the ΣPAI as a monitoring index are that it tends to integrate both favorable forage conditions for pink salmon as well as predation impacts, and it is relatively inexpensive, making coverage of broad geographic areas practical. The large increases of pristane in mussels during spring require the simultaneous presence of abundant *Neocalanus* copepods, and of abundant zooplanktivores such as pink salmon. Years of low primary productivity will constrain the abundance of the former, and intense predation will constrain the latter. High abundances of *Neocalanus* copepods provide more readily available prey for juvenile pink salmon, and might correlate with increased abundances of other zooplankton species as well, which would favor salmon survival. High abundances of *Neocalanus* copepods may also provide a predation shelter for juvenile pink salmon, wherein piscine predators of juvenile pink salmon target *Neocalanus* copepods instead during years of high copepod abundances (Willette 2001, Willette et al. 2001).

However, predation impacts on juvenile pink salmon are imperfectly reflected by the ΣPAI index, because ingestion of pristane inhibits the growth of salmonid predators of *Neocalanus* or *Calanus* (Luquet et al. 1983, Luquet et al. 1984, Short in prep [c]), and it seems likely that growth of other zooplanktivorous fishes that prey on these copepods would be inhibited also. Secondary consumers that prey selectively on these copepods may consequently suffer impaired growth and hence increased vulnerability to size-selective predation subsequently, and such subsequent mortality would not be reflected by the ΣPAI index. Hence, it is possible that large increases of pristane concentrations in mussels during spring may at once reflect (1) favorable foraging conditions for juvenile pink salmon in general, with a variety of abundant prey alternatives available, (2) a more effective predation shelter for juvenile pink salmon, through provision of abundant alternative prey for their predators such as pollock (*Theragra chalcogramma*), but also (3) a higher size-selective predation risk for juvenile pink salmon, if these juveniles experience slow growth rates as a result of ingesting pristane contained in *Neocalanus* and *Calanus* copepods. The inability to distinguish which is more important, and the possibility that their importance may fluctuate from year to year, may largely account for why the index is not more closely associated with the overall marine survival of pink salmon in PWS. The correlation between the ΣPAI index and survival of hatchery pink salmon would have improved considerably had survivals been lower for the releases in 2000 and 2001, and the higher survivals realized despite the low ΣPAI index values for those years might simply reflect high abundances of zooplankton prey other than *Neocalanus* or *Calanus* copepods during spring of those years, but no data are available to support this conjecture.

A number of other factors would tend to weaken the correlation of the ΣPAI index and the marine survival of pink salmon in PWS, especially as the spatial scale of the index is reduced. The release strategy used by hatcheries was not consistent during the period monitored – ranging from releases of a few millions in each of up to 14 release groups throughout the spring, to several tens of millions in one or two release groups, as hatchery managers sought strategies to reduce initial predation losses. These changes in release strategy could affect the relation between the ΣPAI index and marine survival, especially with regard for the ΣPAI^r index applied to stations nearest a hatchery and survival of salmon released by the hatchery. Another important factor is variability in marine survivals after juvenile pink salmon leave the near shore a few weeks after beginning their marine residence. While most marine mortality probably occurs within the first few weeks of marine residence (Parker 1962, Parker 1968, Ricker 1976, Hartt 1980, Peterman 1987, Karpenko 1998, Willette et al. 2001), any variability in subsequent mortality would not be related to the ΣPAI index. Also, other near-shore zooplanktivores preying on *Neocalanus* or *Calanus* copepods may serve to obscure the relation of pristane accumulation by mussels and survival of juvenile pink salmon, the overall association between the spatial distributions of near-shore zooplanktivores and the monitored mussel beds may vary interannually, and interannual variation in storms and wind-driven currents may lead to differences in the advection of fecal material produced by zooplanktivores toward or away from monitored mussel beds. Given this range of possibilities, it is doubtful that the ΣPAI index would explain most of the variation in survival of hatchery pink salmon, but with refinements it might yet have some utility for explaining a useful portion of it.

Results from an intensive multidisciplinary investigation of the factors affecting the marine survival of pink salmon confirm earlier work emphasizing the importance of both "bottom-up" (i.e. production) and "top-down" (i.e. predation) processes (Willette et al. 2001, Willette 2001) in PWS. As noted above, an advantage of the ΣPAI index is that it provides an inexpensive (if imperfect) indication of zooplankton consumption by near-shore zooplanktivores over a broad geographic area, and might be useful for characterizing interannual changes in zooplankton forage abundance interannually for PWS as a whole. If this index were combined with data on zooplankton composition and predator abundance, especially near hatcheries during spring, it might be possible to construct a composite index incorporating data from these three sources that has some value for forecasting recruitment of pink salmon to the PWS fishery. This could potentially lead to a more precise identification of the factors affecting the early marine survival of pink salmon, which may help improve management of this important fishery in PWS.

Conclusions

Concentrations of pristane increase dramatically in mussels of PWS during spring, especially in the western portion of the sound at monitoring stations near deep-water overwintering and reproductive habitat for *Neocalanus* and *Calanus* copepods, the source of the pristane. Mussels accumulate pristane through ingestion of feces produced by near-shore zooplanktivores that prey on *Neocalanus* or *Calanus* copepods. Factors determining stations where large increases of pristane concentrations occur appear to contain substantial random components, which were probably more important than site-specific characteristics of the stations monitored. Comparison of increases of pristane in mussels at monitoring stations occupied from 1995 through 2001 shows that production of pristane-laden feces changed little from 1995 through 1997, increased by 50% in 1998 and 1999, and then declined by a factor of 3 – 4 in 2000 and 2001, which probably reflects substantial interannual differences in the abundances of *Neocalanus* or *Calanus* copepods near shore during spring.

An index of pristane concentration increases in mussels was weakly correlated ($r = 0.667$) with the marine survival of juvenile pink salmon released by large hatcheries in PWS at a significance level of $\alpha = 0.10$, suggesting that production of pristane might be related to marine survival in PWS considered as a whole, but more monitoring years are necessary to determine whether this relationship can be established more clearly. Attempts to find consistent correlations between the index and marine survival of hatchery pink salmon at smaller spatial scales within PWS generally failed. However, a combination of pristane monitoring, zooplankton composition monitoring and predator monitoring near hatcheries may enable construction of a more robust index for forecasting recruitment of pink salmon to the PWS fishery through assessment of factors favoring survival during the initial phase of marine residence.

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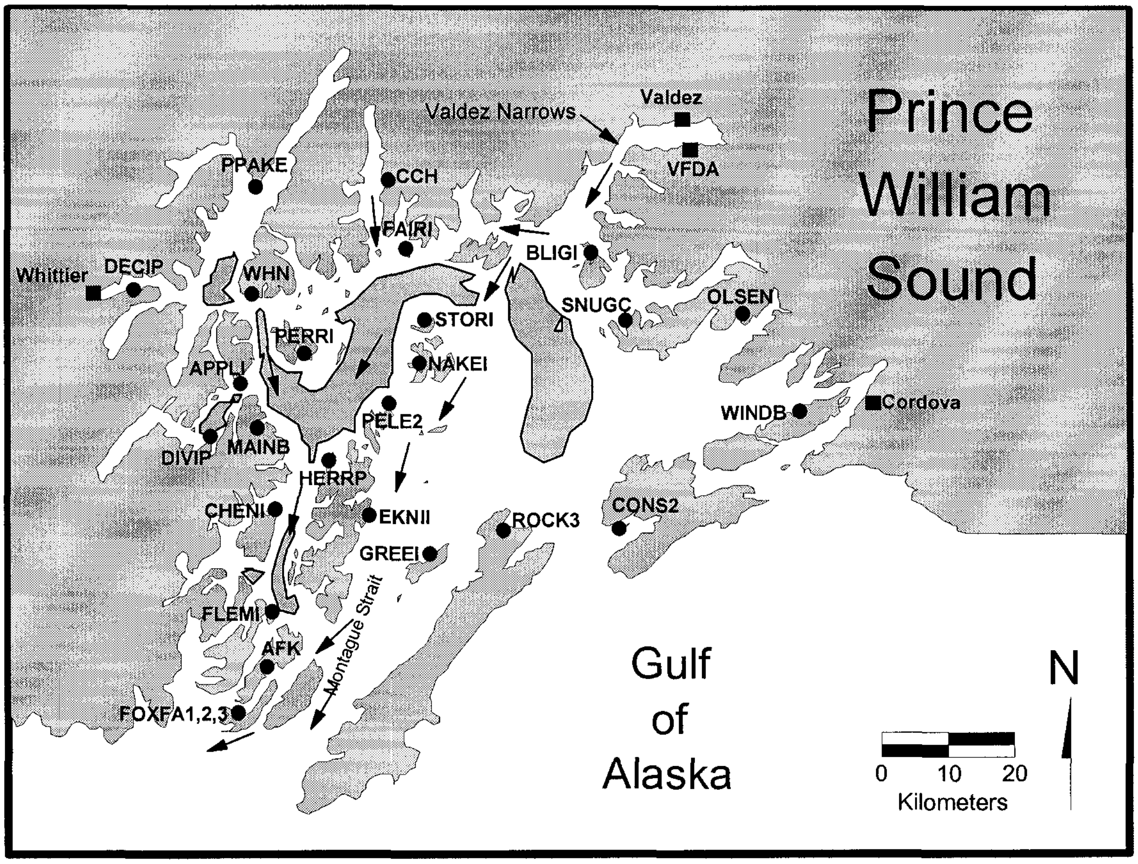

Figure 4.1. Mussel sampling stations in Prince William Sound, Alaska. Sampling stations denoted by filled circles (See Table 4.1 for abbreviations). Arrows indicate path of outmigrating juvenile pink salmon. Shaded areas indicate 400 m isobath (overwintering habitat for *Neocalanus spp.*) Filled squares indicate towns and VFDA hatchery. Other pink salmon hatcheries: AFK – Armin F. Koening, CCH – Cannery Creek, WHN – Wally H. Noerenburg.

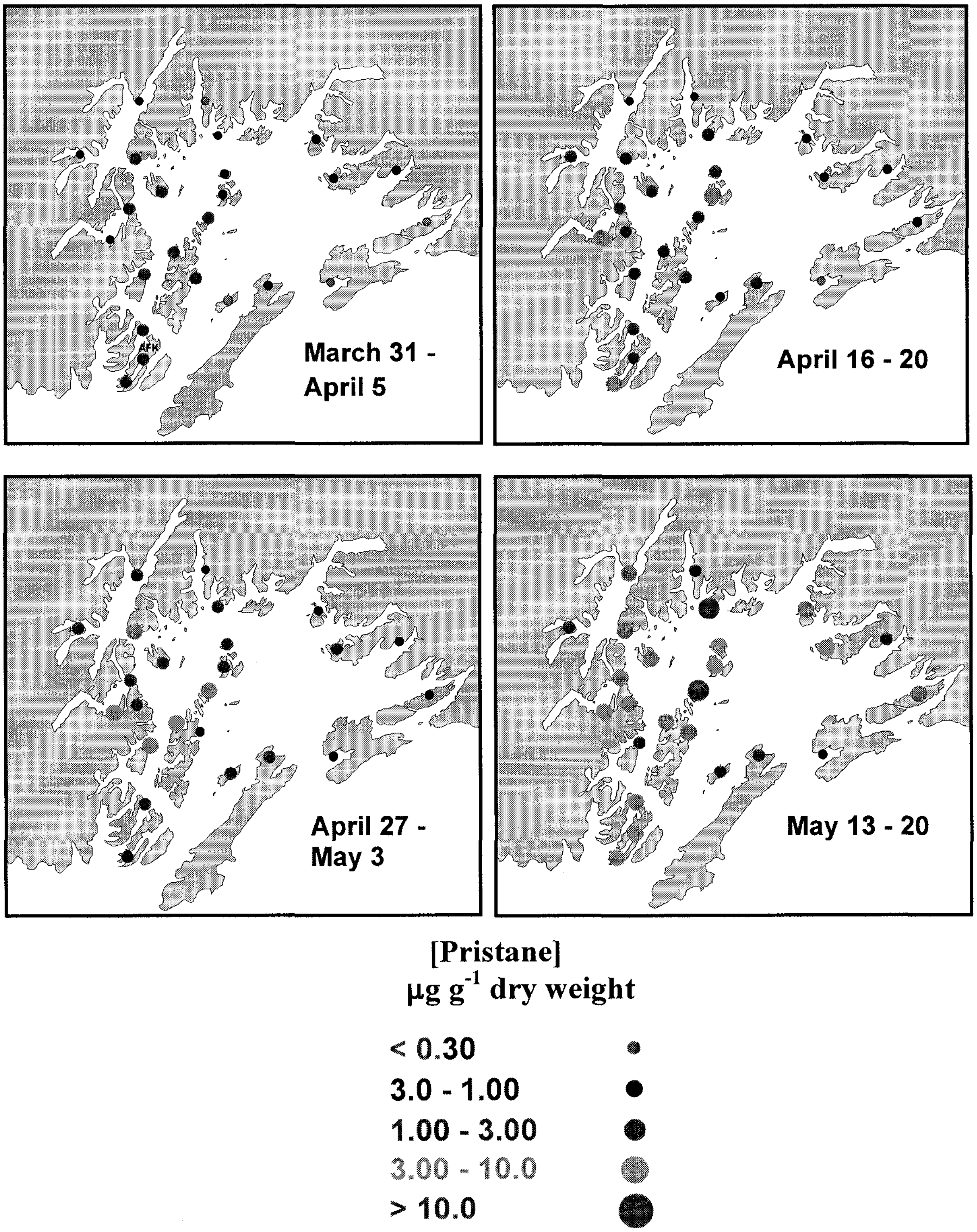

Figure 4.2. Pristane in mussels during April and May, 1995. Pristane concentrations at each station and sampling are coded according to the legend above.

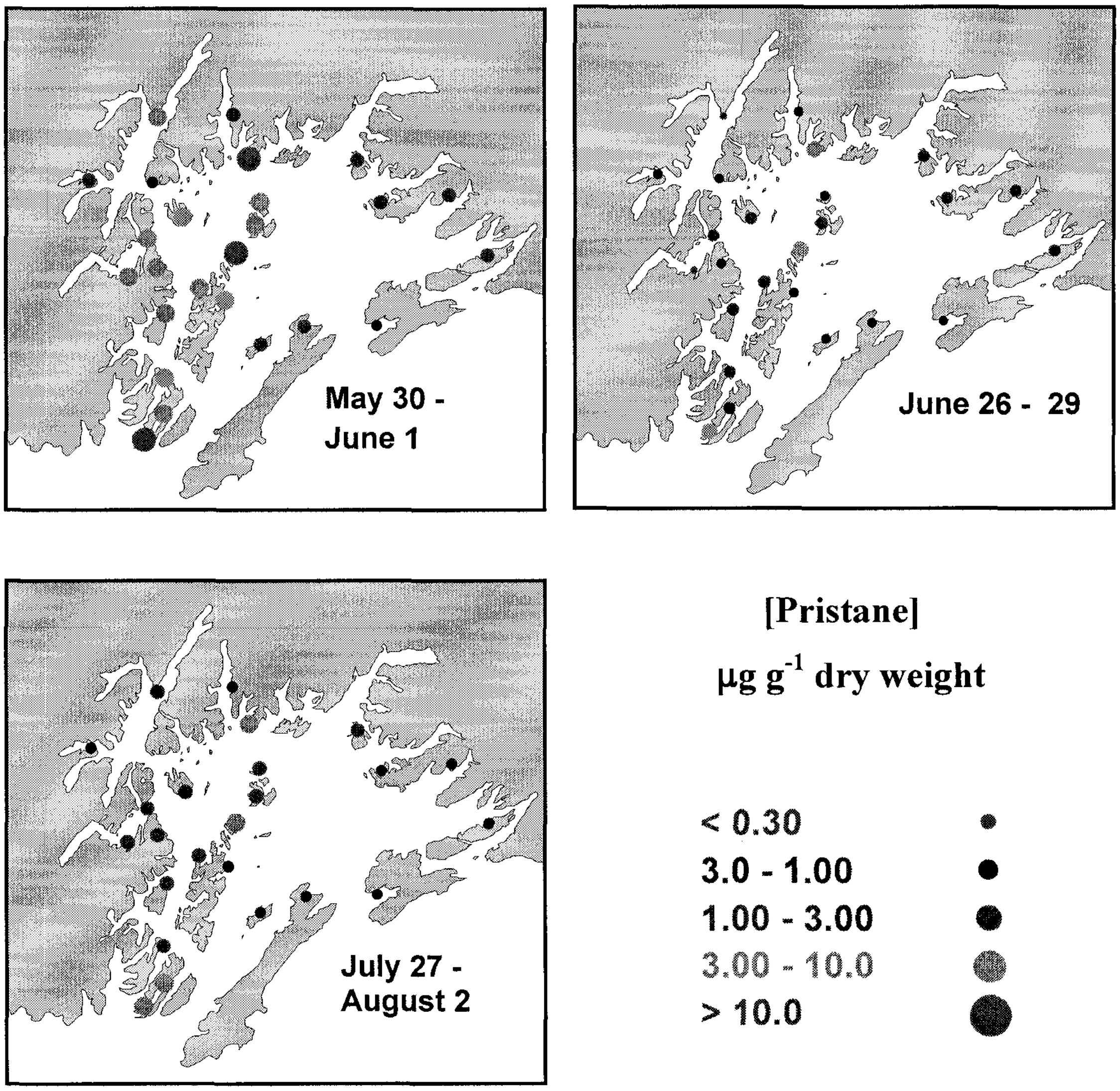

Figure 4.3. Pristane in mussels during late May through early August, 1995. Pristane concentrations at each station and sampling are coded according to the legend above.

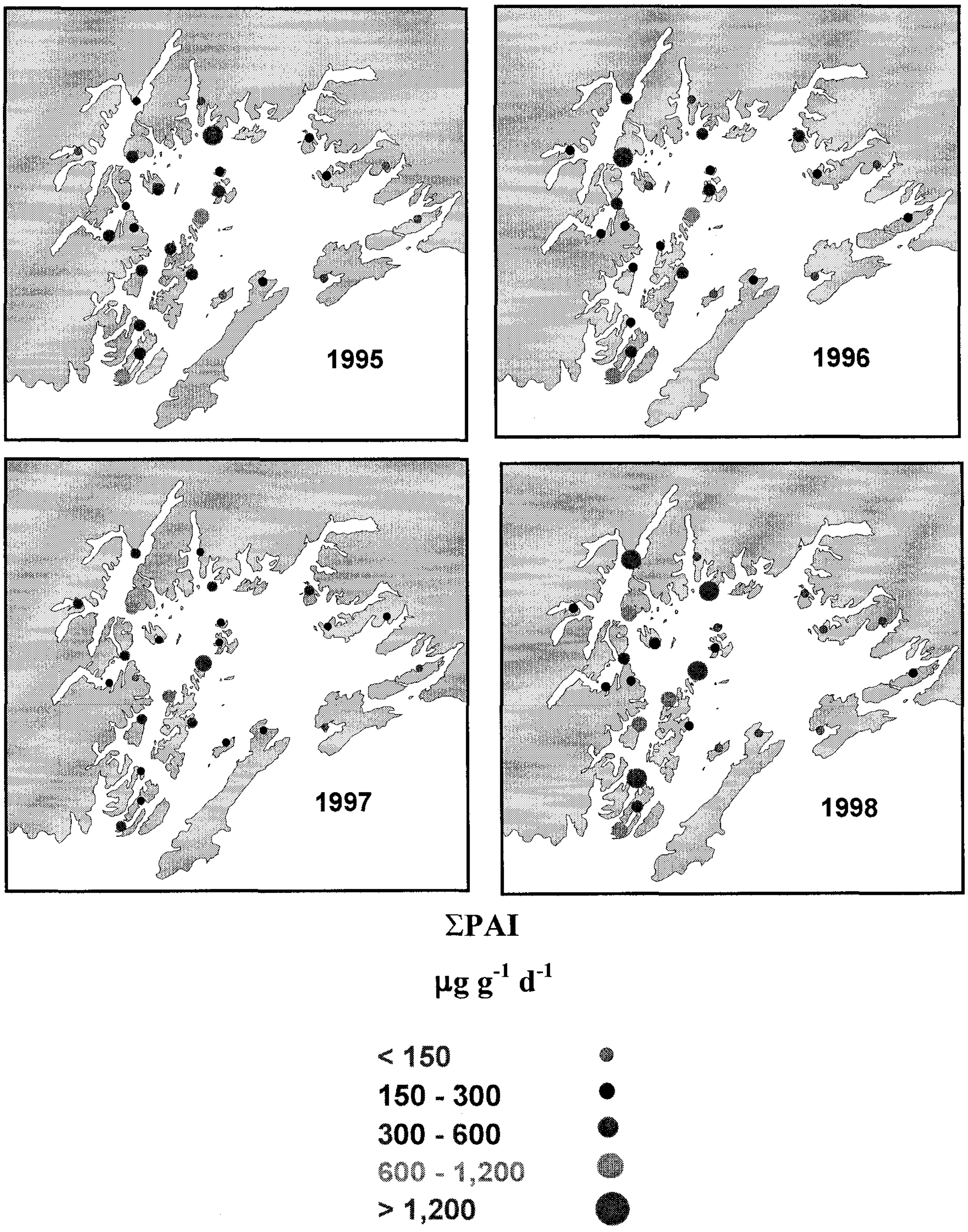

Figure 4.4. Pristane accumulation index (ΣPAI) for 1995 – 1998. Index values for each station are coded according to the legend above.

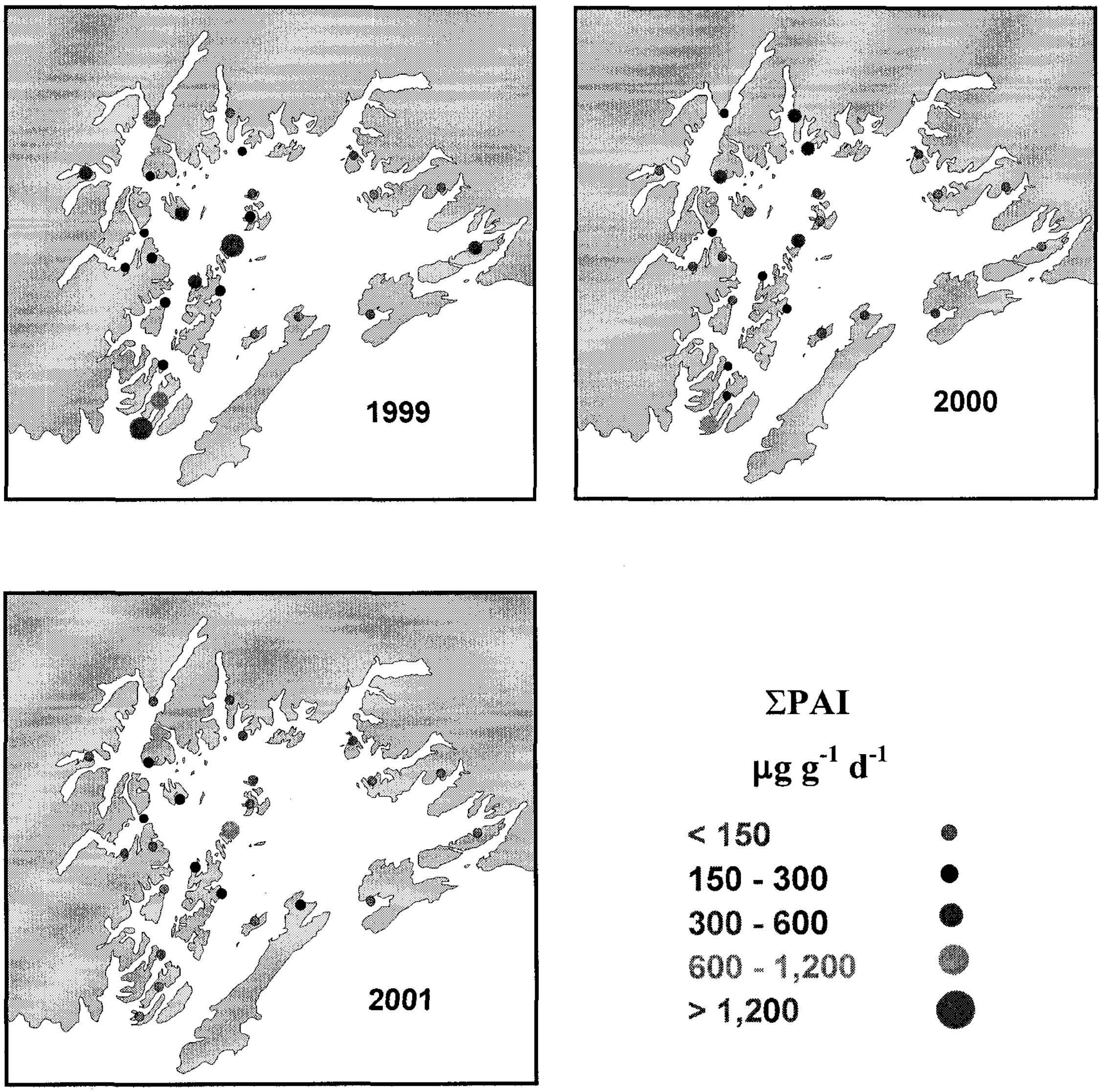

Figure 4.5. Pristane accumulation index (ΣPAI) for 1999 – 2001. Index values for each station are coded according to the legend above.

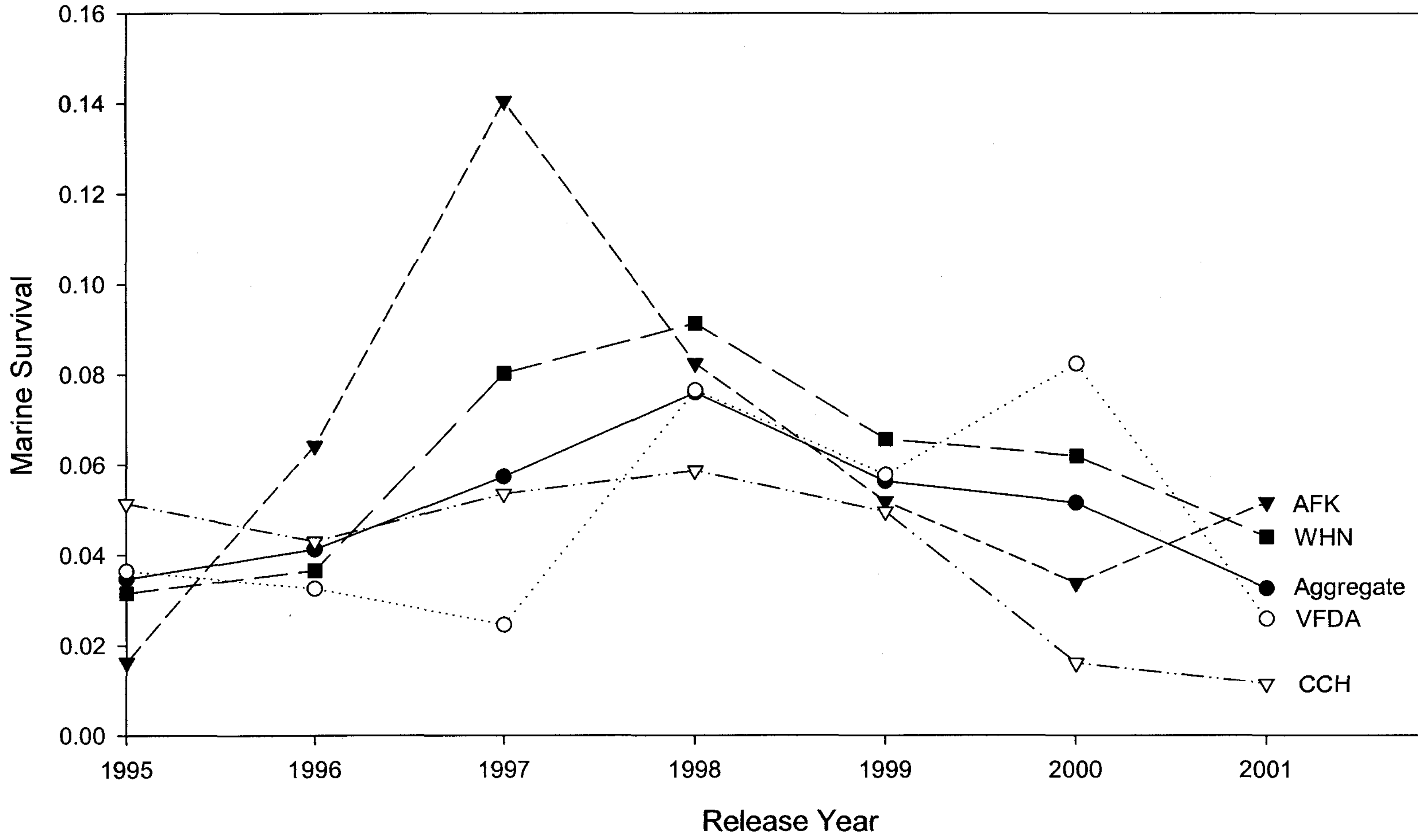

Figure 4.6. Marine survivals of pink salmon from PWS hatcheries. Salmon were released from the hatcheries on the year indicated, the year following the brood year. Hatchery abbreviations as in Figure 4.1. The aggregated marine survival of the four hatcheries combined is also indicated.

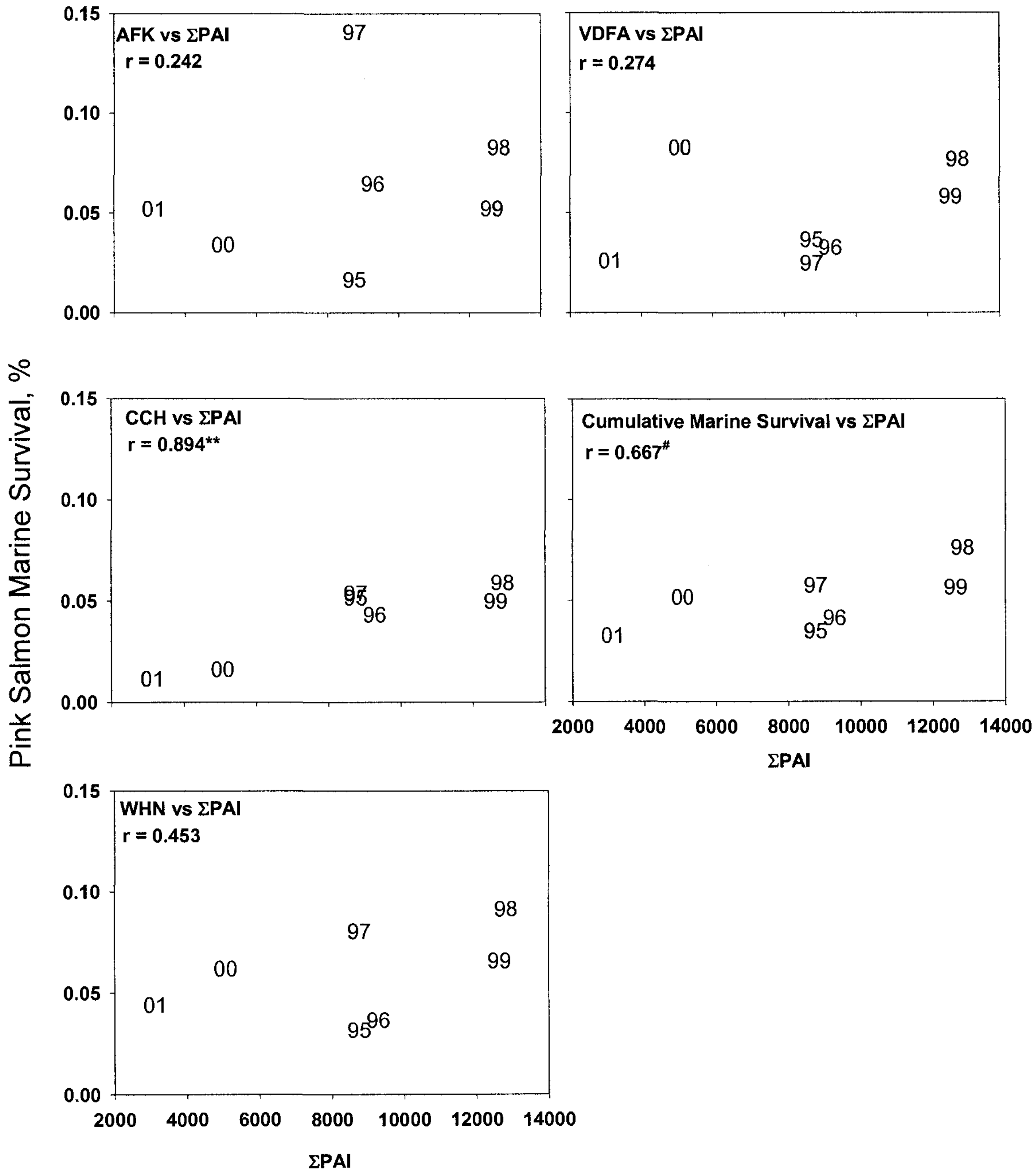

Figure 4.7. Correlation of pink salmon marine survival and pristane accumulation index (ΣPAI). The units of the ΣPAI are (μg pristane)-d. Statistical significance level of the correlation coefficient (r) is indicated by asterisks ($^{\#}$: P = 0.10, **: P < 0.01).

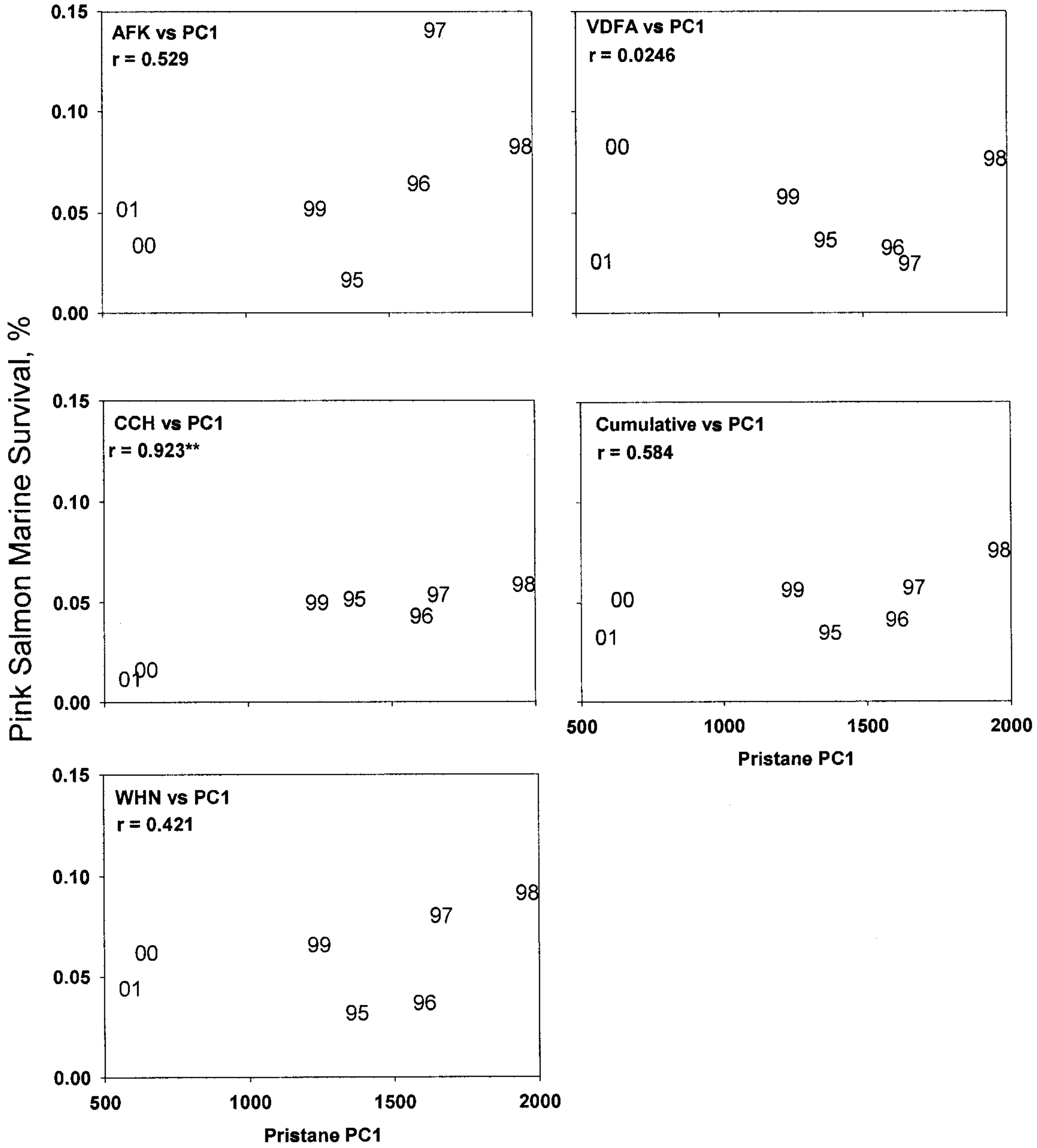

Figure 4.8. Correlation of pink salmon marine survival and the first principal component score of pristane concentrations in mussels (PC1). Statistical significance of the correlation coefficient (r) is indicated by asterisks (*: P = 0.10, **: P < 0.01).

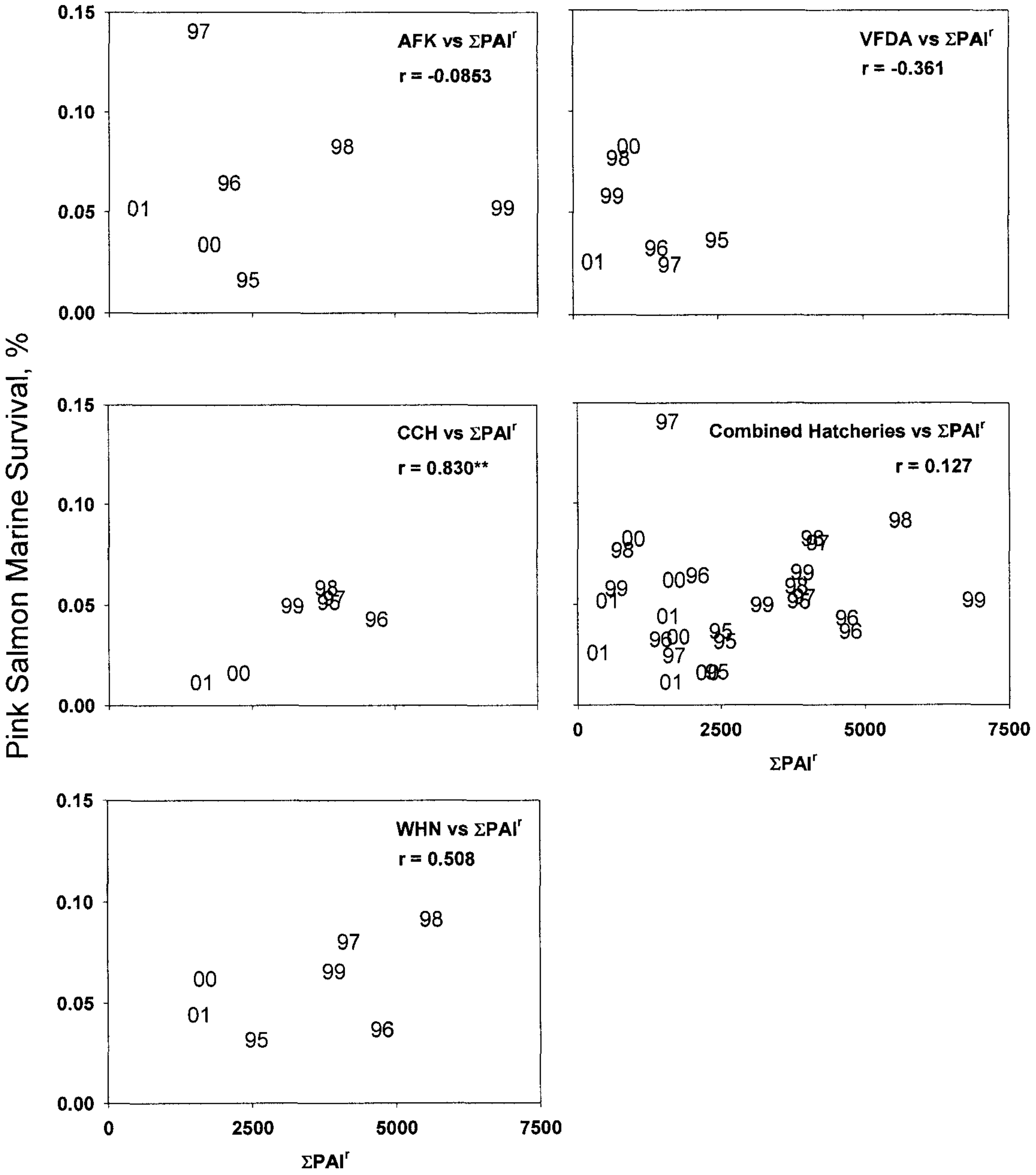

Figure 4.9. Correlation of pink salmon marine survival and the reduced pristane accumulation index (ΣPAI^r, see Methods). Statistical significance of the correlation coefficient (r) is indicated by asterisks (**: $P < 0.01$).

Table 4.1. Locations and abbreviations of mussel collection stations. The abbreviations are also used in Figure 4.1. PC1 refers to the station contributions to the first principal component of the seasonal variation of pristane concentration in mussels during the seven-year sampling period.

Station Abbreviation	**Station Name**	**Latitude**	**Longitude**	**PC1**
AFKHA	AFK Hatchery	60° 03' 08"N	148° 03' 30"W	0.098
APPLI	Applegate Island	60° 37' 30"	148° 08' 10"	0.252
BLIGI	Bligh Island	60° 52' 02"	146° 44' 59"	0.241
CANNC	Cannery Creek Hatchery	60° 59' 39"	147° 32' 19"	-0.095
CHENI	Chenega Island	60° 23' 11"	148° 00' 04"	0.182
CONSH	Constantine Harbor	60° 21' 16"	146° 40' 25"	0.256
DECIP	Decision Point	60° 48' 21"	148° 28' 35"	0.172
DIVIP	Division Point	60° 28' 55"	148° 17' 13"	0.231
EKNII	East Knight Island	60° 20' 49"	147° 38' 32"	0.308
ESTHI	Esther Is. (WN Hatchery)	60° 47' 07"	148° 03' 30"	0.223
FAIRI	Fairmont Island	60° 52' 51"	147° 26' 17"	0.094
FLEMI	Fleming Island	60° 10' 29"	148° 02' 03"	0.145
FOXF1	Fox Farm 1	59° 58' 15"	148° 08' 22"	-0.009
FOXF2	Fox Farm 2	59° 58' 07"	148° 06' 36"	-
FOXF3	Fox Farm 3	59° 58' 10"	148° 10' 22"	-
GREEI	Green Island	60° 16' 55"	147° 24' 57"	0.228
HERRP	Herring Point	60° 28' 28"	147° 47' 27"	0.233
MAINB	Main Bay	60° 32' 00"	148° 03' 30"	0.223
NAKEI	Naked Island	60° 39' 03"	147° 26' 24"	0.227
OLSEN	Olsen Bay	60° 44' 30"	146° 11' 58"	0.243
PELEA	Point Eleanor	60° 34' 33"	147° 33' 49"	0.186
PERRI	Perry Island	60° 40' 40"	147° 54' 50"	0.136
PPAKE	Point Pakenham	60° 00' 23"	148° 05' 07"	0.158
ROCKB	Rocky Bay	60° 20' 14"	147° 07' 32"	0.141
SNUGC	Snug Corner Cove	60° 44' 08"	146° 37' 32"	0.271
STORI	Storey Island	60° 43' 41"	147° 27' 02"	0.213
WINDB	Windy Bay	60° 34' 22"	145° 57' 29"	0.140

Table 4.2. Comparison of the pristane accumulation index PAI and marine survival of pink salmon.

Release Year	Number Released	Number Returning	Marine Survival	Pristane Accumulation Index (ΣPAI), μg g^{-1} d
1995	407,787,101	13,750,087	3.37%	8,670
1996	418,587,142	19,287,167	4.61%	9,200
1997	295,663,840	23,111,900	7.82%	8,670
1998	347,221,007	26,279,599	7.57%	12,600
1999	388,222,261	20,475,091	5.27%	12,600
2000	390,843,348	14,012,760	3.59%	4,990
2001	417,164,895	14,964,789	3.59%	3,130

GENERAL CONCLUSIONS

Comparison of the distribution of pristane concentrations among the biota samples analyzed for the 1989 *Exxon Valdez* oil spill (EVOS) with concentrations in *Neocalanus* copepods confirms these copepods are the dominant source of pristane in the marine food web of PWS (Short in prep [a]). Other potential biological sources, such as zooplankton in genera other than *Neocalanus* or *Calanus*, are negligible in comparison to the magnitude of pristane introduced annually by *Neocalanus sp.*, and catastrophic inputs from anthropogenic sources such as the EVOS are rare but may be comparable during the years that such catastrophes occur.

The main ecological pathway followed by pristane from *Neocalanus* to mussels involves ingestion of pristane-laden feces produced by near-shore zooplanktivores that prey on *Neocalanus* (Short in prep [b]). This pathway can account for large (i.e. hundred-fold or greater) increases of pristane concentrations in mussels. Juvenile pink salmon are often the most important of the zooplanktivores that mediate this transfer because of their preference for habitats that are very close to shorelines during the initial phase of their marine residence, when they may defecate directly on mussel beds during high tides. Mussels may also accumulate smaller increases of pristane from the dissolved state (Short in prep [c]), or from fecal pellets produced by *Neocalanus* when abundances of these copepods are high.

Biosynthesis of pristane may afford *Neocalanus* and *Calanus* copepods a measure of chemical protection from predation, because of the inhibitory effect of pristane on growth of juvenile fishes (Short in prep [c]). Compared with alternative prey, juvenile salmonids that prey mostly on *Neocalanus* copepods experience markedly slower growth per unit ingested ration (Short in prep [c], Luquet et al. 1983, 1984), which may prolong exposure of juveniles to size-selective predation by their predators. Any resulting increase in mortality would decrease predation pressure on *Neocalanus* copepods. Hence, the nutritive value of these copepods may be substantially lower than is usually assumed, not only in PWS, but throughout the North Pacific and North Atlantic oceans as well, where these two taxa are seasonally common potential forage for zooplanktivores (Parsons and Lalli 1988).

The inhibitory effect of pristane on salmonid growth complicates interpretation of the relation between pristane increases in mussels during spring and the marine survival of juvenile pink salmon in PWS. Absent this effect, large increases of pristane in mussels on shorelines near salmon hatcheries or near reproductive habitat of wild pink salmon would imply favorable conditions for carbon transfer from *Neocalanus* to pink salmon and other zooplanktivores, because of the concurrently high abundances of *Neocalanus* and of zooplanktivores necessary for large increases of pristane in mussels to occur. However, growth-inhibition by pristane suggests that these abundant forage conditions may not translate into favorable survival conditions, if juveniles consuming *Neocalanus* are more vulnerable to predation when predators are abundant.

Despite the complications introduced by the inhibitory effect of pristane on salmonid growth, comparison of an integrative index of pristane accumulation by mussels throughout PWS with the combined survivals of hatchery pink salmon was suggestive if not statistically significant (Short in prep [d]). A more focussed monitoring program that tracks zooplankton composition and predator abundance, when combined with a region-wide index of zooplankton abundance might be more readily related to the marine survival of pink salmon, which has the potential to improve management of the fishery through prediction of recruitment at some level of significant accuracy.

Several lines of inquiry developed in this dissertation deserve further exploration. First, the distribution of pristane among copepod taxa may provide insight into the utility, if any, of this hydrocarbon to copepods. I have argued herein that pristane may afford a measure of chemical defense against predation for copepods, but this argument may implicitly involve a problematical relation with the notion of group selection. Knowledge of which copepod genera and species produce pristane concentrations that are comparable with those reported here for *Neocalanus spp.* might provide clues to evolutionary and geographic relationships that may elucidate the utility of pristane, and may also serve to suggest which populations of predators of these copepods are at risk to growth inhibition when preying on them. Currently, the pristane content of about half the species of *Calanus* and *Neocalanus* has been measured, and only one report for one species, *Calanus helgolandicus*, has indicated pristane concentrations that are substantially below those of the other species examined (Prahl et al. 1984). *Calanus helgolandicus* is a temperate-water species (Mauchline 1998), so it may be that high pristane concentrations in *Calanus* and *Neocalanus* copepods are limited to sub-arctic and arctic species. This suggests persuit of a second line of inquiry, namely the determination of which species and taxa of copepod predators are vulnerable to growth inhibition by pristane. Growth inhibition has been definitely established only in two species of salmonids to date (Short in prep [c], Luquet et al. 1983, 1984), but *Calanus* and *Neocalanus* copepods are prey for a wide variety of predators, many of which are commercially important.

Taxonomic patterns of vulnerability to growth inhibition by pristane would not only indicate which commercially or ecologically important species may be affected, but may also provide insights into a third line of inquiry, which is the biochemical mechanism of growth inhibition in affected predators. These two inquiries are related, in that knowledge of the biochemical pathways may suggest vulnerable species, and insights from other taxa may be crucial for elucidation of the biochemical pathways. Finally, knowledge of the lifetime and the biochemical fate of pristane in biota would be helpful to refine the utility of pristane as a food-web probe. Although the overall depuration rate of pristane from rainbow trout has been examined (LeBon et al. 1987, 1988a, 1988b), the persistence of pristane in storage compartments may be considerably longer than would be expected from an overall depuration rate. If so, sampling that is focussed on storage lipids may have considerable advantages for providing evidence of direct or indirect food-web dependence on *Calanus* or *Neocalanus* copepods, with the potential to provide evidence to complement results from other approaches to food web analysis such as methods based on stable elemental isotopes or analysis of fatty acids. This potential for complementing existing methods derives from the fact that pristane analysis may serve to identify more precisely which branch of a complicated marine food web is important to the predator species analyzed, if *Calanus* or *Neocalanus* copepods are important in the food web under consideration.

Advances in these lines of suggested research may have important consequences for our understanding of how marine ecosystems function. A substantial fraction of primary productivity in the world's oceans is captured by *Calanus* and *Neocalanus* copepods (Parsons and Lalli 1988), at least in arctic and sub-arctic waters where productivity is often high. If growth inhibition by pristane is widespread among predator taxa of these copepods, the capacity of these marine ecosystems to support biota in upper trophic levels may require significant adjustment to a somewhat lower estimate.

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Short JW (in prep [b]) Accumulation of pristane by mussels (*Mytilus trossulus*) mediated by juvenile pink salmon (*Oncorhynchus gorbuscha*) predation on *Neocalanus* copepods II: field study. For submission to Mar Ecol Prog Ser

Short JW (in prep [a]) Pristane in the neritic ecosystem of the northern Gulf of Alaska. For submission to Mar Ecol Prog Ser

Short JW (in prep [c]) Accumulation of pristane by mussels (*Mytilus trossulus*) mediated by juvenile pink salmon (*Oncorhynchus gorbuscha*) predation on *Neocalanus* copepods I: laboratory study. For submission to Mar Ecol Prog Ser

Short, JW (in prep [d]) Relationship between pristane accumulation by mussels (*Mytilus trossulus*) and marine survival of pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska. For submission to Mar Ecol Prog Ser

Appendix 1. Concentrations of pristane in zooplankton. Samples were collected in Prince William Sound (PWS) or in Southeastern Alaska (SEAK). Sample number identifies the sample in an archival database at the Auke Bay Laboratory, where additional sampling information may be found. The number of individual zooplankters pooled together for analysis is also indicated (Ind.).

Species	Collection Location	Ind.	Sample Number	Collection Date	Wet Wt. (mg)	Dry Wt. (mg)	[Pristane] (μg g^{-1})
Chiridius sp.	PWS	25	903110	18-Jul-98	41.0	6.91	15.6
Calanus marshallae	SEAK	1	507525	25-Jun-91	24.5	19.3	6,389
CV & Adult Female		1	507543	25-Jun-91	63.1	17.5	5,628
		1	507544	25-Jun-91	32.9	15.2	6,242
Calanus marshallae	PWS	1	1100707	06-May-00	1.79	0.410	7,304
CV		1	1100708	06-May-00	2.05	0.600	6,344
		1	1100709	06-May-00	2.59	0.790	6,547
		1	1100710	06-May-00	25.7	0.750	5,449
		1	1100711	06-May-00	1.26	0.290	6,487
		1	1100712	06-May-00	1.80	0.800	6,660
Calanus marshallae	PWS	1	1100713	06-May-00	0.670	0.150	606
CIV		1	1100714	06-May-00	0.590	0.090	1,032
		1	1100715	06-May-00	0.430	0.110	1,622
Eucalanus bungii	SEAK	1	507526	26-Jun-91	11.3	10.7	107
CV & Adult Female		1	507545	26-Jun-91	13.4	4.30	205
		1	507546	26-Jun-91	16.7	9.80	61.6
Euchaeta elongata	SEAK	1	507548	18-Jun-91	29.5	18.0	600
CV & Adult Female		1	507527	28-Jun-91	21.3	20.0	388
		1	507547	28-Jun-91	20.2	12.8	455
	PWS	2	903102	19-Jul-98	7.16	2.18	24.0
		2	903103	19-Jul-98	10.7	2.31	23.6
Metridia pacifica Female	PWS	28	903113	18-Jul-98	19.8	1.99	30.8
Metrida okhotensis	SEAK	1	507528	28-Jun-91	14.4	13.6	672
CV & Adult Female		1	507549	28-Jun-91	36.5	7.10	660
		1	507550	28-Jun-91	44.9	11.6	509
Metridia lucens	SEAK	1	507530	27-Jun-91	9.40	9.20	121
CV & Adult Female		1	507553	27-Jun-91	19.9	11.4	86.6
		1	507554	27-Jun-91	39.8	13.6	74.8
Neocalanus cristatus	SEAK	1	507524	28-Jun-91	34.1	7.80	3,965
CV & Adult Female		1	507541	28-Jun-91	23.5	8.40	6,072
		1	507542	28-Jun-91	18.9	6.20	4,460
Neocalanus cristatus	PWS	1	1100251	06-May-00	5.87	0.650	2,436
CV		1	1100252	06-May-00	13.9	1.17	1,958
		1	1100253	06-May-00	15.9	3.62	5,190
		1	1100254	06-May-00	10.8	1.11	2,781
		1	1100706	06-May-00	17.9	1.46	2,055

Appendix 1 (cont'd)

Neocalanus plumchrus	SEAK	1	507529	28-Jun-91	9.00	8.50	7,895
CV & Adult Female		1	507551	28-Jun-91	40.6	15.0	6,982
		1	507552	28-Jun-91	18.0	6.30	11,261
Neocalanus plumchrus		1	1100239	06-May-00	3.03	1.14	5,534
CV	PWS	1	1100240	06-May-00	4.66	1.98	8,159
		1	1100241	06-May-00	2.40	0.620	8,846
		1	1100242	06-May-00	2.48	0.790	8,019
		1	1100243	06-May-00	1.87	0.560	4,012
Neocalanus plumchrus	PWS	1	1100244	06-May-00	1.35	0.380	6,705
CIV		1	1100245	06-May-00	1.63	0.290	2,858
		1	1100246	06-May-00	1.33	0.450	5,620
		1	1100247	06-May-00	1.38	0.260	2,663
		1	1100248	06-May-00	0.880	0.300	4,432
Neocalanus plumchrus	PWS	4	1100249	06-May-00	0.880	0.310	731
CIII							
Pseudocalanus sp.	PWS	16	1100250	06-May-00	1.74	0.690	117
Thysanoessa inermis	PWS	1	903134	21-May-98	91.0	36.5	34.8
		1	903134	21-May-98	106	28.7	43.2
Thysanoessa raschii	PWS	1	903133	10-Jun-98	96.7	24.9	9.09
Thysanoessa spinifera	PWS	1	903131	19-Jul-98	114	33.2	1.84
		1	903131	19-Jul-98	87.7	23.1	5.00

Appendix 2. Concentrations of pristane in biota of the northwestern Gulf of Alaska. Samples were collected and analyzed for the 1989 *Exxon Valdez* oil spill, and are archived in the *Exxon Valdez* Oil spill of 1989 State/Federal Trustee Council Hydrocarbon Database (EVTHD) at the Auke Bay Laboratory. Sample number identifies the sample in this database, where additional sampling information may be found.

Group	Species	Matrix	Sample Number	Collection Date	Wet Weight (g)	Dry Weight (g)	[Pristane] (μg g^{-1})
I. Birds							
	Bald Eagle						
		Eggs	21920	7/27/1990	1.010	0.150	16.344
			21931	6/5/1990	1.020	0.150	18.919
			23579	7/6/1990	1.020	0.160	1.165
			20052	6/11/1989	1.030	0.180	4.846
			21934	7/6/1990	1.030	0.150	30.408
			23578	7/6/1990	1.050	0.170	2.459
			21936	7/6/1990	1.070	0.220	30.793
			21937	7/6/1990	1.070	0.200	27.964
			20053	7/6/1989	1.100	0.170	2.612
			21935	7/6/1990	1.150	0.200	19.150
			23576	7/6/1990	1.180	0.190	26.770
			23577	7/6/1990	1.250	0.180	12.264
			20022	5/30/1989	5.000	0.778	10.578
			20025	6/1/1989	5.000	0.952	18.007
			20027	6/1/1989	5.000	0.841	27.362
			20196	7/2/1989	5.000	0.673	21.923
			21358	6/1/1990	5.000	0.962	9.389
			21362	6/4/1990	5.000	1.037	39.546
			21364	6/5/1990	5.000	0.782	16.301
			21354	6/1/1990	5.010	0.984	46.780
			20028	5/25/1989	5.020	0.774	20.403
			20192	7/8/1989	5.020	0.952	12.688
			20188	7/17/1989	5.030	1.086	5.746
			20020	5/30/1989	5.040	0.993	5.555
			20046	6/8/1989	5.040	0.662	62.172
			20034	6/17/1989	5.040	1.115	31.755
			20190	7/17/1989	5.040	1.042	4.728
			20037	6/18/1989	5.050	1.047	7.436
			20194	7/7/1989	5.050	1.085	4.929
			21360	6/4/1990	5.050	0.959	46.416
			20062	6/13/1989	5.060	0.712	9.316
			21356	6/1/1990	5.060	1.005	44.276
			20534	6/8/1989	5.070	0.674	34.097

Appendix 2 (cont'd)

Barrow's Goldeneye	Liver	21301	1/8/1990	1.000	0.336	1.029
		21023	1/8/1990	1.010	0.334	1.226
		20990	2/1/1990	1.010	0.298	1.157
		21020	1/8/1990	1.020	0.329	ND
		21304	1/8/1990	1.040	0.341	0.314
		20825	1/12/1990	1.120	0.338	0.925
Black-Legged Kittiwake	Eggs	20380	8/6/1989	1.110	0.210	61.663
		24433	7/30/1990	5.000	1.960	1.510
		24429	7/30/1990	5.010	2.180	23.750
		24431	7/30/1990	5.020	1.550	5.701
		24435	7/30/1990	5.020	1.380	4.445
	Liver	28433	11/8/1990	1.820	0.530	168.533
		28043	12/5/1990	1.860	0.670	106.392
		28049	12/5/1990	1.880	0.550	18.999
		20414	8/12/1989	1.935	0.575	137.482
		28361	11/8/1990	1.940	0.640	103.361
		28391	11/8/1990	1.960	0.550	88.801
		20420	8/12/1989	1.981	0.689	13.265
		20419	8/12/1989	1.996	0.629	764.474
		20394	8/12/1989	2.009	0.695	25.012
		20411	8/12/1989	2.014	0.638	87.071
		20393	8/12/1989	2.019	0.652	587.948
		20391	8/12/1989	2.032	0.662	226.823
		20413	8/12/1989	2.040	0.675	144.276
		28031	12/4/1990	2.060	0.630	2.371
		28397	11/8/1990	2.080	0.710	319.016
		20386	8/12/1989	2.092	0.684	214.284
		20390	8/12/1989	2.135	0.728	568.277
Black Turnstone	Liver	24537	8/11/1989	0.520	0.170	0.367
		24529	8/11/1990	0.920	0.330	0.771
		24503	8/11/1989	1.050	0.380	6.445
		20509	1/9/1990	1.422	0.523	5.106
		24508	8/11/1989	1.500	0.570	40.426
		24513	8/11/1989	1.540	0.550	0.648
		24500	8/11/1989	1.600	0.540	0.144
		20513	1/9/1990	2.007	0.708	5.671
		24533	8/11/1989	2.020	0.740	1.858
		24521	8/11/1989	2.040	0.690	1.047
Common Goldeneye	Liver	20987	1/31/1990	1.020	0.279	0.623
		20117	12/3/1989	1.040	0.331	0.233
		20911	1/7/1990	1.040	0.303	0.944
		20119	12/3/1989	1.070	0.301	0.266

Appendix 2 (cont'd)

		21035	12/2/1989	1.120	0.362	1.322
Common Loon	Liver	21487	4/29/1989	2.040	0.629	228.688
Fork-Tailed Storm Petrel	Eggs	24484	7/30/1990	0.680	0.330	968.702
		24489	7/30/1990	1.080	0.600	600.173
		21375	7/6/1989	1.390	0.370	752.180
		24463	7/30/1990	1.460	0.600	978.006
		21374	7/6/1989	1.720	0.420	1624.110
		24465	7/30/1990	1.870	0.890	558.020
		24481	7/30/1990	2.240	1.190	29.665
		24471	7/30/1990	2.500	1.120	119.229
		24476	7/30/1990	2.500	0.870	905.813
		24468	7/30/1990	2.870	1.100	330.600
		24480	7/30/1990	3.060	1.160	313.321
		24458	7/30/1990	3.500	0.580	519.499
		24470	7/30/1990	3.540	1.000	1292.731
		24473	7/30/1990	3.640	0.990	280.508
		24461	7/30/1990	4.050	1.600	557.137
		24492	7/30/1990	4.200	2.670	353.087
		24478	7/30/1990	4.950	1.340	390.558
		24474	7/30/1990	5.090	1.340	150.430
		24487	7/30/1990	5.190	1.760	3.072
Harlequin Duck	Liver	20972	9/15/1989	0.660	0.209	2.500
		21005	1/15/1990	1.000	0.299	0.403
		21028	9/15/1989	1.010	0.310	1.669
		20042	9/15/1989	1.010	0.308	0.216
		20733	9/27/1989	1.010	0.305	ND
		21002	1/15/1990	1.010	0.295	0.830
		20999	1/15/1990	1.010	0.281	0.253
		20917	9/15/1989	1.020	0.266	0.405
		21014	1/15/1990	1.050	0.328	ND
		20830	9/15/1989	1.060	0.335	0.727
		21032	12/3/1989	1.060	0.357	ND
		20993	1/15/1990	1.060	0.327	0.356
		20735	9/27/1989	1.070	0.331	ND
		21031	12/3/1989	1.070	0.352	ND
		21011	7/17/1990	1.070	0.317	ND
		21025	9/15/1989	1.080	0.321	2.201
Marbled Murrelet	Liver	24256	8/3/1990	1.240	0.350	172.603
		24259	8/3/1990	1.750	0.520	34.941
		20426	8/12/1989	1.993	0.646	99.059
		24271	8/3/1990	2.000	0.600	101.862
		20421	8/12/1989	2.009	0.645	44.298
		24268	8/3/1990	2.020	0.640	192.664

Appendix 2 (cont'd)

		20422	8/12/1989	2.023	0.629	33.048
		24223	8/3/1990	2.030	0.630	120.042
		24274	8/3/1990	2.030	0.590	280.000
		24247	8/3/1990	2.030	0.530	213.845
		24226	8/3/1990	2.040	0.650	105.562
		24229	8/3/1990	2.050	0.650	29.554
		24238	8/3/1990	2.050	0.590	1.764
		24244	8/3/1990	2.050	0.550	44.371
		24232	8/3/1990	2.060	0.620	6.625
		24250	8/3/1990	2.060	0.580	29.443
		20425	8/12/1989	2.068	0.668	8.698
		20428	8/12/1989	2.081	0.643	253.711
		20429	8/12/1989	2.088	0.689	47.008
		24235	8/3/1990	2.090	0.630	97.615
		24253	8/3/1990	2.090	0.600	222.098
		24241	8/3/1990	2.100	0.660	46.035
		24265	8/3/1990	2.100	0.600	3.858
		20424	8/12/1989	2.106	0.697	25.536
		24262	8/3/1990	2.120	0.610	46.051
		20423	8/12/1989	2.131	0.731	40.438
		20427	8/12/1989	2.154	0.659	313.954
Peregrine Falcon						
	Eggs	21975	6/1/1990	5.000	0.880	0.163
		20809	6/2/1990	5.010	0.870	1.035
		20286	6/23/1990	5.010	0.970	1.541
		20569	5/23/1990	5.020	0.960	1.571
		20378	7/30/1990	5.040	1.000	ND
		20818	5/20/1990	5.050	0.850	ND
		20812	5/23/1990	5.050	0.920	1.592
		20815	5/30/1990	5.070	0.860	0.546
		20572	5/19/1990	5.090	0.950	0.679
		21807	6/1/1990	5.130	0.830	ND
		21969	5/18/1990	5.180	0.970	4.705
		21980	6/2/1990	5.410	0.950	12.163
Pigeon Guillemot						
	Liver	20399	11/2/1989	2.196	0.670	1.149
		20400	11/2/1989	2.208	0.818	3.668
		20397	11/2/1989	2.277	0.793	0.507
		20398	11/2/1989	2.327	0.779	0.129
		20396	11/2/1989	2.342	0.804	64.493
Shearwater						
	Liver	21492	5/11/1989	0.520	0.153	1961.982
Surfbird						
	Liver	20521	1/9/1990	2.324	0.739	7.402
		20525	1/9/1990	2.566	0.875	19.096
		20505	1/9/1990	2.872	0.988	12.859

Appendix 2 (cont'd)

	Surf Scoter						
		Liver	20822	9/27/1989	1.000	0.283	ND
			20741	9/27/1989	1.010	0.288	ND
			20875	1/8/1990	1.080	0.319	1.013
	White-winged Scoter						
		Liver	20828	1/8/1990	1.010	0.307	1.796
			20153	12/3/1989	1.020	0.303	0.234
			20198	12/3/1989	1.040	0.303	0.232
			20126	12/3/1989	1.050	0.336	ND
			20210	12/3/1989	1.080	0.346	0.333
			20128	12/3/1989	1.080	0.300	0.374
II. Fish							
	Black Prickleback						
		Whole	194002	6/11/1990	1.050	0.280	13.251
			194005	6/23/1990	2.170	0.450	9.132
			194011	6/28/1990	2.230	0.450	6.401
	Dusky Rockfish						
		Whole	10321	10/17/1989	5.120	1.410	34.632
			10322	10/17/1989	4.190	1.160	66.635
			10320	10/17/1989	3.840	1.030	5.046
	Herring						
		Eggs	1608	4/28/1989	2.687	1.155	4.298
			1606	4/28/1989	2.171	0.786	14.362
			1607	4/28/1989	2.570	0.686	7.607
			1616	4/28/1989	2.368	0.308	18.257
			1618	4/28/1989	2.272	0.295	19.245
			1614	4/28/1989	2.148	0.288	18.667
			1612	4/28/1989	2.230	0.277	18.007
			1615	4/28/1989	2.189	0.271	15.436
			1619	4/28/1989	2.009	0.271	20.544
			1620	4/28/1989	2.109	0.268	19.007
			1613	4/28/1989	2.131	0.266	13.244
			1611	4/28/1989	2.102	0.254	15.491
			1610	4/28/1989	2.048	0.240	16.742
			1609	4/28/1989	2.092	0.236	14.982
			1617	4/28/1989	2.093	0.228	13.972
			2144	5/2/1989	5.407	0.633	14.748
			2146	5/2/1989	5.574	0.591	15.521
			2145	5/2/1989	5.174	0.554	15.624
			2169	5/2/1989	2.303	0.274	13.605
			2156	5/2/1989	2.155	0.267	15.568
			2157	5/2/1989	2.296	0.262	13.405
			2159	5/2/1989	2.225	0.254	12.469
			2147	5/2/1989	2.314	0.248	13.737
			2158	5/2/1989	2.050	0.248	13.726
			1884	5/2/1989	2.131	0.247	13.189

Appendix 2 (cont'd)

2168	5/2/1989	2.014	0.246	10.481
2154	5/2/1989	2.230	0.245	13.946
2165	5/2/1989	2.216	0.244	15.000
2149	5/2/1989	2.249	0.241	15.436
2155	5/2/1989	2.099	0.239	14.180
2141	5/2/1989	2.135	0.235	14.997
2150	5/2/1989	2.043	0.231	15.234
2142	5/2/1989	2.086	0.227	13.500
2151	5/2/1989	2.111	0.226	17.042
2160	5/2/1989	2.112	0.224	11.880
2153	5/2/1989	2.076	0.220	13.041
2163	5/2/1989	2.034	0.220	11.926
2152	5/2/1989	2.034	0.216	15.178
2148	5/2/1989	2.070	0.215	14.600
2161	5/2/1989	2.028	0.213	11.627
2166	5/2/1989	2.045	0.213	13.534
2162	5/2/1989	2.022	0.212	11.319
2167	5/2/1989	2.012	0.211	12.015
2164	5/2/1989	2.020	0.208	11.557
2143	5/2/1989	2.010	0.205	14.280
1928	5/3/1989	2.287	0.910	3.210
1929	5/3/1989	2.527	0.601	4.525
1927	5/3/1989	2.355	0.257	10.535
1920	5/3/1989	2.342	0.255	14.541
1921	5/3/1989	2.084	0.238	41.792
1918	5/3/1989	2.169	0.232	14.587
1923	5/3/1989	2.130	0.232	115.731
1926	5/3/1989	2.050	0.232	12.642
1922	5/3/1989	2.034	0.220	26.013
1915	5/3/1989	2.168	0.217	10.845
1932	5/3/1989	2.102	0.217	12.631
1931	5/3/1989	2.090	0.215	13.329
1919	5/3/1989	2.016	0.214	14.664
1925	5/3/1989	2.067	0.213	12.354
1930	5/3/1989	2.087	0.213	13.876
1924	5/3/1989	2.031	0.211	9.340
1916	5/3/1989	2.117	0.202	10.492
1917	5/3/1989	2.088	0.192	10.498
1955	5/4/1989	5.481	0.691	15.685
1954	5/4/1989	5.452	0.687	14.314
1953	5/4/1989	5.058	0.622	15.148
1962	5/4/1989	2.906	0.369	15.581
1963	5/4/1989	2.434	0.295	16.701
1968	5/4/1989	2.282	0.288	16.312
1961	5/4/1989	2.102	0.282	12.831
1960	5/4/1989	2.026	0.276	12.631
1957	5/4/1989	2.183	0.273	15.191
1959	5/4/1989	2.091	0.272	12.687
1964	5/4/1989	2.287	0.272	16.244
1970	5/4/1989	2.026	0.261	16.220
1958	5/4/1989	2.050	0.256	14.567
1956	5/4/1989	2.046	0.254	16.244

	1969	5/4/1989	2.021	0.247	18.342
	104002	4/21/1990	5.714	0.863	10.740
	104003	4/21/1990	5.790	0.857	10.571
	104001	4/21/1990	2.483	0.333	23.910
	103707	4/25/1990	2.285	0.414	21.718
	103701	4/25/1990	2.235	0.378	14.808
	103704	4/25/1990	2.055	0.347	21.408
	103709	4/28/1990	2.097	0.394	24.911
	103708	4/28/1990	2.257	0.386	24.146
	103705	4/28/1990	2.055	0.323	25.170
	103706	4/28/1990	2.088	0.317	25.406
	103702	4/28/1990	2.003	0.316	15.631
	103703	4/28/1990	2.076	0.301	16.715
	127611	4/29/1990	5.223	0.349	7.640
	127612	4/29/1990	5.786	0.342	7.239
	127610	4/29/1990	5.656	0.334	7.294
	127406	5/10/1990	2.095	0.281	24.054
	127404	5/10/1990	2.006	0.265	22.553
	127405	5/10/1990	2.010	0.245	22.348
Gonad	1389	4/12/1989	2.212	0.524	17.408
	1390	4/12/1989	2.052	0.484	25.688
	1388	4/12/1989	2.062	0.466	7.302
	1410	4/13/1989	3.299	0.901	2.444
	1411	4/13/1989	3.012	0.542	48.805
	1412	4/13/1989	2.341	0.538	30.034
	1421	4/14/1989	2.578	0.572	6.788
	1419	4/14/1989	2.266	0.571	7.287
	1420	4/14/1989	1.772	0.500	25.095
	115605	4/7/1990	0.927	0.200	1.146
	115621	4/9/1990	2.009	0.494	5.916
	115645	4/10/1990	2.469	0.605	30.666
	115640	4/10/1990	2.110	0.530	40.572
	115634	4/10/1990	2.062	0.506	9.948
	115714	4/11/1990	5.382	1.378	20.785
	115719	4/11/1990	2.494	0.611	14.435
	115610	4/9/1990	5.491	1.570	19.376
	115616	4/9/1990	5.572	1.376	15.920
	115709	4/11/1990	2.443	0.606	27.668
	115606	4/7/1990	2.006	0.570	12.260
	115615	4/9/1990	5.822	1.263	1.085
	115609	4/9/1990	2.731	0.574	8.148
	115622	4/9/1990	2.032	0.435	30.423
	115644	4/10/1990	2.130	0.447	10.067
	115639	4/10/1990	2.037	0.440	9.639
	115633	4/10/1990	2.024	0.425	13.898
	115713	4/11/1990	5.321	1.080	14.800
	115708	4/11/1990	3.017	0.606	10.909
	115718	4/11/1990	2.085	0.457	24.384
Viscera	1370	4/11/1989	2.073	0.471	37.591
	1372	4/11/1989	2.054	0.446	430.790
	1371	4/11/1989	2.030	0.443	783.524
	1379	4/12/1989	2.148	0.485	88.921

Appendix 2 (cont'd)

		1381	4/12/1989	2.086	0.480	532.441
		1380	4/12/1989	2.067	0.449	204.813
		1406	4/13/1989	2.084	0.496	196.420
		1405	4/13/1989	2.081	0.466	87.532
		1404	4/13/1989	2.059	0.453	161.066
		1422	4/14/1989	2.095	0.450	80.643
		1423	4/14/1989	2.090	0.435	123.779
		1424	4/14/1989	1.570	0.334	74.520
		115602	4/7/1990	2.032	0.512	132.784
		115608	4/9/1990	2.021	0.505	79.868
		115618	4/9/1990	2.034	0.466	42.718
		115614	4/9/1990	0.804	0.189	54.867
		115631	4/10/1990	2.032	0.472	36.588
		115642	4/10/1990	2.060	0.468	24.129
		115637	4/10/1990	2.056	0.233	126.923
		115716	4/11/1990	4.639	1.044	285.454
		115711	4/11/1990	2.001	0.536	150.853
		115706	4/11/1990	2.265	0.494	356.810
	Muscle	115603	4/7/1990	2.310	0.552	33.103
		115619	4/9/1990	5.015	1.061	72.489
		115607	4/9/1990	2.625	0.601	100.542
		115613	4/9/1990	2.299	0.545	106.913
		115630	4/10/1990	5.020	1.235	196.861
		115636	4/10/1990	5.004	1.200	189.444
		115641	4/10/1990	2.170	0.499	85.257
		115715	4/11/1990	5.311	1.099	89.875
		115705	4/11/1990	2.200	0.526	249.598
		115710	4/11/1990	2.104	0.473	98.745
		115603	4/7/1990	2.310	0.552	33.103
Pacific Cod						
	Whole	10288	10/14/1989	0.760	0.170	8.091
		10398	10/24/1989	5.250	1.090	0.072
		10421	10/24/1989	5.050	1.030	0.087
		10423	10/25/1989	2.670	0.590	ND
Pink Salmon						
	Alevin	1546	4/20/1989	5.122	0.654	0.604
		1547	4/21/1989	5.550	0.877	2.734
		1549	4/23/1989	5.410	1.028	4.635
		1548	4/23/1989	5.450	0.970	4.376
		1551	4/24/1989	5.293	1.037	2.643
		1553	4/24/1989	5.463	0.961	3.033
		1552	4/24/1989	5.487	0.960	5.170
		1550	4/24/1989	5.195	0.909	37.517
		1557	4/24/1989	5.483	0.894	4.257
		1556	4/24/1989	5.495	0.824	2.057
		106806	3/16/1990	5.220	0.720	7.572
		106804	3/16/1990	0.440	0.110	4.565
		106803	3/17/1990	1.300	0.240	2.906
		106801	3/18/1990	5.150	0.970	4.904
		106736	3/19/1990	2.040	0.440	3.015

Appendix 2 (cont'd)

	106739	3/19/1990	2.020	0.430	9.105
	106741	3/19/1990	2.020	0.370	5.477
	106733	3/20/1990	2.030	0.450	4.906
	106722	3/21/1990	2.030	0.460	5.429
	106725	3/21/1990	2.050	0.400	4.152
	106710	3/22/1990	2.040	0.380	5.698
	106720	3/28/1990	2.010	0.420	6.236
	106731	3/28/1990	2.020	0.300	7.105
	106746	3/29/1990	5.230	0.820	4.355
	106719	3/29/1990	2.020	0.360	2.490
	106749	3/30/1990	5.160	1.100	2.698
	106743	3/30/1990	2.020	0.420	8.136
	106708	3/30/1990	2.010	0.400	5.135
	106705	3/31/1990	5.080	1.130	4.582
	106706	3/31/1990	2.070	0.380	5.679
	106702	4/6/1990	5.010	0.900	4.030
	106728	4/10/1990	2.010	0.450	5.022
	106716	4/11/1990	2.040	0.610	2.440
	106713	4/11/1990	2.090	0.420	1.420
Fry	117902	5/17/1989	0.355	0.098	160.005
	117901	5/18/1989	1.552	0.095	1032.253
	117907	5/19/1989	0.480	0.149	295.095
	117904	5/21/1989	2.130	0.626	117.412
	117903	5/21/1989	1.538	0.460	127.381
	117906	6/4/1989	4.731	1.192	72.596
	117905	6/19/1989	0.608	0.152	29.140
	1456	4/13/1989	5.673	0.658	69.139
	1470	4/15/1989	5.753	0.788	11.721
	1801	4/15/1989	5.257	0.455	13.034
	1806	4/17/1989	9.750	2.416	ND
	1807	4/17/1989	9.680	2.398	ND
	1808	4/17/1989	5.016	0.652	61.105
	1805	4/17/1989	5.045	0.636	63.557
	1486	4/17/1989	5.041	0.539	63.122
	1809	4/21/1989	6.880	1.705	78.894
	1811	4/21/1989	5.860	1.452	57.303
	1810	4/21/1989	1.990	0.250	105.820
	9020	5/1/1989	8.040	1.992	25.494
	3048	5/3/1989	5.098	0.795	58.839
	3050	5/3/1989	4.284	0.673	52.663
	3055	5/4/1989	8.070	2.000	ND
	3057	5/4/1989	7.910	1.960	ND
	3056	5/4/1989	2.000	0.280	155.804
	3068	5/5/1989	5.087	4.039	34.900
	3066	5/5/1989	7.760	1.923	ND
	3067	5/5/1989	5.080	0.681	179.391
	3133	5/7/1989	5.087	0.926	227.645
	3132	5/7/1989	5.370	0.913	241.776
	3173	5/9/1989	8.350	2.069	ND
	3174	5/9/1989	2.090	0.330	176.138
	3202	5/11/1989	8.300	2.057	39.472
	3201	5/11/1989	7.990	1.980	40.005

Appendix 2 (cont'd)

3212	5/13/1989	2.030	0.220	329.070
3237	5/16/1989	4.270	1.058	0.755
3253	5/17/1989	5.027	0.408	148.632
3276	5/19/1989	8.130	2.014	ND
3277	5/19/1989	1.990	0.280	156.135
3291	5/20/1989	7.380	1.829	38.909
3290	5/20/1989	7.040	1.744	42.527
3289	5/20/1989	2.030	0.170	45.160
3340	5/21/1989	7.550	1.871	101.442
3316	5/21/1989	7.200	1.784	226.525
3315	5/21/1989	1.980	0.290	207.854
3343	5/22/1989	7.620	1.888	66.919
3342	5/22/1989	7.600	1.883	64.957
3341	5/22/1989	2.030	0.160	66.065
3362	5/24/1989	7.190	1.781	1.048
3384	5/25/1989	7.270	1.801	15.147
3383	5/25/1989	7.200	1.784	17.669
3382	5/25/1989	2.060	0.200	8.695
3582	5/30/1989	2.000	0.320	60.890
3588	5/31/1989	8.140	2.017	48.612
3589	5/31/1989	7.370	1.826	90.724
3587	5/31/1989	2.010	0.310	74.031
118009	9/7/1990	2.020	0.530	179.294
118002	9/7/1990	2.020	0.530	479.893
118005	9/7/1990	2.010	0.500	331.779
118007	9/7/1990	2.000	0.490	152.180
118008	9/7/1990	2.030	0.490	147.902
118006	9/7/1990	2.020	0.480	276.105
118004	9/7/1990	1.700	0.440	295.933
118003	9/7/1990	0.930	0.270	415.657
118001	9/7/1990	0.640	0.190	346.782
118018	9/10/1990	2.000	0.520	39.296
118020	9/10/1990	2.010	0.510	13.381
118012	9/10/1990	2.010	0.510	94.576
118014	9/10/1990	2.010	0.500	71.166
118010	9/10/1990	2.000	0.480	65.437
118015	9/10/1990	2.000	0.480	141.791
118016	9/10/1990	2.010	0.470	104.835
118013	9/10/1990	2.000	0.460	141.404
118019	9/10/1990	2.000	0.450	334.786
118017	9/10/1990	2.000	0.450	10.790
118011	9/10/1990	2.020	0.450	95.323
118021	9/10/1990	2.000	0.440	11.116
118022	9/10/1990	1.610	0.410	130.894
1453	4/13/1989	5.251	0.761	64.618
3019	5/1/1989	9.450	1.623	ND
3018	5/1/1989	8.850	1.520	ND
3032	5/2/1989	5.147	1.029	33.926
3031	5/2/1989	5.123	0.968	34.552
3037	5/2/1989	5.027	0.920	359.178
3038	5/2/1989	5.051	0.919	305.390
3599	6/1/1989	7.640	1.312	57.867

Appendix 2 (cont'd)

3605	6/2/1989	8.050	1.382	27.157
3607	6/2/1989	8.000	1.374	31.069
3606	6/2/1989	7.970	1.368	42.716
3633	6/4/1989	9.540	1.638	ND
3613	6/4/1989	8.220	1.411	84.508
3612	6/4/1989	7.900	1.356	81.077
3632	6/4/1989	7.820	1.343	ND
3611	6/4/1989	2.060	0.360	78.239
3631	6/4/1989	2.050	0.330	136.183
3650	6/6/1989	8.650	1.485	79.272
3679	6/8/1989	7.460	1.281	119.155
3680	6/8/1989	7.430	1.276	147.949
3681	6/8/1989	2.020	0.330	124.969
3695	6/9/1989	8.880	1.525	62.903
4713	6/18/1989	8.920	1.532	24.191
4724	6/18/1989	8.540	1.466	18.150
4723	6/18/1989	5.182	0.871	19.599
4725	6/18/1989	5.045	0.772	29.747
4714	6/18/1989	5.005	0.601	9.830
4715	6/18/1989	5.081	0.600	11.558
4743	6/20/1989	5.029	0.603	16.433
4742	6/20/1989	5.033	0.599	15.380
4811	6/24/1989	2.050	0.310	11.997
4833	6/25/1989	8.840	1.518	73.841
4835	6/25/1989	5.073	0.837	121.695
4834	6/25/1989	5.007	0.786	55.443
116122	4/18/1990	5.302	1.691	121.214
116121	4/18/1990	4.949	1.173	167.607
116120	4/18/1990	5.206	0.875	278.998
116133	4/19/1990	5.276	1.715	5.177
116134	4/19/1990	5.358	1.216	6.602
116135	4/19/1990	5.251	0.772	10.656
116146	4/20/1990	5.326	1.795	55.278
116147	4/20/1990	5.253	1.576	55.993
116145	4/20/1990	5.156	0.866	99.214
116210	4/21/1990	5.205	0.718	83.057
116208	4/21/1990	5.128	0.715	75.544
116209	4/21/1990	3.746	0.517	83.739
116228	4/23/1990	5.061	0.697	175.793
116342	4/24/1990	4.043	0.559	84.062
116431	4/26/1990	5.182	0.726	241.908
116502	5/3/1990	5.138	0.729	367.600
116501	5/3/1990	5.055	0.706	376.591
116503	5/3/1990	5.040	0.685	307.718
116528	5/4/1990	5.051	0.694	243.113
116545	5/5/1990	5.602	1.133	25.672
116544	5/5/1990	5.051	0.991	28.038
116546	5/5/1990	5.142	0.868	22.776
116539	5/5/1990	5.035	0.719	39.322
116537	5/5/1990	5.037	0.706	36.883
116538	5/5/1990	5.030	0.700	37.036
116548	5/6/1990	5.175	1.014	256.499

Appendix 2 (cont'd)

			116549	5/6/1990	5.081	1.006	316.740
			116547	5/6/1990	5.675	0.976	267.248
			116601	5/7/1990	5.892	1.020	134.876
			116602	5/7/1990	5.847	1.017	94.905
			116603	5/7/1990	5.343	0.966	82.269
			116605	5/8/1990	5.585	0.963	223.487
			116606	5/8/1990	5.299	0.870	225.708
			116607	5/8/1990	4.765	0.631	172.122
			116732	5/10/1990	5.548	0.903	23.976
			116730	5/10/1990	5.709	0.779	44.442
			116731	5/10/1990	5.662	0.777	56.260
	Prickleback						
		Whole	194006	6/23/1990	2.050	0.460	7.104
			194010	6/28/1990	1.070	0.280	7.401
			194012	8/21/1990	2.030	0.530	5.550
III. Molluscs							
	Butter Clams						
		Whole	29864	8/16/1990	1.010	0.150	ND
			29873	8/15/1991	1.000	0.150	ND
			29876	8/16/1991	1.130	0.180	ND
			29874	8/16/1991	1.160	0.170	ND
			29875	8/16/1991	1.070	0.150	ND
			29879	8/18/1991	1.080	0.210	ND
			29878	8/18/1991	1.130	0.190	ND
			29877	8/18/1991	1.060	0.170	ND
			29880	8/22/1991	1.260	0.190	0.530
			29882	8/25/1991	1.260	0.220	ND
			29883	8/25/1991	1.120	0.200	ND
			29881	8/25/1991	1.110	0.190	ND
			29869	8/26/1991	1.040	0.190	ND
			29870	8/26/1991	1.010	0.190	ND
			29871	8/26/1991	1.030	0.190	ND
			29872	8/27/1991	1.080	0.210	ND
			29865	8/28/1991	1.080	0.200	ND
			29866	8/28/1991	1.030	0.160	ND
			29867	8/28/1991	1.040	0.150	ND
			29868	8/29/1991	1.000	0.160	ND
			1679	4/20/1989	5.235	0.979	0.403
			1684	4/20/1989	5.050	0.954	0.106
			1680	4/20/1989	5.228	0.889	0.199
			1691	4/21/1989	5.390	0.879	0.263
			1685	4/21/1989	5.388	0.878	0.250
			1692	4/21/1989	5.050	0.838	0.181
			1864	4/22/1989	5.124	0.866	0.390
			1862	4/22/1989	5.138	0.822	0.598
			1863	4/22/1989	4.967	0.790	0.515
			1861	4/23/1989	5.011	0.847	0.248
			7179	8/16/1989	5.064	1.144	0.059
			7177	8/16/1989	5.058	1.093	0.061
			7181	8/16/1989	5.316	1.069	0.075

Appendix 2 (cont'd)

		8671	9/15/1989	5.421	1.041	ND
		8674	9/15/1989	5.258	0.941	0.308
		8676	9/15/1989	5.395	0.912	0.140
		8677	9/15/1989	5.273	0.912	0.244
		104212	4/10/1990	5.169	0.879	0.275
		104217	4/10/1990	5.249	0.861	0.398
		104215	4/10/1990	5.174	0.815	0.415
		104219	4/10/1990	5.179	0.754	0.242
		104305	4/11/1990	4.619	0.808	0.080
		104232	4/11/1990	5.219	0.781	0.333
		104233	4/11/1990	5.346	0.749	0.368
		104237	4/11/1990	4.202	0.652	0.311
		104235	4/11/1990	4.049	0.622	0.298
		104303	4/12/1990	5.281	0.739	ND
		104318	4/23/1990	4.228	1.311	0.243
		104323	4/23/1990	5.040	0.867	0.307
		104321	4/23/1990	4.276	0.663	0.312
		104319	4/23/1990	0.727	0.152	ND
		104340	4/24/1990	5.205	0.869	0.500
		104337	4/24/1990	3.014	0.567	0.513
		104335	4/24/1990	1.097	0.147	0.745
		104403	4/25/1990	5.189	1.007	0.504
		104404	4/25/1990	5.103	0.990	0.599
		104407	4/25/1990	1.797	0.255	0.316
		104423	4/26/1990	5.082	0.940	2.851
		104421	4/26/1990	5.121	0.917	2.903
		104439	4/27/1990	5.160	0.934	3.581
		104437	4/27/1990	1.874	0.365	3.749
		104435	4/27/1990	1.745	0.304	4.333
		104505	4/28/1990	5.058	1.017	3.837
		104507	4/28/1990	1.643	0.330	3.368
		104521	4/29/1990	2.532	0.484	4.300
		104519	4/29/1990	0.626	0.098	6.795
		104824	6/24/1990	5.130	1.140	0.187
Kennerly's Venus Clam	Whole	29913	8/22/1991	1.040	0.170	ND
		29911	8/22/1991	1.030	0.160	0.581
		29912	8/22/1991	1.040	0.160	ND
		29910	8/26/1991	0.810	0.080	ND
		29908	8/29/1991	1.100	0.190	ND
		29909	8/29/1991	1.110	0.180	ND
Littleneck Clams	Whole	29903	8/15/1991	1.020	0.170	0.858
		29902	8/15/1991	1.040	0.150	ND
		29904	8/16/1991	1.080	0.180	0.494
		29906	8/25/1991	1.400	0.200	0.400
		29905	8/25/1991	1.100	0.170	0.647
		29907	8/25/1991	1.080	0.160	1.021
		29896	8/27/1991	1.380	0.240	ND

Appendix 2 (cont'd)

29898	8/27/1991	1.460	0.230	ND
29899	8/27/1991	1.210	0.210	ND
29895	8/27/1991	1.120	0.200	ND
29901	8/27/1991	1.050	0.200	ND
29893	8/27/1991	1.120	0.190	ND
29894	8/27/1991	1.070	0.180	ND
29897	8/27/1991	1.220	0.160	ND
29900	8/27/1991	1.040	0.160	ND
29884	8/28/1991	1.220	0.200	ND
29887	8/28/1991	1.180	0.200	ND
29888	8/28/1991	1.250	0.200	ND
29889	8/28/1991	1.080	0.170	ND
29885	8/28/1991	1.190	0.160	ND
29886	8/28/1991	1.040	0.160	ND
29891	8/29/1991	1.820	0.300	ND
29890	8/29/1991	1.330	0.220	ND
29892	8/29/1991	1.020	0.150	ND
1681	4/20/1989	5.329	0.954	0.129
1682	4/20/1989	5.065	0.876	0.258
1683	4/20/1989	4.062	0.715	0.115
1693	4/21/1989	5.165	0.718	0.214
1695	4/21/1989	5.064	0.663	0.624
1694	4/21/1989	5.052	0.652	0.199
1859	4/22/1989	5.157	0.902	0.669
1860	4/22/1989	5.283	0.798	0.841
1858	4/22/1989	5.129	0.790	0.729
1857	4/23/1989	5.233	0.659	0.407
1856	4/23/1989	5.077	0.599	0.356
1855	4/23/1989	5.020	0.542	0.307
2699	5/5/1989	5.070	0.619	0.339
2698	5/5/1989	2.041	0.212	1.409
6402	8/1/1989	5.631	0.636	0.189
6403	8/1/1989	4.982	0.593	ND
6400	8/1/1989	2.248	0.188	ND
6401	8/1/1989	1.070	0.136	ND
6407	8/2/1989	5.144	0.581	0.186
6404	8/2/1989	5.544	0.565	ND
6405	8/2/1989	5.569	0.550	0.231
6406	8/2/1989	4.831	0.468	0.168
6431	8/3/1989	0.533	0.767	ND
6430	8/3/1989	5.590	0.524	0.318
6428	8/3/1989	3.039	0.328	0.190
6432	8/3/1989	0.655	0.065	ND
7176	8/16/1989	5.434	1.081	0.159
7180	8/16/1989	5.383	0.974	0.166
7182	8/16/1989	5.478	0.838	0.159
7178	8/16/1989	5.307	0.828	0.134
7193	8/17/1989	5.529	0.824	ND
7196	8/17/1989	5.651	0.819	ND
7194	8/17/1989	5.272	0.743	ND
7195	8/17/1989	5.339	0.683	ND
7152	8/20/1989	0.515	0.675	ND

Appendix 2 (cont'd)

7163	8/21/1989	4.925	0.527	ND
7164	8/21/1989	5.360	0.517	ND
7165	8/21/1989	3.469	0.298	ND
8692	9/14/1989	5.188	0.887	0.342
8691	9/14/1989	5.136	0.853	0.352
8689	9/14/1989	5.363	0.815	0.284
8690	9/14/1989	5.329	0.805	0.328
8672	9/15/1989	5.249	0.824	0.734
8673	9/15/1989	5.324	0.735	0.658
8678	9/15/1989	5.038	0.730	0.516
8675	9/15/1989	5.092	0.672	0.774
8718	9/16/1989	4.915	1.116	0.137
8719	9/16/1989	5.076	0.924	0.215
8706	9/17/1989	5.349	0.690	0.448
8705	9/17/1989	5.296	0.608	0.329
104218	4/10/1990	5.215	0.757	0.429
104216	4/10/1990	5.009	0.698	0.869
104214	4/10/1990	4.468	0.649	0.342
104213	4/10/1990	2.113	0.254	0.522
104230	4/11/1990	5.224	0.822	0.563
104234	4/11/1990	5.173	0.776	0.525
104231	4/11/1990	5.006	0.697	0.450
104236	4/11/1990	4.163	0.649	0.623
104249	4/12/1990	5.319	0.718	0.143
104248	4/12/1990	5.021	0.642	0.135
104250	4/12/1990	5.203	0.598	0.120
104304	4/12/1990	5.106	0.541	0.178
104322	4/23/1990	5.028	0.875	0.557
104320	4/23/1990	5.438	0.865	0.639
104317	4/23/1990	5.039	0.852	0.651
104316	4/23/1990	5.135	0.822	0.602
104336	4/24/1990	5.044	0.772	0.788
104339	4/24/1990	5.030	0.744	0.730
104338	4/24/1990	5.113	0.741	0.732
104334	4/24/1990	5.067	0.603	0.668
104406	4/25/1990	1.307	0.207	1.431
104422	4/26/1990	5.274	0.933	3.760
104420	4/26/1990	5.036	0.871	4.100
104418	4/26/1990	2.652	0.451	3.693
104436	4/27/1990	3.371	0.492	6.680
104434	4/27/1990	1.324	0.217	7.795
104503	4/28/1990	5.001	0.795	7.788
104506	4/28/1990	5.049	0.717	7.126
104504	4/28/1990	3.799	0.642	6.091
104502	4/28/1990	5.032	0.538	6.731
104523	4/29/1990	5.119	0.742	3.463
104520	4/29/1990	5.078	0.741	3.720
104518	4/29/1990	5.232	0.712	3.664
104522	4/29/1990	5.150	0.690	2.856
104601	5/9/1990	5.090	1.050	2.274
104605	5/9/1990	2.020	0.350	2.282
104607	5/10/1990	5.110	0.850	1.728

Appendix 2 (cont'd)

104611	5/10/1990	2.170	0.360	1.727
104614	5/22/1990	5.100	1.080	7.940
104619	5/22/1990	2.180	0.370	7.193
104613	5/22/1990	2.020	0.360	7.246
104620	5/23/1990	5.040	1.000	0.928
104624	5/23/1990	2.050	0.300	0.884
104626	5/24/1990	5.140	1.000	2.385
104630	5/24/1990	3.340	0.350	2.790
104701	6/20/1990	5.090	0.820	0.181
104734	6/22/1990	5.160	0.810	1.394
104821	6/24/1990	5.040	0.980	0.170
104841	6/25/1990	5.110	0.940	0.501
104911	7/21/1990	2.040	0.440	0.635
105201	9/5/1990	5.210	0.730	0.128
105218	9/5/1990	2.260	0.400	0.308
105204	9/5/1990	2.350	0.350	0.193
105243	9/6/1990	2.600	0.350	ND
105228	9/6/1990	2.070	0.300	0.277
105303	9/7/1990	5.080	0.740	0.446
105238	9/7/1990	5.010	0.700	0.316
105237	9/7/1990	1.020	0.150	0.575
105246	9/7/1990	1.080	0.140	ND
105306	9/8/1990	2.460	0.300	0.613
200007	4/14/1991	5.140	0.670	0.156
200009	4/14/1991	1.030	0.130	ND
200008	4/14/1991	1.110	0.120	0.574
200017	4/17/1991	5.230	0.600	0.345
200020	4/17/1991	2.140	0.310	0.536
200027	4/19/1991	5.080	0.650	0.412
200028	4/19/1991	2.040	0.260	0.568
200037	4/20/1991	4.160	0.670	0.220
200047	4/20/1991	4.200	0.530	0.206
200040	4/20/1991	2.190	0.330	0.644
200049	4/20/1991	2.060	0.230	1.263
200107	4/22/1991	3.010	0.490	ND
200110	4/22/1991	2.180	0.280	0.374
200201	8/29/1991	2.090	0.320	0.287
200204	8/29/1991	2.160	0.310	0.352
200206	9/6/1991	2.050	0.280	0.352
200224	9/7/1991	2.150	0.340	0.364
200223	9/7/1991	2.070	0.320	0.360
200222	9/7/1991	2.250	0.310	0.244
200243	9/8/1991	2.040	0.320	0.418
200314	9/9/1991	2.000	0.350	0.293
200304	9/9/1991	2.020	0.300	0.304
400205	6/18/1993	8.190	0.780	ND
400208	6/19/1993	8.750	1.440	0.540
400210	6/20/1993	8.960	1.360	0.890
400213	6/21/1993	8.380	1.300	0.360
506107	8/6/1994	8.980	0.650	ND

Appendix 2 (cont'd)

Macoma Clams						
	Whole	29862	8/16/1990	1.040	0.160	ND
		29863	8/16/1990	1.040	0.160	ND
		29861	8/16/1991	1.060	0.170	0.375
		29845	8/26/1991	1.080	0.190	ND
		29846	8/26/1991	1.010	0.180	ND
		29847	8/26/1991	1.040	0.130	ND
		29854	8/27/1991	1.030	0.180	0.623
		29848	8/27/1991	1.040	0.170	ND
		29850	8/27/1991	1.040	0.160	ND
		29856	8/27/1991	1.030	0.160	ND
		29849	8/27/1991	1.030	0.150	ND
		29851	8/27/1991	1.010	0.150	ND
		29855	8/27/1991	0.820	0.150	ND
		29858	8/27/1991	0.910	0.150	ND
		29859	8/27/1991	0.870	0.130	ND
		29852	8/27/1991	0.840	0.110	ND
		29853	8/27/1991	0.480	0.090	ND
		29857	8/27/1991	0.550	0.090	ND
		29842	8/28/1991	1.080	0.180	ND
		29841	8/28/1991	1.080	0.170	ND
		29844	8/28/1991	1.040	0.170	ND
		29843	8/28/1991	1.120	0.160	ND
Bay Mussels						
	Whole	601428	5/13/1995	8.570	1.260	6.705
		601710	5/13/1995	9.170	1.260	6.705
		601715	5/13/1995	9.340	1.210	17.860
		601427	5/13/1995	8.470	1.160	5.130
		601430	5/13/1995	9.390	1.160	6.630
		601714	5/13/1995	9.540	1.140	6.460
		601711	5/13/1995	9.100	1.130	4.950
		601426	5/13/1995	8.550	1.110	5.475
		601712	5/13/1995	9.240	1.020	4.824
		601713	5/13/1995	8.180	1.010	5.645
		601431	5/13/1995	8.500	0.950	5.684
		601429	5/13/1995	8.620	0.920	5.894
		601716	5/13/1995	9.480	0.770	3.706
		601437	5/14/1995	9.930	1.080	3.057
		601447	5/14/1995	9.360	1.040	4.154
		601446	5/14/1995	9.250	1.010	7.005
		601824	5/14/1995	9.710	0.950	8.324
		601440	5/14/1995	9.580	0.930	3.557
		601443	5/14/1995	9.490	0.920	2.149
		601444	5/14/1995	9.070	0.910	5.796
		601432	5/14/1995	8.640	0.900	2.259
		601433	5/14/1995	9.140	0.880	2.201
		601818	5/14/1995	9.060	0.880	6.861
		601442	5/14/1995	9.250	0.870	2.861
		601441	5/14/1995	8.530	0.850	3.412
		601434	5/14/1995	8.500	0.840	1.907
		601435	5/14/1995	8.540	0.840	1.636

Appendix 2 (cont'd)

601815	5/14/1995	9.220	0.840	7.082
601822	5/14/1995	9.700	0.840	7.933
601436	5/14/1995	8.530	0.820	2.214
601439	5/14/1995	8.520	0.820	2.520
601823	5/14/1995	8.460	0.820	7.405
601445	5/14/1995	8.510	0.790	6.724
601438	5/14/1995	8.530	0.780	1.900
601817	5/14/1995	8.950	0.740	5.283
601816	5/14/1995	8.510	0.680	8.317
601819	5/14/1995	8.650	0.660	5.768
601820	5/14/1995	9.000	0.350	5.527
601821	5/14/1995	8.760	0.340	12.243
601914	5/15/1995	9.570	1.260	6.439
601913	5/15/1995	8.500	1.180	6.604
601930	5/15/1995	8.670	1.170	23.349
601909	5/15/1995	9.160	1.150	3.820
601916	5/15/1995	8.590	1.150	3.347
601910	5/15/1995	8.770	1.140	4.218
601912	5/15/1995	9.270	1.140	3.016
601928	5/15/1995	8.520	1.120	18.571
601911	5/15/1995	8.570	1.100	4.880
601834	5/15/1995	9.270	1.080	3.202
601915	5/15/1995	9.220	1.050	6.259
601836	5/15/1995	8.880	1.020	2.451
601840	5/15/1995	8.500	1.010	3.562
601837	5/15/1995	8.420	0.990	3.751
601835	5/15/1995	8.530	0.960	3.761
601838	5/15/1995	8.500	0.960	2.904
601839	5/15/1995	8.510	0.960	4.716
601929	5/15/1995	8.520	0.900	20.042
601937	5/16/1995	9.160	1.680	4.343
601938	5/16/1995	9.100	1.650	3.875
601941	5/16/1995	9.460	1.640	3.260
601942	5/16/1995	9.090	1.550	4.165
601939	5/16/1995	9.490	1.540	3.945
601940	5/16/1995	9.290	1.420	3.341
601931	5/16/1995	9.220	1.380	4.870
602204	5/16/1995	9.150	1.380	4.071
602205	5/16/1995	9.370	1.350	3.236
601933	5/16/1995	8.880	1.310	6.970
601935	5/16/1995	8.760	1.310	8.968
601932	5/16/1995	9.570	1.300	4.862
601936	5/16/1995	8.880	1.280	5.283
602201	5/16/1995	9.150	1.270	4.197
602203	5/16/1995	9.120	1.260	4.285
602202	5/16/1995	8.990	1.250	4.590
601934	5/16/1995	8.790	1.220	4.562
602210	5/17/1995	10.060	1.100	13.990
602211	5/17/1995	9.360	1.080	11.581
602209	5/17/1995	8.730	1.030	13.064
602213	5/17/1995	9.310	0.980	10.719
602212	5/17/1995	8.530	0.920	7.379

Appendix 2 (cont'd)

602214	5/17/1995	8.720	0.800	9.627
602227	5/18/1995	8.630	1.400	13.180
602225	5/18/1995	8.510	1.370	10.937
602226	5/18/1995	8.620	1.280	9.507
602229	5/20/1995	9.080	1.150	4.413
602230	5/20/1995	8.680	1.150	3.799
602228	5/20/1995	8.400	1.080	3.889
604208	7/10/1995	8.900	0.860	0.902
604210	7/10/1995	8.280	0.860	1.031
604212	7/10/1995	8.460	0.800	1.033
604203	7/10/1995	8.660	0.710	1.202
604205	7/10/1995	8.660	0.700	1.174
604201	7/10/1995	8.760	0.690	1.601
604233	7/11/1995	9.560	0.940	0.316
604215	7/11/1995	8.470	0.850	1.693
604217	7/11/1995	8.480	0.850	2.133
604222	7/11/1995	8.490	0.830	0.368
604226	7/11/1995	8.820	0.770	0.290
604219	7/11/1995	7.990	0.740	2.848
604224	7/11/1995	8.350	0.740	0.281
604229	7/11/1995	8.630	0.740	0.396
604231	7/11/1995	8.290	0.740	0.307
604240	7/12/1995	8.680	0.840	0.362
604236	7/12/1995	8.290	0.780	0.353
604101	7/12/1995	8.500	0.770	ND
604105	7/12/1995	8.820	0.740	ND
604245	7/12/1995	8.430	0.730	0.482
604103	7/12/1995	8.970	0.720	ND
604247	7/12/1995	8.630	0.710	ND
604238	7/12/1995	8.400	0.650	ND
604243	7/12/1995	7.850	0.580	ND
604110	7/13/1995	8.210	0.810	11.053
604112	7/13/1995	8.300	0.800	11.524
604108	7/13/1995	8.800	0.780	19.202
604115	7/13/1995	8.260	0.640	15.684
604427	8/8/1995	8.510	0.960	1.561
604425	8/8/1995	8.690	0.840	2.361
604416	8/8/1995	9.060	0.700	1.645
604422	8/8/1995	9.190	0.700	2.129
604426	8/8/1995	8.510	0.700	1.022
604421	8/8/1995	8.530	0.680	0.927
604417	8/8/1995	8.930	0.670	1.428
604419	8/8/1995	9.070	0.670	0.866
604424	8/8/1995	8.500	0.670	2.283
604418	8/8/1995	8.530	0.610	1.800
604420	8/8/1995	8.530	0.610	1.241
604423	8/8/1995	8.800	0.600	2.328
604448	8/9/1995	9.030	0.790	1.043
604447	8/9/1995	8.530	0.680	ND
604449	8/9/1995	8.690	0.680	0.308
604446	8/9/1995	8.800	0.660	0.371
604519	8/9/1995	9.360	0.650	ND

Appendix 2 (cont'd)

604514	8/9/1995	8.910	0.620	ND
604515	8/9/1995	9.150	0.610	ND
604506	8/9/1995	8.790	0.600	1.303
604505	8/9/1995	9.020	0.590	0.414
604521	8/9/1995	8.640	0.530	ND
604508	8/9/1995	8.580	0.520	ND
604513	8/9/1995	8.330	0.500	ND
604520	8/9/1995	8.400	0.490	ND
604504	8/9/1995	8.460	0.470	ND
604509	8/9/1995	8.570	0.440	ND
604507	8/9/1995	8.610	0.320	ND
604628	8/10/1995	9.060	0.740	0.453
604626	8/10/1995	8.910	0.720	ND
604627	8/10/1995	8.530	0.710	0.339
604631	8/10/1995	8.540	0.680	0.320
604618	8/10/1995	8.520	0.670	ND
604620	8/10/1995	8.560	0.650	0.680
604621	8/10/1995	8.670	0.630	ND
604530	8/10/1995	8.890	0.630	0.772
604541	8/10/1995	8.500	0.620	ND
604542	8/10/1995	8.350	0.620	0.537
604533	8/10/1995	8.530	0.620	0.363
604540	8/10/1995	8.950	0.610	ND
604623	8/10/1995	8.850	0.610	0.337
604629	8/10/1995	8.530	0.610	ND
604622	8/10/1995	8.480	0.600	ND
604625	8/10/1995	8.640	0.580	ND
604531	8/10/1995	8.540	0.580	ND
604619	8/10/1995	8.420	0.560	ND
604624	8/10/1995	8.510	0.550	ND
604630	8/10/1995	9.000	0.510	ND
604532	8/10/1995	8.410	0.490	ND
604617	8/10/1995	8.670	0.480	ND
604719	8/11/1995	8.500	0.790	ND
604716	8/11/1995	8.530	0.730	ND
604728	8/11/1995	9.080	0.720	ND
604723	8/11/1995	8.520	0.710	ND
604729	8/11/1995	8.600	0.650	ND
604727	8/11/1995	8.460	0.640	ND
604715	8/11/1995	8.470	0.620	ND
604718	8/11/1995	8.760	0.620	ND
604721	8/11/1995	8.050	0.620	ND
604722	8/11/1995	8.510	0.620	ND
604720	8/11/1995	8.320	0.530	ND
604717	8/11/1995	8.510	0.520	ND
604750	8/12/1995	9.700	0.830	ND
604806	8/12/1995	8.530	0.730	ND
604733	8/12/1995	9.220	0.720	ND
604743	8/12/1995	8.660	0.720	0.734
604735	8/12/1995	9.080	0.690	ND
604742	8/12/1995	8.750	0.690	1.409
604734	8/12/1995	8.970	0.660	ND

Appendix 2 (cont'd)

604804	8/12/1995	8.610	0.660	ND
604802	8/12/1995	8.280	0.600	ND
604805	8/12/1995	8.460	0.590	ND
604803	8/12/1995	8.400	0.580	ND
604801	8/12/1995	8.440	0.520	ND
604817	8/13/1995	8.500	0.620	ND
604822	8/13/1995	8.500	0.620	ND
604824	8/13/1995	8.530	0.620	ND
604823	8/13/1995	8.500	0.610	ND
604810	8/13/1995	8.950	0.610	ND
604816	8/13/1995	8.530	0.560	ND
604811	8/13/1995	8.510	0.560	ND
604818	8/13/1995	8.460	0.470	ND
604812	8/13/1995	8.290	0.470	ND
1004	3/26/1989	10.300	1.030	ND
1003	3/26/1989	9.270	1.020	ND
1005	3/26/1989	11.100	1.000	ND
1034	3/28/1989	9.840	0.787	ND
1031	3/28/1989	9.650	0.772	ND
1032	3/28/1989	9.270	0.742	ND
1024	3/28/1989	10.200	0.711	ND
1027	3/28/1989	9.260	0.648	ND
1028	3/28/1989	9.080	0.636	ND
1016	3/29/1989	10.800	1.080	ND
1015	3/29/1989	10.100	0.809	ND
1017	3/29/1989	9.520	0.762	ND
1036	3/30/1989	10.100	0.704	ND
1037	3/30/1989	10.800	0.647	ND
1038	3/30/1989	10.400	0.626	0.492
1065	3/31/1989	9.820	0.982	0.262
1066	3/31/1989	9.520	0.952	0.311
1067	3/31/1989	10.400	0.829	0.270
1073	4/1/1989	11.100	1.120	0.288
1072	4/1/1989	9.540	0.954	0.375
1071	4/1/1989	10.100	0.904	0.453
1104	4/6/1989	10.000	1.100	ND
1106	4/6/1989	10.100	1.010	ND
1105	4/6/1989	9.880	0.988	ND
1095	4/7/1989	11.200	1.010	0.223
1096	4/7/1989	11.100	0.996	ND
1101	4/7/1989	10.400	0.935	0.384
1094	4/7/1989	9.940	0.895	0.352
1102	4/7/1989	10.600	0.844	ND
1100	4/7/1989	9.840	0.787	0.383
3562	4/9/1989	5.461	2.359	0.092
3548	4/10/1989	5.365	1.062	0.517
1451	4/13/1989	5.037	1.023	3.164
3540	4/14/1989	5.266	1.016	0.115
1475	4/16/1989	5.012	0.802	0.394
1485	4/17/1989	5.040	0.953	1.656
1501	4/19/1989	5.097	0.683	3.089
1509	4/20/1989	5.298	0.583	9.232

Appendix 2 (cont'd)

1575	4/27/1989	9.200	1.580	9.807
1574	4/27/1989	8.980	1.570	9.908
1573	4/27/1989	8.730	1.533	10.178
1581	4/27/1989	9.380	1.450	23.372
1579	4/27/1989	8.310	1.330	23.420
1580	4/27/1989	8.260	1.270	18.960
1585	4/27/1989	9.280	0.818	3.476
1587	4/27/1989	8.680	0.761	2.550
1592	4/28/1989	5.124	3.464	0.714
1593	4/28/1989	5.057	0.956	1.197
1601	4/28/1989	5.090	0.890	2.853
1598	4/28/1989	5.060	0.850	9.101
1599	4/28/1989	5.120	0.820	16.277
1604	4/28/1989	5.030	0.810	3.572
1596	4/28/1989	5.030	0.750	4.551
1595	4/28/1989	5.180	0.720	5.823
1602	4/28/1989	5.070	0.670	3.391
1605	4/28/1989	5.030	0.650	2.582
1591	4/28/1989	5.006	0.641	2.447
1603	4/28/1989	1.110	0.210	5.158
1594	4/28/1989	1.050	0.170	7.301
1597	4/28/1989	1.160	0.160	13.645
1600	4/28/1989	1.030	0.160	3.543
3013	4/30/1989	5.031	0.805	2.031
1724	5/1/1989	10.700	1.070	0.445
3020	5/1/1989	5.202	1.004	0.447
1723	5/1/1989	9.470	0.852	0.696
1725	5/1/1989	10.100	0.808	ND
1900	5/2/1989	8.330	1.530	1.208
1909	5/2/1989	8.520	1.510	9.274
1731	5/2/1989	11.400	1.250	4.579
1912	5/2/1989	8.300	1.160	9.316
1904	5/2/1989	5.780	1.130	9.291
1898	5/2/1989	5.030	0.980	3.516
1886	5/2/1989	5.050	0.940	9.019
1889	5/2/1989	5.097	0.928	4.877
1887	5/2/1989	5.490	0.910	10.739
1899	5/2/1989	5.040	0.880	3.200
1729	5/2/1989	8.580	0.858	3.320
1730	5/2/1989	10.700	0.854	5.778
1897	5/2/1989	4.430	0.850	2.563
1893	5/2/1989	4.671	0.827	19.618
1910	5/2/1989	5.010	0.810	14.154
1888	5/2/1989	5.224	0.773	5.223
1902	5/2/1989	5.010	0.740	1.370
1894	5/2/1989	4.243	0.721	5.211
1890	5/2/1989	3.940	0.713	4.231
1911	5/2/1989	5.010	0.700	6.926
1907	5/2/1989	4.190	0.620	3.532
1895	5/2/1989	2.954	0.571	5.955
1891	5/2/1989	4.937	0.568	17.758
1896	5/2/1989	2.907	0.526	5.912

Appendix 2 (cont'd)

1906	5/2/1989	8.920	0.480	9.033
1901	5/2/1989	2.570	0.450	1.748
1903	5/2/1989	3.200	0.400	4.084
1905	5/2/1989	2.000	0.400	11.884
1914	5/2/1989	2.080	0.310	14.535
1908	5/2/1989	1.500	0.280	2.874
1913	5/2/1989	2.000	0.280	13.789
1885	5/2/1989	1.050	0.190	4.932
1738	5/3/1989	10.700	0.859	ND
1737	5/3/1989	10.300	0.826	ND
1739	5/3/1989	10.200	0.714	0.343
1934	5/3/1989	2.060	0.350	12.993
1946	5/3/1989	2.050	0.300	2.607
1947	5/3/1989	2.110	0.290	1.972
1935	5/3/1989	2.070	0.280	17.584
1937	5/3/1989	1.620	0.280	8.354
1941	5/3/1989	2.020	0.270	63.480
1940	5/3/1989	1.570	0.220	61.307
1938	5/3/1989	0.880	0.190	5.403
1945	5/3/1989	1.080	0.170	2.481
1933	5/3/1989	0.970	0.140	7.319
1939	5/3/1989	1.030	0.140	45.474
1971	5/4/1989	10.370	2.300	3.822
1750	5/4/1989	10.100	1.610	2.207
1749	5/4/1989	9.570	1.150	4.235
1751	5/4/1989	11.100	0.995	2.652
3063	5/4/1989	5.074	0.893	2.669
1966	5/4/1989	4.759	0.728	2.283
1967	5/4/1989	4.918	0.684	2.819
1965	5/4/1989	4.840	0.566	2.759
1983	5/4/1989	2.580	0.450	5.422
1984	5/4/1989	2.020	0.340	6.130
3065	5/5/1989	5.000	0.890	3.329
1949	5/6/1989	8.820	1.640	5.172
1761	5/6/1989	11.500	0.921	0.531
1763	5/6/1989	11.200	0.898	0.930
1756	5/6/1989	10.200	0.715	1.843
1762	5/6/1989	9.790	0.685	0.431
2406	5/7/1989	10.900	0.868	9.559
2408	5/7/1989	10.500	0.840	12.951
2407	5/7/1989	10.200	0.716	9.411
2414	5/8/1989	10.600	1.270	10.734
2413	5/8/1989	10.100	1.110	14.981
2418	5/8/1989	9.280	0.928	5.470
2412	5/8/1989	9.260	0.926	20.212
2419	5/9/1989	8.250	0.908	20.688
2420	5/9/1989	8.370	0.837	5.747
3192	5/10/1989	5.071	1.105	4.322
2425	5/10/1989	9.440	0.755	12.979
20234	5/11/1989	4.460	2.060	0.103
3203	5/11/1989	5.059	0.749	5.098
3226	5/15/1989	5.048	0.909	1.970

Appendix 2 (cont'd)

3236	5/16/1989	5.106	0.950	1.335
3288	5/20/1989	5.094	0.683	4.403
4301	5/30/1989	10.200	1.530	3.262
4300	5/30/1989	10.600	1.490	1.910
92002	5/30/1989	9.880	1.480	2.896
92092	5/30/1989	11.300	1.470	2.619
92005	5/30/1989	8.650	1.470	12.105
92000	5/30/1989	9.410	1.220	2.766
4304	5/30/1989	10.500	1.160	6.945
92001	5/30/1989	9.590	1.050	1.173
92004	5/30/1989	9.560	1.050	1.483
92003	5/30/1989	9.940	0.994	2.003
4302	5/30/1989	9.900	0.990	0.670
4305	5/30/1989	9.780	0.980	14.498
3584	5/30/1989	5.054	0.879	2.246
3591	5/31/1989	5.142	0.807	3.499
92021	6/1/1989	10.100	1.920	11.419
92023	6/1/1989	10.700	1.820	10.473
4312	6/1/1989	10.200	1.740	8.795
92022	6/1/1989	9.480	1.710	11.531
4311	6/1/1989	9.690	1.650	7.698
92017	6/1/1989	10.200	1.520	19.742
4309	6/1/1989	9.960	1.490	18.083
92025	6/1/1989	9.260	1.480	7.537
92018	6/1/1989	9.440	1.420	17.110
92020	6/1/1989	10.100	1.410	10.423
92012	6/1/1989	9.950	1.390	9.296
92019	6/1/1989	10.600	1.380	13.834
92015	6/1/1989	10.600	1.380	4.696
4313	6/1/1989	10.400	1.360	3.668
4310	6/1/1989	10.200	1.320	14.993
4306	6/1/1989	10.200	1.320	6.148
92044	6/1/1989	10.100	1.310	3.205
92043	6/1/1989	9.830	1.280	1.473
92027	6/1/1989	10.500	1.260	4.322
92040	6/1/1989	9.480	1.230	6.497
4308	6/1/1989	10.200	1.220	2.614
4332	6/1/1989	10.100	1.210	1.693
92013	6/1/1989	10.100	1.210	8.079
4307	6/1/1989	10.000	1.200	4.191
4330	6/1/1989	10.600	1.160	5.176
92011	6/1/1989	10.200	1.120	7.786
92009	6/1/1989	10.100	1.110	3.943
92014	6/1/1989	10.100	1.110	4.441
92042	6/1/1989	9.860	1.080	6.070
92016	6/1/1989	9.670	1.060	1.784
92010	6/1/1989	10.500	1.050	3.720
92039	6/1/1989	10.300	1.030	6.829
92036	6/1/1989	10.200	1.020	5.810
4331	6/1/1989	10.200	1.020	6.315
92028	6/1/1989	9.100	1.000	2.418
92026	6/1/1989	9.910	0.991	3.143

Appendix 2 (cont'd)

92041	6/1/1989	9.940	0.990	7.784
3596	6/1/1989	5.320	0.952	2.186
92024	6/1/1989	9.300	0.930	19.180
92093	6/2/1989	10.500	1.470	17.154
92047	6/2/1989	9.730	1.460	19.213
4333	6/2/1989	9.620	1.440	48.719
92094	6/2/1989	10.500	1.250	21.366
4335	6/2/1989	10.300	1.140	16.330
92046	6/2/1989	10.400	1.140	29.941
4334	6/2/1989	10.100	1.110	24.510
92045	6/2/1989	10.200	1.020	35.309
92082	6/2/1989	9.230	0.923	22.097
4337	6/3/1989	9.920	1.590	15.263
92096	6/3/1989	9.690	1.550	8.840
92049	6/3/1989	9.790	1.270	11.959
4336	6/3/1989	9.440	1.230	10.751
92048	6/3/1989	10.200	1.230	13.728
92097	6/3/1989	10.900	1.190	8.866
92095	6/3/1989	9.460	1.140	13.529
4338	6/3/1989	9.960	1.100	5.325
92050	6/3/1989	10.600	1.060	0.680
4339	6/4/1989	10.300	1.440	8.361
92052	6/4/1989	10.200	1.420	12.347
4340	6/4/1989	10.100	1.410	13.132
92098	6/4/1989	10.900	1.300	12.494
92099	6/4/1989	10.400	1.240	12.703
93002	6/4/1989	10.200	1.220	3.770
93000	6/4/1989	10.800	1.190	9.507
92055	6/4/1989	10.800	1.180	2.796
93003	6/4/1989	10.200	1.130	1.513
4342	6/4/1989	10.200	1.120	4.871
4343	6/4/1989	9.990	1.100	4.061
92051	6/4/1989	8.450	1.100	25.435
93001	6/4/1989	9.950	1.090	3.530
4344	6/4/1989	10.300	1.030	1.545
92054	6/4/1989	10.000	1.000	3.506
4341	6/4/1989	9.940	0.990	16.097
92053	6/4/1989	9.480	0.948	11.822
92056	6/4/1989	10.000	0.901	2.561
3608	6/4/1989	5.032	0.896	6.681
4345	6/6/1989	8.530	1.280	20.487
92090	6/6/1989	9.840	1.080	27.920
3698	6/9/1989	5.186	0.705	9.744
4900	6/16/1989	9.640	1.350	2.184
4704	6/16/1989	5.081	0.594	1.253
4712	6/17/1989	5.076	0.695	0.448
4475	6/18/1989	11.200	1.340	2.054
4474	6/18/1989	10.800	1.190	1.763
4477	6/18/1989	11.900	1.070	0.781
4482	6/18/1989	8.370	1.000	26.429
4478	6/18/1989	9.580	0.958	0.597
4481	6/18/1989	10.600	0.844	0.294

Appendix 2 (cont'd)

4476	6/18/1989	9.300	0.837	0.818
4479	6/18/1989	9.280	0.742	0.424
4480	6/18/1989	9.820	0.589	ND
4490	6/19/1989	11.100	0.774	0.393
4491	6/19/1989	9.710	0.583	0.590
4741	6/20/1989	5.006	0.641	2.815
4508	6/21/1989	10.600	1.700	1.708
4902	6/21/1989	9.720	1.460	4.144
4507	6/21/1989	9.160	1.010	1.967
4506	6/21/1989	9.930	0.993	3.072
4512	6/21/1989	8.280	0.828	0.664
4511	6/21/1989	8.870	0.710	0.432
25439	6/22/1989	10.710	2.260	0.728
23267	6/22/1989	4.380	2.190	0.756
23495	6/22/1989	12.320	2.180	0.495
23271	6/22/1989	4.260	2.130	1.716
23477	6/22/1989	12.830	2.130	0.405
23300	6/22/1989	4.240	2.120	1.714
23291	6/22/1989	4.180	2.090	0.716
23274	6/22/1989	4.100	2.050	0.793
23278	6/22/1989	4.060	2.030	0.300
23303	6/22/1989	4.060	2.030	1.290
23268	6/22/1989	4.040	2.020	1.571
23479	6/22/1989	8.670	2.020	0.800
23277	6/22/1989	4.020	2.010	1.088
23308	6/22/1989	4.000	2.000	0.884
23275	6/22/1989	3.980	1.990	1.722
4790	6/23/1989	5.060	0.622	0.677
4620	6/24/1989	9.360	0.749	1.314
4621	6/24/1989	8.820	0.689	0.829
4832	6/25/1989	5.017	0.727	6.089
5311	7/8/1989	10.500	1.370	0.714
5317	7/8/1989	10.100	1.310	0.369
5310	7/8/1989	10.100	1.110	0.924
5312	7/8/1989	10.400	1.040	0.225
5318	7/8/1989	10.500	0.839	1.044
5316	7/8/1989	9.350	0.748	0.536
5319	7/9/1989	9.710	1.070	ND
5326	7/9/1989	11.400	1.020	ND
5327	7/9/1989	10.200	1.020	0.526
5321	7/9/1989	10.100	1.010	0.836
5325	7/9/1989	10.000	1.000	ND
5324	7/9/1989	9.740	0.974	0.503
5320	7/9/1989	10.000	0.300	0.836
5331	7/10/1989	10.600	1.280	2.747
5335	7/10/1989	10.200	1.230	2.407
5332	7/10/1989	9.590	1.150	2.791
5336	7/10/1989	9.580	1.150	1.277
5334	7/10/1989	10.100	1.110	0.855
5328	7/10/1989	10.200	1.020	8.756
5333	7/10/1989	10.100	0.913	3.633
5329	7/10/1989	9.770	0.782	4.148

Appendix 2 (cont'd)

5330	7/10/1989	11.800	0.706	11.146
8020	7/19/1989	5.055	0.326	ND
8022	7/19/1989	5.085	0.312	ND
7220	7/20/1989	7.580	0.830	0.260
7269	7/20/1989	5.239	0.791	0.582
7268	7/20/1989	5.171	0.719	0.442
7233	7/20/1989	5.137	0.699	ND
7270	7/20/1989	5.028	0.674	0.566
7257	7/20/1989	5.077	0.665	0.179
7222	7/20/1989	7.210	0.650	ND
7221	7/20/1989	7.470	0.600	0.392
8029	7/20/1989	5.176	0.590	0.880
8033	7/20/1989	5.271	0.532	1.097
8031	7/20/1989	5.180	0.372	0.327
8027	7/20/1989	5.094	0.341	ND
7258	7/20/1989	2.251	0.297	0.386
8025	7/20/1989	5.096	0.187	ND
11581	7/21/1989	8.880	1.150	0.321
11580	7/21/1989	9.700	1.070	0.253
11586	7/21/1989	9.230	1.020	ND
11579	7/21/1989	7.370	0.960	0.224
8042	7/21/1989	5.397	0.691	0.291
8046	7/21/1989	5.253	0.651	0.196
8055	7/21/1989	5.393	0.620	0.149
8053	7/21/1989	5.152	0.608	0.865
8044	7/21/1989	5.049	0.515	0.360
8048	7/21/1989	5.171	0.512	0.331
8056	7/21/1989	5.164	0.494	ND
8040	7/21/1989	5.171	0.451	0.454
8036	7/21/1989	5.189	0.408	3.475
8038	7/21/1989	5.237	0.373	0.319
8054	7/21/1989	5.172	0.333	0.216
8073	7/22/1989	5.225	1.568	0.087
11578	7/22/1989	8.570	0.690	ND
8057	7/22/1989	5.261	0.589	1.893
11576	7/22/1989	8.150	0.570	ND
11577	7/22/1989	8.170	0.570	ND
8068	7/22/1989	5.325	0.564	0.316
8061	7/22/1989	5.083	0.523	0.352
8077	7/22/1989	5.484	0.521	0.484
8063	7/22/1989	5.336	0.510	0.520
8065	7/22/1989	5.124	0.508	ND
8059	7/22/1989	5.023	0.490	0.278
8075	7/22/1989	5.138	0.453	2.034
8070	7/22/1989	5.022	0.445	0.867
8087	7/23/1989	5.338	0.710	0.336
8089	7/24/1989	5.493	1.448	0.133
8091	7/24/1989	5.323	1.421	0.054
8099	7/24/1989	5.460	1.234	ND
8095	7/24/1989	5.309	1.030	0.095
8097	7/24/1989	5.389	0.905	ND
8105	7/24/1989	4.892	0.665	ND

Appendix 2 (cont'd)

8093	7/24/1989	5.053	0.409	0.268
6482	7/25/1989	11.000	1.210	0.445
92063	7/25/1989	11.000	1.210	0.264
92080	7/25/1989	10.100	1.210	ND
6479	7/25/1989	10.700	1.180	ND
6481	7/25/1989	9.970	0.798	ND
6480	7/25/1989	9.640	0.771	ND
92062	7/25/1989	9.840	0.689	ND
8101	7/25/1989	5.087	0.661	ND
8103	7/25/1989	5.333	0.587	ND
8109	7/25/1989	5.349	0.504	0.555
8113	7/25/1989	5.097	0.455	0.855
8107	7/25/1989	5.203	0.431	0.605
8111	7/25/1989	5.220	0.401	0.271
8120	7/26/1989	5.322	0.601	0.279
8128	7/26/1989	5.037	0.574	0.142
8122	7/26/1989	5.374	0.559	ND
8130	7/26/1989	5.168	0.543	ND
8115	7/26/1989	5.490	0.533	2.129
8132	7/26/1989	5.144	0.530	0.227
8124	7/26/1989	5.132	0.488	0.151
8126	7/26/1989	5.083	0.467	ND
8118	7/26/1989	5.310	0.449	1.917
8148	7/27/1989	5.122	0.598	0.252
8136	7/27/1989	5.280	0.579	ND
8138	7/27/1989	5.386	0.567	0.165
8150	7/27/1989	5.193	0.487	0.226
8134	7/27/1989	5.401	0.484	ND
8141	7/27/1989	4.429	0.465	0.272
8144	7/27/1989	5.367	0.454	0.168
8146	7/27/1989	4.521	0.356	0.203
8174	7/28/1989	5.289	2.359	0.188
6524	7/28/1989	10.600	1.160	0.326
92064	7/28/1989	9.990	0.999	ND
6522	7/28/1989	9.540	0.954	0.324
92065	7/28/1989	10.200	0.916	ND
6523	7/28/1989	9.500	0.855	ND
92084	7/28/1989	10.200	0.818	0.314
8188	7/28/1989	5.341	0.742	0.618
8168	7/28/1989	4.899	0.637	0.205
8166	7/28/1989	4.908	0.604	ND
8164	7/28/1989	5.041	0.580	0.245
8176	7/28/1989	4.863	0.535	0.171
8158	7/28/1989	5.407	0.443	ND
8170	7/28/1989	5.463	0.391	0.184
8160	7/28/1989	4.800	0.381	ND
8192	7/29/1989	5.298	1.166	0.203
6216	7/29/1989	5.085	0.615	0.130
92085	7/30/1989	10.100	1.110	0.287
92066	7/30/1989	10.000	1.100	0.485
8197	7/30/1989	5.427	1.096	0.304
6585	7/30/1989	10.000	0.902	0.727

Appendix 2 (cont'd)

6582	7/30/1989	9.500	0.760	0.488
8195	7/30/1989	5.227	0.747	0.281
8199	7/30/1989	5.291	0.677	0.448
6217	7/30/1989	5.054	0.637	0.227
8203	7/30/1989	5.467	0.585	0.250
6584	7/30/1989	6.990	0.559	0.871
8201	7/30/1989	5.043	0.464	0.280
8222	7/31/1989	5.426	6.840	0.193
11770	7/31/1989	5.249	0.827	0.402
8220	7/31/1989	5.481	0.756	0.413
8212	7/31/1989	5.121	0.743	0.241
8224	7/31/1989	5.147	0.737	0.897
8218	7/31/1989	5.557	0.728	0.337
8228	7/31/1989	5.420	0.650	0.177
6226	7/31/1989	5.067	0.638	0.250
8210	7/31/1989	5.343	0.614	0.171
11771	7/31/1989	5.199	0.597	0.414
8206	7/31/1989	5.418	0.533	0.422
8208	7/31/1989	5.327	0.491	0.126
6626	8/1/1989	10.100	1.420	0.497
92067	8/1/1989	10.300	1.230	0.557
6627	8/1/1989	10.100	0.910	ND
6625	8/1/1989	10.100	0.908	ND
92068	8/1/1989	10.400	0.831	ND
6798	8/1/1989	9.910	0.793	ND
6235	8/1/1989	5.092	0.662	0.232
8230	8/1/1989	5.002	0.554	0.123
8232	8/2/1989	5.282	0.798	0.143
8236	8/2/1989	5.278	0.544	0.168
8234	8/2/1989	5.586	0.535	ND
8238	8/2/1989	5.264	0.505	ND
6668	8/3/1989	10.700	1.610	0.440
6324	8/3/1989	11.000	1.320	0.356
92070	8/3/1989	9.710	1.260	0.286
6669	8/3/1989	10.500	1.250	0.223
6321	8/3/1989	9.450	1.230	0.180
92069	8/3/1989	9.950	1.190	ND
92086	8/3/1989	10.600	1.170	0.425
6296	8/3/1989	10.000	1.140	0.322
92075	8/3/1989	10.300	1.140	0.214
6330	8/3/1989	10.300	1.130	0.251
97001	8/3/1989	9.310	1.120	0.801
6301	8/3/1989	10.100	1.110	ND
6325	8/3/1989	9.090	1.090	0.865
6332	8/3/1989	9.870	1.090	1.473
6792	8/3/1989	9.590	1.060	0.361
6303	8/3/1989	10.100	1.010	ND
6306	8/3/1989	9.860	0.986	0.246
6307	8/3/1989	10.300	0.927	ND
6670	8/3/1989	10.000	0.903	ND
6305	8/3/1989	9.190	0.827	ND
6311	8/3/1989	9.640	0.675	ND

Appendix 2 (cont'd)

8242	8/3/1989	5.190	0.640	0.219
8244	8/3/1989	5.092	0.610	ND
8240	8/3/1989	5.369	0.569	ND
8257	8/3/1989	5.254	0.552	0.150
8246	8/3/1989	5.437	0.541	ND
8259	8/3/1989	5.030	0.528	ND
8248	8/3/1989	5.389	0.525	ND
8255	8/3/1989	5.500	0.525	ND
8253	8/3/1989	5.248	0.512	ND
8251	8/3/1989	5.193	0.468	ND
6341	8/4/1989	14.600	1.460	0.365
6364	8/4/1989	9.700	1.070	0.641
6334	8/4/1989	9.700	1.070	0.234
6352	8/4/1989	10.200	1.020	0.749
6336	8/4/1989	8.530	0.938	0.387
6338	8/4/1989	9.050	0.905	0.584
6358	8/5/1989	9.990	1.200	0.583
6368	8/5/1989	10.500	1.150	0.184
6366	8/5/1989	9.280	0.928	ND
6371	8/5/1989	10.300	0.928	ND
6785	8/9/1989	10.400	1.880	0.151
92071	8/9/1989	10.200	1.640	0.358
92074	8/9/1989	10.700	1.600	0.255
6786	8/9/1989	10.100	1.510	0.350
92087	8/9/1989	9.630	1.440	0.373
6778	8/9/1989	10.900	1.410	0.207
6777	8/9/1989	11.400	1.360	0.311
92091	8/9/1989	10.300	1.340	0.350
92072	8/9/1989	10.600	1.170	ND
92073	8/9/1989	10.800	1.080	ND
6788	8/9/1989	8.950	0.985	ND
6783	8/9/1989	10.400	0.938	ND
6782	8/9/1989	9.300	0.837	ND
6779	8/9/1989	9.970	0.698	ND
8269	8/13/1989	5.021	0.417	0.222
8265	8/14/1989	5.305	0.585	ND
8271	8/14/1989	4.932	0.508	0.135
6844	8/15/1989	10.500	0.627	0.369
6842	8/15/1989	9.700	0.582	ND
8275	8/15/1989	5.434	0.577	0.115
6843	8/15/1989	9.030	0.550	0.608
6864	8/16/1989	11.300	0.902	ND
6863	8/16/1989	9.660	0.869	ND
6856	8/16/1989	9.960	0.740	ND
6865	8/16/1989	9.080	0.726	ND
6849	8/16/1989	10.100	0.704	ND
6850	8/16/1989	9.940	0.695	ND
6858	8/16/1989	9.940	0.665	0.674
6857	8/16/1989	9.860	0.653	ND
6872	8/16/1989	10.200	0.614	ND
6851	8/16/1989	9.710	0.582	ND
6886	8/17/1989	9.120	0.638	0.321

Appendix 2 (cont'd)

6877	8/17/1989	8.970	0.628	ND
6884	8/17/1989	9.950	0.613	ND
6879	8/17/1989	10.000	0.601	ND
6878	8/17/1989	9.710	0.583	ND
6914	8/18/1989	9.290	0.807	0.367
6915	8/18/1989	8.980	0.741	0.689
6908	8/18/1989	8.550	0.732	0.682
6909	8/18/1989	8.350	0.653	0.598
6907	8/18/1989	7.940	0.635	0.391
7080	8/20/1989	9.430	0.943	ND
6932	8/20/1989	9.810	0.882	ND
6931	8/20/1989	9.770	0.879	ND
6933	8/20/1989	9.950	0.796	ND
7120	8/22/1989	7.180	1.290	ND
92078	8/22/1989	3.910	0.645	0.322
8261	8/23/1989	5.543	0.545	0.243
8452	8/29/1989	10.400	1.250	0.194
8450	8/29/1989	8.910	1.070	0.917
8451	8/29/1989	9.450	0.945	0.635
8460	8/30/1989	14.800	1.330	ND
8455	8/30/1989	11.700	1.170	ND
8462	8/30/1989	9.250	1.020	ND
8457	8/30/1989	9.960	1.000	ND
92079	8/30/1989	10.900	0.874	ND
8463	8/30/1989	10.400	0.830	ND
8473	8/31/1989	10.200	1.330	ND
8467	8/31/1989	10.300	1.230	ND
8474	8/31/1989	7.480	1.118	ND
8466	8/31/1989	10.000	1.100	ND
8471	8/31/1989	10.200	1.020	ND
8482	9/1/1989	9.660	1.260	ND
8478	9/1/1989	10.000	1.000	ND
8481	9/1/1989	9.850	0.985	ND
8476	9/1/1989	9.970	0.897	ND
8479	9/1/1989	9.820	0.884	ND
11800	9/3/1989	2.010	0.265	ND
8487	9/4/1989	9.730	1.460	0.215
8485	9/4/1989	10.100	1.110	ND
8486	9/4/1989	9.640	0.868	ND
7710	9/5/1989	10.300	1.160	0.430
7712	9/5/1989	10.000	0.946	ND
7713	9/5/1989	9.930	0.846	ND
7715	9/5/1989	9.810	0.687	ND
7736	9/6/1989	9.820	0.982	ND
7791	9/6/1989	9.990	0.942	ND
8500	9/7/1989	10.100	1.290	ND
8495	9/7/1989	10.400	1.140	ND
8499	9/7/1989	10.100	1.010	ND
8492	9/7/1989	12.400	0.994	ND
8502	9/7/1989	10.100	0.909	ND
8496	9/7/1989	9.770	0.879	ND
7868	9/8/1989	10.500	1.370	0.304

Appendix 2 (cont'd)

7872	9/8/1989	10.500	1.350	ND
8508	9/8/1989	9.190	1.290	0.338
7867	9/8/1989	10.100	1.210	0.282
8506	9/8/1989	10.100	1.210	ND
7871	9/8/1989	9.790	1.130	0.252
8505	9/8/1989	9.510	1.050	ND
8507	9/8/1989	10.100	1.010	ND
7853	9/8/1989	10.300	0.926	ND
8509	9/8/1989	9.570	0.861	ND
7873	9/8/1989	8.960	0.721	ND
7870	9/8/1989	8.670	0.694	ND
7854	9/8/1989	9.840	0.689	ND
7923	9/9/1989	9.340	0.841	ND
7887	9/9/1989	9.780	0.782	ND
7974	9/10/1989	9.830	1.160	0.183
7976	9/10/1989	9.940	1.060	ND
7977	9/10/1989	9.870	0.762	ND
10120	9/18/1989	5.150	0.639	ND
10121	9/18/1989	5.013	0.464	ND
10122	9/19/1989	5.023	0.633	ND
10126	9/25/1989	5.340	0.742	ND
10439	10/10/1989	5.122	0.477	0.341
116110	4/17/1990	9.130	0.985	0.337
116119	4/18/1990	8.520	0.472	3.075
116132	4/19/1990	8.380	0.787	0.924
116144	4/20/1990	9.220	0.654	6.343
103906	4/21/1990	5.110	0.894	2.285
103903	4/21/1990	4.484	0.758	2.341
116203	4/21/1990	8.080	0.558	1.689
103907	4/21/1990	3.400	0.527	2.731
103904	4/21/1990	3.087	0.512	2.093
103908	4/21/1990	2.889	0.500	2.791
103905	4/21/1990	2.490	0.473	2.175
103901	4/21/1990	2.390	0.385	1.862
103902	4/21/1990	2.079	0.347	2.287
103909	4/21/1990	1.656	0.242	3.550
116224	4/22/1990	8.990	0.754	11.077
116219	4/22/1990	8.480	0.625	0.541
108512	4/23/1990	5.070	0.750	6.233
108505	4/23/1990	5.090	0.740	4.334
108519	4/23/1990	5.030	0.730	3.987
108528	4/24/1990	11.100	1.110	1.426
108527	4/24/1990	10.300	1.030	1.216
108534	4/24/1990	10.300	1.030	0.359
108526	4/24/1990	5.090	0.780	2.477
108535	4/24/1990	9.220	0.738	0.492
108540	4/24/1990	5.050	0.730	7.686
108710	4/25/1990	11.200	1.240	3.031
108717	4/25/1990	11.300	1.240	1.272
108711	4/25/1990	11.000	1.210	4.587
108718	4/25/1990	10.100	1.010	1.397
108547	4/25/1990	10.100	0.909	0.295

Appendix 2 (cont'd)

108546	4/25/1990	10.100	0.905	ND
108709	4/25/1990	5.080	0.740	5.422
108716	4/25/1990	5.080	0.720	2.554
108731	4/26/1990	9.380	1.030	6.536
108725	4/26/1990	8.880	1.000	9.452
108724	4/26/1990	9.580	0.958	15.552
108732	4/26/1990	9.480	0.948	6.463
108739	4/26/1990	9.750	0.878	5.251
108723	4/26/1990	5.100	0.840	19.452
108737	4/26/1990	5.000	0.830	7.316
108738	4/26/1990	10.200	0.712	5.737
108730	4/26/1990	5.000	0.700	8.244
108807	4/27/1990	5.080	1.010	2.317
108744	4/27/1990	5.010	1.010	2.267
108801	4/27/1990	5.010	0.820	5.509
103711	4/28/1990	4.192	1.128	3.254
108814	4/28/1990	10.500	0.942	1.365
108823	4/28/1990	10.300	0.929	0.437
108821	4/28/1990	10.200	0.914	0.536
103710	4/28/1990	5.282	0.903	4.123
108815	4/28/1990	10.800	0.864	1.756
103720	4/28/1990	4.199	0.836	7.064
103712	4/28/1990	5.178	0.834	5.124
103717	4/28/1990	5.132	0.811	10.253
103716	4/28/1990	3.535	0.802	4.089
103721	4/28/1990	4.228	0.791	7.524
103714	4/28/1990	4.740	0.777	3.765
103718	4/28/1990	5.137	0.755	5.093
103719	4/28/1990	5.059	0.678	5.340
108822	4/28/1990	5.050	0.670	1.236
108816	4/28/1990	5.020	0.650	2.905
103726	4/28/1990	3.571	0.607	4.658
103723	4/28/1990	3.014	0.543	4.585
103713	4/28/1990	2.434	0.540	3.841
103727	4/28/1990	2.828	0.520	6.157
103722	4/28/1990	2.048	0.487	4.095
103725	4/28/1990	3.042	0.444	4.732
103715	4/28/1990	2.273	0.425	4.921
103724	4/28/1990	1.600	0.342	5.548
127602	4/29/1990	3.750	0.632	3.825
127603	4/29/1990	5.240	0.597	1.920
127601	4/29/1990	5.130	0.560	1.967
127403	5/10/1990	5.253	0.872	17.579
127401	5/10/1990	5.052	0.738	14.903
115902	5/15/1990	9.110	0.729	ND
116809	5/16/1990	8.120	0.743	2.212
116822	5/17/1990	10.150	0.698	1.447
120708	5/18/1990	5.190	0.710	15.204
116835	5/18/1990	9.080	0.674	1.352
116847	5/19/1990	8.500	1.140	8.700
116909	5/20/1990	9.290	0.837	4.254
116922	5/21/1990	8.530	1.025	3.587

Appendix 2 (cont'd)

116935	5/22/1990	9.370	0.585	3.987
116947	5/23/1990	8.650	0.921	6.641
120712	5/23/1990	5.020	0.800	9.023
120713	5/23/1990	2.290	0.260	4.960
120716	5/24/1990	5.220	0.760	3.289
120714	5/24/1990	2.810	0.370	4.652
111307	5/31/1990	11.800	2.000	2.929
111302	5/31/1990	13.100	1.710	2.692
111306	5/31/1990	10.300	1.640	5.467
111308	5/31/1990	10.300	1.340	12.112
111303	5/31/1990	10.600	0.952	1.622
111304	5/31/1990	10.300	0.931	11.644
117310	6/2/1990	8.840	0.759	0.806
117322	6/3/1990	9.080	0.443	ND
111319	6/4/1990	10.600	1.160	1.984
111318	6/4/1990	9.830	0.786	1.002
111320	6/4/1990	9.780	0.782	0.275
111313	6/4/1990	9.590	0.671	1.379
117331	6/4/1990	9.610	0.660	ND
117341	6/5/1990	8.160	0.640	1.604
117416	6/6/1990	8.480	0.649	1.135
120902	6/7/1990	4.920	0.720	0.346
117415	6/7/1990	8.130	0.698	0.451
120901	6/7/1990	4.910	0.590	0.235
120904	6/8/1990	5.630	0.702	3.412
120905	6/8/1990	5.040	0.680	4.982
120907	6/9/1990	5.060	0.970	7.581
122603	6/9/1990	5.130	0.800	3.797
120910	6/11/1990	5.010	0.640	3.537
120911	6/11/1990	5.330	0.640	2.488
122606	6/12/1990	5.170	0.820	0.970
120914	6/12/1990	5.210	0.730	0.129
122605	6/12/1990	5.030	0.730	1.462
120913	6/12/1990	5.150	0.517	0.204
117530	6/13/1990	9.800	0.684	1.263
121101	6/14/1990	5.040	0.780	2.074
110203	6/15/1990	9.160	1.280	1.421
110212	6/16/1990	9.160	1.010	0.938
121104	6/18/1990	5.010	0.710	51.362
110207	6/19/1990	9.810	1.570	0.435
110204	6/19/1990	11.700	1.290	ND
108915	6/20/1990	5.540	1.069	4.338
110215	6/20/1990	9.090	1.000	0.657
108908	6/20/1990	5.100	0.923	4.738
108901	6/20/1990	5.020	0.804	8.583
108910	6/20/1990	5.110	0.701	6.702
108924	6/21/1990	10.700	1.280	1.494
108923	6/21/1990	11.000	1.210	1.231
108937	6/21/1990	10.700	0.963	0.218
108922	6/21/1990	5.430	0.875	2.089
108938	6/21/1990	10.800	0.865	0.276
108931	6/21/1990	8.180	0.698	0.458

Appendix 2 (cont'd)

108936	6/21/1990	5.160	0.669	0.362
108930	6/21/1990	8.140	0.636	0.323
121110	6/21/1990	5.010	0.610	1.248
108929	6/21/1990	4.050	0.511	0.613
109003	6/22/1990	10.300	1.130	0.515
109002	6/22/1990	10.900	1.090	0.298
109009	6/22/1990	10.600	0.951	1.015
109023	6/22/1990	9.930	0.930	ND
109010	6/22/1990	11.000	0.876	0.651
109024	6/22/1990	9.830	0.866	ND
109001	6/22/1990	5.390	0.845	0.573
109008	6/22/1990	5.250	0.685	1.627
109022	6/22/1990	5.160	0.685	0.308
109030	6/23/1990	10.700	1.180	1.673
109029	6/23/1990	5.590	0.957	2.529
109031	6/23/1990	10.600	0.952	1.856
109036	6/23/1990	5.050	0.894	3.242
121116	6/23/1990	4.980	0.860	4.803
109123	6/24/1990	5.500	0.951	3.331
109101	6/24/1990	5.180	0.919	1.697
109116	6/24/1990	5.090	0.784	2.388
109108	6/24/1990	5.440	0.779	1.821
109138	6/25/1990	11.200	1.690	0.740
126508	6/25/1990	10.500	1.580	1.339
126507	6/25/1990	10.200	1.530	1.090
109139	6/25/1990	11.300	1.470	0.750
126503	6/25/1990	9.070	1.180	0.856
126502	6/25/1990	10.700	1.170	0.941
109131	6/25/1990	11.500	1.150	0.336
109137	6/25/1990	5.380	1.069	1.288
109132	6/25/1990	11.700	1.060	0.335
126504	6/25/1990	10.200	1.010	0.394
126509	6/25/1990	9.110	0.911	1.283
109130	6/25/1990	5.840	0.758	0.704
126524	6/26/1990	9.180	8.130	0.113
126612	6/26/1990	9.150	7.470	0.345
126606	6/26/1990	8.540	7.190	0.304
126602	6/26/1990	8.350	6.890	0.548
126531	6/26/1990	10.200	1.930	0.799
126610	6/26/1990	11.900	1.790	1.496
126516	6/26/1990	13.100	1.440	1.154
126517	6/26/1990	9.400	1.410	1.842
126518	6/26/1990	10.500	1.260	1.605
126515	6/26/1990	9.710	1.260	1.315
126523	6/26/1990	9.160	1.190	2.140
126611	6/26/1990	9.650	1.160	2.665
126521	6/26/1990	7.600	1.140	1.017
126522	6/26/1990	10.800	1.080	1.427
126534	6/26/1990	10.700	1.070	2.563
126609	6/26/1990	10.600	1.060	2.166
126511	6/26/1990	9.170	1.010	1.856
109144	6/26/1990	5.450	0.991	4.621

Appendix 2 (cont'd)

126616	6/27/1990	8.810	7.540	0.190
124504	6/27/1990	11.140	1.750	0.898
126617	6/27/1990	10.200	1.420	1.743
124506	6/27/1990	10.430	1.390	0.782
126618	6/27/1990	9.640	0.964	1.219
121122	6/27/1990	4.990	0.730	0.934
122613	6/27/1990	1.000	0.190	1.388
121125	6/30/1990	4.990	0.860	2.044
121202	7/5/1990	0.990	0.150	ND
122618	7/6/1990	5.330	0.890	0.577
121204	7/6/1990	1.130	0.220	ND
122622	7/7/1990	5.030	0.600	1.037
122623	7/8/1990	5.330	0.690	1.440
121210	7/9/1990	10.040	1.460	0.998
121213	7/10/1990	10.820	1.670	0.475
121212	7/10/1990	10.110	1.560	0.793
106914	7/16/1990	5.160	0.740	0.381
106904	7/16/1990	5.150	0.700	0.095
106918	7/16/1990	5.010	0.670	0.375
106906	7/16/1990	5.020	0.660	ND
106911	7/16/1990	5.170	0.620	0.103
106916	7/16/1990	5.240	0.580	0.242
106921	7/16/1990	5.070	0.550	0.314
106909	7/16/1990	5.070	0.520	ND
106924	7/16/1990	5.200	0.470	0.216
106936	7/17/1990	5.110	0.800	0.240
106926	7/17/1990	4.570	0.720	0.174
106940	7/17/1990	5.160	0.710	0.431
106931	7/17/1990	5.180	0.690	0.276
106942	7/17/1990	5.160	0.680	0.180
106938	7/17/1990	5.070	0.660	0.314
106928	7/17/1990	5.020	0.590	0.221
106947	7/18/1990	5.280	0.870	3.460
107434	7/18/1990	5.050	0.810	5.540
106944	7/18/1990	5.050	0.740	0.813
107004	7/18/1990	5.050	0.720	0.811
106949	7/18/1990	5.130	0.670	0.108
107001	7/18/1990	5.010	0.670	0.311
107021	7/19/1990	5.100	0.740	0.566
107023	7/19/1990	5.130	0.700	1.467
107014	7/19/1990	5.130	0.690	0.164
107012	7/19/1990	5.070	0.670	0.175
107016	7/19/1990	5.040	0.630	0.277
107039	7/20/1990	5.230	0.960	1.316
107025	7/20/1990	5.240	0.850	1.441
107037	7/20/1990	5.360	0.750	0.834
107030	7/20/1990	5.020	0.710	0.344
107033	7/20/1990	5.020	0.710	ND
107027	7/20/1990	5.020	0.590	0.568
107035	7/20/1990	5.120	0.580	0.122
107102	7/21/1990	5.810	0.800	0.445
107043	7/21/1990	5.200	0.760	0.164

Appendix 2 (cont'd)

107048	7/21/1990	5.130	0.750	0.205
107106	7/21/1990	5.950	0.720	0.279
107046	7/21/1990	5.020	0.670	0.214
107050	7/21/1990	5.010	0.670	0.328
107041	7/21/1990	5.160	0.660	0.169
107104	7/21/1990	5.040	0.630	0.164
107109	7/21/1990	5.220	0.630	0.099
107118	7/22/1990	5.020	0.700	0.100
107116	7/22/1990	5.250	0.680	0.120
107113	7/22/1990	5.180	0.640	0.118
107111	7/22/1990	3.920	0.520	ND
124837	7/23/1990	5.230	0.680	0.198
107133	7/23/1990	5.170	0.640	ND
107121	7/23/1990	5.220	0.580	0.194
107128	7/23/1990	5.020	0.560	0.228
107123	7/23/1990	5.070	0.530	ND
107126	7/23/1990	5.000	0.520	0.407
107137	7/23/1990	5.070	0.510	0.183
107139	7/23/1990	5.040	0.490	0.176
107130	7/23/1990	5.110	0.470	ND
113602	7/24/1990	8.510	7.670	ND
107201	7/24/1990	5.070	0.740	0.337
107205	7/24/1990	5.150	0.740	0.218
107203	7/24/1990	5.100	0.680	0.231
107224	7/24/1990	5.130	0.680	0.489
107214	7/24/1990	5.040	0.660	0.364
107443	7/24/1990	5.080	0.660	ND
107440	7/24/1990	5.100	0.650	0.133
107208	7/24/1990	5.060	0.640	0.256
107218	7/24/1990	5.020	0.640	0.131
107216	7/24/1990	5.100	0.580	0.172
107212	7/24/1990	5.040	0.570	0.228
107222	7/24/1990	5.010	0.560	ND
107149	7/24/1990	5.050	0.550	0.162
107220	7/24/1990	4.350	0.550	0.133
107146	7/24/1990	5.030	0.540	0.142
124907	7/24/1990	2.730	0.530	0.324
113606	7/25/1990	8.290	7.430	ND
107229	7/25/1990	5.030	0.800	0.135
107236	7/25/1990	5.190	0.730	ND
107226	7/25/1990	5.070	0.690	0.101
107238	7/25/1990	5.010	0.690	0.160
107234	7/25/1990	5.240	0.670	ND
107247	7/25/1990	5.050	0.670	0.195
107240	7/25/1990	5.060	0.630	0.274
107232	7/25/1990	5.210	0.610	0.214
113610	7/26/1990	8.770	7.800	0.029
107305	7/26/1990	5.070	0.880	0.955
124920	7/26/1990	5.520	0.870	0.346
107302	7/26/1990	5.170	0.820	2.202
107309	7/26/1990	5.030	0.820	0.246
107307	7/26/1990	5.050	0.750	1.924

Appendix 2 (cont'd)

107311	7/26/1990	5.060	0.600	ND
107314	7/26/1990	5.060	0.480	ND
124919	7/26/1990	2.010	0.230	0.470
107326	7/27/1990	5.330	0.930	0.132
107328	7/27/1990	5.050	0.710	0.154
107321	7/27/1990	5.030	0.680	0.119
107317	7/27/1990	5.020	0.610	ND
107324	7/27/1990	5.100	0.570	ND
107334	7/29/1990	5.040	1.020	0.188
107336	7/29/1990	5.140	0.950	0.201
107341	7/29/1990	5.060	0.760	0.166
107338	7/29/1990	5.110	0.720	0.116
107331	7/29/1990	5.040	0.630	ND
107405	7/30/1990	5.180	0.700	0.240
107407	7/30/1990	5.010	0.670	0.386
107343	7/30/1990	5.100	0.640	0.120
107350	7/30/1990	5.080	0.620	0.151
107402	7/30/1990	5.010	0.620	1.244
107346	7/30/1990	5.140	0.580	0.144
107348	7/30/1990	5.220	0.510	0.207
113614	7/31/1990	8.750	7.320	0.036
107426	7/31/1990	5.030	0.830	0.242
107419	7/31/1990	5.050	0.800	0.109
107409	7/31/1990	5.180	0.800	0.078
107449	7/31/1990	5.050	0.740	ND
107421	7/31/1990	5.030	0.600	0.126
107416	7/31/1990	5.180	0.580	0.119
107424	7/31/1990	5.040	0.580	0.116
107413	7/31/1990	5.270	0.570	ND
107411	7/31/1990	5.190	0.500	ND
110308	8/1/1990	8.850	0.531	ND
113618	8/2/1990	8.350	7.290	ND
24440	8/2/1990	4.460	2.150	ND
110332	8/2/1990	10.900	1.520	0.141
110330	8/2/1990	9.720	1.160	ND
110326	8/2/1990	10.200	1.020	ND
110331	8/2/1990	10.200	1.020	ND
113629	8/3/1990	9.490	8.390	ND
113622	8/3/1990	8.410	7.180	ND
24441	8/3/1990	4.520	2.190	0.083
113625	8/3/1990	9.100	0.728	ND
117805	8/4/1990	10.600	1.270	ND
107429	8/4/1990	5.140	0.600	0.237
141429	8/5/1990	10.900	1.200	0.198
141431	8/5/1990	10.500	1.160	ND
117808	8/5/1990	10.500	1.050	ND
141430	8/5/1990	10.200	1.010	ND
117807	8/5/1990	9.160	1.010	ND
141422	8/5/1990	10.900	0.875	ND
141424	8/5/1990	11.500	0.807	ND
141423	8/5/1990	11.000	0.769	ND
117812	8/5/1990	8.880	0.710	0.377

Appendix 2 (cont'd)

141436	8/5/1990	8.350	0.655	ND
117810	8/5/1990	8.710	0.610	0.622
141509	8/6/1990	11.300	1.010	ND
141508	8/6/1990	10.500	0.941	ND
141510	8/6/1990	9.800	0.882	ND
141545	8/8/1990	11.400	1.140	ND
141544	8/8/1990	11.100	1.100	ND
141543	8/8/1990	10.900	0.875	ND
125014	8/8/1990	1.200	0.240	ND
125015	8/8/1990	1.020	0.190	ND
141610	8/9/1990	11.200	1.450	0.164
141609	8/9/1990	10.800	1.180	ND
141602	8/9/1990	11.200	1.120	ND
141608	8/9/1990	10.900	1.030	0.377
141601	8/9/1990	11.300	0.906	ND
141603	8/9/1990	10.400	0.729	ND
123110	8/9/1990	2.170	0.300	ND
107447	8/10/1990	5.070	0.560	0.198
107445	8/12/1990	5.020	0.720	0.188
125024	8/13/1990	2.000	0.290	1.241
125023	8/13/1990	0.990	0.200	ND
125026	8/14/1990	1.020	0.190	ND
142601	9/4/1990	9.280	1.020	0.846
142602	9/4/1990	10.100	1.010	0.780
142603	9/4/1990	8.210	0.903	0.413
195092	9/6/1990	10.700	1.390	0.237
142609	9/6/1990	8.270	1.080	0.303
142614	9/6/1990	9.450	1.040	0.320
142605	9/6/1990	9.460	1.040	0.341
195091	9/6/1990	9.130	1.000	0.251
142615	9/6/1990	8.520	0.852	0.325
142610	9/6/1990	7.740	0.851	5.300
142618	9/6/1990	9.240	0.832	ND
195094	9/6/1990	9.170	0.825	ND
142617	9/6/1990	9.020	0.722	0.468
142619	9/6/1990	9.190	0.643	ND
142611	9/6/1990	7.900	0.632	ND
142613	9/6/1990	9.340	0.560	0.562
142623	9/7/1990	10.000	1.100	0.264
142622	9/7/1990	9.890	1.090	0.375
142621	9/7/1990	9.820	1.080	0.496
195095	9/7/1990	9.250	1.020	0.331
195098	9/9/1990	10.800	1.720	0.923
195097	9/9/1990	10.700	1.710	2.469
142633	9/9/1990	9.870	1.580	0.999
142629	9/9/1990	9.250	1.480	2.651
142641	9/10/1990	8.880	1.330	0.731
142637	9/10/1990	9.530	1.140	0.703
195099	9/10/1990	9.400	1.130	0.645
142647	9/11/1990	9.620	1.050	0.290
142646	9/11/1990	9.130	1.000	0.475
142645	9/11/1990	9.330	0.746	ND

Appendix 2 (cont'd)

142649	9/13/1990	8.170	0.980	0.605
142503	9/14/1990	9.220	0.738	0.875
142507	9/15/1990	9.510	0.951	0.733
210828	4/15/1991	9.660	0.966	10.197
210834	4/15/1991	9.520	0.952	0.462
210833	4/15/1991	9.720	0.875	0.395
210826	4/15/1991	9.390	0.845	10.471
210835	4/15/1991	10.100	0.810	0.589
210847	4/17/1991	8.880	0.799	ND
210848	4/17/1991	9.020	0.722	ND
210849	4/17/1991	9.290	0.650	ND
210913	4/18/1991	8.860	1.060	0.473
210912	4/18/1991	9.150	1.010	0.539
210905	4/18/1991	8.140	0.733	0.538
210907	4/18/1991	9.110	0.729	1.800
210906	4/18/1991	8.860	0.709	ND
210927	4/19/1991	9.290	0.836	9.967
210929	4/19/1991	8.840	0.796	0.660
210928	4/19/1991	8.800	0.792	0.523
210936	4/19/1991	9.460	0.664	ND
210935	4/19/1991	8.110	0.511	ND
210934	4/19/1991	8.160	0.490	ND
210943	4/20/1991	8.770	0.789	0.764
210948	4/20/1991	8.880	0.622	0.353
210950	4/20/1991	8.690	0.608	0.448
210949	4/20/1991	8.530	0.597	0.398
211517	5/2/1991	8.960	0.717	1.114
211515	5/2/1991	8.830	0.706	1.029
211516	5/2/1991	8.730	0.698	0.972
208801	5/11/1991	2.440	0.490	ND
208803	5/13/1991	5.320	0.810	ND
206501	5/15/1991	5.030	0.940	0.530
206502	5/15/1991	2.440	0.460	0.412
208809	5/15/1991	2.730	0.430	0.898
208811	5/17/1991	5.600	1.010	0.089
208815	5/18/1991	5.660	1.010	0.150
208819	5/19/1991	5.380	0.760	0.524
206602	5/19/1991	5.270	0.740	2.886
206603	5/19/1991	5.260	0.650	2.058
206509	5/20/1991	5.160	0.750	0.169
206510	5/20/1991	2.630	0.420	ND
208015	5/20/1991	2.040	0.400	2.624
208827	5/21/1991	2.450	0.370	0.229
208102	5/25/1991	5.260	0.820	6.978
208017	5/25/1991	5.090	0.720	528.167
208104	5/26/1991	5.170	0.730	23.978
206702	5/27/1991	5.150	0.590	1.674
208106	5/27/1991	5.150	0.580	27.155
208112	5/31/1991	5.110	0.930	2.953
206716	5/31/1991	5.000	0.460	0.917
208114	6/1/1991	5.030	0.710	23.149
208116	6/2/1991	5.090	0.860	16.452

Appendix 2 (cont'd)

208118	6/3/1991	5.030	0.880	1.128
213604	6/5/1991	9.850	1.580	0.652
213606	6/5/1991	9.530	1.430	4.046
213605	6/5/1991	8.250	1.320	0.923
213609	6/6/1991	8.910	1.250	14.701
213614	6/6/1991	9.010	1.170	7.798
213615	6/6/1991	8.640	1.040	4.820
213610	6/6/1991	9.110	1.000	0.232
213611	6/6/1991	8.090	0.890	7.900
213616	6/6/1991	9.540	0.858	6.898
213623	6/7/1991	9.450	1.420	23.318
213619	6/7/1991	9.420	1.320	10.280
213624	6/7/1991	9.400	1.320	7.086
213620	6/7/1991	9.210	1.290	7.972
213621	6/7/1991	9.540	0.954	7.293
213625	6/7/1991	8.960	0.806	4.839
213628	6/8/1991	10.600	1.270	12.129
213634	6/8/1991	9.090	1.270	5.393
213629	6/8/1991	9.140	1.190	4.861
213633	6/8/1991	9.400	1.130	5.409
213635	6/8/1991	8.590	0.945	3.153
213630	6/8/1991	10.500	0.941	0.436
213639	6/9/1991	9.540	1.430	2.517
213638	6/9/1991	10.300	1.230	4.639
208202	6/9/1991	5.090	0.660	0.242
213648	6/10/1991	10.200	1.840	4.210
213641	6/10/1991	8.540	1.450	2.375
213647	6/10/1991	8.830	1.240	2.618
213642	6/10/1991	8.970	1.080	1.866
213649	6/10/1991	8.870	0.976	1.592
213643	6/10/1991	9.880	0.889	1.586
208204	6/10/1991	5.820	0.750	71.994
208206	6/12/1991	2.550	0.390	20.801
208208	6/14/1991	2.650	0.390	9.412
208210	6/15/1991	5.730	1.070	1.801
208212	6/17/1991	5.850	1.190	1.141
214014	6/26/1991	8.560	0.856	0.967
214013	6/27/1991	10.200	0.920	0.877
214012	6/27/1991	9.550	0.859	1.029
214022	6/28/1991	8.770	1.050	3.087
214020	6/28/1991	10.200	1.020	1.741
214021	6/28/1991	10.000	1.000	2.488
214040	6/28/1991	10.500	0.945	0.834
214027	6/28/1991	10.200	0.914	0.292
214035	6/28/1991	9.030	0.903	2.538
214036	6/28/1991	8.680	0.781	2.455
214042	6/28/1991	9.470	0.758	0.686
214028	6/28/1991	8.190	0.737	0.595
214041	6/28/1991	8.230	0.658	0.530
214048	6/29/1991	9.150	0.915	0.627
214047	6/29/1991	11.400	0.912	0.787
214049	6/29/1991	8.900	0.712	1.429

Appendix 2 (cont'd)

214107	6/29/1991	8.310	0.665	1.494
206723	7/1/1991	5.000	0.690	0.786
206722	7/1/1991	5.060	0.670	0.724
214203	8/7/1991	7.530	0.377	0.767
215701	9/6/1991	8.520	0.767	0.345
215705	9/6/1991	8.460	0.761	0.762
215706	9/6/1991	8.330	0.750	1.812
215703	9/6/1991	9.160	0.733	0.318
215704	9/6/1991	8.410	0.673	0.518
215702	9/6/1991	7.530	0.527	0.498
215727	9/7/1991	8.280	0.662	0.544
215726	9/7/1991	8.650	0.605	0.770
215728	9/7/1991	8.490	0.594	1.922
215733	9/8/1991	8.800	0.792	0.270
215732	9/8/1991	8.640	0.778	ND
300802	4/18/1992	8.580	0.880	ND
300803	4/18/1992	8.190	0.700	ND
300801	4/18/1992	8.730	0.690	ND
301207	5/16/1992	8.600	1.280	1.083
301204	5/16/1992	8.920	1.130	0.944
301201	5/16/1992	8.370	1.070	1.072
301208	5/16/1992	8.850	1.030	0.892
301213	5/16/1992	9.570	0.987	0.626
301202	5/16/1992	8.920	0.980	0.685
301209	5/16/1992	9.500	0.894	0.549
301216	5/16/1992	8.400	0.794	0.424
301203	5/16/1992	7.040	0.680	0.413
301308	5/17/1992	8.180	1.350	1.813
301306	5/17/1992	8.400	1.260	1.842
301324	5/17/1992	8.900	1.160	0.963
301304	5/17/1992	8.660	1.120	1.124
301307	5/17/1992	8.480	1.100	1.225
301305	5/17/1992	8.510	1.090	1.483
301317	5/17/1992	8.360	1.070	1.134
301321	5/17/1992	8.840	1.070	1.021
301319	5/17/1992	9.850	1.050	0.915
301309	5/17/1992	8.610	1.030	1.016
301311	5/17/1992	8.540	1.020	1.302
301322	5/17/1992	9.400	0.987	0.774
301302	5/17/1992	8.320	0.980	1.448
301315	5/17/1992	9.550	0.917	0.786
301313	5/17/1992	9.470	0.896	0.760
301310	5/17/1992	9.570	0.850	0.730
301312	5/17/1992	8.180	0.800	0.788
301318	5/17/1992	8.610	0.770	1.017
301821	5/18/1992	9.190	1.310	1.628
301806	5/18/1992	8.600	1.230	4.049
301815	5/18/1992	8.480	1.180	2.172
301818	5/18/1992	8.820	1.160	1.767
301802	5/18/1992	8.340	1.030	2.369
301816	5/18/1992	9.290	1.000	2.546
301819	5/18/1992	8.100	0.956	2.471

Appendix 2 (cont'd)

301812	5/18/1992	8.840	0.950	1.842
301803	5/18/1992	8.100	0.900	2.533
301814	5/18/1992	8.020	0.890	2.725
301827	5/19/1992	8.200	0.990	0.324
301825	5/19/1992	7.990	0.730	0.406
301847	5/20/1992	8.420	1.420	5.063
301848	5/20/1992	8.430	1.410	2.958
301837	5/20/1992	8.400	1.140	1.256
301840	5/20/1992	8.960	1.090	1.222
301842	5/20/1992	8.650	0.990	1.352
301841	5/20/1992	8.510	0.980	1.182
301836	5/20/1992	9.330	0.970	1.220
301839	5/20/1992	8.530	0.830	0.854
301838	5/20/1992	8.000	0.800	0.997
302414	6/8/1992	8.800	1.010	0.675
302421	6/8/1992	9.260	0.995	0.619
302410	6/8/1992	8.660	0.980	0.755
302417	6/8/1992	7.670	0.970	0.371
302419	6/8/1992	8.860	0.870	0.445
302412	6/8/1992	8.280	0.849	0.962
302403	6/8/1992	8.740	0.835	0.538
302405	6/8/1992	8.860	0.791	0.636
302407	6/8/1992	8.280	0.782	0.587
302426	6/10/1992	8.660	0.781	30.243
302424	6/10/1992	8.560	0.775	39.785
302428	6/10/1992	7.170	0.660	33.614
302213	6/15/1992	9.790	0.750	0.278
302214	6/15/1992	9.040	0.730	0.417
302215	6/15/1992	8.020	0.720	0.288
302106	6/16/1992	9.080	1.000	0.317
302513	6/21/1992	9.920	1.080	0.767
302504	6/21/1992	9.750	1.000	0.693
302506	6/21/1992	9.940	1.000	0.706
302511	6/21/1992	10.040	0.960	0.689
302518	6/21/1992	9.770	0.890	ND
302520	6/21/1992	9.960	0.850	ND
302508	6/21/1992	9.740	0.840	0.378
302522	6/21/1992	9.940	0.770	0.326
302536	6/22/1992	10.020	1.100	2.643
302532	6/22/1992	9.500	1.060	2.473
302534	6/22/1992	9.740	0.980	2.328
302525	6/22/1992	9.900	0.910	1.197
302529	6/22/1992	9.350	0.884	1.396
302527	6/22/1992	9.890	0.806	0.764
302543	6/23/1992	9.790	1.020	0.613
302541	6/23/1992	9.770	0.999	0.489
302548	6/23/1992	9.310	0.797	0.262
302550	6/23/1992	9.950	0.755	0.354
302546	6/23/1992	9.840	0.744	0.285
302603	6/24/1992	9.960	1.070	2.710
302607	6/24/1992	8.250	0.980	4.274
302605	6/24/1992	8.200	0.960	4.227

Appendix 2 (cont'd)

302704	8/6/1992	8.760	0.740	1.197
302702	8/6/1992	8.620	0.621	ND
302706	8/6/1992	8.170	0.550	ND
304701	8/25/1992	8.120	0.933	ND
304703	8/25/1992	8.240	0.923	ND
304716	8/25/1992	8.230	0.823	ND
304715	8/25/1992	8.380	0.771	ND
304702	8/25/1992	8.270	0.736	ND
304717	8/25/1992	8.240	0.733	ND
304204	8/26/1992	8.250	1.310	ND
304038	8/26/1992	9.450	0.992	ND
304723	8/26/1992	8.070	0.936	ND
304037	8/26/1992	9.450	0.879	ND
304045	8/26/1992	10.350	0.849	0.278
304722	8/26/1992	8.140	0.847	ND
304039	8/26/1992	8.490	0.781	ND
304203	8/26/1992	8.320	0.780	ND
304202	8/26/1992	8.020	0.746	ND
304043	8/26/1992	9.170	0.743	0.348
304724	8/26/1992	8.230	0.667	ND
304050	8/26/1992	8.750	0.639	0.372
304049	8/26/1992	8.830	0.600	0.365
304044	8/26/1992	8.090	0.598	ND
304315	8/27/1992	8.560	1.180	0.199
304314	8/27/1992	8.590	1.160	0.263
304313	8/27/1992	8.950	1.030	ND
304738	8/27/1992	9.600	0.880	ND
304321	8/27/1992	9.940	0.878	0.509
304250	8/27/1992	8.970	0.870	ND
304730	8/27/1992	9.360	0.840	ND
304731	8/27/1992	8.720	0.820	ND
304301	8/27/1992	8.240	0.820	ND
304306	8/27/1992	8.420	0.800	ND
304308	8/27/1992	9.030	0.800	ND
304309	8/27/1992	8.140	0.800	ND
304312	8/27/1992	8.550	0.800	ND
304248	8/27/1992	8.440	0.780	ND
304736	8/27/1992	9.340	0.770	ND
304319	8/27/1992	9.340	0.770	0.519
304744	8/27/1992	8.690	0.756	ND
304729	8/27/1992	9.400	0.740	ND
304247	8/27/1992	8.110	0.740	ND
304743	8/27/1992	8.360	0.727	ND
304310	8/27/1992	8.260	0.720	0.288
304307	8/27/1992	8.620	0.710	ND
304311	8/27/1992	8.730	0.690	ND
304737	8/27/1992	9.090	0.680	ND
304745	8/27/1992	8.660	0.650	ND
304423	8/28/1992	8.490	1.050	0.292
304427	8/28/1992	9.980	0.940	ND
304426	8/28/1992	9.670	0.920	ND
304434	8/28/1992	9.340	0.920	ND

Appendix 2 (cont'd)

304424	8/28/1992	8.500	0.880	ND
304422	8/28/1992	8.120	0.820	ND
304435	8/28/1992	9.640	0.810	ND
304425	8/28/1992	7.160	0.630	ND
304433	8/28/1992	7.560	0.570	ND
304548	8/29/1992	7.910	1.210	0.485
304547	8/29/1992	7.810	1.040	0.280
304549	8/29/1992	9.280	0.910	0.356
304603	8/29/1992	8.380	0.900	0.608
304602	8/29/1992	8.530	0.860	0.387
304545	8/29/1992	7.870	0.790	0.435
304601	8/29/1992	8.230	0.650	0.353
304541	8/29/1992	8.510	0.640	0.346
304542	8/29/1992	8.100	0.620	ND
304631	8/30/1992	9.560	0.888	0.343
304632	8/30/1992	8.150	0.740	0.337
304627	8/30/1992	8.280	0.730	0.315
304628	8/30/1992	8.920	0.730	ND
304633	8/30/1992	8.590	0.696	ND
304635	8/30/1992	8.450	0.640	ND
304634	8/30/1992	8.300	0.620	ND
304626	8/30/1992	9.390	0.510	0.503
304625	8/30/1992	8.220	0.500	0.618
400704	6/1/1993	10.230	1.590	11.185
400706	6/1/1993	8.760	1.430	12.483
400711	6/1/1993	8.220	1.220	20.506
400713	6/1/1993	8.470	1.200	18.849
400709	6/1/1993	8.950	1.160	14.205
400702	6/1/1993	8.800	1.140	9.299
400721	6/2/1993	8.840	1.010	0.424
400717	6/2/1993	8.660	0.950	0.345
400724	6/2/1993	9.340	0.770	0.309
400726	6/2/1993	8.920	0.720	0.360
400733	6/2/1993	9.630	0.720	ND
400731	6/2/1993	8.740	0.710	0.350
400728	6/2/1993	8.600	0.690	0.369
400735	6/2/1993	8.350	0.670	ND
400750	6/3/1993	8.480	1.000	0.521
400746	6/3/1993	9.030	0.920	0.603
400748	6/3/1993	9.070	0.900	0.538
400743	6/3/1993	8.740	0.760	0.475
400741	6/3/1993	8.860	0.700	0.508
400739	6/3/1993	8.720	0.660	0.559
400803	6/3/1993	8.300	0.660	0.693
400805	6/3/1993	8.920	0.650	0.376
400807	6/3/1993	8.290	0.590	2.098
400811	6/4/1993	8.760	1.010	1.283
400815	6/4/1993	8.680	0.960	6.130
400820	6/4/1993	8.500	0.910	3.298
400818	6/4/1993	8.230	0.870	5.705
400822	6/4/1993	8.640	0.810	1.546
400813	6/4/1993	8.290	0.480	1.455

Appendix 2 (cont'd)

400830	6/5/1993	9.030	1.100	4.434
400828	6/5/1993	8.220	1.050	4.120
400842	6/5/1993	8.170	1.010	5.986
400826	6/5/1993	8.880	0.960	3.984
400840	6/5/1993	8.630	0.960	3.418
400837	6/5/1993	8.400	0.880	5.702
400844	6/5/1993	8.840	0.810	9.917
400833	6/5/1993	8.580	0.730	8.586
400835	6/5/1993	8.130	0.730	3.959
400848	6/7/1993	9.600	0.670	12.483
400902	6/7/1993	8.740	0.530	4.032
400850	6/7/1993	8.270	0.460	6.798
400304	6/17/1993	9.500	0.790	ND
400305	6/17/1993	8.250	0.780	ND
400306	6/17/1993	8.510	0.700	ND
400335	6/18/1993	8.250	0.720	1.439
401002	6/18/1993	8.720	0.710	0.760
400313	6/18/1993	9.740	0.690	0.339
401006	6/18/1993	8.880	0.680	0.895
400334	6/18/1993	9.050	0.670	0.333
401004	6/18/1993	8.950	0.660	0.498
400312	6/18/1993	9.290	0.650	ND
400311	6/18/1993	9.680	0.640	0.329
400327	6/18/1993	9.400	0.630	0.404
400336	6/18/1993	8.800	0.630	ND
400320	6/18/1993	8.320	0.620	0.335
400329	6/18/1993	8.920	0.590	2.459
400328	6/18/1993	8.580	0.560	0.590
400321	6/18/1993	9.720	0.560	0.518
400319	6/18/1993	9.110	0.540	0.443
400322	6/18/1993	8.760	0.470	ND
400440	6/19/1993	9.270	0.920	0.805
400441	6/19/1993	9.030	0.830	0.513
400435	6/19/1993	8.170	0.810	1.349
400449	6/19/1993	9.160	0.780	0.724
400433	6/19/1993	8.910	0.760	0.409
400448	6/19/1993	8.100	0.740	0.685
400450	6/19/1993	8.760	0.740	1.108
400504	6/19/1993	9.250	0.730	ND
400505	6/19/1993	9.040	0.710	ND
400439	6/19/1993	10.290	0.680	0.379
400506	6/19/1993	9.270	0.680	ND
400607	6/20/1993	8.020	0.914	0.925
400604	6/20/1993	8.910	0.830	0.961
400548	6/20/1993	9.220	0.820	0.610
400605	6/20/1993	7.670	0.720	0.978
400549	6/20/1993	8.560	0.700	0.769
400616	6/20/1993	9.000	0.690	0.693
400606	6/20/1993	7.210	0.680	0.755
400609	6/20/1993	8.610	0.680	0.824
400542	6/20/1993	9.150	0.670	0.545
400617	6/20/1993	9.620	0.640	0.505

Appendix 2 (cont'd)

400547	6/20/1993	7.490	0.640	0.707
400615	6/20/1993	8.740	0.630	0.612
400543	6/20/1993	9.220	0.620	0.377
400550	6/20/1993	8.790	0.580	0.565
400608	6/20/1993	8.380	0.553	1.644
400541	6/20/1993	7.750	0.550	0.617
400601	6/20/1993	7.220	0.530	0.856
402641	6/21/1993	8.380	0.855	0.707
402705	6/21/1993	10.060	0.760	0.395
402704	6/21/1993	9.530	0.750	0.778
402643	6/21/1993	9.590	0.740	0.629
402711	6/21/1993	8.940	0.710	1.053
402648	6/21/1993	9.800	0.680	ND
402640	6/21/1993	8.930	0.650	0.561
402710	6/21/1993	9.020	0.650	0.922
402646	6/21/1993	8.450	0.642	0.423
402639	6/21/1993	9.320	0.630	0.774
402703	6/21/1993	7.250	0.630	0.713
402706	6/21/1993	8.770	0.630	0.715
402650	6/21/1993	9.240	0.620	0.442
402649	6/21/1993	9.290	0.610	ND
402642	6/21/1993	8.370	0.580	0.593
402647	6/21/1993	10.030	0.580	0.607
402712	6/21/1993	8.240	0.550	0.640
400648	6/22/1993	8.970	0.830	0.407
400647	6/22/1993	9.250	0.800	0.579
400646	6/22/1993	8.540	0.730	1.084
400639	6/22/1993	9.030	0.690	0.341
400641	6/22/1993	8.840	0.640	ND
400650	6/22/1993	8.910	0.610	0.654
400637	6/22/1993	7.130	0.590	0.817
400640	6/22/1993	7.330	0.550	0.745
400649	6/22/1993	8.340	0.550	0.594
400638	6/22/1993	7.030	0.490	0.454
402735	6/23/1993	9.710	0.750	0.422
402739	6/23/1993	8.930	0.730	0.809
402736	6/23/1993	8.290	0.720	1.124
402738	6/23/1993	8.400	0.700	0.813
402742	6/23/1993	9.330	0.660	ND
402734	6/23/1993	9.550	0.650	0.384
402740	6/23/1993	8.380	0.640	0.536
402741	6/23/1993	8.890	0.550	ND
402743	6/23/1993	8.350	0.520	ND
402750	6/24/1993	8.470	0.540	0.671
403901	8/1/1993	9.120	0.780	ND
403903	8/1/1993	8.930	0.670	ND
403902	8/1/1993	8.170	0.640	ND
501210	4/25/1994	8.270	0.900	1.674
501309	4/28/1994	8.660	0.870	1.076
501308	4/28/1994	8.800	0.780	1.016
501307	4/28/1994	8.360	0.680	1.175
501310	4/29/1994	8.410	1.030	2.026

Appendix 2 (cont'd)

501312	4/29/1994	8.320	0.980	2.219
501311	4/29/1994	8.880	0.960	1.404
501329	4/30/1994	7.770	1.200	0.663
501328	4/30/1994	8.220	0.730	0.697
501327	4/30/1994	8.040	0.640	0.455
501501	5/23/1994	8.270	0.840	4.721
501502	5/23/1994	8.320	0.760	5.295
501525	5/25/1994	8.340	0.760	4.535
501527	5/25/1994	8.360	0.730	35.963
501526	5/25/1994	8.130	0.650	9.504
501529	5/25/1994	8.300	0.640	8.898
501524	5/25/1994	8.160	0.550	9.409
501530	5/25/1994	8.260	0.530	11.021
501528	5/25/1994	8.270	0.440	12.385
501729	5/27/1994	8.100	1.060	5.383
501719	5/27/1994	8.240	0.940	3.298
501728	5/27/1994	8.700	0.900	2.219
501717	5/27/1994	8.010	0.900	2.754
501718	5/27/1994	8.840	0.860	2.632
501745	5/28/1994	8.490	1.560	9.804
501735	5/28/1994	8.530	1.410	12.590
501743	5/28/1994	8.600	1.360	13.032
501742	5/28/1994	8.580	1.350	8.794
501744	5/28/1994	8.630	1.320	10.030
501741	5/28/1994	8.560	1.290	11.976
501736	5/28/1994	9.060	1.240	8.972
501734	5/28/1994	8.460	1.150	5.977
501819	5/29/1994	9.000	0.850	0.413
501803	5/29/1994	8.100	0.840	3.803
501804	5/29/1994	8.620	0.790	4.202
501820	5/29/1994	8.320	0.720	ND
501821	5/29/1994	8.160	0.690	0.356
501805	5/29/1994	8.150	0.680	3.006
506611	7/21/1994	9.140	0.790	0.265
506612	7/21/1994	8.180	0.700	0.318
506621	7/21/1994	8.490	0.700	ND
506609	7/21/1994	8.120	0.660	0.521
506622	7/21/1994	8.720	0.640	ND
506623	7/21/1994	8.260	0.640	ND
506610	7/21/1994	8.160	0.590	ND
506613	7/21/1994	8.020	0.590	ND
506608	7/21/1994	8.250	0.520	ND
506633	7/22/1994	8.230	0.720	0.475
506632	7/22/1994	8.940	0.700	ND
506634	7/22/1994	8.690	0.620	ND
506631	7/22/1994	8.230	0.590	ND
506643	7/23/1994	8.590	1.010	0.419
506642	7/23/1994	8.190	0.960	0.815
506644	7/23/1994	8.420	0.890	0.280
506648	7/23/1994	8.950	0.810	0.560
506647	7/23/1994	8.100	0.790	0.272
506649	7/23/1994	8.860	0.730	ND

Appendix 2 (cont'd)

506645	7/23/1994	8.330	0.610	ND
506646	7/23/1994	8.480	0.570	ND
506735	7/24/1994	8.190	1.560	ND
506722	7/24/1994	8.580	1.350	ND
506725	7/24/1994	7.750	1.030	ND
506708	7/24/1994	9.620	0.960	ND
506732	7/24/1994	8.580	0.840	ND
506733	7/24/1994	8.100	0.830	0.554
506723	7/24/1994	8.120	0.820	0.471
506709	7/24/1994	8.360	0.800	ND
506721	7/24/1994	8.150	0.800	0.343
506707	7/24/1994	8.180	0.750	ND
506737	7/24/1994	8.270	0.740	0.301
506734	7/24/1994	8.350	0.730	ND
506736	7/24/1994	8.140	0.630	ND
506724	7/24/1994	8.350	0.440	ND
506802	7/25/1994	8.020	0.740	0.515
506747	7/25/1994	8.110	0.730	0.416
506745	7/25/1994	8.430	0.720	1.155
506801	7/25/1994	8.500	0.690	1.112
506749	7/25/1994	8.310	0.670	1.338
506744	7/25/1994	8.120	0.660	0.595
506746	7/25/1994	8.240	0.630	0.899
506748	7/25/1994	8.220	0.610	ND
506750	7/25/1994	8.340	0.580	0.630
506103	8/6/1994	8.620	0.840	ND
506114	8/6/1994	8.160	0.830	ND
506105	8/6/1994	8.240	0.790	ND
506106	8/6/1994	8.440	0.790	ND
506112	8/6/1994	8.380	0.760	ND
506111	8/6/1994	8.410	0.750	ND
506101	8/6/1994	8.360	0.740	ND
506102	8/6/1994	8.370	0.740	ND
506104	8/6/1994	8.400	0.740	ND
506113	8/6/1994	8.320	0.740	ND
506134	8/7/1994	8.920	0.840	0.253
506121	8/7/1994	9.050	0.830	ND
506127	8/7/1994	8.830	0.830	ND
506128	8/7/1994	8.930	0.830	ND
506132	8/7/1994	8.690	0.790	ND
506122	8/7/1994	8.590	0.760	ND
506133	8/7/1994	8.170	0.740	ND
506120	8/7/1994	8.210	0.690	ND
506126	8/7/1994	8.380	0.670	ND
507011	8/8/1994	8.640	0.780	0.265
507001	8/8/1994	8.480	0.770	ND
507004	8/8/1994	8.050	0.740	ND
507012	8/8/1994	8.320	0.740	ND
507009	8/8/1994	8.700	0.720	ND
507010	8/8/1994	8.340	0.700	ND
507008	8/8/1994	8.020	0.690	ND
506144	8/8/1994	8.760	0.680	0.335

Appendix 2 (cont'd)

506145	8/8/1994	8.470	0.680	0.399
507002	8/8/1994	8.480	0.680	ND
507006	8/8/1994	8.530	0.680	ND
507003	8/8/1994	8.460	0.670	ND
507007	8/8/1994	8.100	0.670	ND
506143	8/8/1994	8.200	0.660	0.312
507005	8/8/1994	8.690	0.660	ND
507038	8/9/1994	9.230	0.800	ND
507035	8/9/1994	8.640	0.790	ND
507031	8/9/1994	8.260	0.780	ND
507030	8/9/1994	8.350	0.770	ND
507034	8/9/1994	8.340	0.730	ND
507029	8/9/1994	8.740	0.710	ND
507036	8/9/1994	8.820	0.710	ND
507032	8/9/1994	8.400	0.690	ND
507037	8/9/1994	8.210	0.650	0.419
507033	8/9/1994	8.160	0.630	ND
507039	8/9/1994	8.290	0.620	ND
506907	8/10/1994	8.420	0.710	ND
506914	8/10/1994	8.340	0.700	0.295
506915	8/10/1994	8.680	0.680	ND
506916	8/10/1994	8.250	0.670	0.545
506917	8/10/1994	8.350	0.670	ND
506906	8/10/1994	8.540	0.640	ND
506905	8/10/1994	8.130	0.600	0.463
506920	8/11/1994	8.190	0.850	ND
506922	8/11/1994	8.520	0.820	0.273
506921	8/11/1994	8.750	0.810	ND
507148	8/18/1994	8.450	0.830	ND
507144	8/18/1994	8.360	0.790	ND
507145	8/18/1994	8.250	0.790	ND
507138	8/18/1994	8.610	0.780	ND
507146	8/18/1994	8.710	0.740	ND
507143	8/18/1994	8.370	0.720	ND
507147	8/18/1994	8.430	0.710	ND
507136	8/18/1994	8.810	0.690	ND
507135	8/18/1994	8.980	0.680	ND
507140	8/18/1994	8.380	0.680	ND
507142	8/18/1994	8.320	0.670	ND
507139	8/18/1994	8.210	0.650	0.333
507134	8/18/1994	8.470	0.640	ND
507141	8/18/1994	8.100	0.640	ND
507137	8/18/1994	8.330	0.610	ND
507131	8/18/1994	8.190	0.590	ND
507132	8/18/1994	8.060	0.590	ND
507130	8/18/1994	8.500	0.550	ND
507133	8/18/1994	8.100	0.550	ND
507129	8/18/1994	8.340	0.500	ND
507128	8/18/1994	8.150	0.490	ND
507216	8/19/1994	8.540	0.950	0.312
507212	8/19/1994	9.270	0.870	ND
507220	8/19/1994	9.050	0.830	ND

Appendix 2 (cont'd)

507214	8/19/1994	8.510	0.820	0.412
507223	8/19/1994	8.730	0.820	0.332
507204	8/19/1994	8.650	0.820	ND
507225	8/19/1994	8.790	0.810	ND
507202	8/19/1994	8.980	0.810	ND
507215	8/19/1994	8.560	0.790	0.279
507217	8/19/1994	8.670	0.790	0.358
507226	8/19/1994	8.800	0.770	ND
507219	8/19/1994	8.430	0.730	1.061
507207	8/19/1994	8.370	0.720	ND
507222	8/19/1994	8.160	0.710	ND
507203	8/19/1994	8.260	0.710	0.317
507201	8/19/1994	8.190	0.700	ND
507205	8/19/1994	8.130	0.680	0.585
507206	8/19/1994	8.840	0.670	ND
507209	8/19/1994	8.070	0.660	ND
507211	8/19/1994	8.150	0.640	ND
507224	8/19/1994	8.770	0.640	ND
507213	8/19/1994	8.180	0.630	ND
507208	8/19/1994	8.370	0.630	ND
507210	8/19/1994	8.150	0.610	ND
507221	8/19/1994	8.320	0.590	0.453
507312	8/19/1994	8.500	0.450	ND
507218	8/19/1994	8.190	0.440	0.689
303241	7/1/1992	8.300	0.790	0.314
303243	7/1/1992	8.900	0.770	ND
303242	7/1/1992	8.330	0.750	0.388
402716	6/22/1993	10.930	0.850	0.363
402718	6/22/1993	9.240	0.800	0.321
402717	6/22/1993	9.870	0.770	ND
404013	8/1/1993	8.140	0.895	ND
404011	8/1/1993	7.540	0.800	ND
404009	8/1/1993	8.810	0.620	ND
404010	8/1/1993	8.030	0.620	ND
404014	8/1/1993	9.080	0.540	ND
404007	8/1/1993	8.190	0.540	0.378
404015	8/1/1993	9.560	0.530	0.933
404008	8/1/1993	8.420	0.510	ND
404012	8/1/1993	7.400	0.500	ND
404002	8/1/1993	8.240	0.490	0.652
404003	8/1/1993	8.190	0.490	0.442
404004	8/1/1993	8.850	0.480	ND
404005	8/1/1993	8.280	0.430	ND
404001	8/1/1993	8.330	0.420	ND
404006	8/1/1993	8.190	0.380	ND
402912	8/17/1993	9.390	0.830	0.253
402910	8/17/1993	8.920	0.750	ND
402906	8/17/1993	9.460	0.660	ND
402911	8/17/1993	8.350	0.660	ND
402904	8/17/1993	8.650	0.620	ND
402905	8/17/1993	8.220	0.550	ND
402916	8/18/1993	9.510	0.890	0.363

Appendix 2 (cont'd)

		402917	8/18/1993	9.430	0.810	0.285
		402930	8/18/1993	9.180	0.800	0.281
		402923	8/18/1993	9.860	0.740	ND
		402929	8/18/1993	8.470	0.710	ND
		402918	8/18/1993	8.800	0.690	0.395
		402922	8/18/1993	9.030	0.640	ND
		402924	8/18/1993	8.940	0.620	0.929
		402928	8/18/1993	9.570	0.560	ND
		403034	8/22/1993	9.660	0.850	ND
		403036	8/22/1993	9.170	0.760	ND
		403035	8/22/1993	9.480	0.710	ND
		403025	8/22/1993	9.490	0.700	ND
		403026	8/22/1993	9.580	0.660	ND
		403024	8/22/1993	7.470	0.610	0.473
		403027	8/22/1993	7.070	0.440	ND
		501213	4/25/1994	8.700	0.970	1.799
Pacific Oysters						
	Whole	1396	4/13/1989	5.367	0.697	0.625
		1395	4/13/1989	5.414	0.397	0.779
		1393	4/13/1989	5.198	0.356	0.248
		1394	4/13/1989	5.121	0.303	0.828
		1397	4/14/1989	5.265	1.185	ND
		1398	4/14/1989	5.093	1.029	0.201
		1391	4/14/1989	5.101	0.352	ND
		1392	4/14/1989	2.170	0.152	1.787
		2724	5/13/1989	5.527	0.746	0.507
		2722	5/17/1989	5.301	0.398	0.349
		2723	5/17/1989	5.017	0.365	0.626
		4514	6/21/1989	5.205	1.291	0.457
		4513	6/21/1989	5.276	1.140	0.381
		80001	7/13/1989	5.590	0.844	0.242
		80000	7/13/1989	5.424	0.759	0.179
		7980	9/10/1989	5.506	1.250	ND
		7979	9/10/1989	5.238	0.508	0.165
		7978	9/10/1989	5.118	0.407	ND
		7982	9/11/1989	5.195	0.399	ND
		8282	9/19/1989	5.572	0.903	0.180
		8280	9/19/1989	5.304	0.796	ND
		8284	9/19/1989	5.296	0.667	ND
		8281	9/19/1989	5.272	0.120	1.195
		108602	4/24/1990	5.110	0.620	0.156
		109802	5/2/1990	5.050	0.810	0.362
		109804	5/2/1990	5.130	0.780	0.172
		109801	5/2/1990	5.170	0.720	0.381
		117001	5/22/1990	5.150	0.860	1.204
		117003	5/22/1990	5.020	0.680	1.385
Periwinkle Snail						
	Whole	20246	5/11/1989	4.170	2.360	2.260
		20243	5/11/1989	3.640	2.310	0.751
		21555	5/11/1989	17.240	2.120	0.632

Appendix 2 (cont'd)

		20247	5/11/1989	3.440	2.040	3.199
Pazor Clams						
	Whole	6101	4/6/1989	5.206	0.859	ND
		6102	4/6/1989	5.303	0.859	ND
		6103	4/6/1989	5.058	0.835	ND
		6100	4/7/1989	5.461	1.038	ND
		6099	4/7/1989	5.327	1.033	ND
		6098	4/7/1989	5.335	1.019	ND
		6088	7/7/1989	5.120	1.290	0.132
		6083	7/7/1989	5.136	1.280	0.114
		6092	7/7/1989	5.308	1.280	0.064
		6095	7/7/1989	5.554	1.280	0.134
		6084	7/7/1989	4.968	1.200	0.130
		6091	7/7/1989	5.167	1.200	0.083
		6089	7/7/1989	5.312	1.190	0.095
		6096	7/7/1989	5.147	1.190	0.128
		6093	7/7/1989	5.251	1.170	0.071
		6090	7/7/1989	5.333	1.130	0.124
		6094	7/7/1989	4.393	1.130	0.098
		6081	7/7/1989	4.934	1.110	0.125
		6075	7/7/1989	4.994	1.109	0.149
		6077	7/7/1989	5.350	1.080	0.131
		6097	7/7/1989	5.057	1.077	0.130
		6086	7/7/1989	4.936	1.070	0.134
		6082	7/7/1989	5.124	1.040	0.111
		6087	7/7/1989	5.226	1.040	0.283
		6085	7/7/1989	5.265	1.000	0.243
		6076	7/7/1989	5.403	0.999	0.104
		6080	7/7/1989	5.088	0.992	0.145
		6079	7/7/1989	5.276	0.976	0.107
		6074	7/7/1989	4.740	0.953	0.173
		6078	7/7/1989	5.375	0.946	0.134
		105005	8/6/1990	5.590	0.940	0.102
		105014	8/7/1990	5.020	0.840	ND
		105022	8/8/1990	5.010	0.830	ND
		105105	8/19/1990	4.890	0.760	0.145
Sunset Clam						
	Whole	29916	8/26/1991	1.340	0.230	ND
		29915	8/26/1991	1.400	0.210	ND
		29918	8/26/1991	1.000	0.180	ND
		29917	8/26/1991	1.010	0.140	ND
		29914	8/29/1991	1.060	0.170	ND
Weathervane Scallop						
	Whole	11781	12/21/1989	5.270	0.912	0.482
		11782	12/21/1989	5.172	0.869	0.409
		11780	12/21/1989	5.299	0.816	0.079
Razor Clam						
	Whole	6101	4/6/1989	5.206	0.859	ND
		6102	4/6/1989	5.303	0.859	ND
		6103	4/6/1989	5.058	0.835	ND

Appendix 2 (cont'd)

		6100	4/7/1989	5.461	1.038	ND
		6099	4/7/1989	5.327	1.033	ND
		6098	4/7/1989	5.335	1.019	ND
		6088	7/7/1989	5.120	1.290	0.132
		6083	7/7/1989	5.136	1.280	0.114
		6092	7/7/1989	5.308	1.280	0.064
		6095	7/7/1989	5.554	1.280	0.134
		6084	7/7/1989	4.968	1.200	0.130
		6091	7/7/1989	5.167	1.200	0.083
		6089	7/7/1989	5.312	1.190	0.095
		6096	7/7/1989	5.147	1.190	0.128
		6093	7/7/1989	5.251	1.170	0.071
		6090	7/7/1989	5.333	1.130	0.124
		6094	7/7/1989	4.393	1.130	0.098
		6081	7/7/1989	4.934	1.110	0.125
		6075	7/7/1989	4.994	1.109	0.149
		6077	7/7/1989	5.350	1.080	0.131
		6097	7/7/1989	5.057	1.077	0.130
		6086	7/7/1989	4.936	1.070	0.134
		6082	7/7/1989	5.124	1.040	0.111
		6087	7/7/1989	5.226	1.040	0.283
		6085	7/7/1989	5.265	1.000	0.243
		6076	7/7/1989	5.403	0.999	0.104
		6080	7/7/1989	5.088	0.992	0.145
		6079	7/7/1989	5.276	0.976	0.107
		6074	7/7/1989	4.740	0.953	0.173
		6078	7/7/1989	5.375	0.946	0.134
		105005	8/6/1990	5.590	0.940	0.102
		105014	8/7/1990	5.020	0.840	ND
		105022	8/8/1990	5.010	0.830	ND
		105105	8/19/1990	4.890	0.760	0.145
IV. Crustaceans						
Barnacle						
	Whole	21547	5/11/1989	3.410	2.130	1.740
		20239	5/11/1989	3.480	2.060	1.964
		20240	5/11/1989	3.370	2.040	0.579
		20238	5/11/1989	2.810	2.020	1.180
		20241	5/11/1989	15.910	2.020	2.207
Dungeness Crab						
	Eggs	116004	5/20/1990	0.766	0.142	ND
		116012	5/22/1990	1.465	0.388	3.915
		126405	5/24/1990	1.894	0.443	ND
		126403	5/24/1990	1.977	0.419	ND
	Hepato-pancreas	8747	9/27/1989	2.446	0.819	0.243
		8745	9/27/1989	2.146	0.755	0.178
		8755	9/28/1989	1.945	0.669	ND
		8754	9/28/1989	2.144	0.660	0.608
		8756	9/28/1989	2.019	0.594	ND
		8774	9/29/1989	2.078	0.734	ND
		8765	9/29/1989	2.326	0.702	0.733

Appendix 2 (cont'd)

		8772	9/29/1989	2.038	0.609	0.281
		8794	10/1/1989	2.430	1.033	36.042
		8800	10/1/1989	2.367	0.973	4.167
		8786	10/1/1989	2.030	0.879	4.891
		8797	10/1/1989	2.002	0.833	5.420
		8789	10/1/1989	2.231	0.736	14.087
		8799	10/1/1989	2.374	0.677	2.634
		8785	10/1/1989	2.066	0.535	1.397
		8790	10/1/1989	2.028	0.535	0.785
		8788	10/1/1989	1.925	0.522	2.974
		8796	10/1/1989	2.449	0.478	6.591
		8804	10/2/1989	2.398	0.671	9.822
		8809	10/3/1989	2.201	0.757	7.801
		8813	10/3/1989	2.183	0.731	21.360
		8816	10/3/1989	2.163	0.701	10.676
		8819	10/3/1989	2.100	0.695	5.428
		8815	10/3/1989	2.280	0.689	30.053
		8812	10/3/1989	2.230	0.524	15.728
		8818	10/3/1989	2.023	0.473	464.693
		116005	5/20/1990	5.888	1.366	0.537
		116013	5/22/1990	5.336	2.193	0.278
		116011	5/22/1990	5.769	1.298	0.261
		126404	5/24/1990	5.395	1.041	0.065
		126402	5/24/1990	5.487	0.960	ND
King Crab						
	Eggs	8292	9/3/1989	2.774	1.221	2.880
		8295	9/4/1989	2.433	0.968	2.933
		8298	9/4/1989	2.053	0.811	4.202
		8301	9/5/1989	2.467	1.088	2.984
		8309	9/7/1989	2.527	1.104	5.865
	Hepato-pancreas	8294	9/4/1989	2.617	1.751	90.058
		8297	9/4/1989	2.446	1.509	8.672
		8300	9/5/1989	2.285	1.250	33.317
		8305	9/6/1989	2.613	2.310	72.094
		8303	9/6/1989	2.246	1.276	39.078
Spot Shrimp						
	Eggs	11000	11/8/1989	4.781	1.826	4.598
		11004	11/8/1989	5.236	1.063	140.959
		11013	11/9/1989	2.427	0.961	2.840
		11017	11/9/1989	2.144	0.892	5.635
		11015	11/9/1989	1.805	0.745	1.650
		11025	11/10/1989	5.290	1.936	24.290
		11028	11/10/1989	0.895	0.237	76.401
		11046	11/12/1989	2.009	0.890	2.046
		11044	11/12/1989	2.035	0.783	28.731
		11038	11/12/1989	1.921	0.771	4.610
		11040	11/12/1989	1.823	0.713	15.166
		11036	11/12/1989	1.796	0.665	25.481
		11042	11/12/1989	1.434	0.584	7.284
		11056	11/13/1989	2.872	1.068	8.513

Appendix 2 (cont'd)

		11049	11/13/1989	2.464	0.902	2.102
		11052	11/13/1989	2.039	0.836	2.836
		11054	11/13/1989	1.386	0.513	9.630
		128601	11/6/1990	2.010	0.770	223.257
		128614	11/8/1990	2.470	0.940	5.101
		128628	11/9/1990	3.440	1.300	35.311
		128640	11/11/1990	1.310	0.510	2.822
		128650	11/12/1990	2.450	0.960	12.260
Tanner Crab	Eggs	2891	5/23/1989	0.490	0.200	18.605
		2892	5/23/1989	0.510	0.200	33.176
		2945	5/26/1989	0.570	0.250	2.644
		2948	5/26/1989	0.590	0.230	2.638
		2943	5/26/1989	0.520	0.210	1.974
		4020	5/29/1989	0.550	0.210	3.034
		4023	5/29/1989	0.530	0.210	0.773
		4026	5/29/1989	0.530	0.190	0.466
		4056	5/31/1989	0.570	0.230	1.242
		4062	5/31/1989	0.510	0.220	0.564
		4059	5/31/1989	0.510	0.210	1.007
		4102	6/2/1989	0.680	0.280	21.561
		4105	6/2/1989	0.620	0.230	20.250
		4108	6/2/1989	0.550	0.200	16.687
		4415	6/19/1989	0.660	0.270	19.291
		2893	6/23/1989	0.550	0.220	15.114
	Hepato-pancreas	2812	5/19/1989	0.580	0.210	361.540
		2814	5/21/1989	0.580	0.210	4.368
		2862	5/22/1989	0.520	0.270	4.521
		2864	5/22/1989	0.540	0.210	24.236
		2860	5/22/1989	0.510	0.150	29.172
		2947	5/26/1989	0.560	0.140	15.372
		2950	5/26/1989	0.550	0.120	24.457
		2944	5/26/1989	0.540	0.110	12.146
		4019	5/29/1989	0.530	0.170	27.113
		4022	5/29/1989	0.560	0.170	37.511
		4025	5/29/1989	0.520	0.150	6.297
		4058	5/31/1989	0.540	0.190	28.912
		4055	5/31/1989	0.510	0.170	39.165
		4061	5/31/1989	0.570	0.160	26.804
		4103	6/2/1989	0.600	0.180	42.254
		4106	6/2/1989	0.580	0.130	229.823
		4109	6/2/1989	0.560	0.130	34.307
		4389	6/18/1989	0.620	0.180	25.505
		4414	6/19/1989	0.570	0.120	75.374
		110437	6/14/1990	0.840	0.210	7.814
		110438	6/14/1990	0.600	0.190	12.993
		110446	6/14/1990	0.600	0.140	20.783
		110444	6/14/1990	0.550	0.120	0.928
		110445	6/14/1990	0.530	0.100	35.038
		110439	6/14/1990	0.520	0.100	11.137
		119013	6/18/1990	0.600	0.180	74.938

Appendix 2 (cont'd)

			119024	6/18/1990	0.550	0.170	31.213
			119014	6/18/1990	0.620	0.120	6.957
			119012	6/18/1990	0.810	0.100	1.616
			119349	6/19/1990	1.110	0.530	478.320
			119342	6/19/1990	1.040	0.410	75.207
			119348	6/19/1990	1.040	0.410	15.346
			119213	6/19/1990	1.020	0.240	37.518
			119214	6/19/1990	1.030	0.230	4.739
			119345	6/19/1990	1.020	0.200	8.156
			119621	6/21/1990	1.180	0.500	41.924
			119622	6/21/1990	1.030	0.170	7.239
			119923	6/22/1990	1.150	0.540	12.128
			119924	6/22/1990	1.060	0.380	2.150
			119925	6/22/1990	1.060	0.310	2.294
			120036	6/23/1990	1.120	0.440	4.129
			120034	6/23/1990	1.000	0.190	3.263
			120035	6/23/1990	1.050	0.140	ND
V. Echinoderm							
	Green Sea Urchin						
		Gonad	12004	11/9/1989	2.081	0.641	0.451
			12003	11/9/1989	2.035	0.539	1.304
			12005	11/9/1989	2.016	0.524	0.397
			12007	11/17/1989	2.052	0.554	0.121
			12008	11/17/1989	2.047	0.512	0.358
			12009	11/17/1989	2.019	0.489	0.163
			12011	11/20/1989	2.038	0.550	0.189
			12012	11/20/1989	2.055	0.530	0.244
			12010	11/20/1989	2.046	0.507	0.236
			12014	12/6/1989	2.049	0.492	2.258
			12015	12/6/1989	2.039	0.479	0.322
			12013	12/6/1989	2.085	0.450	0.196
			12016	12/9/1989	2.010	0.466	0.245
			12018	12/9/1989	2.047	0.456	0.355
			12017	12/9/1989	2.096	0.432	0.257
VI. Mammals							
	Brown Bear						
		Liver	27550	8/20/1989	0.560	0.150	0.684
	Gray Whale						
		Blubber	50246	5/18/1989	1.056	0.766	8.967
		Liver	51350	5/18/1989	2.188	0.840	0.314
			50882	6/6/1989	2.396	0.589	3.581
	Harbor Porpoise						
		Blubber	50312	6/8/1989	1.022	1.022	174.783
			50334	7/3/1989	1.113	1.110	0.234
		Liver	50315	6/8/1989	2.163	0.768	32.711
			50908	7/3/1989	2.340	0.718	0.604
			50344	7/3/1989	2.299	0.538	ND

Appendix 2 (cont'd)

Harbor Seal	Blood	190800	4/29/1989	1.920	0.620	0.522
		50540	6/16/1989	1.900	0.680	0.785
		51185	6/18/1989	4.460	1.090	0.448
		51155	6/18/1989	2.490	0.720	0.628
		190518	7/9/1989	0.150	0.050	ND
		190605	4/12/1990	2.590	0.640	1.178
	Blubber	50270	5/16/1989	0.760	0.750	102.619
		50043	5/30/1989	0.620	0.540	0.399
		50022	5/30/1989	0.690	0.490	20.089
		50001	5/31/1989	0.620	0.430	50.863
		50547	6/16/1989	1.210	1.147	133.550
		50599	6/17/1989	1.058	1.015	0.826
		50785	6/17/1989	1.008	0.965	137.941
		50742	6/17/1989	1.012	0.955	152.222
		190801	7/9/1989	0.760	0.720	2.823
		50844	4/22/1989	1.012	1.010	0.322
	Brain	50790	6/17/1989	2.076	0.517	ND
		51200	6/18/1989	2.046	0.561	0.357
		50678	6/18/1989	2.099	0.552	0.187
		51167	6/18/1989	2.031	0.481	0.322
		50456	7/6/1989	2.002	0.494	0.312
		51708	10/26/1989	2.019	0.487	1.676
		51754	11/1/1989	2.085	0.619	0.168
		60000	*4/11/1990*	*2.230*	*0.540*	*0.252*
		60055	4/12/1990	2.029	0.726	0.110
		60029	4/12/1990	2.028	0.552	0.472
		60086	4/12/1990	2.050	0.441	0.544
		60087	4/12/1990	2.006	0.291	1.208
		60134	4/13/1990	2.026	0.559	0.339
		60164	4/13/1990	2.138	0.475	2.052
	Heart	50556	6/16/1989	5.147	1.297	3.413
		50748	6/17/1989	5.068	1.252	8.948
		50793	6/17/1989	5.095	1.213	4.293
	Kidney	50562	6/16/1989	2.077	0.496	57.405
		50800	6/17/1989	2.016	0.516	22.224
		50607	6/17/1989	2.012	0.481	0.942
		50751	6/17/1989	2.000	0.464	3.651
	Liver	51584	4/29/1989	2.339	0.826	7.931
		51585	4/29/1989	2.006	0.461	ND
		50260	5/15/1989	2.333	0.714	0.280
		50274	5/16/1989	2.397	0.820	2.867
		50291	5/16/1989	2.054	0.614	ND
		50055	5/30/1989	2.116	0.707	ND
		50034	5/30/1989	2.400	0.679	0.597
		50010	5/31/1989	2.202	0.865	0.590
		50611	6/17/1989	2.075	0.747	14.590
		50754	6/17/1989	2.053	0.690	61.199
		50807	6/17/1989	2.022	0.615	3.247
	Lung	50572	6/16/1989	2.218	0.559	1.073
		50757	6/17/1989	2.061	0.484	3.375

Appendix 2 (cont'd)

		51521	6/17/1989	2.075	0.438	0.749
	Mammary	50550	6/16/1989	2.218	0.876	71.893
		50814	6/17/1989	2.010	0.746	97.418
		50760	6/17/1989	2.213	0.677	313.084
		51212	6/18/1989	1.140	0.440	572.198
		51175	6/18/1989	1.170	0.400	293.791
		51460	6/25/1989	1.120	0.540	291.072
		51492	6/30/1989	1.110	0.360	52.932
		51501	7/6/1989	1.080	0.290	45.864
	Milk	50578	6/16/1989	2.061	1.855	5.870
		50731	6/16/1989	2.098	1.131	4.717
		50763	6/17/1989	2.017	1.220	100.936
		50615	6/17/1989	2.018	0.965	32.290
		51177	6/18/1989	1.020	0.490	19.717
		51495	6/30/1989	1.050	0.620	54.048
	Ovary	50585	6/16/1989	2.080	0.399	2.535
		50767	6/17/1989	2.016	0.270	5.593
Killer Whale						
	Blubber	190100	4/19/1990	4.370	3.723	251.420
		190104	5/23/1990	3.670	2.830	628.174
		190107	7/31/1990	1.970	1.406	37.301
	Liver	190101	4/19/1990	1.000	0.304	5.256
Minke Whale						
	Blubber	50863	8/11/1989	1.189	1.190	8.019
	Liver	50867	8/11/1989	2.063	0.512	0.136
Sitka Black-Tailed Deer						
	Liver	20474	5/30/1989	2.209	0.699	ND
		20475	5/30/1989	2.093	0.687	ND
		20478	6/1/1989	2.499	0.628	ND
		20480	6/8/1989	2.507	0.743	ND
		20481	6/8/1989	2.553	0.570	ND
Sea Lion						
	Blubber	50139	6/9/1989	1.154	1.154	138.009
		50162	6/9/1989	1.004	0.384	0.333
		51812	10/11/1989	1.020	0.990	48.633
		51865	10/11/1989	1.020	0.990	108.347
		51895	10/11/1989	1.010	0.970	74.637
		51834	10/11/1989	1.040	0.960	115.443
	Liver	51133	5/2/1989	2.124	0.741	80.290
		51698	6/6/1989	2.093	0.749	2.127
		50148	6/9/1989	2.142	0.739	5.529
		51404	6/9/1989	2.335	0.640	3.096
		50169	6/9/1989	2.117	0.455	ND
		50495	6/19/1989	2.143	0.553	13.285
		50100	6/23/1989	2.123	0.645	5.064
		51817	10/11/1989	1.970	0.660	89.331
		51871	10/11/1989	2.080	0.660	0.497
		51901	10/11/1989	1.980	0.620	59.653

Appendix 2 (cont'd)

		51843	10/11/1989	1.960	0.570	20.209
		50237	5/12/1990	2.260	1.092	678.601
Sea Otter						
	Fat	24045	3/16/1989	0.450	0.390	0.628
		24037	3/16/1989	0.440	0.190	1.686
		24048	3/18/1989	0.570	0.150	ND
		24194	4/28/1989	0.600	0.440	2.407
		24190	4/28/1989	0.530	0.430	1.410
		24188	4/29/1989	0.520	0.380	2.456
		24196	4/30/1989	0.790	0.700	0.787
		24198	4/30/1989	0.810	0.200	0.494
		24000	11/6/1989	0.630	0.280	3.760
		24004	11/7/1989	0.530	0.450	2.212
		24013	11/12/1989	1.000	0.840	1.758
		24017	11/13/1989	0.430	0.390	1.070
		24028	11/15/1989	0.450	0.430	1.764
		24033	11/15/1989	0.360	0.320	1.757
		24035	11/16/1989	0.510	0.360	1.629
		24050	3/22/1990	0.470	0.150	ND
		24054	3/24/1990	0.490	0.450	1.547
		24056	3/24/1990	0.410	0.310	ND
		24064	3/26/1990	0.390	0.100	ND
		24068	4/4/1990	0.320	0.240	0.810
		24072	4/5/1990	0.360	0.100	ND
		24077	4/9/1990	0.440	0.370	3.219
		24083	4/11/1990	0.340	0.260	1.146
		24081	4/11/1990	0.460	0.140	0.595
		24085	4/11/1990	0.360	0.130	1.025
		24089	4/11/1990	0.490	0.120	ND
		24101	4/13/1990	0.780	0.630	3.153
		24111	4/13/1990	0.740	0.590	13.967
		24107	4/13/1990	0.710	0.580	5.210
		24105	4/13/1990	0.560	0.540	1.451
		24109	4/13/1990	0.460	0.380	4.025
		24095	4/13/1990	0.430	0.340	3.661
		24113	4/13/1990	0.770	0.180	2.055
		24097	4/13/1990	0.430	0.100	ND
		24115	4/13/1990	0.390	0.100	1.366
		24099	4/13/1990	0.410	0.090	1.294
		24123	4/22/1990	0.750	0.420	5.963
		24127	4/23/1990	0.560	0.420	4.199
		24133	4/24/1990	0.830	0.640	4.160
		24129	4/24/1990	0.790	0.210	2.540
		24142	4/26/1990	0.560	0.510	1.665
		24138	4/26/1990	0.540	0.490	1.283
		24140	4/26/1990	0.510	0.460	2.286
		24144	4/27/1990	0.490	0.130	ND
		24148	4/28/1990	0.450	0.360	0.818
		24146	4/28/1990	0.560	0.350	1.309
	Liver	20493	4/6/1989	2.422	0.770	10.967
		27887	4/22/1989	1.920	0.560	ND

Appendix 2 (cont'd)

			29013	4/28/1989	5.170	1.340	ND
			29029	4/29/1989	2.150	0.580	0.192
			29037	4/30/1989	2.010	0.550	10.724
			29042	5/1/1989	2.370	0.650	1.716
			29051	5/4/1989	0.510	0.150	ND
			29069	5/6/1989	1.020	0.180	ND
			29073	5/7/1989	1.300	0.400	ND
			29086	5/11/1989	1.940	0.570	ND
			29133	5/15/1989	2.130	0.680	ND
			29142	5/15/1989	2.010	0.490	ND
			29147	5/16/1989	2.050	0.510	ND
			29175	5/17/1989	1.790	0.430	ND
			29124	5/18/1989	2.020	0.530	ND
			25031	5/24/1989	2.070	0.540	0.119
			29189	5/31/1989	2.140	0.570	1.886
			29196	5/31/1989	2.420	0.520	ND
			29201	6/4/1989	2.190	0.560	2.283
			25117	6/11/1989	2.030	0.490	0.272
			25118	6/12/1989	2.050	0.520	13.489
			25169	6/19/1989	2.140	0.640	0.391
			25172	6/19/1989	2.180	0.590	ND
			20497	7/5/1989	2.159	0.803	0.338
VII. Plants							
	Fucus						
		Whole	20202	5/3/1989	16.06	2.04	5.950
			20203	5/3/1989	11.35	1.77	4.763
			20201	5/3/1989	9.5	1.15	4.528
			20204	5/3/1989	2.224	0.641	5.683
			20205	5/3/1989	2.884	0.51	9.021
			11271	9/14/1989	4.972	1.119	ND
			11270	9/14/1989	5.18	0.922	ND
			11265	9/18/1989	5.071	1.531	ND
			11266	9/19/1989	5.044	1.725	ND
			11267	9/25/1989	5.242	1.961	ND
			11363	10/6/1989	5.223	1.368	ND
	Eelgrass						
		Whole	20200	5/3/1989	16.97	1.32	5.04

Appendix 3. Concentrations of pristane in mussel uptake and depuration experiments.

Treatment	Days After Initial Exposure	Rep	Mussel Wet Wt. (g)	Mussel Dry Wt. (g)	[Pristane] (µg g^{-1})
Whole Feces From PWS Zooplankton	0	1	4.84	0.580	0.175
		2	4.80	0.572	0.213
		3	4.83	0.536	0.165
	2	1	4.78	0.567	26.0
		2	4.87	0.563	24.7
		3	4.87	0.526	33.3
	4	1	4.90	0.623	21.5
		2	4.87	0.581	50.3
		3	4.90	0.520	44.9
	7	1	4.87	0.542	78.4
		2	4.78	0.550	76.9
		3	4.86	0.558	113
	14	1	4.84	0.643	159
		2	4.94	0.615	127
		3	4.86	0.577	166
	16	1	4.92	0.606	106
		2	4.87	0.492	63.1
		3	4.60	0.538	113
	18	1	4.86	0.479	71.5
		2	4.92	0.548	60.9
		3	4.55	0.555	98.7
	21	1	4.92	0.572	76.1
		2	4.89	0.574	48.6
		3	4.81	0.575	47.8
	28	1	4.86	0.560	59.5
		2	4.85	0.555	30.1
		3	4.89	0.580	44.9
	42	1	4.89	0.559	10.5
		2	4.93	0.531	11.9
		3	4.91	0.553	27.7
Homogenized Feces From PWS Zooplankton	0	1	4.89	0.638	0.174
		2	4.85	0.550	0.244
		3	4.81	0.554	0.223
	2	1	4.88	0.589	86.0
		2	4.93	0.631	105
		3	4.79	0.558	151
	4	1	4.89	0.547	176
		2	4.93	0.534	202
		3	4.86	0.518	172
	7	1	4.88	0.491	214
		2	4.85	0.507	209
		3	4.81	0.460	200
	14	1	4.81	0.558	292
		2	4.83	0.552	340
		3	4.86	0.492	569
	16	1	4.93	0.623	437

Appendix 3 (cont'd)

		2	4.87	0.582	185
		3	4.88	0.580	461
	18	1	4.89	0.528	148
		2	4.89	0.559	249
		3	4.91	0.497	146
	21	1	4.79	0.558	143
		2	4.88	0.578	220
		3	4.87	0.571	127
	28	1	4.87	0.492	87.0
		2	4.83	0.574	95.5
		3	4.76	0.575	76.5
	42	1	4.85	0.563	69.5
		2	4.94	0.553	76.1
		3	4.89	0.469	63.1
Homogenized Feces From Artemia sp.	0	1	4.92	0.616	0.199
		2	4.86	0.550	0.186
		3	4.84	0.622	0.325
	2	1	4.91	0.633	1.22
		2	4.78	0.607	1.26
		3	4.90	0.574	1.04
	4	1	4.73	0.454	3.06
		2	4.83	0.567	1.98
		3	4.83	0.530	1.57
	7	1	4.78	0.524	7.35
		2	4.85	0.585	2.67
		3	4.89	0.645	1.73
	14	1	4.86	0.507	15.3
		2	4.89	0.532	13.3
		3	4.84	0.589	7.37
	16	1	4.79	0.530	12.2
		2	4.93	0.574	11.5
		3	4.91	0.515	5.57
	18	1	4.89	0.575	8.57
		2	4.83	0.515	8.74
		3	4.89	0.585	2.76
	21	1	4.90	0.578	6.72
		2	4.93	0.527	2.42
		3	4.89	0.528	3.02
	28	1	4.72	0.504	5.03
		2	4.86	0.531	2.60
		3	4.86	0.437	1.76
	42	1	4.77	0.479	1.68
		2	4.86	0.584	1.64
		3	4.92	0.473	0.638
Control Mussels For Fecal Exposure Experiments	0	1	4.89	0.600	0.155
		2	4.88	0.560	0.199
		3	4.83	0.535	0.187
	2	1	4.82	0.547	0.165
		2	4.82	0.622	0.280
		3	4.88	0.515	0.157
	4	1	4.91	0.548	0.266
		2	4.85	0.393	0.322

Appendix 3 (cont'd)

		3	4.88	0.512	0.463
	7	1	4.86	0.530	0.271
		2	4.85	0.586	0.406
		3	4.85	0.527	0.565
	14	1	4.87	0.526	0.430
		2	4.76	0.499	0.212
		3	4.88	0.522	0.358
	16	1	4.83	0.491	0.757
		2	4.92	0.568	0.927
		3	4.92	0.506	0.828
	18	1	4.90	0.617	0.666
		2	4.88	0.555	1.04
		3	4.88	0.513	0.878
	21	1	4.88	0.650	0.678
		2	4.87	0.539	0.420
		3	4.87	0.470	0.351
	28	1	4.86	0.480	0.544
		2	5.09	0.588	0.273
		3	4.89	0.541	0.231
	42	1	4.87	0.464	0.253
		2	4.89	0.521	0.372
		3	4.86	0.520	0.348
Dissolved Pristane Exposures	0	1	4.88	0.608	0.197
		2	4.93	0.582	0.240
		3	4.89	0.560	0.192
	2	1	4.92	0.602	3.89
		2	4.95	0.585	3.08
		3	4.93	0.606	3.75
	4	1	4.94	0.558	5.28
		2	4.93	0.589	3.58
		3	4.94	0.604	4.24
	8	1	4.93	0.562	7.70
		2	4.94	0.561	7.13
		3	4.01	0.476	7.50
	14	1	4.92	0.488	4.93
		2	4.90	0.589	8.43
		3	4.93	0.579	8.46
	16	1	4.85	0.542	3.24
		2	4.89	0.547	8.66
		3	4.89	0.571	5.03
	18	1	4.35	0.507	4.67
		2	4.85	0.513	3.29
		3	4.92	0.538	3.83
	23	1	4.70	0.515	3.09
		2	4.92	0.517	4.44
		3	4.85	0.458	3.01
	28	1	4.82	0.433	1.29
		2	4.84	0.585	1.66
		3	4.93	0.589	1.88
	44	1	4.39	0.424	0.510
		2	4.90	0.527	0.982
		3	3.42	0.372	0.714

Appendix 3 (cont'd)

Control Mussels For Dissolved Pristane Experiment	0	1	4.90	0.499	0.308
		2	4.95	0.400	0.525
		3	4.78	0.600	0.210
	2	1	4.92	0.589	0.302
		2	4.89	0.590	0.262
		3	4.95	0.627	0.298
	4	1	4.93	0.591	0.299
		2	4.89	0.522	0.191
		3	4.93	0.484	0.309
	8	1	4.96	0.612	0.300
		2	4.92	0.543	0.315
		3	4.91	0.565	0.290
	14	1	4.92	0.577	0.314
		2	3.97	0.439	0.318
		3	4.92	0.570	0.281
	16	1	4.88	0.563	0.286
		2	4.90	0.547	0.265
		3	5.16	0.566	0.266
	18	1	4.23	0.401	0.057
		2	3.88	0.445	0.029
		3	4.93	0.536	0.363
	23	1	4.86	0.476	0.000
		2	4.85	0.430	0.038
		3	4.90	0.335	0.000
	28	1	4.90	0.488	0.000
		2	4.97	0.542	0.167
		3	4.91	0.551	0.526
	44	1	4.90	0.523	0.250
		2	4.92	0.505	0.252
		3	4.95	0.545	0.604

Appendix 4. Characteristics of zooplankton consumed by juvenile pink salmon.

Zooplankton Batch	Wet Wt. (g)	Dry Wt. (g)	[Pristane] (μg g^{-1} Dry Wt.)	Blotted:Frozen Weight Ratio
PWS-Zooplankton				
WHN-04248-01Z	0.177	0.020	4,995	0.283
WHN-04248-02Z	0.116	0.008	16,047	ND
WHN-04248-03Z	0.270	0.037	5,317	0.354
WHN-04248-04z	0.169	0.020	15,536	0.245
WHN-04248-05z	0.153	0.028	6,614	0.341
WHN-04248-06z	0.252	0.037	1,587	0.313
WHN-04248-07z	0.304	0.019	13,233	0.298
WHN-04248-08z	0.099	0.015	5,031	0.392
WHN-04238-01z	0.161	0.043	1,701	ND
WHN-04258-01z	0.087	0.007	9,580	0.287
WHN-04298-01z	0.335	0.052	2,293	0.247
WHN-04308-01z	0.118	0.015	7,459	ND
Artemia				
Artemia rep 1	1.94	0.363	0.959	ND
Artemia rep 2	2.08	0.361	1.40	ND
Artemia rep 3	1.98	0.313	1.35	ND
7/20/1998 rep 1	1.88	0.089	ND	ND
7/20/1998 rep 2	1.54	0.097	ND	ND
7/20/1998 rep 3	1.83	0.091	ND	ND
7/30/1998 rep 1	1.64	0.144	ND	ND
7/30/1998 rep 2	3.24	0.283	ND	ND
7/30/1998 rep 3	2.36	0.210	ND	ND
7/25/1998AM	ND	ND	ND	0.483
7/25/1998PM	ND	ND	ND	0.387
7/26/1998AM	ND	ND	ND	0.360
7/26/1998PM	ND	ND	ND	0.339
7/27/1998AM	ND	ND	ND	0.380
7/27/1998PM	ND	ND	ND	0.447
7/28/1998AM	ND	ND	ND	0.521
7/28/1998PM	ND	ND	ND	0.491
7/29/1998AM	ND	ND	ND	0.588
7/29/1998PM	ND	ND	ND	0.553
7/30/1998AM	ND	ND	ND	0.571
7/30/1998PM	ND	ND	ND	0.546
7/31/1998AM	ND	ND	ND	0.476
7/31/1998PM	ND	ND	ND	0.640
8/1/1998AM	ND	ND	ND	0.569

Appendix 5. Zooplankton consumed by juvenile pink salmon.

Treatment Group	Feeding Date & Time	Zooplankton Batch	Ration Offered g Wet Wt	Ration Not Consumed g Wet Wt
Whole Feces – PWS Zooplankton – Rep 1	7/20/1998AM	WHN-04248-02Z	7.05	0.736
	7/20/1998PM	WHN-04248-01Z	7.03	1.27
	7/21/1998AM	WHN-04248-01Z	6.91	1.14
	7/21/1998PM	WHN-04298-01Z	6.90	0.570
	7/22/1998AM	WHN-04298-01Z	6.93	1.02
	7/22/1998PM	WHN-04298-01Z	7.10	0.408
	7/23/1998AM	WHN-04298-01Z	6.98	0.775
	7/23/1998PM	WHN-04308-01Z	6.96	0.614
	7/24/1998AM	WHN-04298-01Z	7.01	0.952
	7/24/1998PM	WHN-04308-01Z	7.09	0.654
	7/25/1998AM	WHN-04308-01Z	6.94	0.816
	7/25/1998PM	WHN-04248-07Z	6.90	0.885
	7/26/1998AM	WHN-04248-08Z	6.85	0.484
	7/26/1998PM	WHN-04248-08Z	7.09	0.469
	7/27/1998AM	WHN-04258-01Z	6.89	0.396
	7/27/1998PM	WHN-04258-01Z	7.03	0.449
	7/28/1998AM	WHN-04298-01Z	7.02	0.374
	7/28/1998PM	WHN-04298-01Z	7.15	0.394
	7/29/1998AM	WHN-04248-05Z	6.89	0.711
	7/29/1998PM	WHN-04248-06Z	6.97	0.533
	7/30/1998AM	WHN-04248-06Z	7.09	0.605
	7/30/1998PM	WHN-04248-06Z	6.91	0.571
	7/31/1998AM	WHN-04248-07Z	7.02	0.513
	7/31/1998PM	WHN-04248-07Z	7.14	0.475
	8/1/1998AM	WHN-04248-03Z	6.97	0.781
	8/1/1998PM	WHN-04248-04Z	7.03	0.501
	8/2/1998AM	WHN-04248-04Z	6.98	0.567
	8/2/1998PM	WHN-04248-04Z	6.93	ND
Whole Feces – PWS Zooplankton – Rep 2	7/20/1998AM	WHN-04248-02Z	7.06	0.686
	7/20/1998PM	WHN-04248-01Z	6.95	0.871
	7/21/1998AM	WHN-04238-01Z	7.13	0.927
	7/21/1998PM	WHN-04298-01Z	6.94	0.475
	7/22/1998AM	WHN-04298-01Z	6.94	0.910
	7/22/1998PM	WHN-04298-01Z	6.92	0.326
	7/23/1998AM	WHN-04298-01Z	6.97	0.753
	7/23/1998PM	WHN-04308-01Z	7.10	0.572
	7/24/1998AM	WHN-04298-01Z	6.92	0.704
	7/24/1998PM	WHN-04308-01Z	7.03	0.554
	7/25/1998AM	WHN-04248-07Z	7.11	0.831
	7/25/1998PM	WHN-04248-07Z	7.01	0.862
	7/26/1998AM	WHN-04248-08Z	7.14	0.655
	7/26/1998PM	WHN-04248-08Z	6.90	0.840
	7/27/1998AM	WHN-04258-01Z	6.93	0.470
	7/27/1998PM	WHN-04258-01Z	6.93	0.407
	7/28/1998AM	WHN-04298-01Z	6.91	0.541
	7/28/1998PM	WHN-04298-01Z	6.86	0.352
	7/29/1998AM	WHN-04248-05Z	6.88	0.710

Appendix 5 (cont'd)

	7/29/1998PM	WHN-04248-06Z	6.97	0.500
	7/30/1998AM	WHN-04248-06Z	7.14	0.654
	7/30/1998PM	WHN-04248-06Z	7.15	0.670
	7/31/1998AM	WHN-04248-07Z	7.13	0.566
	7/31/1998PM	WHN-04248-07Z	7.11	0.454
	8/1/1998AM	WHN-04248-04Z	7.16	0.787
	8/1/1998PM	WHN-04248-04Z	6.91	0.485
	8/2/1998AM	WHN-04248-04Z	6.97	0.679
	8/2/1998PM	WHN-04248-04Z	7.10	ND
Whole Feces – PWS Zooplankton – Rep 3	7/20/1998AM	WHN-04248-02Z	6.99	0.503
	7/20/1998PM	WHN-04248-01Z	6.94	0.901
	7/21/1998AM	WHN-04238-01Z	7.11	1.04
	7/21/1998PM	WHN-04298-01Z	7.00	0.587
	7/22/1998AM	WHN-04298-01Z	7.10	1.06
	7/22/1998PM	WHN-04298-01Z	6.94	0.433
	7/23/1998AM	WHN-04298-01Z	6.94	0.644
	7/23/1998PM	WHN-04308-01Z	7.09	0.590
	7/24/1998AM	WHN-04298-01Z	6.93	0.636
	7/24/1998PM	WHN-04308-01Z	7.05	0.560
	7/25/1998AM	WHN-04248-07Z	6.96	0.851
	7/25/1998PM	WHN-04248-07Z	6.95	0.640
	7/26/1998AM	WHN-04248-08Z	7.08	0.662
	7/26/1998PM	WHN-04248-08Z	7.07	0.635
	7/27/1998AM	WHN-04258-01Z	7.13	0.456
	7/27/1998PM	WHN-04258-01Z	6.87	0.410
	7/28/1998AM	WHN-04298-01Z	7.03	0.552
	7/28/1998PM	WHN-04248-05Z	6.98	0.543
	7/29/1998AM	WHN-04248-05Z	6.91	0.733
	7/29/1998PM	WHN-04248-06Z	6.97	0.631
	7/30/1998AM	WHN-04248-06Z	6.94	0.637
	7/30/1998PM	WHN-04248-07Z	6.91	0.558
	7/31/1998AM	WHN-04248-07Z	7.13	0.560
	7/31/1998PM	WHN-04248-07Z	7.01	0.743
	8/1/1998AM	WHN-04248-04Z	6.92	0.697
	8/1/1998PM	WHN-04248-04Z	6.98	0.805
	8/2/1998AM	WHN-04248-04Z	7.00	0.665
	8/2/1998PM	WHN-04248-04Z	6.92	ND
Homogenized Feces – PWS Zooplankton Rep 1	7/20/1998AM	WHN-04248-02Z	6.97	ND
	7/20/1998PM	WHN-04248-01Z	7.12	0.555
	7/21/1998AM	WHN-04238-01Z	7.00	0.763
	7/21/1998PM	WHN-04298-01Z	7.09	0.605
	7/22/1998AM	WHN-04298-01Z	6.94	0.628
	7/22/1998PM	WHN-04298-01Z	7.03	0.527
	7/23/1998AM	WHN-04308-01Z	7.06	0.633
	7/23/1998PM	WHN-04308-01Z	7.13	0.628
	7/24/1998AM	WHN-04308-01Z	6.92	0.620
	7/24/1998PM	WHN-04308-01Z	7.05	0.634
	7/25/1998AM	WHN-04248-07Z	7.14	0.708
	7/25/1998PM	WHN-04248-07Z	7.00	0.889
	7/26/1998AM	WHN-04248-08Z	6.94	0.592
	7/26/1998PM	WHN-04258-01Z	7.05	0.573
	7/27/1998AM	WHN-04258-01Z	6.98	0.403

Appendix 5 (cont'd)

	7/27/1998PM	WHN-04298-01Z	6.90	0.443
	7/28/1998AM	WHN-04298-01Z	7.13	0.449
	7/28/1998PM	WHN-04248-05Z	6.96	0.559
	7/29/1998AM	WHN-04248-05Z	7.09	0.883
	7/29/1998PM	WHN-04248-06Z	6.98	0.615
	7/30/1998AM	WHN-04248-06Z	6.94	0.780
	7/30/1998PM	WHN-04248-07Z	6.85	0.536
	7/31/1998AM	WHN-04248-07Z	7.09	0.752
	7/31/1998PM	WHN-04248-07Z	7.04	0.594
	8/1/1998AM	WHN-04248-04Z	6.89	0.670
	8/1/1998PM	WHN-04248-04Z	6.96	0.592
	8/2/1998AM	WHN-04248-04Z	7.10	0.566
	8/2/1998PM	WHN-04248-04Z	7.04	ND
	8/3/1998AM	WHN-04248-05Z	7.05	ND
	8/3/1998PM	WHN-04248-05Z	6.99	ND
Homogenized Feces – PWS Zooplankton Rep 2	7/20/1998AM	WHN-04248-01Z	7.11	ND
	7/20/1998PM	WHN-04248-01Z	6.99	0.696
	7/21/1998AM	WHN-04238-01Z	7.02	0.777
	7/21/1998PM	WHN-04298-01Z	6.99	0.620
	7/22/1998AM	WHN-04298-01Z	6.99	0.743
	7/22/1998PM	WHN-04298-01Z	7.16	0.630
	7/23/1998AM	WHN-04308-01Z	7.12	0.630
	7/23/1998PM	WHN-04308-01Z	7.00	0.459
	7/24/1998AM	WHN-04308-01Z	6.90	0.499
	7/24/1998PM	WHN-04308-01Z	7.06	0.776
	7/25/1998AM	WHN-04248-07Z	7.10	0.974
	7/25/1998PM	WHN-04248-07Z	7.11	0.873
	7/26/1998AM	WHN-04248-08Z	7.01	0.689
	7/26/1998PM	WHN-04258-01Z	6.95	0.668
	7/27/1998AM	WHN-04258-01Z	6.89	0.410
	7/27/1998PM	WHN-04298-01Z	6.95	0.432
	7/28/1998AM	WHN-04298-01Z	6.96	0.454
	7/28/1998PM	WHN-04248-05Z	6.92	0.560
	7/29/1998AM	WHN-04248-05Z	7.11	0.885
	7/29/1998PM	WHN-04248-06Z	7.08	0.692
	7/30/1998AM	WHN-04248-06Z	6.89	0.818
	7/30/1998PM	WHN-04248-07Z	7.02	0.788
	7/31/1998AM	WHN-04248-07Z	7.02	0.277
	7/31/1998PM	WHN-04248-03Z	7.04	0.676
	8/1/1998AM	WHN-04248-04Z	7.06	0.797
	8/1/1998PM	WHN-04248-04Z	6.95	0.624
	8/2/1998AM	WHN-04248-04Z	6.91	0.569
	8/2/1998PM	WHN-04248-04Z	7.09	ND
	8/3/1998AM	WHN-04248-05Z	6.94	ND
	8/3/1998PM	WHN-04248-05Z	6.92	ND
Homogenized Feces – PWS Zooplankton Rep 3	7/20/1998AM	WHN-04248-01Z	6.95	ND
	7/20/1998PM	WHN-04248-01Z	6.97	0.750
	7/21/1998AM	WHN-04238-01Z	7.02	1.00
	7/21/1998PM	WHN-04298-01Z	7.05	0.662
	7/22/1998AM	WHN-04298-01Z	6.94	0.807
	7/22/1998PM	WHN-04298-01Z	7.11	0.616
	7/23/1998AM	WHN-04308-01Z	7.03	0.869

Appendix 5 (cont'd)

	7/23/1998PM	WHN-04308-01Z	6.94	0.545
	7/24/1998AM	WHN-04308-01Z	6.96	0.563
	7/24/1998PM	WHN-04308-01Z	7.05	0.841
	7/25/1998AM	WHN-04248-07Z	6.93	0.989
	7/25/1998PM	WHN-04248-08Z	6.92	0.958
	7/26/1998AM	WHN-04248-08Z	6.97	0.824
	7/26/1998PM	WHN-04258-01Z	6.91	0.393
	7/27/1998AM	WHN-04258-01Z	6.84	0.503
	7/27/1998PM	WHN-04298-01Z	7.13	0.383
	7/28/1998AM	WHN-04298-01Z	6.89	0.516
	7/28/1998PM	WHN-04248-05Z	6.95	0.702
	7/29/1998AM	WHN-04248-05Z	7.11	0.717
	7/29/1998PM	WHN-04248-06Z	6.95	0.718
	7/30/1998AM	WHN-04248-06Z	7.12	0.814
	7/30/1998PM	WHN-04248-07Z	6.96	0.507
	7/31/1998AM	WHN-04248-07Z	7.03	0.479
	7/31/1998PM	WHN-04248-03Z	7.01	0.758
	8/1/1998AM	WHN-04248-04Z	6.94	0.670
	8/1/1998PM	WHN-04248-04Z	7.09	0.579
	8/2/1998AM	WHN-04248-04Z	7.13	0.689
	8/2/1998PM	WHN-04248-05Z	7.09	ND
	8/3/1998AM	WHN-04248-05Z	6.95	ND
	8/3/1998PM	WHN-04248-05Z	6.86	ND
Homogenized Feces – Artemia Rep 1	7/20/1998AM		7.073	ND
	7/20/1998PM		6.910	0.543
	7/21/1998AM		7.027	1.88
	7/21/1998PM		6.998	1.11
	7/22/1998AM		7.155	0.766
	7/22/1998PM		7.173	1.29
	7/23/1998AM		7.100	1.63
	7/23/1998PM		7.091	1.22
	7/24/1998AM		6.924	0.877
	7/24/1998PM		7.002	1.09
	7/25/1998AM		7.045	0.959
	7/25/1998PM		6.930	0.596
	7/26/1998AM		7.018	0.961
	7/26/1998PM		7.092	0.281
	7/27/1998AM		7.029	1.3
	7/27/1998PM		7.039	0.531
	7/28/1998AM		6.893	0.583
	7/28/1998PM		7.175	0.979
	7/29/1998AM		6.930	1.18
	7/29/1998PM		7.151	0.499
	7/30/1998AM		6.895	0.803
	7/30/1998PM		7.026	1.34
	7/31/1998AM		7.037	0.970
	7/31/1998PM		7.015	1.32
	8/1/1998AM		6.980	1.01
	8/1/1998PM		6.898	1.47
	8/2/1998AM		6.984	1.17
	8/2/1998PM		6.969	ND
	8/3/1998AM		7.125	ND

Appendix 5 (cont'd)

	8/3/1998PM	7.113	ND
Homogenized Feces – Artemia Rep 2	7/20/1998AM	7.02	ND
	7/20/1998PM	6.95	0.222
	7/21/1998AM	7.07	2.33
	7/21/1998PM	7.08	0.926
	7/22/1998AM	7.13	0.817
	7/22/1998PM	6.93	0.500
	7/23/1998AM	7.00	1.13
	7/23/1998PM	6.89	0.992
	7/24/1998AM	7.02	1.05
	7/24/1998PM	7.12	1.20
	7/25/1998AM	6.97	1.19
	7/25/1998PM	7.16	0.388
	7/26/1998AM	6.96	1.02
	7/26/1998PM	6.97	0.362
	7/27/1998AM	7.04	0.732
	7/27/1998PM	7.01	0.690
	7/28/1998AM	7.00	0.712
	7/28/1998PM	7.02	0.727
	7/29/1998AM	7.13	1.33
	7/29/1998PM	7.04	0.989
	7/30/1998AM	6.98	1.19
	7/30/1998PM	7.16	0.729
	7/31/1998AM	6.89	1.08
	7/31/1998PM	6.97	1.90
	8/1/1998AM	6.96	1.52
	8/1/1998PM	7.05	2.10
	8/2/1998AM	7.13	0.999
	8/2/1998PM	7.02	ND
	8/3/1998AM	6.90	ND
	8/3/1998PM	7.14	ND
Homogenized Feces – Artemia Rep 1	7/20/1998AM	6.92	ND
	7/20/1998PM	7.07	1.92
	7/21/1998AM	7.01	1.89
	7/21/1998PM	7.10	0.866
	7/22/1998AM	7.08	0.718
	7/22/1998PM	7.03	0.683
	7/23/1998AM	6.90	0.968
	7/23/1998PM	6.93	0.440
	7/24/1998AM	7.03	1.25
	7/24/1998PM	7.03	1.12
	7/25/1998AM	7.06	1.19
	7/25/1998PM	7.07	0.479
	7/26/1998AM	6.89	0.605
	7/26/1998PM	7.04	0.394
	7/27/1998AM	6.83	0.700
	7/27/1998PM	7.10	0.333
	7/28/1998AM	7.11	0.703
	7/28/1998PM	7.09	0.087
	7/29/1998AM	7.09	0.996
	7/29/1998PM	7.05	1.15
	7/30/1998AM	7.03	1.37

Appendix 5 (cont'd)

7/30/1998PM	7.11	0.589
7/31/1998AM	6.99	1.06
7/31/1998PM	7.12	1.67
8/1/1998AM	7.14	0.802
8/1/1998PM	7.03	1.41
8/2/1998AM	7.09	0.841
8/2/1998PM	6.88	ND
8/3/1998AM	7.03	ND
8/3/1998PM	6.98	ND

Appendix 6. Feces produced by juvenile pink salmon.

Treatment Group	Fecal Collection Date & Time	Feces Collected for Mussel Exposures (g Wet Wt.)	Feces Collected for Determination of Dry Wt. and [Pristane] (g Wet Wt.)
Whole Feces – PWS Zooplankton – Rep 1	7/20/1998PM	0.243	0.033
	7/21/1998AM	0.252	0.070
	7/21/1998PM	0.188	0.015
	7/22/1998AM	0.292	0.040
	7/22/1998PM	0.238	0.008
	7/23/1998AM	0.383	0.022
	7/23/1998PM	0.212	0.055
	7/24/1998AM	0.481	0.042
	7/24/1998PM	0.234	0.077
	7/25/1998AM	0.380	0.051
	7/25/1998PM	0.214	0.073
	7/26/1998AM	0.428	0.039
	7/26/1998PM	0.336	0.036
	7/27/1998AM	0.428	0.035
	7/27/1998PM	0.310	0.046
	7/28/1998AM	0.370	0.040
	7/28/1998PM	0.275	0.069
	7/29/1998AM	0.399	0.039
	7/29/1998PM	0.288	0.064
	7/30/1998AM	0.296	0.092
	7/30/1998PM	0.289	0.035
	7/31/1998AM	0.398	0.076
	7/31/1998PM	0.248	0.072
	8/1/1998AM	0.393	0.080
	8/1/1998PM	0.281	0.035
	8/2/1998AM	0.341	0.071
	8/2/1998PM	0.234	0.066
	8/3/1998AM	0.405	0.000
Whole Feces – PWS Zooplankton – Rep 2	7/20/1998PM	0.237	0.060
	7/21/1998AM	0.208	0.052
	7/21/1998PM	0.280	0.030
	7/22/1998AM	0.281	0.027
	7/22/1998PM	0.226	0.050
	7/23/1998AM	0.387	0.060
	7/23/1998PM	0.194	0.062
	7/24/1998AM	0.403	0.044
	7/24/1998PM	0.277	0.048
	7/25/1998AM	0.433	0.054
	7/25/1998PM	0.272	0.062
	7/26/1998AM	0.429	0.044
	7/26/1998PM	0.323	0.044
	7/27/1998AM	0.444	0.078
	7/27/1998PM	0.311	0.055
	7/28/1998AM	0.363	0.060
	7/28/1998PM	0.212	0.063

Appendix 6 (cont'd)

	7/29/1998AM	0.332	0.032
	7/29/1998PM	0.305	0.067
	7/30/1998AM	0.316	0.078
	7/30/1998PM	0.282	0.044
	7/31/1998AM	0.326	0.066
	7/31/1998PM	0.242	0.093
	8/1/1998AM	0.357	0.053
	8/1/1998PM	0.301	0.075
	8/2/1998AM	0.336	0.074
	8/2/1998PM	0.260	0.082
	8/3/1998AM	0.407	0.000
Whole Feces – PWS Zooplankton – Rep 3	7/20/1998PM	0.148	0.027
	7/21/1998AM	0.242	0.043
	7/21/1998PM	0.199	0.037
	7/22/1998AM	0.245	0.026
	7/22/1998PM	0.201	0.052
	7/23/1998AM	0.325	0.047
	7/23/1998PM	0.261	0.055
	7/24/1998AM	0.415	0.037
	7/24/1998PM	0.286	0.054
	7/25/1998AM	0.408	0.020
	7/25/1998PM	0.275	0.053
	7/26/1998AM	0.403	0.034
	7/26/1998PM	0.281	0.021
	7/27/1998AM	0.395	0.032
	7/27/1998PM	0.236	0.039
	7/28/1998AM	0.352	0.041
	7/28/1998PM	0.326	0.049
	7/29/1998AM	0.361	0.040
	7/29/1998PM	0.212	0.075
	7/30/1998AM	0.334	0.067
	7/30/1998PM	0.328	0.064
	7/31/1998AM	0.241	0.073
	7/31/1998PM	0.255	0.068
	8/1/1998AM	0.340	0.066
	8/1/1998PM	0.237	0.048
	8/2/1998AM	0.302	0.081
	8/2/1998PM	0.223	0.074
	8/3/1998AM	0.404	0.000
Homogenized Feces – PWS Zooplankton Rep 1	7/21/1998AM	0.290	0.050
	7/21/1998PM	0.245	0.038
	7/22/1998AM	0.314	0.036
	7/22/1998PM	0.227	0.060
	7/23/1998AM	0.464	0.033
	7/23/1998PM	0.225	0.049
	7/24/1998AM	0.316	0.061
	7/24/1998PM	0.202	0.054
	7/25/1998AM	0.449	0.037
	7/25/1998PM	0.258	0.061
	7/26/1998AM	0.410	0.064
	7/26/1998PM	0.289	0.065
	7/27/1998AM	0.399	0.049

Appendix 6 (cont'd)

	7/27/1998PM	0.274	0.068
	7/28/1998AM	0.296	0.054
	7/28/1998PM	0.293	0.053
	7/29/1998AM	0.428	0.035
	7/29/1998PM	0.248	0.083
	7/30/1998AM	0.255	0.060
	7/30/1998PM	0.276	0.060
	7/31/1998AM	0.274	0.056
	7/31/1998PM	0.266	0.055
	8/1/1998AM	0.354	0.047
	8/1/1998PM	0.304	0.061
	8/2/1998AM	0.294	0.043
	8/2/1998PM	0.275	0.094
	8/3/1998AM	0.298	0.064
	8/3/1998PM	0.346	0.035
	8/4/1998AM	0.379	0.000
Homogenized Feces – PWS Zooplankton Rep 2	7/21/1998AM	0.329	0.030
	7/21/1998PM	0.232	0.022
	7/22/1998AM	0.325	0.021
	7/22/1998PM	0.185	0.064
	7/23/1998AM	0.322	0.036
	7/23/1998PM	0.315	0.025
	7/24/1998AM	0.349	0.031
	7/24/1998PM	0.345	0.044
	7/25/1998AM	0.520	0.042
	7/25/1998PM	0.314	0.074
	7/26/1998AM	0.372	0.032
	7/26/1998PM	0.393	0.051
	7/27/1998AM	0.422	0.041
	7/27/1998PM	0.229	0.043
	7/28/1998AM	0.310	0.069
	7/28/1998PM	0.241	0.051
	7/29/1998AM	0.398	0.062
	7/29/1998PM	0.289	0.061
	7/30/1998AM	0.267	0.087
	7/30/1998PM	0.228	0.053
	7/31/1998AM	0.250	0.071
	7/31/1998PM	0.217	0.061
	8/1/1998AM	0.313	0.065
	8/1/1998PM	0.218	0.062
	8/2/1998AM	0.223	0.068
	8/2/1998PM	0.220	0.063
	8/3/1998AM	0.249	0.053
	8/3/1998PM	0.312	0.020
	8/4/1998AM	0.317	0.000
Homogenized Feces – PWS Zooplankton Rep 3	7/21/1998AM	0.316	0.057
	7/21/1998PM	0.204	0.034
	7/22/1998AM	0.269	0.038
	7/22/1998PM	0.215	0.038
	7/23/1998AM	0.394	0.035
	7/23/1998PM	0.316	0.024
	7/24/1998AM	0.310	0.045

Appendix 6 (cont'd)

	7/24/1998PM	0.265	0.032
	7/25/1998AM	0.483	0.041
	7/25/1998PM	0.279	0.044
	7/26/1998AM	0.357	0.029
	7/26/1998PM	0.287	0.073
	7/27/1998AM	0.405	0.036
	7/27/1998PM	0.261	0.046
	7/28/1998AM	0.318	0.044
	7/28/1998PM	0.184	0.063
	7/29/1998AM	0.354	0.054
	7/29/1998PM	0.221	0.053
	7/30/1998AM	0.219	0.061
	7/30/1998PM	0.291	0.042
	7/31/1998AM	0.269	0.048
	7/31/1998PM	0.268	0.045
	8/1/1998AM	0.363	0.064
	8/1/1998PM	0.271	0.050
	8/2/1998AM	0.299	0.075
	8/2/1998PM	0.186	0.058
	8/3/1998AM	0.307	0.056
	8/3/1998PM	0.249	0.015
	8/4/1998AM	0.292	0.000
Homogenized Feces – Artemia Rep 1	7/21/1998AM	0.277	0.037
	7/21/1998PM	0.374	0.020
	7/22/1998AM	0.214	0.020
	7/22/1998PM	0.201	0.005
	7/23/1998AM	0.073	0.013
	7/23/1998PM	0.055	0.004
	7/24/1998AM	0.134	0.010
	7/24/1998PM	0.080	0.021
	7/25/1998AM	0.258	0.014
	7/25/1998PM	0.123	0.041
	7/26/1998AM	0.265	0.020
	7/26/1998PM	0.164	0.025
	7/27/1998AM	0.177	0.054
	7/27/1998PM	0.122	0.052
	7/28/1998AM	0.121	0.024
	7/28/1998PM	0.164	0.034
	7/29/1998AM	0.341	0.030
	7/29/1998PM	0.245	0.093
	7/30/1998AM	0.354	0.064
	7/30/1998PM	0.254	0.047
	7/31/1998AM	0.361	0.050
	7/31/1998PM	0.303	0.096
	8/1/1998AM	0.312	0.070
	8/1/1998PM	0.338	0.093
	8/2/1998AM	0.439	0.067
	8/2/1998PM	0.407	0.057
	8/3/1998AM	0.365	0.067
	8/3/1998PM	0.354	0.052
	8/4/1998AM	0.245	0.000

Appendix 6 (cont'd)

Homogenized Feces – Artemia Rep 2	7/21/1998AM	0.154	0.032
	7/21/1998PM	0.131	0.013
	7/22/1998AM	0.192	0.020
	7/22/1998PM	0.156	0.026
	7/23/1998AM	0.147	0.014
	7/23/1998PM	0.114	0.041
	7/24/1998AM	0.156	0.020
	7/24/1998PM	0.094	0.038
	7/25/1998AM	0.169	0.017
	7/25/1998PM	0.084	0.054
	7/26/1998AM	0.179	0.022
	7/26/1998PM	0.120	0.039
	7/27/1998AM	0.130	0.033
	7/27/1998PM	0.158	0.040
	7/28/1998AM	0.088	0.035
	7/28/1998PM	0.214	0.049
	7/29/1998AM	0.363	0.056
	7/29/1998PM	0.237	0.044
	7/30/1998AM	0.439	0.083
	7/30/1998PM	0.424	0.081
	7/31/1998AM	0.373	0.053
	7/31/1998PM	0.252	0.097
	8/1/1998AM	0.396	0.089
	8/1/1998PM	0.407	0.059
	8/2/1998AM	0.403	0.096
	8/2/1998PM	0.352	0.046
	8/3/1998AM	0.431	0.071
	8/3/1998PM	0.383	0.035
	8/4/1998AM	0.325	0.000
Homogenized Feces – Artemia Rep 3	7/21/1998AM	0.294	0.050
	7/21/1998PM	0.251	0.035
	7/22/1998AM	0.225	0.025
	7/22/1998PM	0.164	0.030
	7/23/1998AM	0.181	0.037
	7/23/1998PM	0.097	0.027
	7/24/1998AM	0.157	0.013
	7/24/1998PM	0.095	0.030
	7/25/1998AM	0.228	0.025
	7/25/1998PM	0.166	0.082
	7/26/1998AM	0.246	0.019
	7/26/1998PM	0.133	0.026
	7/27/1998AM	0.187	0.037
	7/27/1998PM	0.178	0.033
	7/28/1998AM	0.173	0.021
	7/28/1998PM	0.299	0.054
	7/29/1998AM	0.345	0.054
	7/29/1998PM	0.261	0.088
	7/30/1998AM	0.338	0.058
	7/30/1998PM	0.434	0.044
	7/31/1998AM	0.353	0.059
	7/31/1998PM	0.333	0.054

Appendix 6 (cont'd)

8/1/1998AM	0.482	0.055
8/1/1998PM	0.363	0.063
8/2/1998AM	0.400	0.087
8/2/1998PM	0.267	0.042
8/3/1998AM	0.482	0.066
8/3/1998PM	0.410	0.047
8/4/1998AM	0.296	0.000

Appendix 7. Wet weight, dry weight, pristane concentration of feces produced by juvenile pink salmon fry.

Fecal Group	Wet Wt. (g)	Dry Wt. (g)	[Pristane] (μg g^{-1} Dry Wt.)
Feces from PWS Zooplankton			
abl-07188 rep 1	1.07	0.128	ND
abl-07188 rep 2	0.835	0.098	ND
abl-07188 rep 3	1.01	0.110	ND
abl-07188 rep 4	1.10	0.119	ND
abl-07188 rep 5	0.900	0.098	ND
abl-07218 rep 1	0.290	0.036	ND
abl-07218 rep 2	0.329	0.048	ND
abl-07218 rep 3	0.316	0.037	ND
abl-07248-pm	0.309	0.034	414
abl-07258-am	0.245	0.022	342
abl-07258-pm	0.367	0.034	458
abl-07268-am	0.242	0.024	660
abl-07268-pm	0.290	0.027	632
abl-07278-am	0.271	0.030	275
abl-07278-pm	0.297	0.026	605
abl-07288-am	0.308	0.030	646
abl-07288-pm	0.348	0.033	225
abl-07298-am	0.262	0.022	295
abl-07298-pm	0.403	0.037	333
abl-07308-am	0.445	0.047	335
abl-07308-pm	0.298	0.033	208
abl-07318-am	0.390	0.041	256
abl-07318-pm	0.394	0.037	349
abl-08018-am	0.375	0.041	291
abl-08018-pm	0.331	0.024	350
abl-08029-am	0.412	0.047	401
abl-08028-pm	0.437	0.051	607
abl-08038-am	0.173	0.020	137
abl-08038-pm	0.070	0.008	216
Feces from *Artemia*			
abl-07218 rep 1			ND
abl-07218 rep 2			ND
abl-07218 rep 3			ND
abl-07258-am	0.056	0.008	3.80
abl-07258-pm	0.177	0.005	6.04
abl-07268-am	0.061	0.002	36.0
abl-07268-pm	0.090	0.005	0.02
abl-07298-am	0.140	0.008	9.10
abl-07298-pm	0.225	0.017	2.37
abl-07278-am	0.124	0.009	2.97
abl-07278-pm	0.125	0.007	8.26
abl-07308-am	0.205	0.010	15.1
abl-07308-pm	0.172	0.018	7.40

Appendix 7 (cont'd)

abl-08018-am	0.214	0.013	8.80
abl-08018-pm	0.215	0.018	0.43
abl-08028-am	0.250	0.016	25.2
abl-08028-pm	0.145	0.010	10.0
abl-08038-am	0.204	0.013	22.4
abl-08038-pm	0.134	0.010	4.00
abl-07248-pm	0.089	0.005	21.9
abl-07288-am	0.080	0.005	10.7
abl-97288-pm	0.080	0.006	15.2
abl-07318-am	0.162	0.010	9.11
abl-07318-pm	0.247	0.012	30.8

Appendix 8. Weighing dates and times, and weights of juvenile pink salmon.

Treatment Group	Date & Time of Initial Weighing	Date & Time of Final Weighing	Initial Wet Weight (g)	Final Wet Weight (g)
PWS-Zooplankton				
Whole Feces, rep 1	7/24/1998; 1530 h	8/2/1998; 1535 h	37.2	40.4
rep 2	7/24/1998; 1530 h	8/2/1998; 1535 h	40.3	41.6
rep 3	7/24/1998; 1530 h	8/2/1998; 1535 h	38.6	40.5
Homogenized Feces, rep 1	7/24/1998; 1530 h	8/2/1998; 1535 h	38.3	41.4
rep 2	7/24/1998; 1530 h	8/2/1998; 1535 h	38.1	39.7
rep 3	7/24/1998; 1530 h	8/2/1998; 1535 h	33.5	35.4
Artemia				
Homogenized Feces, rep 1	7/25/1998; 2115 h	8/2/1998; 1535 h	40.9	48.1
rep 2	7/25/1998; 2115 h	8/2/1998; 1535 h	40.5	47.1
rep 3	7/24/1998; 1530 h	8/2/1998; 1535 h	42.5	52.0

Appendix 9. Pristane in mussels near the W. H. Noerenburg Hatchery.

Station	Collection Date	Mussel Wet Wt. (g)	Mussel Dry Wt. (g)	[Pristane] ($\mu g\ g^{-1}$)
Esther Light	4/28/1996	4.86	0.580	1.44
	4/30/1996	5.02	0.510	1.81
	5/1/1996	4.80	0.440	2.85
	5/2/1996	5.00	0.390	1.81
	5/3/1996	5.05	0.490	7.47
	5/4/1996	4.99	0.500	2.25
	5/5/1996	5.02	0.490	8.54
	5/6/1996	5.04	0.680	12.0
	5/9/1996	4.62	0.520	14.0
Lake Bay	4/28/1996	4.85	0.830	2.29
	4/30/1996	5.00	0.740	1.46
	5/1/1996	5.04	0.510	5.41
	5/2/1996	5.03	0.650	3.63
	5/3/1996	5.04	0.750	3.35
	5/4/1996	5.02	0.640	3.38
	5/5/1996	4.95	0.620	23.5
	5/6/1996	5.10	0.790	15.3
	5/9/1996	5.01	0.460	23.9
Hodgkins Point	4/28/1996	5.00	0.430	4.19
	4/30/1996	5.02	0.510	4.47
	5/1/1996	3.85	0.420	5.57
	5/2/1996	4.88	0.480	3.67
	5/3/1996	4.79	0.550	6.34
	5/4/1996	5.01	0.520	6.56
	5/5/1996	5.01	0.580	4.36
	5/6/1996	5.01	0.500	6.03
	5/9/1996	4.93	0.450	13.9
Esther Light	4/26/1998	4.42	0.425	1.76
	4/27/1998	5.41	0.563	4.14
	4/29/1998	4.61	0.488	3.12
	4/30/1998	4.89	0.413	1.12
	5/1/1998	4.93	0.338	2.01
	5/2/1998	4.99	0.429	3.18
	5/4/1998	5.09	0.523	2.32
	5/5/1998	4.71	0.374	1.08
	5/6/1998	4.79	0.360	1.32
	5/7/1998	4.74	0.359	2.22
	5/8/1998	4.76	0.441	10.5
	5/10/1998	4.81	0.370	1.76
	5/11/1998	4.73	0.435	9.54
	5/14/1998	4.75	0.364	5.12
Lake Bay	4/26/1998	4.47	0.473	0.763
	4/27/1998	4.44	0.422	2.28
	4/29/1998	4.90	0.459	1.91
	4/30/1998	4.97	0.518	2.78
	5/1/1998	4.96	0.498	2.69
	5/2/1998	5.01	0.505	4.01

Appendix 9 (cont'd)

	5/4/1998	5.06	0.569	9.59
	5/5/1998	4.90	0.497	9.13
	5/6/1998	4.79	0.445	6.45
	5/7/1998	4.88	0.414	8.63
	5/8/1998	4.84	0.409	16.3
	5/10/1998	4.73	0.562	4.10
	5/11/1998	4.84	0.403	11.2
	5/14/1998	4.81	0.489	15.4
Hodgkins Point	4/26/1998	5.10	0.562	1.97
	4/27/1998	4.48	0.419	1.15
	4/29/1998	4.95	0.511	0.650
	4/30/1998	5.00	0.538	1.24
	5/1/1998	4.97	0.483	4.22
	5/2/1998	4.64	0.451	3.59
	5/4/1998	4.96	0.478	1.70
	5/5/1998	4.83	0.461	2.21
	5/6/1998	4.76	0.435	2.14
	5/7/1998	4.82	0.470	9.13
	5/8/1998	4.92	0.550	4.36
	5/10/1998	4.83	0.542	2.48
	5/11/1998	4.75	0.467	4.00
	5/14/1998	4.83	0.631	5.06
	5/8/1998	4.76	0.435	4.46

Appendix 10. Pristane concentration in feces produced by zooplankton. The species composition of the zooplankton from which the feces were derived is also listed. CM = *Calanus marshallae*, NFP = *Neocalanus plumchrus/flemingerii*, HYP = *Hyperiid* amphipod, PSC = *Pseudocalanus sp.*

Zooplankton Batch	Sampling Date	Split Ratio	NPF Stage V	NPF Stage IV	CM Stage V	CM Stage IV	NPF & CM Stage III	PSC	HYP	Other	[Pristane] in Zooplankton Fecal Pellets ($\mu g\ g^{-1}$)
WHN-05056-01Z	5/5/1996	1/1	189	134	17	34		183	15	6	61.2
WHN-04286-01Z	4/28/1996	1/2	60	93	9	3	15	3	3	5	160
WHN-05036-01Z	5/3/1996	1/2	164	75	22	9	32	11	5	2	50.3
WHN-04306-02Z	4/30/1996	1/1	226	36	21	13	9	2	9	3	64.7
WHN-04306-01Z	4/30/1996	1/2	172	94	16	5	19	8	2	1	41.8
WHN-05046-01Z	5/4/1996	1/2	110	25	1	2	5	2	5	1	43.2
WHN-04296-01Z	4/29/1996	1/4	101	103	6	2	14	5	5	3	122
WHN-05016-01Z	5/1/1996	1/4	73	26	10	3	7	8	6	1	98.1

Appendix 11. Species composition of zooplankton collected in 1998. Abbreviations of zooplankton are: AC = *Acartia sp.*, BL = bryozoan larvae, CM = *Calanus marshallae*, NFP = *Neocalanus plumchrus/flemingerii*, OIT = *Oithona sp.*, OKP = *Oikopleura sp.*, PSC = ***Pseudocalanus sp.***

Mesh Size	Station	Sampling Date & Time	Split Ratio	AC	BL	CM	NPF	OIT	OKP	PSC	Other
505 µm	Lake Bay	4/26/1998AM	1:32				118			2	
		4/29/1998AM	1:32	1			89		15	7	7
		4/29/1998PM	1:32				235		30	3	3
		4/30/1998AM	1:32			12	171		18	6	3
		4/30/1998PM	1:16			13	101		33	6	3
		5/1/1998AM	1:16			17	148		39	9	4
		5/4/1998AM	1:16		1	2	111	1	9	20	7
		5/5/1998AM	1:16	1		1	109		1	17	13
		5/6/1998AM	1:16			3	107		8	12	9
		5/7/1998AM	1:16	5		3	104			21	14
		5/7/1998PM	1:4	3		4	119		70	39	15
		5/8/1998AM	1:8	1		17	116		18	10	15
	Esther Light	4/26/1998AM	1:32				254			2	2
		4/29/1998AM	1:128			4	210		3	1	4
		4/29/1998PM	1:32				102		38	2	29
		4/30/1998AM	1:32			4	202		10	2	4
		4/30/1998PM	1:16	3		22	159		45	19	3
		5/1/1998AM	1:32		1	18	199	1	15	4	3
		5/4/1998AM	1:16	2		3	142		13	22	6
		5/5/1998AM	1:16	3		5	137		15	19	4
		5/6/1998AM	1:8	1		5	149		23	40	13
		5/7/1998AM	1:16				125			9	7
		5/7/1998PM	1:8	1		4	118		45	14	8
		5/8/1998AM	1:16	2		33	148		2	4	6
	Hodgkins Point	4/26/1998AM	1:16			1	309			5	2
		4/29/1998AM	1:32	2		3	188		11	3	3

Appendix 11 (cont'd)

		4/29/1998PM	1:32		2		188		60	8	5
		4/30/1998AM	1:32			4	130		11	1	2
		4/30/1998PM	**1:32**			**33**	**169**		**24**	**11**	**2**
		5/1/1998AM	**1:16**	**2**		**32**	**200**		**22**	**14**	**4**
		5/4/1998AM	**1:16**			**8**	**84**		**27**	**20**	**10**
		5/5/1998AM	1:16	5	1	1	54	1	39	42	9
		5/6/1998AM	1:8		1	12	147		29	42	13
		5/7/1998AM	1:8			1	169			23	12
		5/7/1998PM	1:16		2	14	96		13	41	2
		5/8/1998AM	1:8	1		15	117		19	25	14
202 µm	Lake Bay	4/26/1998AM	1:32	28			65			51	6
		4/29/1998AM	1:128	3	3	1	79		21	65	3
		4/29/1998PM	1:128	7		1	96		29	219	
		4/30/1998AM	1:32	8	14	6	93		39	278	3
		4/30/1998PM	1:64	6	13	6	47	2	38	102	9
		5/1/1998AM	1:64	6	22	13	49	4	35	107	2
		5/4/1998AM	1:128	12	9		20	1	6	162	2
		5/5/1998AM	1:64	23	19	2	25	6	7	136	4
		5/6/1998AM	1:32	61	24		20	21	9	193	14
		5/7/1998AM	1:32	81			27			276	6
		5/7/1998PM	1:64	33	17	2	14	7	17	184	6
		5/8/1998AM	1:256	9	6		6	4	2	94	1
	Esther Light	4/26/1998AM	1:32	16			296			66	3
		4/29/1998AM	1:64	15	6	7	37	3	26	59	4
		4/29/1998PM	1:32	10	5		102	1	43	100	3
		4/30/1998AM	1:64	2	14	5	87	1	12	105	5
		4/30/1998PM	1:64	10	18		45	1	25	60	11
		5/1/1998AM	1:64	2	24	21	77	5	25	146	1
		5/4/1998AM	**1:64**	**18**	**31**		**48**	**6**	**6**	**168**	**7**
		5/5/1998AM	**1:256**	**14**	**3**		**5**	**6**	**2**	**106**	**1**
		5/6/1998AM	1:128	9	8		13	10	6	226	1
		5/7/1998AM	1:64	45	1	1	33			261	3
		5/7/1998PM	1:64	10	13	1	19	5	14	20	7
		5/8/1998AM	1:256	6	2	7	20	1		254	1
	Hodgkins Point	4/26/1998AM	1:64	3		1	113			89	2
		4/29/1998AM	1:128	5	2	1	60		11	69	2

Appendix 11 (cont'd)

4/29/1998PM	1:32	27			100		45	247	6
4/30/1998AM	1:32	3	7		64		8	122	4
4/30/1998PM	1:64	5	13	8	85	2	20	149	2
5/1/1998AM	1:64	4	16	5	55	1	10	113	3
5/4/1998AM	1:128	4	16	6	16	1	4	178	3
5/5/1998AM	1:128	13	15		6	7	15	180	5
5/6/1998AM	1:64	17	6	2	23	7	15	182	6
5/7/1998AM	1:64	18	9		24			129	10
5/7/1998PM	1:64	13	11	2	33	8	7	200	7
5/8/1998AM	1:64	19	10		5	10	1	197	4

Appendix 12. Stomach contents of juvenile pink salmon near W. H. Noerenberg hatchery. Fork length (FL), and number of individuals of *Neocalanus sp.*, of *Pseudocalanus sp.* and of all other prey in stomachs of juvenile pink salmon following release from the hatchery in 1996 and 1998. "Unreleased" indicates results for cohorts retained within net pens. The concentration of pristane in a pooled sample of five individuals from the same group subsampled for stomach content analysis is also given for samples collected in 1996.

Year	Hours After Release	Station	Pink Salmon FL (mm)	*Neocalanus sp.*	*Pseudocalanus sp.*	Other	[Pristane] ($\mu g\ g^{-1}$)
1996	0	Unreleased	37	0	0	0	0.380
			39	0	0	0	
			38	0	0	0	
			38	0	0	0	
			35	0	0	0	
			33	0	0	0	
			40	0	0	0	
	42	Lake Bay	35	6	41	2	70.2
			35	7	38	0	
			33	0	105	1	
			37	9	203	6	
			38	13	105	4	
			32	7	81	0	
			32	4	61	6	
	42	Esther Light	35	7	18	0	42.3
			34	6	71	1	
			35	4	0	1	
			36	10	34	0	
			32	2	20	0	
			35	5	36	0	
			33	6	82	0	
	42	Hodgkins Point	36	10	44	0	65.6
			38	8	29	0	

Appendix 12 (cont'd)

			36	9	49	0
			34	12	19	0
			34	**0**	**129**	**0**
			35	12	19	0
			33	4	23	0
1998	0	Unreleased	35	0	0	0
			38	0	0	0
			37	0	0	0
			38	0	0	0
			39	0	0	0
			40	0	0	0
			38	0	0	0
			39	0	0	0
			38	0	0	0
			36	0	0	0
	25	Lake Bay	37	24	0	1
			39	20	4	0
			36	19	12	0
			38	26	23	1
			38	33	38	1
			36	19	24	0
			35	18	5	0
	25	Esther Light	**36**	**21**	**51**	**0**
			34	**28**	**56**	**0**
			31	9	41	1
			31	5	59	2
			32	9	55	1
			32	17	30	1
			30	0	2	0

Appendix 12 (cont'd)

65	Lake Bay	30	0	23	6
		35	7	17	0
		35	10	56	0
		34	17	17	4
		35	11	40	2
		34	8	22	1
		35	5	2	0
65	Esther Light	33	3	11	0
		31	11	13	1
		33	3	5	0
		30	5	15	3
		33	7	12	0
		31	5	17	0
		32	5	14	15
65	Hodgkins Point	39	5	10	0
		38	5	4	1
		38	5	12	0
		39	3	49	5
		37	7	13	0
		37	5	3	0
		37	5	13	0

Appendix 13. Concentration of dissolved and of particle-bound pristane in seawater. Estimated method detection limit is 0.041 μg L^{-1}.

Year	Station	Sampling Date	Particulate [Pristane] (μg L^{-1})	Particulate [Pristane] (μg L^{-1})
1996	Lake Bay	4/27/1996	0.000	0.014
		4/28/1996	0.009	0.006
		4/29/1996	0.015	0.051
		4/30/1996	0.010	0.034
		5/1/1996	0.000	0.083
		5/3/1996	0.019	0.041
		5/4/1996	0.020	0.017
		5/5/1996	0.013	0.026
		5/6/1996	0.018	0.057
1998	Lake Bay	4/26/1998	0.024	0.024
		4/29/1998	0.021	0.026
		4/30/1998	0.011	0.019
		5/1/1998	0.013	0.040
		5/4/1998	0.000	0.022
		5/5/1998	0.013	0.042
		5/6/1998	0.055	0.000
		5/7/1998	0.028	0.000
		5/8/1998	0.020	0.000
	Esther Light	4/26/1998	0.039	0.000
		4/29/1998	0.015	0.000
		4/30/1998	0.000	0.107
		5/1/1998	0.000	0.022
		5/4/1998	0.020	0.046
		5/5/1998	0.019	0.016
		5/6/1998	0.066	0.044
		5/7/1998	0.049	0.000
		5/8/1998	0.011	0.000
	Hodgkins Point	4/26/1998	0.000	0.009
		4/29/1998	0.031	0.000
		4/30/1998	0.017	0.000
		5/1/1998	0.019	0.025
		5/4/1998	0.000	0.019
		5/5/1998	0.010	0.011
		5/6/1998	0.031	0.000
		5/7/1998	0.036	0.031
		5/8/1998	0.014	0.000

Appendix 14. Concentrations of pristane in mussels from Prince William Sound. See Table 4.1 in text for station abbreviations. Parenthetical identifiers for samples from Point Pakenham collected 3 May 2000 indicate relative vertical elevation in the intertidal.

Year	Station	Sampling Date	Mussel Wet Wt. (g)	Mussel Dry Wt. (g)	[Pristane] ($\mu g\ g^{-1}$)
1995	AFKHA	02-Mar-95	5.71	0.860	0.634
	AFKHA	03-Apr-95	7.05	1.16	1.26
	AFKHA	20-Apr-95	6.26	1.25	2.15
	AFKHA	16-May-95	6.58	1.31	5.14
	AFKHA	31-May-95	6.12	1.24	6.33
	AFKHA	27-Jun-95	6.88	1.29	2.44
	AFKHA	28-Jul-95	6.66	0.670	3.82
	APPLI	02-Apr-95	7.60	0.590	1.59
	APPLI	17-Apr-95	6.87	0.700	2.37
	APPLI	27-Apr-95	7.06	0.940	2.09
	APPLI	20-May-95	6.92	0.830	4.35
	APPLI	31-May-95	6.84	1.28	3.87
	APPLI	27-Jun-95	6.84	0.500	1.08
	APPLI	31-Jul-95	6.87	0.500	1.31
	BLIGI	31-Mar-95	6.79	0.400	0.836
	BLIGI	16-Apr-95	6.95	0.650	0.562
	BLIGI	27-Apr-95	6.84	0.510	0.655
	BLIGI	19-May-95	7.00	0.680	5.46
	BLIGI	31-May-95	6.09	0.960	2.85
	BLIGI	27-Jun-95	6.71	0.520	1.39
	BLIGI	02-Aug-95	7.26	0.470	1.94
	CANNC	20-Apr-95	6.92	0.550	0.410
	CANNC	29-Apr-95	6.98	0.730	0.507
	CANNC	17-May-95	6.52	1.23	1.55
	CANNC	01-Jun-95	6.96	1.10	1.68
	CANNC	29-Jun-95	6.90	0.660	0.631
	CANNC	30-Jul-95	6.53	0.680	0.368
	CHENI	02-Apr-95	7.05	0.520	1.24
	CHENI	17-Apr-95	6.89	0.960	2.22
	CHENI	29-Apr-95	6.89	1.05	3.06
	CHENI	16-May-95	6.82	1.03	2.84
	CHENI	31-May-95	6.78	1.26	5.95
	CHENI	28-Jun-95	6.93	1.02	1.33
	CHENI	01-Aug-95	7.08	0.380	1.12
	CONS2	29-Apr-95	6.65	0.430	0.670
	CONS2	18-May-95	7.07	0.680	0.609
	CONS2	01-Jun-95	4.13	0.600	0.727
	CONS2	28-Jun-95	6.99	0.460	0.813
	CONS2	01-Aug-95	6.89	0.400	0.590
	DECIP	31-Mar-95	7.06	0.530	0.593
	DECIP	17-Apr-95	6.74	0.460	1.34
	DECIP	27-Apr-95	6.98	0.550	1.45

Appendix 14 (cont'd)

DECIP	19-May-95	7.02	0.690	1.27
DECIP	31-May-95	6.96	0.930	1.23
DECIP	27-Jun-95	6.99	0.510	0.423
DECIP	31-Jul-95	6.95	0.500	0.940
DIVIP	02-Apr-95	7.04	0.770	0.919
DIVIP	17-Apr-95	6.18	1.03	4.10
DIVIP	27-Apr-95	6.99	1.14	3.29
DIVIP	20-May-95	7.21	1.04	6.22
DIVIP	31-May-95	5.29	1.01	6.73
DIVIP	28-Jun-95	6.95	0.570	0.241
DIVIP	31-Jul-95	6.66	0.390	1.28
EKNII	02-Apr-95	6.15	0.370	1.24
EKNII	17-Apr-95	6.94	0.480	1.45
EKNII	27-Apr-95	7.01	0.550	0.925
EKNII	14-May-95	6.96	1.13	5.17
EKNII	31-May-95	3.10	0.490	6.47
EKNII	28-Jun-95	6.71	0.660	1.01
EKNII	31-Jul-95	6.93	0.520	2.02
ESTHI	03-Apr-95	6.96	0.500	1.15
ESTHI	20-Apr-95	6.89	0.820	2.58
ESTHI	02-May-95	6.95	0.880	4.42
ESTHI	19-May-95	6.80	0.710	9.16
ESTHI	27-Jun-95	6.96	0.550	1.50
ESTHI	27-Jul-95	7.28	0.540	0.836
FAIR2	31-Mar-95	7.16	0.490	0.739
FAIR2	16-Apr-95	7.02	0.900	1.80
FAIR2	27-Apr-95	6.88	0.780	1.41
FAIR2	19-May-95	7.03	1.19	31.2
FAIR2	31-May-95	4.43	0.870	27.9
FAIR2	27-Jun-95	6.71	0.850	4.28
FAIR2	31-Jul-95	6.80	0.610	6.18
FLEMI	02-Apr-95	6.84	0.820	1.60
FLEMI	17-Apr-95	6.76	0.890	1.86
FLEMI	28-Apr-95	6.88	0.990	2.75
FLEMI	17-May-95	6.88	1.06	3.76
FLEMI	01-Jun-95	4.15	0.760	3.89
FLEMI	01-Jun-95	6.05	1.22	5.15
FLEMI	28-Jun-95	6.86	0.870	1.61
FLEMI	01-Aug-95	7.06	0.600	1.25
FOXF1	02-Apr-95	7.32	0.720	2.91
FOXF1	17-Apr-95	6.27	0.520	4.04
FOXF1	28-Apr-95	7.17	0.700	2.72
FOXF1	18-May-95	6.85	0.620	9.47
FOXF1	01-Jun-95	6.70	0.710	24.1
FOXF1	01-Jun-95	5.68	1.09	21.8
FOXF1	28-Jun-95	7.28	0.670	9.07
FOXF1	01-Aug-95	7.03	0.640	4.18
GREE2	19-Apr-95	6.93	0.620	0.979
GREE2	27-Apr-95	6.84	0.610	1.15
GREE3	18-May-95	6.73	0.760	1.10
GREE3	01-Jun-95	3.75	0.560	2.33
GREE3	28-Jun-95	6.71	0.630	0.436

Appendix 14 (cont'd)

GREE3	01-Aug-95	7.11	0.670	0.609
HERRP	02-Apr-95	7.25	0.470	1.20
HERRP	17-Apr-95	6.70	0.680	2.88
HERRP	27-Apr-95	7.37	0.550	3.17
HERRP	19-May-95	7.45	0.600	4.33
HERRP	31-May-95	5.69	0.360	8.98
HERRP	31-May-95	2.63	0.900	7.07
HERRP	28-Jun-95	6.61	0.580	1.89
HERRP	31-Jul-95	7.17	0.550	1.94
MAINB	20-Apr-95	6.92	0.910	1.97
MAINB	03-May-95	7.21	0.770	2.46
MAINB	18-May-95	6.82	0.880	5.55
MAINB	01-Jun-95	6.55	0.720	4.16
MAINB	29-Jun-95	6.83	0.450	0.773
MAINB	30-Jul-95	6.81	0.370	2.06
NAKEI	31-Mar-95	6.52	0.590	0.890
NAKEI	16-Apr-95	6.85	0.630	3.40
NAKEI	27-Apr-95	6.96	1.02	2.95
NAKEI	19-May-95	7.13	1.05	7.85
NAKEI	31-May-95	5.63	1.16	8.83
NAKEI	27-Jun-95	6.82	0.770	1.45
NAKEI	31-Jul-95	7.15	0.570	1.53
OLSEN	31-Mar-95	6.46	0.500	0.783
OLSEN	16-Apr-95	6.86	0.910	0.245
OLSEN	16-Apr-95	6.97	1.22	0.774
OLSEN	27-Apr-95	6.96	1.02	0.767
OLSEN	19-May-95	7.15	0.910	2.47
OLSEN	31-May-95	6.98	1.27	1.67
OLSEN	27-Jun-95	7.28	0.860	1.17
OLSEN	02-Aug-95	6.99	0.620	0.316
PELE2	02-Apr-95	4.01	0.460	1.46
PELE2	17-Apr-95	7.12	0.650	2.24
PELE2	27-Apr-95	4.52	0.440	4.04
PELE2	13-May-95	6.25	0.710	12.3
PELE2	31-May-95	4.73	0.420	13.1
PELE2	31-May-95	2.29	0.740	12.0
PELE2	27-Jun-95	6.79	0.630	3.55
PELE2	31-Jul-95	6.62	0.510	3.89
PERRI	31-Mar-95	7.15	0.360	1.80
PERRI	17-Apr-95	6.73	0.700	1.69
PERRI	27-Apr-95	7.03	1.12	1.86
PERRI	19-May-95	6.86	1.08	9.16
PERRI	31-May-95	5.25	0.910	5.96
PERRI	27-Jun-95	6.86	0.820	1.83
PERRI	31-Jul-95	7.00	0.530	1.12
PPAKE	31-Mar-95	6.76	0.370	0.576
PPAKE	17-Apr-95	6.11	0.640	0.664
PPAKE	27-Apr-95	5.84	0.700	1.50
PPAKE	19-May-95	6.98	0.690	9.48
PPAKE	31-May-95	5.74	0.740	3.58
PPAKE	27-Jun-95	6.77	0.610	0.162
PPAKE	31-Jul-95	6.99	0.630	1.14

Appendix 14 (cont'd)

	ROCK3	02-Apr-95	6.22	0.670	0.498
	ROCK3	19-Apr-95	6.86	0.710	1.99
	ROCK3	28-Apr-95	7.01	0.930	2.14
	ROCK3	18-May-95	7.62	1.06	2.76
	ROCK3	01-Jun-95	5.53	0.890	2.81
	ROCK3	28-Jun-95	6.77	0.780	0.320
	ROCK3	01-Aug-95	7.18	0.610	0.751
	SNUGC	31-Mar-95	6.51	0.740	0.483
	SNUGC	16-Apr-95	6.98	0.970	0.356
	SNUGC	27-Apr-95	6.93	1.03	1.05
	SNUGC	19-May-95	6.92	1.05	4.83
	SNUGC	31-May-95	7.07	1.19	2.23
	SNUGC	27-Jun-95	6.67	0.910	2.15
	SNUGC	02-Aug-95	7.15	0.500	0.611
	STORI	31-Mar-95	7.03	0.520	0.658
	STORI	16-Apr-95	7.00	0.660	1.83
	STORI	27-Apr-95	5.86	0.690	2.00
	STORI	19-May-95	6.87	1.09	6.32
	STORI	31-May-95	5.65	1.03	5.09
	STORI	27-Jun-95	6.89	0.700	0.836
	STORI	31-Jul-95	6.89	0.580	1.20
	WINDB	02-Apr-95	6.68	0.650	0.241
	WINDB	16-Apr-95	7.11	0.650	0.764
	WINDB	17-Apr-95	6.98	0.720	0.393
	WINDB	27-Apr-95	6.88	0.660	0.341
	WINDB	19-May-95	7.32	0.810	3.04
	WINDB	31-May-95	4.69	0.750	2.08
	WINDB	27-Jun-95	6.85	0.670	1.28
	WINDB	02-Aug-95	6.57	0.500	0.664
1996	AFKHA	19-Mar-96	5.03	0.450	1.82
	AFKHA	07-Apr-96	5.00	0.500	1.35
	AFKHA	19-Apr-96	5.04	0.580	1.54
	AFKHA	06-May-96	4.94	0.620	6.37
	AFKHA	17-May-96	5.08	0.490	6.96
	AFKHA	03-Jun-96	4.94	0.590	5.69
	AFKHA	01-Jul-96	4.99	0.420	2.73
	AFKHA	30-Jul-96	5.05	0.370	1.45
	APPLI	21-Mar-96	5.44	0.380	0.687
	APPLI	07-Apr-96	5.08	0.380	2.21
	APPLI	18-Apr-96	5.14	0.450	1.74
	APPLI	06-May-96	4.93	0.480	3.79
	APPLI	19-May-96	4.89	0.440	11.8
	APPLI	02-Jun-96	5.17	0.370	3.47
	APPLI	01-Jul-96	5.00	0.360	1.20
	APPLI	01-Aug-96	4.91	0.280	1.36
	BLIGI	20-Mar-96	5.00	0.260	0.760
	BLIGI	08-Apr-96	5.10	0.410	0.267
	BLIGI	17-Apr-96	4.81	0.310	0.510
	BLIGI	04-May-96	4.75	0.700	12.3
	BLIGI	16-May-96	5.00	0.490	5.04
	BLIGI	01-Jun-96	4.80	0.540	2.92
	BLIGI	30-Jun-96	5.02	0.450	1.22

Appendix 14 (cont'd)

BLIGI	31-Jul-96	5.02	0.320	0.971
CANNC	22-Mar-96	5.07	0.370	1.21
CANNC	08-Apr-96	5.02	0.400	0.521
CANNC	19-Apr-96	4.88	0.670	0.548
CANNC	06-May-96	4.99	0.490	0.993
CANNC	17-May-96	4.94	0.590	3.88
CANNC	06-Jun-96	4.71	0.760	0.862
CANNC	04-Jul-96	4.92	0.540	0.430
CANNC	31-Jul-96	4.92	0.390	0.876
CHENB	24-Apr-96	4.70	0.480	4.33
CHENB	26-Apr-96	4.66	0.710	3.65
CHENB	29-Apr-96	4.37	0.630	26.4
CHENB	30-Apr-96	5.03	0.600	28.5
CHENB	01-May-96	4.91	0.620	29.9
CHENB	03-May-96	4.98	0.510	21.3
CHENB	05-May-96	4.86	0.510	26.6
CHENB	10-May-96	4.48	0.670	36.7
CHENB	20-May-96	4.73	0.690	9.51
CHENI	21-Mar-96	5.30	0.430	0.901
CHENI	07-Apr-96	5.04	0.460	1.21
CHENI	18-Apr-96	4.96	0.630	1.64
CHENI	05-May-96	4.96	0.730	2.30
CHENI	18-May-96	4.88	0.600	2.00
CHENI	03-Jun-96	4.86	0.550	2.03
CHENI	01-Jul-96	5.12	0.490	1.86
CHENI	01-Aug-96	4.93	0.390	0.906
CONS2	22-Mar-96	5.18	0.440	0.482
CONS2	08-Apr-96	5.12	0.360	0.530
CONS2	18-Apr-96	5.08	0.380	1.23
CONS2	04-May-96	4.96	0.440	0.396
CONS2	16-May-96	4.98	0.350	1.41
CONS2	01-Jun-96	4.90	0.470	1.08
CONS2	30-Jun-96	4.96	0.410	0.275
CONS2	31-Jul-96	5.02	0.550	0.177
DECIP	21-Mar-96	5.51	0.600	1.16
DECIP	07-Apr-96	5.27	0.390	0.668
DECIP	18-Apr-96	4.75	0.350	0.460
DECIP	06-May-96	4.89	0.350	3.15
DECIP	19-May-96	4.88	0.390	1.77
DECIP	02-Jun-96	4.97	0.370	1.19
DECIP	01-Jul-96	4.95	0.370	1.66
DECIP	01-Aug-96	5.03	0.360	0.986
DIVIP	21-Mar-96	5.34	0.500	1.17
DIVIP	07-Apr-96	5.22	0.520	1.73
DIVIP	18-Apr-96	4.92	0.660	3.18
DIVIP	05-May-96	5.03	0.520	3.30
DIVIP	19-May-96	5.14	0.410	4.88
DIVIP	02-Jun-96	4.82	0.400	1.93
DIVIP	01-Jul-96	5.00	0.310	1.42
DIVIP	01-Aug-96	4.98	0.290	0.896
EKNII	21-Mar-96	5.22	0.530	0.580
EKNII	07-Apr-96	4.99	0.300	0.421

Appendix 14 (cont'd)

EKNII	18-Apr-96	5.09	0.590	0.469
EKNII	05-May-96	5.05	0.670	2.16
EKNII	16-May-96	5.04	0.660	6.82
EKNII	01-Jun-96	4.92	0.710	6.63
EKNII	30-Jun-96	4.99	0.540	1.19
EKNII	31-Jul-96	5.00	0.420	0.544
FAIR2	21-Mar-96	5.59	0.410	1.43
FAIR2	07-Apr-96	5.03	0.570	1.38
FAIR2	18-Apr-96	4.97	0.820	2.45
FAIR2	06-May-96	4.98	0.800	3.27
FAIR2	16-May-96	4.98	0.780	4.85
FAIR2	01-Jun-96	4.77	0.730	5.78
FAIR2	30-Jun-96	4.84	0.700	0.666
FAIR2	31-Jul-96	4.73	0.430	0.591
FLEMI	25-Mar-96	5.56	0.920	1.04
FLEMI	07-Apr-96	4.92	0.430	2.07
FLEMI	19-Apr-96	4.72	0.600	2.55
FLEMI	05-May-96	4.79	0.710	4.00
FLEMI	19-May-96	4.90	0.730	3.79
FLEMI	03-Jun-96	4.83	0.550	2.82
FLEMI	01-Jul-96	4.98	0.550	0.461
FLEMI	02-Aug-96	4.96	0.430	0.485
FOXF1	01-Feb-96	5.17	0.390	2.43
FOXF1	25-Mar-96	5.49	0.400	1.75
FOXF1	08-Apr-96	4.99	0.340	3.62
FOXF1	19-Apr-96	4.78	0.400	2.98
FOXF1	05-May-96	4.94	0.650	6.19
FOXF1	19-May-96	5.01	0.570	5.08
FOXF1	02-Jun-96	4.86	0.480	21.3
FOXF1	01-Jul-96	5.02	0.510	1.60
FOXF1	02-Aug-96	4.95	0.430	0.821
FOXF2	01-Feb-96	5.40	0.490	3.64
FOXF2	25-Mar-96	5.20	0.400	0.950
FOXF2	08-Apr-96	4.98	0.410	2.49
FOXF2	19-Apr-96	5.04	0.470	2.43
FOXF2	05-May-96	5.12	0.490	5.07
FOXF2	19-May-96	4.93	0.540	11.5
FOXF2	02-Jun-96	4.73	0.580	53.0
FOXF2	01-Jul-96	4.99	0.450	2.02
FOXF2	02-Aug-96	4.93	0.420	1.01
FOXF3	01-Feb-96	5.06	0.480	4.64
FOXF3	25-Mar-96	5.20	0.500	1.18
FOXF3	08-Apr-96	5.24	0.530	1.57
FOXF3	19-Apr-96	4.56	0.470	2.60
FOXF3	05-May-96	4.94	0.620	3.23
FOXF3	19-May-96	4.91	0.750	35.9
FOXF3	02-Jun-96	5.05	0.510	30.3
FOXF3	01-Jul-96	5.02	0.530	1.81
FOXF3	02-Aug-96	4.89	0.450	1.09
GREE3	25-Mar-96	5.30	0.380	0.473
GREE3	08-Apr-96	5.22	0.420	0.294
GREE3	19-Apr-96	5.01	0.490	0.188

Appendix 14 (cont'd)

GREE3	04-May-96	4.88	0.630	0.607
GREE3	16-May-96	5.06	0.590	1.57
GREE3	01-Jun-96	4.89	0.490	2.57
GREE3	30-Jun-96	4.97	0.660	0.355
GREE3	01-Aug-96	5.10	0.450	0.402
HERRP	21-Mar-96	5.06	0.340	2.43
HERRP	07-Apr-96	5.06	0.380	0.829
HERRP	18-Apr-96	5.01	0.480	1.99
HERRP	05-May-96	4.81	0.360	2.88
HERRP	18-May-96	4.98	0.440	2.25
HERRP	03-Jun-96	4.96	0.420	2.77
HERRP	01-Jul-96	5.01	0.440	1.16
HERRP	01-Aug-96	4.92	0.280	0.886
MAINB	21-Mar-96	4.71	0.530	0.645
MAINB	04-Apr-96	4.84	0.660	0.805
MAINB	18-Apr-96	4.79	0.790	1.18
MAINB	06-May-96	4.81	0.550	2.56
MAINB	20-May-96	4.97	0.470	9.47
MAINB	03-Jun-96	4.96	0.410	1.21
MAINB	03-Jul-96	4.84	0.410	1.97
MAINB	01-Aug-96	4.99	0.340	4.12
NAKEI	21-Mar-96	5.59	0.360	0.492
NAKEI	07-Apr-96	5.01	0.370	1.71
NAKEI	18-Apr-96	5.02	0.500	0.371
NAKEI	06-May-96	5.07	0.720	2.73
NAKEI	16-May-96	5.03	0.610	10.3
NAKEI	01-Jun-96	5.04	0.620	3.05
NAKEI	30-Jun-96	4.99	0.500	1.41
NAKEI	31-Jul-96	5.00	0.420	0.487
OLSEN	20-Mar-96	5.08	0.370	0.401
OLSEN	08-Apr-96	5.07	0.550	0.296
OLSEN	17-Apr-96	5.00	0.660	0.200
OLSEN	04-May-96	4.91	0.740	0.584
OLSEN	16-May-96	4.96	0.500	0.947
OLSEN	01-Jun-96	4.93	0.500	0.273
OLSEN	30-Jun-96	4.95	0.530	0.228
OLSEN	01-Aug-96	4.88	0.310	0.383
PELE2	21-Mar-96	5.07	0.390	1.21
PELE2	07-Apr-96	5.02	0.360	1.56
PELE2	18-Apr-96	5.11	0.560	1.92
PELE2	05-May-96	4.94	0.440	44.0
PELE2	16-May-96	5.02	0.510	69.6
PELE2	02-Jun-96	4.95	0.440	26.8
PELE2	30-Jun-96	4.95	0.490	5.52
PELE2	31-Jul-96	4.84	0.340	1.88
PERRI	21-Mar-96	5.93	0.500	0.836
PERRI	07-Apr-96	5.19	0.570	0.457
PERRI	18-Apr-96	4.90	0.650	0.878
PERRI	06-May-96	4.85	0.580	2.36
PERRI	19-May-96	5.01	0.580	1.13
PERRI	02-Jun-96	4.97	0.460	1.08
PERRI	01-Jul-96	5.09	0.470	0.193

Appendix 14 (cont'd)

	PERRI	01-Aug-96	4.95	0.330	0.447
	PPAKE	21-Mar-96	5.40	0.390	3.11
	PPAKE	07-Apr-96	5.16	0.530	4.83
	PPAKE	18-Apr-96	5.05	0.560	0.527
	PPAKE	06-May-96	4.84	0.520	7.45
	PPAKE	19-May-96	4.93	0.640	1.89
	PPAKE	02-Jun-96	4.95	0.560	3.32
	PPAKE	01-Jul-96	4.92	0.420	1.09
	PPAKE	01-Aug-96	4.93	0.380	4.54
	ROCK3	21-Mar-96	5.30	0.450	0.807
	ROCK3	08-Apr-96	4.72	0.390	0.421
	ROCK3	18-Apr-96	4.70	0.440	1.67
	ROCK3	04-May-96	5.02	0.620	1.46
	ROCK3	16-May-96	4.99	0.540	5.80
	ROCK3	01-Jun-96	4.88	0.570	2.99
	ROCK3	30-Jun-96	5.03	0.490	0.678
	ROCK3	31-Jul-96	4.86	0.450	0.181
	SNUGC	20-Mar-96	5.92	0.480	0.597
	SNUGC	08-Apr-96	5.10	0.560	0.442
	SNUGC	17-Apr-96	4.98	0.560	2.38
	SNUGC	04-May-96	4.82	0.600	1.27
	SNUGC	16-May-96	5.09	0.600	3.08
	SNUGC	01-Jun-96	4.87	0.650	1.39
	SNUGC	30-Jun-96	5.00	0.470	0.557
	SNUGC	01-Aug-96	4.98	0.410	0.585
	STORI	21-Mar-96	5.61	0.400	0.998
	STORI	07-Apr-96	5.53	0.440	1.32
	STORI	18-Apr-96	5.08	0.480	1.25
	STORI	06-May-96	5.04	0.620	1.66
	STORI	16-May-96	5.00	0.550	3.21
	STORI	02-Jun-96	4.79	0.580	2.57
	STORI	30-Jun-96	4.96	0.490	1.06
	STORI	31-Jul-96	4.93	0.450	0.617
	WINDB	20-Mar-96	5.11	0.770	0.595
	WINDB	08-Apr-96	4.93	0.360	0.867
	WINDB	17-Apr-96	5.15	0.430	0.383
	WINDB	04-May-96	4.80	0.690	1.17
	WINDB	16-May-96	5.00	0.480	3.57
	WINDB	01-Jun-96	4.98	0.490	3.26
	WINDB	30-Jun-96	5.05	0.540	0.552
	WINDB	31-Jul-96	4.96	0.460	0.430
1997	AFKHA	13-Mar-97	4.84	0.360	0.750
	AFKHA	28-Mar-97	4.79	0.330	0.948
	AFKHA	12-Apr-97	4.85	0.470	1.94
	AFKHA	28-Apr-97	4.81	0.570	0.626
	AFKHA	07-May-97	4.85	0.550	3.49
	AFKHA	23-May-97	4.81	0.460	2.98
	AFKHA	09-Jun-97	4.84	0.320	2.03
	AFKHA	05-Jul-97	4.84	0.380	1.10
	APPLI	12-Feb-97	4.53	0.360	1.52
	APPLI	13-Mar-97	4.83	0.330	1.64
	APPLI	28-Mar-97	4.84	0.400	0.391

Appendix 14 (cont'd)

APPLI	11-Apr-97	4.73	0.600	0.966
APPLI	23-Apr-97	4.90	0.490	1.06
APPLI	08-May-97	4.78	0.560	4.43
APPLI	24-May-97	4.91	0.580	10.2
APPLI	08-Jun-97	4.86	0.520	2.20
APPLI	02-Jul-97	4.81	0.400	3.36
APPLI	04-Aug-97	4.86	0.360	2.36
BLIGI	12-Feb-97	4.89	0.260	0.000
BLIGI	14-Mar-97	4.92	0.310	0.479
BLIGI	28-Mar-97	4.73	0.330	0.753
BLIGI	11-Apr-97	4.89	0.340	0.895
BLIGI	22-Apr-97	4.78	0.440	0.270
BLIGI	07-May-97	4.86	0.410	17.9
BLIGI	23-May-97	4.89	0.380	3.61
BLIGI	07-Jun-97	4.95	0.390	2.75
BLIGI	03-Jul-97	4.90	0.430	6.08
BLIGI	05-Aug-97	4.89	0.460	2.03
CANNC	14-Mar-97	4.51	0.690	0.732
CANNC	28-Mar-97	4.43	0.410	0.808
CANNC	13-Apr-97	4.76	0.520	0.413
CANNC	27-Apr-97	4.46	0.820	0.591
CANNC	11-May-97	4.76	0.970	1.26
CANNC	25-May-97	4.85	0.720	1.19
CANNC	11-Jun-97	4.82	0.630	2.52
CANNC	08-Jul-97	4.85	0.700	3.06
CANNC	03-Aug-97	4.83	0.540	2.33
CHENI	11-Feb-97	4.85	0.420	5.90
CHENI	13-Mar-97	4.84	0.420	1.54
CHENI	29-Mar-97	4.59	0.500	4.06
CHENI	12-Apr-97	4.65	0.710	1.13
CHENI	23-Apr-97	4.78	0.990	1.03
CHENI	08-May-97	4.76	0.700	0.441
CHENI	24-May-97	4.91	0.610	5.34
CHENI	08-Jun-97	4.95	0.610	3.17
CHENI	02-Jul-97	4.95	0.560	2.01
CHENI	04-Aug-97	4.86	0.370	0.481
CONS2	11-Feb-97	4.73	0.380	7.42
CONS2	13-Mar-97	4.88	0.430	2.34
CONS2	29-Mar-97	4.85	0.380	0.828
CONS2	12-Apr-97	4.79	0.430	0.150
CONS2	22-Apr-97	4.69	0.480	0.170
CONS2	08-May-97	4.77	0.470	0.209
CONS2	23-May-97	4.81	0.520	3.27
CONS2	07-Jun-97	4.98	0.480	2.18
CONS2	02-Jul-97	4.75	0.460	0.803
CONS2	03-Aug-97	4.93	0.400	2.06
DECIP	12-Feb-97	4.91	0.420	2.58
DECIP	13-Mar-97	4.88	0.440	1.06
DECIP	28-Mar-97	4.77	0.380	0.816
DECIP	11-Apr-97	4.87	0.520	0.817
DECIP	23-Apr-97	4.80	0.460	1.75
DECIP	08-May-97	4.63	0.830	3.26

Appendix 14 (cont'd)

DECIP	24-May-97	4.75	0.850	4.76
DECIP	08-Jun-97	4.87	0.440	1.47
DECIP	03-Jul-97	4.96	0.430	5.18
DECIP	04-Aug-97	5.03	0.280	0.910
DIVIP	13-Mar-97	4.91	0.400	3.40
DIVIP	28-Mar-97	4.74	0.410	0.531
DIVIP	11-Apr-97	4.68	0.690	0.489
DIVIP	23-Apr-97	4.84	0.490	0.846
DIVIP	08-May-97	5.01	0.580	1.20
DIVIP	24-May-97	4.89	0.440	4.35
DIVIP	08-Jun-97	4.92	0.390	2.05
DIVIP	02-Jul-97	4.83	0.300	2.28
DIVIP	04-Aug-97	4.85	0.380	0.124
EKNII	12-Feb-97	4.95	0.410	0.000
EKNII	13-Mar-97	4.74	0.430	3.33
EKNII	29-Mar-97	4.88	0.370	1.72
EKNII	11-Apr-97	4.83	0.430	0.913
EKNII	23-Apr-97	4.90	0.700	1.53
EKNII	07-May-97	4.67	0.730	6.27
EKNII	23-May-97	4.88	0.560	8.61
EKNII	07-Jun-97	4.88	0.570	3.78
EKNII	02-Jul-97	4.94	0.570	2.90
EKNII	03-Aug-97	4.98	0.350	0.000
ESTHI	12-Feb-97	4.96	0.280	3.60
ESTHI	13-Mar-97	4.86	0.330	0.693
ESTHI	28-Mar-97	4.92	0.380	0.929
ESTHI	10-Apr-97	4.66	0.520	0.635
ESTHI	24-Apr-97	4.92	0.540	0.770
ESTHI	08-May-97	4.94	0.480	18.5
ESTHI	22-May-97	4.97	0.550	9.39
ESTHI	09-Jun-97	5.00	0.350	3.52
ESTHI	03-Jul-97	4.50	0.370	7.01
ESTHI	01-Aug-97	4.95	0.320	1.60
FAIR2	12-Feb-97	4.82	0.510	10.2
FAIR2	14-Mar-97	4.76	0.440	1.65
FAIR2	28-Mar-97	4.68	0.540	1.13
FAIR2	11-Apr-97	4.40	0.600	0.432
FAIR2	22-Apr-97	4.46	0.640	0.778
FAIR2	07-May-97	4.70	0.540	6.46
FAIR2	23-May-97	4.90	0.550	6.87
FAIR2	07-Jun-97	4.96	0.490	3.60
FAIR2	03-Jul-97	4.95	0.530	2.03
FAIR2	05-Aug-97	4.93	0.380	1.60
FLEMI	11-Feb-97	4.82	0.450	5.94
FLEMI	13-Mar-97	4.90	0.500	3.05
FLEMI	29-Mar-97	4.80	0.520	0.671
FLEMI	12-Apr-97	4.42	0.420	1.09
FLEMI	23-Apr-97	4.92	0.840	1.54
FLEMI	08-May-97	4.45	0.370	1.56
FLEMI	24-May-97	4.87	0.700	6.20
FLEMI	08-Jun-97	4.97	0.570	1.68
FLEMI	02-Jul-97	4.80	0.550	1.63

Appendix 14 (cont'd)

FLEMI	04-Aug-97	4.84	0.410	2.30
FOXF1	11-Feb-97	4.94	0.380	5.87
FOXF1	13-Mar-97	4.82	0.360	2.04
FOXF1	29-Mar-97	4.83	0.390	0.734
FOXF1	12-Apr-97	4.87	0.390	0.698
FOXF1	23-Apr-97	4.94	0.660	1.17
FOXF1	08-May-97	4.68	0.590	2.00
FOXF1	23-May-97	4.85	0.620	7.44
FOXF1	08-Jun-97	4.95	0.530	3.57
FOXF1	02-Jul-97	4.74	0.570	3.29
FOXF1	04-Aug-97	4.81	0.510	3.46
FOXF2	11-Feb-97	4.88	0.390	10.9
FOXF2	13-Mar-97	4.86	0.390	2.62
FOXF2	29-Mar-97	4.76	0.420	1.64
FOXF2	12-Apr-97	4.78	0.370	1.30
FOXF2	23-Apr-97	5.00	0.500	1.03
FOXF2	08-May-97	4.50	0.740	1.63
FOXF2	24-May-97	4.86	0.710	2.92
FOXF2	08-Jun-97	4.85	0.660	1.53
FOXF2	02-Jul-97	5.01	0.650	2.88
FOXF2	04-Aug-97	4.87	0.430	2.26
FOXF3	11-Feb-97	4.86	0.450	6.71
FOXF3	13-Mar-97	4.88	0.440	2.91
FOXF3	29-Mar-97	4.87	0.390	1.63
FOXF3	12-Apr-97	4.72	0.420	0.681
FOXF3	23-Apr-97	4.89	0.550	1.46
FOXF3	08-May-97	4.88	0.660	2.41
FOXF3	24-May-97	4.95	0.590	10.6
FOXF3	08-Jun-97	4.91	0.610	3.89
FOXF3	02-Jul-97	5.00	0.570	10.5
FOXF3	04-Aug-97	4.79	0.550	1.92
GREE3	11-Feb-97	4.92	0.530	5.29
GREE3	13-Mar-97	4.86	0.390	2.14
GREE3	29-Mar-97	4.78	0.380	0.717
GREE3	12-Apr-97	4.74	0.430	0.147
GREE3	23-Apr-97	4.20	0.370	0.367
GREE3	08-May-97	4.81	0.650	2.08
GREE3	23-May-97	4.89	0.590	5.63
GREE3	07-Jun-97	5.00	0.460	3.16
GREE3	02-Jul-97	4.74	0.480	2.02
GREE3	03-Aug-97	4.91	0.510	1.54
HANN2	11-Feb-97	4.90	0.460	7.17
HANN2	13-Mar-97	4.78	0.460	3.52
HANN2	29-Mar-97	4.78	0.510	1.79
HANN2	12-Apr-97	4.87	0.510	0.000
HANN2	23-Apr-97	4.92	0.630	0.604
HANN2	08-May-97	4.60	0.760	0.665
HANN2	24-May-97	4.73	0.640	2.92
HANN2	08-Jun-97	4.88	0.670	0.661
HANN2	02-Jul-97	4.99	0.580	2.59
HANN2	04-Aug-97	4.90	0.510	0.676
HERRP	12-Feb-97	6.96	0.330	1.39

Appendix 14 (cont'd)

HERRP	13-Mar-97	4.86	0.280	1.36
HERRP	30-Mar-97	4.84	0.270	0.331
HERRP	11-Apr-97	4.71	0.260	1.09
HERRP	23-Apr-97	4.96	0.440	1.97
HERRP	09-May-97	4.64	0.420	6.44
HERRP	23-May-97	4.95	0.410	5.72
HERRP	07-Jun-97	4.98	0.450	4.39
HERRP	03-Jul-97	4.97	0.410	14.0
HERRP	05-Aug-97	4.79	0.330	1.42
MAINB	12-Mar-97	4.72	0.420	0.389
MAINB	28-Mar-97	4.88	0.560	0.375
MAINB	11-Apr-97	4.90	0.550	0.585
MAINB	25-Apr-97	4.88	1.03	1.56
MAINB	08-May-97	4.82	0.540	2.03
MAINB	22-May-97	4.94	0.520	1.88
MAINB	09-Jun-97	4.94	0.640	1.32
MAINB	05-Jul-97	5.02	0.310	0.000
MAINB	03-Aug-97	4.90	0.260	3.00
NAKEI	12-Feb-97	4.91	0.380	5.96
NAKEI	14-Mar-97	4.81	0.350	1.30
NAKEI	28-Mar-97	4.76	0.340	0.823
NAKEI	11-Apr-97	4.81	0.410	0.620
NAKEI	22-Apr-97	4.38	0.700	0.544
NAKEI	07-May-97	4.97	0.930	2.43
NAKEI	23-May-97	4.86	0.650	6.58
NAKEI	07-Jun-97	4.91	0.480	2.69
NAKEI	02-Jul-97	4.91	0.590	1.58
NAKEI	05-Aug-97	4.82	0.380	1.76
OLSEN	13-Feb-97	5.05	0.360	2.30
OLSEN	14-Mar-97	4.84	0.440	0.895
OLSEN	28-Mar-97	4.88	0.420	0.620
OLSEN	11-Apr-97	4.82	0.480	0.236
OLSEN	22-Apr-97	4.93	0.420	0.205
OLSEN	07-May-97	4.79	0.380	0.000
OLSEN	23-May-97	5.00	0.460	0.208
OLSEN	07-Jun-97	4.81	0.370	2.71
OLSEN	03-Jul-97	4.96	0.520	5.54
OLSEN	05-Aug-97	4.82	0.280	0.433
PELE2	12-Feb-97	4.82	0.330	7.97
PELE2	13-Mar-97	4.88	0.400	2.21
PELE2	28-Mar-97	4.84	0.400	1.66
PELE2	11-Apr-97	4.80	0.410	2.63
PELE2	23-Apr-97	4.86	0.470	0.989
PELE2	07-May-97	4.87	0.470	31.8
PELE2	23-May-97	4.91	0.460	37.8
PELE2	07-Jun-97	4.96	0.470	9.75
PELE2	02-Jul-97	4.92	0.420	4.96
PELE2	03-Aug-97	4.97	0.370	5.62
PERRI	12-Feb-97	4.49	0.400	3.95
PERRI	13-Mar-97	4.89	0.520	1.68
PERRI	28-Mar-97	4.83	0.420	0.817
PERRI	11-Apr-97	4.75	0.660	0.788

Appendix 14 (cont'd)

PERRI	23-Apr-97	4.83	0.890	0.835
PERRI	08-May-97	4.72	0.750	4.92
PERRI	24-May-97	4.91	0.610	2.17
PERRI	08-Jun-97	4.97	0.500	4.10
PERRI	02-Jul-97	4.70	0.500	2.43
PERRI	04-Aug-97	4.86	0.440	1.27
PPAKE	12-Feb-97	4.94	0.470	4.96
PPAKE	13-Mar-97	4.82	0.410	2.49
PPAKE	28-Mar-97	4.66	0.420	1.44
PPAKE	11-Apr-97	4.73	0.490	0.715
PPAKE	23-Apr-97	5.00	0.540	4.91
PPAKE	08-May-97	4.98	0.510	3.49
PPAKE	24-May-97	4.99	0.440	3.80
PPAKE	08-Jun-97	4.85	0.440	2.87
PPAKE	03-Jul-97	4.99	0.430	7.78
PPAKE	04-Aug-97	4.78	0.340	4.71
ROCK3	11-Feb-97	4.91	0.430	7.34
ROCK3	13-Mar-97	4.78	0.390	1.48
ROCK3	29-Mar-97	4.79	0.300	0.520
ROCK3	12-Apr-97	4.87	0.290	0.511
ROCK3	23-Apr-97	4.77	0.380	2.09
ROCK3	07-May-97	4.83	0.590	1.24
ROCK3	23-May-97	4.72	0.670	4.93
ROCK3	07-Jun-97	4.97	0.510	2.10
ROCK3	02-Jul-97	4.93	0.570	1.12
ROCK3	03-Aug-97	4.92	0.620	4.03
SNUGC	13-Feb-97	4.85	0.380	1.28
SNUGC	14-Mar-97	4.95	0.300	0.629
SNUGC	28-Mar-97	4.80	0.340	0.397
SNUGC	11-Apr-97	4.85	0.400	0.347
SNUGC	22-Apr-97	4.85	0.640	0.755
SNUGC	07-May-97	4.82	0.570	0.592
SNUGC	23-May-97	4.97	0.550	2.37
SNUGC	07-Jun-97	4.94	0.520	2.45
SNUGC	03-Jul-97	4.91	0.460	1.63
SNUGC	05-Aug-97	4.75	0.460	3.31
STORI	12-Feb-97	4.83	0.400	1.77
STORI	14-Mar-97	4.84	0.440	1.93
STORI	28-Mar-97	4.76	0.440	1.09
STORI	11-Apr-97	4.03	0.550	0.900
STORI	22-Apr-97	4.64	0.810	1.03
STORI	07-May-97	4.75	0.600	2.33
STORI	23-May-97	5.23	0.780	9.12
STORI	07-Jun-97	4.95	0.490	2.88
STORI	02-Jul-97	4.88	0.500	1.08
STORI	04-Aug-97	4.81	0.410	1.69
WINDB	13-Feb-97	4.82	0.440	14.6
WINDB	14-Mar-97	4.76	0.430	1.26
WINDB	28-Mar-97	4.87	0.370	0.752
WINDB	12-Apr-97	4.72	0.440	0.453
WINDB	22-Apr-97	4.77	0.530	0.255
WINDB	07-May-97	4.80	0.640	0.270

Appendix 14 (cont'd)

	WINDB	23-May-97	4.86	0.600	3.41
	WINDB	08-Jun-97	4.95	0.400	1.57
	WINDB	02-Jul-97	4.97	0.450	1.45
	WINDB	05-Aug-97	4.82	0.340	0.594
1998	AFKHA	02-Mar-98	4.80	0.404	0.753
	AFKHA	01-Apr-98	4.80	0.444	0.720
	AFKHA	14-Apr-98	4.85	0.453	1.24
	AFKHA	28-Apr-98	4.78	0.443	2.48
	AFKHA	12-May-98	4.80	0.444	3.39
	AFKHA	26-May-98	4.69	0.541	13.4
	AFKHA	24-Jun-98	4.87	0.381	1.51
	AFKHA	22-Jul-98	4.88	0.296	0.739
	AFKHA	20-Aug-98	4.60	0.431	1.18
	APPLI	02-Feb-98	4.48	0.341	3.09
	APPLI	02-Mar-98	4.63	0.359	0.941
	APPLI	13-Apr-98	5.00	0.434	4.79
	APPLI	25-Apr-98	4.86	0.513	4.17
	APPLI	10-May-98	4.71	0.542	3.69
	APPLI	29-May-98	4.76	0.526	9.49
	APPLI	26-Jun-98	5.46	0.438	2.13
	APPLI	24-Jul-98	4.74	0.351	0.911
	APPLI	18-Aug-98	4.77	0.375	0.317
	BLIGI	01-Feb-98	4.73	0.272	0.661
	BLIGI	03-Mar-98	4.74	0.280	1.18
	BLIGI	31-Mar-98	4.91	0.415	0.426
	BLIGI	13-Apr-98	4.82	0.172	2.22
	BLIGI	26-Apr-98	4.78	0.673	1.12
	BLIGI	10-May-98	4.85	0.568	1.02
	BLIGI	29-May-98	4.69	0.520	0.822
	BLIGI	26-Jun-98	4.66	0.592	0.257
	BLIGI	26-Jun-98	5.60	0.399	0.270
	BLIGI	26-Jun-98	4.56	0.308	0.477
	BLIGI	21-Jul-98	4.83	0.397	0.273
	BLIGI	19-Aug-98	4.84	0.405	0.653
	CANNC	02-Mar-98	4.84	0.860	0.794
	CANNC	27-Apr-98	4.83	1.19	0.964
	CANNC	28-May-98	4.88	1.05	0.894
	CANNC	25-Jun-98	4.90	1.27	0.363
	CANNC	23-Jul-98	4.88	0.456	0.459
	CANNC	24-Aug-98	4.70	0.572	0.444
	CHENB	04-Mar-98	4.85	0.398	0.690
	CHENB	02-Apr-98	4.78	0.413	0.684
	CHENB	29-Apr-98	4.83	0.529	3.28
	CHENB	27-May-98	4.79	0.490	14.3
	CHENI	02-Feb-98	4.94	0.440	5.18
	CHENI	01-Mar-98	4.57	0.481	0.483
	CHENI	31-Mar-98	4.81	0.589	0.422
	CHENI	13-Apr-98	4.57	0.568	1.86
	CHENI	25-Apr-98	4.73	0.726	1.07
	CHENI	10-May-98	4.83	0.754	4.92
	CHENI	28-May-98	4.82	0.643	31.2
	CHENI	25-Jun-98	5.55	0.616	3.66

Appendix 14 (cont'd)

CHENI	22-Jul-98	4.82	0.364	2.20
CHENI	18-Aug-98	4.88	0.447	0.710
CONS2	02-Feb-98	4.86	0.390	0.000
CONS2	01-Mar-98	4.82	0.382	0.000
CONS2	31-Mar-98	5.06	0.340	0.000
CONS2	13-Apr-98	4.44	0.502	0.404
CONS2	26-Apr-98	4.82	0.454	0.149
CONS2	10-May-98	4.74	0.423	0.314
CONS2	29-May-98	4.52	0.429	0.509
CONS2	26-Jun-98	4.81	0.379	0.000
CONS2	23-Jul-98	4.84	0.415	0.242
CONS2	18-Aug-98	4.96	0.287	0.332
DECIP	02-Feb-98	4.99	0.380	1.43
DECIP	13-Apr-98	4.75	0.492	0.913
DECIP	25-Apr-98	4.74	0.436	1.13
DECIP	10-May-98	4.72	0.531	1.84
DECIP	29-May-98	4.95	0.616	4.67
DECIP	26-Jun-98	5.23	0.545	1.35
DECIP	26-Jun-98	5.79	0.343	1.38
DECIP	26-Jun-98	5.11	0.453	1.40
DECIP	22-Jul-98	4.77	0.358	0.851
DECIP	18-Aug-98	4.95	0.398	0.289
DIVIP	02-Feb-98	4.70	0.314	3.66
DIVIP	02-Mar-98	4.32	0.359	0.164
DIVIP	01-Apr-98	4.54	0.383	0.829
DIVIP	13-Apr-98	4.77	0.699	2.79
DIVIP	25-Apr-98	4.80	0.680	2.29
DIVIP	10-May-98	4.72	0.572	2.23
DIVIP	29-May-98	4.53	0.486	3.69
DIVIP	26-Jun-98	5.24	0.330	0.529
DIVIP	26-Jun-98	4.72	0.378	0.549
DIVIP	26-Jun-98	5.83	0.386	0.691
DIVIP	22-Jul-98	4.74	0.348	0.571
DIVIP	18-Aug-98	4.87	0.266	1.29
EKNII	02-Feb-98	4.45	0.331	1.21
EKNII	01-Mar-98	4.67	0.410	0.000
EKNII	31-Mar-98	4.74	0.430	0.516
EKNII	13-Apr-98	4.60	0.479	0.461
EKNII	26-Apr-98	4.88	0.360	3.16
EKNII	10-May-98	4.75	0.601	5.12
EKNII	29-May-98	4.81	0.526	4.94
EKNII	25-Jun-98	5.20	0.469	1.14
EKNII	24-Jul-98	4.65	0.445	0.469
EKNII	18-Aug-98	4.88	0.416	0.559
ESTHI	02-Feb-98	4.47	0.340	0.945
ESTHI	05-Mar-98	4.86	0.407	0.285
ESTHI	02-Apr-98	4.92	0.391	0.794
ESTHI	13-Apr-98	4.54	0.438	2.49
ESTHI	26-Apr-98	4.47	0.473	0.763
ESTHI	27-Apr-98	4.44	0.422	2.28
ESTHI	29-Apr-98	4.90	0.459	1.91
ESTHI	30-Apr-98	4.97	0.518	2.78

Appendix 14 (cont'd)

ESTHI	01-May-98	4.96	0.498	2.69
ESTHI	02-May-98	5.01	0.505	4.01
ESTHI	04-May-98	5.06	0.569	9.59
ESTHI	05-May-98	4.90	0.497	9.13
ESTHI	06-May-98	4.79	0.445	6.45
ESTHI	07-May-98	4.88	0.414	8.63
ESTHI	08-May-98	4.84	0.409	16.3
ESTHI	10-May-98	4.73	0.562	4.10
ESTHI	11-May-98	4.84	0.403	11.2
ESTHI	14-May-98	4.81	0.489	15.4
ESTHI	28-May-98	4.78	0.475	20.4
ESTHI	25-Jun-98	4.83	0.418	8.59
ESTHI	24-Jul-98	4.79	0.443	1.01
ESTHI	19-Aug-98	4.74	0.445	0.774
FAIR2	01-Feb-98	4.57	0.331	1.23
FAIR2	03-Mar-98	4.67	0.480	0.000
FAIR2	31-Mar-98	4.99	0.475	0.529
FAIR2	13-Apr-98	4.66	0.843	1.81
FAIR2	26-Apr-98	4.89	0.832	3.43
FAIR2	10-May-98	4.86	0.813	3.89
FAIR2	29-May-98	4.84	0.630	4.20
FAIR2	26-Jun-98	4.66	0.456	0.449
FAIR2	26-Jun-98	4.88	0.608	0.582
FAIR2	26-Jun-98	5.10	0.419	0.693
FAIR2	21-Jul-98	4.84	0.568	0.784
FAIR2	19-Aug-98	4.89	0.746	0.433
FLEMI	03-Feb-98	4.62	0.390	4.29
FLEMI	01-Mar-98	4.76	0.401	0.413
FLEMI	31-Mar-98	4.61	0.509	0.670
FLEMI	13-Apr-98	4.84	0.742	0.774
FLEMI	25-Apr-98	4.73	0.770	0.737
FLEMI	10-May-98	4.75	0.679	2.69
FLEMI	28-May-98	4.52	0.686	51.6
FLEMI	25-Jun-98	5.13	0.374	2.05
FLEMI	22-Jul-98	4.84	0.421	0.809
FLEMI	18-Aug-98	4.82	0.411	0.768
FOXF1	03-Feb-98	4.86	0.420	1.89
FOXF1	01-Mar-98	4.85	0.532	1.18
FOXF1	30-Mar-98	4.95	0.480	0.726
FOXF1	13-Apr-98	4.54	0.585	0.736
FOXF1	25-Apr-98	4.70	0.642	1.55
FOXF1	10-May-98	4.75	0.481	23.5
FOXF1	28-May-98	4.69	0.546	24.3
FOXF1	25-Jun-98	5.32	0.493	1.49
FOXF1	22-Jul-98	4.68	0.403	0.792
FOXF1	18-Aug-98	4.89	0.515	1.04
FOXF2	03-Feb-98	4.75	0.480	2.32
FOXF2	01-Mar-98	4.71	0.487	0.143
FOXF2	30-Mar-98	5.01	0.557	1.12
FOXF2	13-Apr-98	4.76	0.504	1.31
FOXF2	25-Apr-98	4.89	0.526	1.07
FOXF2	10-May-98	4.85	0.555	4.96

Appendix 14 (cont'd)

FOXF2	28-May-98	4.62	0.498	11.7
FOXF2	25-Jun-98	4.89	0.431	1.74
FOXF2	22-Jul-98	4.66	0.473	0.671
FOXF2	18-Aug-98	4.86	0.520	0.430
FOXF3	03-Feb-98	4.78	0.520	3.21
FOXF3	01-Mar-98	5.02	0.580	0.886
FOXF3	30-Mar-98	4.91	0.581	0.650
FOXF3	13-Apr-98	5.02	0.623	0.891
FOXF3	25-Apr-98	4.80	0.609	2.10
FOXF3	10-May-98	4.80	0.624	3.60
FOXF3	28-May-98	5.13	0.698	3.10
FOXF3	25-Jun-98	5.30	0.522	1.54
FOXF3	22-Jul-98	4.72	0.608	0.428
FOXF3	18-Aug-98	4.81	0.425	0.745
GREE3	01-Feb-98	4.81	0.344	1.09
GREE3	01-Mar-98	4.64	0.387	0.001
GREE3	30-Mar-98	4.87	0.380	0.127
GREE3	13-Apr-98	4.88	0.405	0.000
GREE3	25-Apr-98	4.82	0.403	0.179
GREE3	10-May-98	4.71	0.463	0.429
GREE3	29-May-98	4.87	0.633	0.875
GREE3	27-Jun-98	4.80	0.360	0.609
GREE3	23-Jul-98	4.87	0.518	0.291
GREE3	18-Aug-98	4.82	0.455	0.251
HANN2	01-Mar-98	4.71	0.328	0.000
HANN2	31-Mar-98	4.54	0.397	0.174
HANN2	13-Apr-98	4.66	0.409	0.407
HANN2	25-Apr-98	4.76	0.622	0.885
HANN2	10-May-98	4.54	0.505	1.23
HANN2	28-May-98	4.81	0.456	0.735
HANN2	25-Jun-98	5.76	0.575	0.405
HANN2	22-Jul-98	4.81	0.362	0.554
HANN2	18-Aug-98	4.84	0.555	0.324
HERRP	02-Feb-98	4.76	0.340	2.90
HERRP	03-Mar-98	5.00	0.320	0.000
HERRP	01-Apr-98	4.63	0.356	0.852
HERRP	13-Apr-98	4.37	0.362	1.84
HERRP	25-Apr-98	4.80	0.786	5.53
HERRP	10-May-98	4.78	0.516	8.31
HERRP	28-May-98	4.76	0.480	17.0
HERRP	25-Jun-98	5.26	0.425	2.73
HERRP	23-Jul-98	4.76	0.312	4.54
HERRP	19-Aug-98	4.87	0.403	0.501
MAINB	03-Mar-98	4.74	0.407	0.392
MAINB	30-Mar-98	4.77	0.645	0.504
MAINB	13-Apr-98	4.79	0.751	0.587
MAINB	27-Apr-98	4.55	0.697	4.40
MAINB	12-May-98	4.84	0.763	2.13
MAINB	27-May-98	4.79	0.753	4.50
MAINB	24-Jun-98	4.64	0.441	2.14
MAINB	23-Jul-98	4.87	0.366	0.865
MAINB	24-Aug-98	4.62	0.488	0.620

Appendix 14 (cont'd)

NAKEI	01-Feb-98	4.65	0.423	1.29
NAKEI	02-Mar-98	4.65	0.373	0.340
NAKEI	01-Apr-98	4.82	0.380	0.392
NAKEI	13-Apr-98	4.60	0.378	0.716
NAKEI	26-Apr-98	4.79	0.492	1.49
NAKEI	10-May-98	4.72	0.486	3.74
NAKEI	29-May-98	4.77	0.434	3.48
NAKEI	25-Jun-98	4.73	0.531	0.219
NAKEI	21-Jul-98	4.78	0.496	0.562
NAKEI	19-Aug-98	4.83	0.493	0.702
OLSEN	03-Feb-98	4.96	0.310	0.000
OLSEN	03-Mar-98	4.59	0.365	0.000
OLSEN	31-Mar-98	4.86	0.474	0.331
OLSEN	13-Apr-98	4.87	0.491	0.528
OLSEN	26-Apr-98	4.87	0.738	0.638
OLSEN	10-May-98	4.73	0.390	0.522
OLSEN	29-May-98	4.86	0.414	0.959
OLSEN	26-Jun-98	5.32	0.528	0.450
OLSEN	21-Jul-98	4.82	0.296	0.483
OLSEN	19-Aug-98	5.02	0.379	0.282
PELE2	01-Feb-98	4.53	0.341	3.33
PELE2	03-Mar-98	4.60	0.280	2.19
PELE2	13-Apr-98	4.68	0.436	2.50
PELE2	26-Apr-98	4.88	0.405	8.85
PELE2	10-May-98	4.92	0.422	13.3
PELE2	29-May-98	4.94	0.396	35.4
PELE2	25-Jun-98	5.00	0.365	1.39
PELE2	24-Jul-98	4.87	0.345	1.10
PELE2	19-Aug-98	4.80	0.339	2.40
PERRI	02-Feb-98	4.53	0.385	0.867
PERRI	02-Mar-98	4.59	0.375	0.000
PERRI	01-Apr-98	4.72	0.606	0.172
PERRI	13-Apr-98	4.86	0.746	1.51
PERRI	25-Apr-98	4.70	0.829	1.57
PERRI	10-May-98	4.82	0.725	2.09
PERRI	29-May-98	4.70	0.646	9.46
PERRI	26-Jun-98	4.81	0.530	1.85
PERRI	23-Jul-98	4.82	0.465	0.414
PERRI	18-Aug-98	4.86	0.497	0.205
PPAKE	02-Feb-98	4.57	0.316	2.65
PPAKE	02-Mar-98	4.56	0.331	0.059
PPAKE	01-Apr-98	4.54	0.363	0.982
PPAKE	13-Apr-98	4.82	0.449	3.82
PPAKE	25-Apr-98	4.79	0.405	3.48
PPAKE	10-May-98	4.84	0.432	3.39
PPAKE	29-May-98	4.89	0.695	32.4
PPAKE	26-Jun-98	4.92	0.844	9.01
PPAKE	26-Jun-98	5.11	0.616	24.3
PPAKE	26-Jun-98	5.10	0.328	60.0
PPAKE	22-Jul-98	4.87	0.711	6.80
PPAKE	18-Aug-98	4.85	0.574	0.540
ROCK3	01-Feb-98	4.53	0.338	0.389

Appendix 14 (cont'd)

	ROCK3	01-Mar-98	4.66	0.338	0.394
	ROCK3	31-Mar-98	4.76	0.360	0.365
	ROCK3	13-Apr-98	4.89	0.626	1.12
	ROCK3	26-Apr-98	4.88	0.590	0.923
	ROCK3	10-May-98	4.80	0.576	1.10
	ROCK3	29-May-98	4.44	0.487	0.903
	ROCK3	26-Jun-98	4.78	0.391	0.269
	ROCK3	23-Jul-98	4.87	0.477	0.237
	ROCK3	18-Aug-98	4.88	0.388	0.467
	SNUGC	01-Feb-98	4.84	0.292	0.000
	SNUGC	03-Mar-98	4.75	0.434	0.000
	SNUGC	31-Mar-98	4.97	0.439	0.279
	SNUGC	13-Apr-98	4.94	0.631	0.476
	SNUGC	26-Apr-98	4.81	0.537	0.687
	SNUGC	10-May-98	4.86	0.619	1.22
	SNUGC	29-May-98	4.84	0.738	0.582
	SNUGC	26-Jun-98	4.05	0.500	0.746
	SNUGC	21-Jul-98	4.78	0.371	0.195
	SNUGC	19-Aug-98	4.89	0.337	0.605
	STORI	01-Feb-98	4.50	0.471	3.33
	STORI	03-Mar-98	4.45	0.460	1.04
	STORI	01-Apr-98	4.96	0.439	0.802
	STORI	13-Apr-98	4.84	0.487	0.860
	STORI	26-Apr-98	4.92	0.584	1.41
	STORI	10-May-98	4.68	0.515	1.49
	STORI	29-May-98	4.60	0.428	1.16
	STORI	25-Jun-98	5.11	0.542	0.203
	STORI	25-Jun-98	4.77	0.542	0.237
	STORI	26-Jun-98	4.70	0.588	0.469
	STORI	21-Jul-98	4.81	0.379	0.355
	STORI	19-Aug-98	4.81	0.529	0.613
	WINDB	02-Feb-98	4.68	0.370	1.16
	WINDB	03-Mar-98	4.58	0.390	0.000
	WINDB	30-Mar-98	4.89	0.437	0.577
	WINDB	13-Apr-98	4.55	0.429	0.000
	WINDB	26-Apr-98	4.79	0.611	0.779
	WINDB	10-May-98	4.79	0.383	5.37
	WINDB	28-May-98	4.62	0.493	3.81
	WINDB	26-Jun-98	5.65	0.580	0.467
	WINDB	21-Jul-98	4.77	0.347	0.426
	WINDB	19-Aug-98	4.76	0.413	0.229
1999	AFKHA	22-Mar-99	5.15	0.567	1.13
	AFKHA	05-Apr-99	4.86	0.629	1.19
	AFKHA	03-May-99	5.22	0.527	6.33
	AFKHA	02-Jun-99	4.83	0.691	22.3
	AFKHA	30-Jun-99	4.92	0.532	2.28
	AFKHA	30-Jul-99	5.00	0.446	2.83
	AFKHA	30-Aug-99	4.95	0.447	2.65
	AFKHA	01-Oct-99	7.13	0.780	0.876
	AFKHA	26-Oct-99	5.01	0.630	0.457
	AFKHA	07-Dec-99	5.83	0.610	0.514
	AFKHA	24-Dec-99	6.26	0.600	1.53

Appendix 14 (cont'd)

APPLI	12-Mar-99	4.61	0.363	0.492
APPLI	06-Apr-99	5.16	0.587	1.13
APPLI	04-May-99	4.79	0.595	2.47
APPLI	03-Jun-99	5.34	0.573	5.28
APPLI	02-Jul-99	5.09	0.395	1.31
BLIGI	08-Mar-99	5.10	0.332	0.350
BLIGI	07-Apr-99	5.17	0.323	0.241
BLIGI	05-May-99	5.18	0.515	0.620
BLIGI	02-Jun-99	5.14	0.474	1.94
BLIGI	02-Jul-99	5.19	0.369	0.335
BLIGI	31-Aug-99	5.36	0.338	0.421
CANNC	05-Apr-99	3.40	1.05	0.357
CANNC	03-May-99	4.99	0.911	1.27
CANNC	01-Jul-99	4.96	0.826	0.695
CANNC	01-Aug-99	4.91	0.422	0.620
CANNC	30-Aug-99	4.85	0.434	0.449
CHENI	12-Mar-99	5.27	0.499	0.518
CHENI	06-Apr-99	5.05	0.576	0.883
CHENI	04-May-99	5.48	0.758	2.81
CHENI	03-Jun-99	5.05	0.595	3.48
CHENI	01-Jul-99	5.21	0.436	0.414
CHENI	26-Jul-99	5.19	0.463	0.774
CHENI	31-Aug-99	4.73	0.258	0.000
CONS2	12-Mar-99	4.96	0.312	0.000
CONS2	06-Apr-99	6.42	0.369	0.081
CONS2	04-May-99	5.04	0.385	0.282
CONS2	02-Jun-99	5.13	0.344	0.324
CONS2	02-Jul-99	5.31	0.452	0.166
CONS2	26-Jul-99	5.06	0.341	0.283
CONS2	31-Aug-99	5.22	0.386	0.237
DECIP	12-Mar-99	4.92	0.348	0.260
DECIP	06-Apr-99	5.00	0.407	1.27
DECIP	04-May-99	5.18	0.531	6.52
DECIP	03-Jun-99	5.21	0.541	2.81
DECIP	02-Jul-99	5.21	0.405	0.264
DECIP	01-Sep-99	4.86	0.296	0.418
DIVIP	12-Mar-99	5.09	0.304	0.696
DIVIP	06-Apr-99	5.55	0.738	1.36
DIVIP	04-May-99	5.15	0.572	3.42
DIVIP	03-Jun-99	5.14	0.499	3.19
DIVIP	01-Jul-99	5.31	0.551	0.430
DIVIP	01-Sep-99	5.13	0.311	0.496
EKNII	06-Apr-99	5.47	0.463	0.080
EKNII	04-May-99	5.18	0.450	3.44
EKNII	03-Jun-99	5.16	0.422	3.81
EKNII	02-Jul-99	5.35	0.614	0.308
EKNII	26-Jul-99	4.96	0.326	0.262
ESTHI	05-Apr-99	4.94	0.686	0.370
ESTHI	06-May-99	5.18	0.947	4.02
ESTHI	03-Jun-99	4.88	0.685	2.88
ESTHI	06-Jul-99	4.91	0.466	1.07
FAIR2	08-Mar-99	5.01	0.498	0.388

Appendix 14 (cont'd)

FAIR2	06-Apr-99	5.22	0.687	0.491
FAIR2	04-May-99	5.19	0.833	1.47
FAIR2	02-Jun-99	4.98	0.791	3.10
FAIR2	02-Jul-99	5.07	0.424	0.218
FAIR2	31-Aug-99	5.01	0.358	0.564
FLEMI	12-Mar-99	4.92	0.330	1.06
FLEMI	06-Apr-99	5.84	0.805	0.906
FLEMI	04-May-99	5.15	0.764	2.49
FLEMI	03-Jun-99	5.38	0.741	3.13
FLEMI	02-Jul-99	5.30	0.456	0.357
FLEMI	26-Jul-99	4.93	0.409	0.318
FLEMI	31-Aug-99	4.94	0.551	0.529
FOXF1	12-Mar-99	5.08	0.525	0.564
FOXF1	06-Apr-99	5.64	0.621	0.650
FOXF1	04-May-99	5.37	0.558	4.12
FOXF1	03-Jun-99	5.08	0.467	171
FOXF1	02-Jul-99	5.06	0.611	5.07
FOXF1	26-Jul-99	5.27	0.493	2.88
FOXF1	31-Aug-99	5.01	0.738	0.546
FOXF2	12-Mar-99	4.97	0.477	0.242
FOXF2	06-Apr-99	5.24	0.512	0.975
FOXF2	04-May-99	5.06	0.489	7.04
FOXF2	03-Jun-99	5.53	0.602	84.4
FOXF2	02-Jul-99	5.05	0.523	9.29
FOXF2	26-Jul-99	4.87	0.507	1.68
FOXF2	31-Aug-99	5.03	0.724	1.00
FOXF3	12-Mar-99	5.01	0.365	0.446
FOXF3	06-Apr-99	6.24	0.595	0.461
FOXF3	04-May-99	5.16	0.645	2.36
FOXF3	03-Jun-99	5.70	0.715	30.3
FOXF3	02-Jul-99	5.27	0.537	1.89
FOXF3	26-Jul-99	5.06	0.569	4.70
FOXF3	31-Aug-99	4.98	0.715	0.599
GREE3	12-Mar-99	4.86	0.339	0.250
GREE3	06-Apr-99	5.98	0.563	0.140
GREE3	04-May-99	4.93	0.626	1.66
GREE3	02-Jun-99	5.34	0.763	2.59
GREE3	02-Jul-99	5.18	0.537	0.193
GREE3	26-Jul-99	5.10	0.510	0.152
GREE3	31-Aug-99	4.88	0.411	0.218
HERRP	13-Mar-99	4.73	0.261	0.271
HERRP	06-Apr-99	5.14	0.379	0.573
HERRP	04-May-99	5.00	0.502	3.65
HERRP	03-Jun-99	5.19	0.541	6.29
HERRP	28-Jun-99	5.02	0.369	1.49
HERRP	26-Jul-99	5.23	0.334	0.092
HERRP	31-Aug-99	4.96	0.407	0.242
MAINB	06-Apr-99	4.96	0.726	0.662
MAINB	02-May-99	4.92	1.02	3.24
MAINB	08-Jun-99	4.94	0.788	2.78
MAINB	04-Jul-99	4.89	0.433	0.399
MAINB	31-Jul-99	4.96	0.348	0.377

Appendix 14 (cont'd)

MAINB	30-Aug-99	4.90	0.357	0.248
NAKEI	08-Mar-99	5.21	0.590	0.421
NAKEI	06-Apr-99	5.69	0.502	0.418
NAKEI	04-May-99	5.22	0.630	4.13
NAKEI	02-Jun-99	5.14	0.596	2.11
NAKEI	02-Jul-99	5.37	0.557	0.711
NAKEI	26-Jul-99	5.39	0.499	0.192
NAKEI	31-Aug-99	5.00	0.606	0.434
OLSEN	08-Mar-99	5.05	0.334	0.328
OLSEN	07-Apr-99	5.07	0.299	0.060
OLSEN	05-May-99	5.13	0.376	0.111
OLSEN	03-Jun-99	5.25	0.384	0.385
OLSEN	24-Jun-99	5.08	0.591	0.302
OLSEN	01-Sep-99	4.93	0.568	0.201
PELE2	13-Mar-99	4.88	0.362	0.481
PELE2	06-Apr-99	5.05	0.377	0.394
PELE2	04-May-99	5.09	0.537	6.81
PELE2	02-Jun-99	5.14	0.494	41.2
PELE2	02-Jul-99	4.89	0.421	4.18
PELE2	26-Jul-99	4.53	0.350	0.657
PELE2	31-Aug-99	4.87	0.381	0.332
PERRI	13-Mar-99	4.92	0.402	0.251
PERRI	06-Apr-99	5.47	0.637	0.376
PERRI	04-May-99	5.10	0.860	6.22
PERRI	03-Jun-99	5.06	0.745	10.5
PERRI	02-Jul-99	5.13	0.446	0.444
PPAKE	12-Mar-99	4.92	0.395	5.00
PPAKE	06-Apr-99	5.14	0.724	3.86
PPAKE	04-May-99	5.34	0.623	14.2
PPAKE	03-Jun-99	5.18	0.576	2.07
PPAKE	02-Jul-99	4.96	0.437	0.496
PPAKE	01-Sep-99	4.95	0.528	9.02
ROCK3	08-Mar-99	4.89	0.434	0.193
ROCK3	06-Apr-99	5.65	0.415	0.170
ROCK3	04-May-99	5.67	0.666	0.563
ROCK3	02-Jun-99	5.14	0.432	1.93
ROCK3	02-Jul-99	5.31	0.464	0.464
ROCK3	26-Jul-99	4.74	0.382	0.203
ROCK3	31-Aug-99	4.86	0.298	0.382
SNUGC	08-Mar-99	4.23	0.357	0.000
SNUGC	07-Apr-99	5.07	0.485	0.209
SNUGC	05-May-99	5.12	0.770	0.284
SNUGC	02-Jun-99	5.22	0.721	0.487
SNUGC	02-Jul-99	5.45	0.545	0.169
SNUGC	31-Aug-99	4.98	0.448	0.256
STORI	12-Mar-99	4.86	0.434	0.959
STORI	06-Apr-99	4.59	0.520	0.646
STORI	04-May-99	5.38	0.820	0.895
STORI	02-Jun-99	5.09	0.607	2.28
STORI	02-Jul-99	5.15	0.427	0.442
STORI	26-Jul-99	5.05	0.425	0.230
STORI	31-Aug-99	5.00	0.429	0.368

Appendix 14 (cont'd)

	WINDB	12-Mar-99	4.97	0.440	0.430
	WINDB	07-Apr-99	5.13	0.464	1.72
	WINDB	05-May-99	5.18	0.746	2.48
	WINDB	03-Jun-99	5.21	0.705	7.29
	WINDB	02-Jul-99	5.26	0.542	1.96
	WINDB	26-Jul-99	5.20	0.416	0.370
	WINDB	01-Sep-99	4.90	0.411	0.207
2000	AFKHA	26-Jan-00	7.00	0.700	1.97
	AFKHA	07-Mar-00	5.31	0.691	1.11
	AFKHA	03-Apr-00	5.35	0.610	0.737
	AFKHA	18-Apr-00	5.49	0.957	1.39
	AFKHA	04-May-00	5.43	0.739	1.75
	AFKHA	30-May-00	5.60	0.760	1.28
	AFKHA	02-Jun-00	5.36	0.545	0.802
	AFKHA	16-Jun-00	5.19	0.554	5.04
	AFKHA	03-Jul-00	7.57	0.920	0.537
	APPLI	03-Apr-00	5.03	0.561	1.98
	APPLI	02-May-00	5.71	0.825	5.56
	APPLI	16-May-00	5.40	0.524	1.86
	APPLI	31-May-00	5.80	0.428	0.257
	APPLI	14-Jun-00	5.75	0.448	0.184
	APPLI	05-Jul-00	5.60	0.449	0.228
	BLIGI	02-Apr-00	4.91	0.268	0.369
	BLIGI	16-Apr-00	6.02	0.478	0.387
	BLIGI	02-May-00	5.99	0.387	1.30
	BLIGI	17-May-00	4.90	0.464	0.861
	BLIGI	01-Jun-00	5.94	0.624	0.245
	BLIGI	14-Jun-00	5.09	0.378	0.204
	BLIGI	05-Jul-00	4.99	0.556	0.204
	CANNC	06-Apr-00	7.60	0.550	0.484
	CANNC	20-Apr-00	6.10	0.720	0.945
	CANNC	05-May-00	4.40	0.740	7.96
	CANNC	18-May-00	4.24	0.560	8.54
	CANNC	01-Jun-00	5.82	0.580	2.73
	CANNC	16-Jun-00	6.58	0.610	1.73
	CANNC	30-Jun-00	5.71	0.610	0.673
	CHENI	03-Apr-00	5.17	0.569	0.839
	CHENI	16-Apr-00	5.09	0.664	1.50
	CHENI	02-May-00	7.61	0.888	2.17
	CHENI	16-May-00	5.10	0.610	1.40
	CHENI	31-May-00	6.57	0.520	0.225
	CHENI	15-Jun-00	5.47	0.529	0.387
	CHENI	04-Jul-00	5.71	0.583	0.199
	CONS2	02-Apr-00	5.02	0.282	0.000
	CONS2	16-Apr-00	6.94	0.505	0.303
	CONS2	02-May-00	8.21	0.667	0.000
	CONS2	16-May-00	5.32	0.513	0.000
	CONS2	31-May-00	7.20	0.593	0.000
	CONS2	15-Jun-00	5.87	0.689	0.000
	CONS2	04-Jul-00	5.91	0.585	0.372
	DECIP	03-Apr-00	5.32	0.441	0.410
	DECIP	17-Apr-00	6.62	0.743	0.516

Appendix 14 (cont'd)

DECIP	02-May-00	5.46	0.950	3.21
DECIP	16-May-00	5.76	0.829	3.42
DECIP	31-May-00	7.15	0.594	0.548
DECIP	14-Jun-00	7.63	0.654	0.482
DECIP	05-Jul-00	5.42	0.455	0.384
DIVIP	03-Apr-00	5.19	0.585	1.11
DIVIP	02-May-00	6.24	0.702	3.90
DIVIP	16-May-00	5.26	0.892	2.02
DIVIP	31-May-00	6.06	0.466	0.297
DIVIP	14-Jun-00	5.67	0.394	0.000
DIVIP	05-Jul-00	5.56	0.400	0.205
EKNII	03-Apr-00	5.03	0.647	0.578
EKNII	16-Apr-00	5.00	0.475	1.13
EKNII	02-May-00	7.01	0.608	2.20
EKNII	16-May-00	5.33	0.466	5.58
EKNII	31-May-00	5.53	0.565	1.75
EKNII	15-Jun-00	4.82	0.396	0.408
EKNII	04-Jul-00	4.62	0.370	0.187
ESTHI	16-Feb-00	3.61	0.460	2.98
ESTHI	07-Mar-00	3.13	0.350	0.765
ESTHI	06-Apr-00	2.86	0.450	1.51
ESTHI	18-Apr-00	3.32	0.550	3.45
ESTHI	03-May-00	4.20	0.810	9.33
ESTHI	18-May-00	4.04	0.690	5.43
ESTHI	25-May-00	3.43	0.630	4.25
ESTHI	02-Jun-00	5.30	0.530	1.75
ESTHI	25-Jun-00	4.13	0.440	0.862
FAIR2	03-Apr-00	5.36	0.517	0.750
FAIR2	16-Apr-00	5.66	0.696	1.16
FAIR2	02-May-00	5.40	0.835	28.3
FAIR2	17-May-00	5.79	0.644	3.34
FAIR2	01-Jun-00	5.37	0.600	0.498
FAIR2	14-Jun-00	5.69	0.484	0.518
FAIR2	05-Jul-00	4.95	0.463	0.391
FLEMI	03-Apr-00	5.35	0.649	0.577
FLEMI	16-Apr-00	5.11	0.765	1.61
FLEMI	02-May-00	6.68	1.17	2.20
FLEMI	16-May-00	5.18	0.681	8.25
FLEMI	31-May-00	5.71	0.661	1.16
FLEMI	15-Jun-00	5.30	0.619	0.464
FLEMI	04-Jul-00	5.39	0.527	0.256
FOXF1	03-Apr-00	5.22	0.446	1.12
FOXF1	16-Apr-00	5.09	0.649	1.44
FOXF1	02-May-00	6.41	0.884	24.0
FOXF1	16-May-00	5.46	0.684	34.0
FOXF1	31-May-00	4.73	0.618	6.93
FOXF1	15-Jun-00	5.78	0.710	0.645
FOXF1	04-Jul-00	5.01	0.728	0.660
FOXF2	03-Apr-00	5.37	0.419	0.712
FOXF2	16-Apr-00	5.08	0.549	1.21
FOXF2	02-May-00	6.76	0.972	0.842
FOXF2	16-May-00	5.09	0.581	18.4

Appendix 14 (cont'd)

FOXF2	31-May-00	5.09	0.680	1.81
FOXF2	15-Jun-00	5.28	0.531	1.19
FOXF2	04-Jul-00	5.54	0.621	0.519
FOXF3	03-Apr-00	5.02	0.696	0.763
FOXF3	16-Apr-00	5.08	0.773	1.43
FOXF3	02-May-00	6.12	1.24	2.48
FOXF3	16-May-00	5.36	0.512	7.42
FOXF3	31-May-00	5.17	0.619	3.73
FOXF3	15-Jun-00	5.82	0.600	1.72
FOXF3	04-Jul-00	5.45	0.624	0.161
GREE3	02-Apr-00	5.67	0.475	0.000
GREE3	16-Apr-00	5.11	0.688	0.197
GREE3	02-May-00	8.29	0.757	0.291
GREE3	16-May-00	4.90	0.565	1.43
GREE3	31-May-00	7.30	0.843	0.176
GREE3	15-Jun-00	5.68	0.676	0.414
GREE3	04-Jul-00	5.88	0.543	0.154
HERRP	03-Apr-00	5.36	0.481	0.907
HERRP	16-Apr-00	4.99	0.778	2.71
HERRP	02-May-00	7.43	1.08	2.40
HERRP	16-May-00	5.43	0.689	9.94
HERRP	31-May-00	7.32	0.670	1.58
HERRP	15-Jun-00	5.30	0.578	0.585
HERRP	04-Jul-00	5.35	0.472	0.321
MAINB	05-Apr-00	7.32	0.920	0.299
MAINB	18-Apr-00	8.76	1.23	0.425
MAINB	06-May-00	7.62	1.12	1.09
MAINB	18-May-00	8.60	1.05	0.709
MAINB	04-Jun-00	7.87	0.690	0.407
MAINB	16-Jun-00	7.40	0.570	0.289
NAKEI	03-Apr-00	5.29	0.375	1.11
NAKEI	16-Apr-00	5.49	0.758	1.02
NAKEI	02-May-00	7.70	0.826	2.04
NAKEI	17-May-00	4.97	0.484	3.35
NAKEI	31-May-00	5.48	0.536	1.29
NAKEI	14-Jun-00	5.56	0.492	0.290
NAKEI	04-Jul-00	5.64	0.533	0.178
OLSEN	02-Apr-00	5.28	0.479	0.210
OLSEN	16-Apr-00	6.36	0.615	0.179
OLSEN	02-May-00	5.83	0.447	0.397
OLSEN	17-May-00	6.49	0.614	0.227
OLSEN	01-Jun-00	6.31	0.557	0.077
OLSEN	14-Jun-00	5.81	0.423	0.000
OLSEN	05-Jul-00	5.57	0.436	0.239
PELE2	03-Apr-00	6.19	0.239	1.03
PELE2	16-Apr-00	5.18	0.428	2.05
PELE2	02-May-00	6.67	0.792	10.7
PELE2	16-May-00	5.31	0.527	3.68
PELE2	31-May-00	7.81	0.470	1.08
PELE2	14-Jun-00	5.40	0.442	1.22
PELE2	04-Jul-00	5.13	0.422	0.925
PERRI	03-Apr-00	5.12	0.561	0.356

Appendix 14 (cont'd)

	PERRI	17-Apr-00	6.07	0.788	0.426
	PERRI	02-May-00	7.05	1.04	1.51
	PERRI	16-May-00	5.26	0.772	2.96
	PERRI	31-May-00	5.53	0.647	1.83
	PERRI	14-Jun-00	6.36	0.564	0.138
	PERRI	05-Jul-00	5.08	0.451	0.154
	PPAKE	03-Apr-00	5.33	0.378	1.06
	PPAKE	17-Apr-00	5.12	0.532	0.883
	PPAKE (Low)	03-May-00	5.20	1.07	0.748
	PPAKE (2nd)	03-May-00	5.71	0.650	1.45
	PPAKE (Mid)	03-May-00	5.23	0.813	2.04
	PPAKE (4th)	03-May-00	5.56	0.780	2.77
	PPAKE (High)	03-May-00	5.96	0.671	2.79
	PPAKE	16-May-00	5.15	0.913	3.57
	PPAKE	01-Jun-00	5.40	0.524	0.512
	PPAKE	14-Jun-00	5.62	0.455	0.272
	PPAKE	05-Jul-00	5.35	0.548	1.41
	ROCK3	03-Apr-00	5.06	0.376	0.433
	ROCK3	16-Apr-00	5.41	0.587	1.21
	ROCK3	02-May-00	7.32	0.594	0.462
	ROCK3	16-May-00	5.17	0.488	0.845
	ROCK3	31-May-00	7.00	0.782	0.193
	ROCK3	15-Jun-00	5.19	0.501	0.214
	ROCK3	04-Jul-00	6.18	0.505	0.291
	SNUGC	02-Apr-00	5.09	0.516	0.213
	SNUGC	16-Apr-00	5.98	0.674	2.01
	SNUGC	02-May-00	6.54	0.866	0.589
	SNUGC	17-May-00	6.49	0.986	0.291
	SNUGC	01-Jun-00	5.80	0.796	0.229
	SNUGC	14-Jun-00	5.59	0.618	0.298
	SNUGC	05-Jul-00	5.47	0.610	0.256
	STORI	02-Apr-00	4.98	0.598	0.875
	STORI	16-Apr-00	5.13	0.706	1.20
	STORI	03-May-00	5.66	1.01	1.45
	STORI	17-May-00	5.09	0.599	1.77
	STORI	31-May-00	5.37	0.574	0.823
	STORI	14-Jun-00	5.36	0.520	0.705
	STORI	04-Jul-00	5.35	0.551	0.290
	WINDB	02-Apr-00	5.71	0.385	1.08
	WINDB	16-Apr-00	7.20	0.679	0.368
	WINDB	02-May-00	6.10	0.526	1.28
	WINDB	17-May-00	5.68	0.683	0.066
	WINDB	01-Jun-00	6.26	0.510	0.092
	WINDB	14-Jun-00	5.44	0.417	0.000
	WINDB	05-Jul-00	5.54	0.434	0.366
2001	AFKHA	10-Apr-01	5.04	0.560	0.717
	AFKHA	20-Apr-01	4.69	0.610	0.541
	AFKHA	09-May-01	5.06	0.830	1.128
	AFKHA	21-May-01	4.99	0.460	0.782
	AFKHA	07-Jun-01	5.02	0.510	0.857
	AFKHA	21-Jun-01	5.16	0.600	0.399
	APPLI	20-Apr-01	7.44	1.11	2.053

Appendix 14 (cont'd)

APPLI	07-May-01	5.28	0.920	4.174
APPLI	22-May-01	5.18	0.970	2.692
APPLI	05-Jun-01	5.31	1.09	1.581
APPLI	20-Jun-01	4.98	0.440	0.877
APPLI	07-Jul-01	5.19	0.632	0.454
BLIGI	07-Apr-01	6.09	0.820	0.194
BLIGI	21-Apr-01	5.58	0.710	0.786
BLIGI	06-May-01	5.15	0.650	0.750
BLIGI	22-May-01	5.29	0.480	0.707
BLIGI	05-Jun-01	5.09	0.760	1.042
BLIGI	21-Jun-01	5.03	0.760	0.138
BLIGI	07-Jul-01	5.02	0.266	0.000
CANNC	09-Apr-01	5.07	0.719	0.518
CANNC	23-Apr-01	5.05	0.701	0.385
CANNC	08-May-01	4.93	0.601	0.371
CANNC	22-May-01	5.04	0.680	0.299
CANNC	05-Jun-01	4.80	1.28	0.970
CANNC	21-Jun-01	4.93	0.616	0.644
CANNC	05-Jul-01	5.09	0.971	0.265
CHENI	08-Apr-01	5.29	0.940	0.754
CHENI	20-Apr-01	5.15	0.950	1.471
CHENI	07-May-01	3.89	0.820	3.182
CHENI	22-May-01	5.04	0.980	1.036
CHENI	05-Jun-01	5.38	0.830	0.865
CHENI	20-Jun-01	5.22	0.740	0.374
CHENI	07-Jul-01	5.03	0.417	0.000
CONS2	07-Apr-01	5.83	0.590	0.000
CONS2	20-Apr-01	6.38	0.870	0.000
CONS2	07-May-01	5.01	0.800	0.000
CONS2	22-May-01	5.27	0.800	0.000
CONS2	05-Jun-01	5.15	0.820	0.140
CONS2	20-Jun-01	4.92	0.550	0.000
CONS2	07-Jul-01	5.16	0.356	0.000
DECIP	08-Apr-01	5.39	0.860	0.456
DECIP	20-Apr-01	5.54	0.830	0.367
DECIP	06-May-01	5.04	1.01	1.754
DECIP	22-May-01	5.06	1.01	1.243
DECIP	05-Jun-01	5.33	0.590	1.335
DECIP	20-Jun-01	4.87	0.440	0.503
DECIP	07-Jul-01	5.15	0.452	0.276
DIVIP	08-Apr-01	6.11	1.46	0.820
DIVIP	20-Apr-01	6.12	1.20	2.194
DIVIP	07-May-01	4.92	1.03	2.441
DIVIP	22-May-01	5.33	1.05	1.150
DIVIP	05-Jun-01	5.07	0.520	0.350
DIVIP	20-Jun-01	5.13	0.370	0.321
DIVIP	07-Jul-01	5.03	0.592	0.252
EKNII	07-Apr-01	5.92	0.720	0.174
EKNII	20-Apr-01	5.11	0.770	2.033
EKNII	07-May-01	5.13	1.19	3.874
EKNII	22-May-01	5.14	1.00	2.493
EKNII	05-Jun-01	5.10	1.08	1.688

Appendix 14 (cont'd)

EKNII	19-Jun-01	4.93	0.350	0.317
EKNII	07-Jul-01	4.86	0.714	0.360
ESTHI	15-Mar-01	5.02	0.360	0.441
ESTHI	09-Apr-01	4.97	0.680	1.358
ESTHI	23-Apr-01	4.87	0.520	1.174
ESTHI	10-May-01	5.04	0.810	4.174
ESTHI	24-May-01	4.98	0.560	2.647
ESTHI	07-Jun-01	5.04	0.490	1.174
ESTHI	21-Jun-01	5.05	0.350	1.046
FAIR2	07-Apr-01	6.95	1.14	0.273
FAIR2	21-Apr-01	5.44	0.850	0.559
FAIR2	06-May-01	5.00	0.840	1.032
FAIR2	22-May-01	5.18	0.900	0.882
FAIR2	05-Jun-01	5.18	0.870	0.496
FAIR2	20-Jun-01	5.15	0.520	0.242
FAIR2	07-Jul-01	5.03	0.306	0.000
FLEMI	08-Apr-01	5.24	0.960	0.406
FLEMI	20-Apr-01	5.26	0.920	1.013
FLEMI	07-May-01	5.50	1.15	1.033
FLEMI	22-May-01	5.74	0.960	0.619
FLEMI	05-Jun-01	5.51	0.620	1.009
FLEMI	20-Jun-01	4.94	0.850	0.368
FLEMI	07-Jul-01	5.02	0.371	0.000
FOXF1	08-Apr-01	5.33	0.760	0.479
FOXF1	20-Apr-01	5.22	0.940	0.520
FOXF1	07-May-01	4.97	0.840	0.393
FOXF1	22-May-01	4.82	0.810	0.481
FOXF1	05-Jun-01	5.39	1.13	0.609
FOXF1	20-Jun-01	4.88	0.800	1.456
FOXF1	07-Jul-01	5.28	0.660	0.287
FOXF2	08-Apr-01	4.33	0.730	0.470
FOXF2	20-Apr-01	5.53	0.810	0.356
FOXF2	07-May-01	4.95	0.990	0.677
FOXF2	22-May-01	4.87	0.820	0.816
FOXF2	05-Jun-01	5.81	0.890	0.566
FOXF2	20-Jun-01	4.89	0.850	0.713
FOXF2	07-Jul-01	5.21	0.655	0.702
FOXF3	08-Apr-01	4.81	0.840	0.745
FOXF3	20-Apr-01	5.11	0.900	0.394
FOXF3	07-May-01	5.09	0.920	0.726
FOXF3	22-May-01	5.02	0.930	0.506
FOXF3	05-Jun-01	5.09	1.15	0.288
FOXF3	20-Jun-01	4.94	0.660	0.279
FOXF3	07-Jul-01	5.00	0.740	0.429
GREE3	07-Apr-01	4.64	0.520	0.000
GREE3	20-Apr-01	5.84	0.890	0.422
GREE3	07-May-01	4.95	0.840	1.132
GREE3	22-May-01	5.37	0.840	0.204
GREE3	05-Jun-01	5.05	0.820	0.139
GREE3	20-Jun-01	4.92	0.560	0.128
GREE3	07-Jul-01	4.98	0.502	0.000
HERRP	07-Apr-01	5.70	0.830	0.725

Appendix 14 (cont'd)

HERRP	20-Apr-01	4.97	0.970	2.115
HERRP	07-May-01	4.05	0.570	5.866
HERRP	22-May-01	4.79	0.810	2.725
HERRP	05-Jun-01	5.41	0.720	1.850
HERRP	20-Jun-01	5.21	0.890	0.969
HERRP	07-Jul-01	4.93	0.577	0.439
MAINB	06-Apr-01	4.57	0.800	0.630
MAINB	20-Apr-01	4.90	0.925	1.202
MAINB	11-May-01	4.83	0.802	1.707
MAINB	25-May-01	5.12	0.624	1.588
MAINB	07-Jun-01	4.99	0.584	0.521
MAINB	22-Jun-01	5.80	0.469	0.202
MAINB	05-Jul-01	5.09	0.463	0.344
NAKEI	07-Apr-01	8.55	1.13	0.090
NAKEI	20-Apr-01	5.12	0.620	1.262
NAKEI	07-May-01	5.08	0.890	1.664
NAKEI	22-May-01	5.14	0.940	0.647
NAKEI	05-Jun-01	5.18	0.730	0.331
NAKEI	20-Jun-01	5.12	0.360	0.313
NAKEI	07-Jul-01	5.28	0.560	0.147
OLSEN	07-Apr-01	6.13	1.31	0.117
OLSEN	21-Apr-01	5.87	0.770	0.282
OLSEN	06-May-01	4.68	0.940	0.767
OLSEN	22-May-01	4.66	0.700	0.370
OLSEN	05-Jun-01	5.30	1.31	0.123
OLSEN	21-Jun-01	5.23	0.540	0.000
OLSEN	07-Jul-01	4.69	0.337	0.000
PELE2	07-Apr-01	5.41	0.620	0.724
PELE2	20-Apr-01	5.12	0.620	4.960
PELE2	07-May-01	5.03	0.810	26.972
PELE2	22-May-01	5.02	0.920	7.972
PELE2	05-Jun-01	6.12	1.03	3.006
PELE2	19-Jun-01	5.01	0.650	2.731
PELE2	07-Jul-01	5.00	0.525	2.497
PERRI	08-Apr-01	4.98	0.860	0.847
PERRI	20-Apr-01	5.49	1.03	1.138
PERRI	07-May-01	5.01	0.950	3.717
PERRI	22-May-01	5.23	1.07	2.622
PERRI	05-Jun-01	5.17	0.900	2.096
PERRI	20-Jun-01	5.24	0.470	0.394
PERRI	07-Jul-01	5.00	0.510	0.000
PPAKE	08-Apr-01	5.23	0.770	0.271
PPAKE	20-Apr-01	5.82	0.730	0.423
PPAKE	06-May-01	5.08	1.59	0.469
PPAKE	22-May-01	5.43	1.23	1.246
PPAKE	05-Jun-01	5.44	1.01	1.238
PPAKE	20-Jun-01	4.96	0.530	0.475
PPAKE	07-Jul-01	5.45	0.578	0.378
ROCK3	07-Apr-01	6.07	0.750	0.163
ROCK3	20-Apr-01	5.24	0.870	2.304
ROCK3	07-May-01	4.92	0.630	6.490
ROCK3	22-May-01	4.87	0.730	1.465

Appendix 14 (cont'd)

ROCK3	05-Jun-01	5.07	1.14	0.236
ROCK3	20-Jun-01	4.64	0.690	0.403
ROCK3	07-Jul-01	4.82	0.371	0.000
SNUGC	07-Apr-01	5.21	0.780	0.208
SNUGC	21-Apr-01	4.87	0.870	0.557
SNUGC	06-May-01	5.20	0.910	0.621
SNUGC	22-May-01	4.76	0.800	0.565
SNUGC	05-Jun-01	4.97	0.840	0.237
SNUGC	21-Jun-01	5.00	0.530	0.408
SNUGC	07-Jul-01	5.15	0.427	0.000
STORI	07-Apr-01	5.48	0.890	0.529
STORI	20-Apr-01	4.88	0.760	0.816
STORI	07-May-01	5.06	0.940	2.790
STORI	22-May-01	5.08	1.09	2.337
STORI	05-Jun-01	5.41	1.09	0.764
STORI	20-Jun-01	4.93	0.490	0.718
STORI	07-Jul-01	5.04	0.795	0.192
WEAGL	07-Apr-01	6.50	1.15	0.505
WEAGL	21-Apr-01	5.46	0.960	1.852
WEAGL	07-May-01	5.09	0.960	1.759
WEAGL	22-May-01	4.77	0.830	1.965
WEAGL	05-Jun-01	4.92	0.890	0.900
WEAGL	20-Jun-01	5.04	0.630	0.700
WEAGL	07-Jul-01	4.74	0.478	0.000
WINDB	07-Apr-01	5.68	0.820	0.154
WINDB	21-Apr-01	5.08	0.600	0.147
WINDB	06-May-01	5.11	0.760	0.258
WINDB	22-May-01	4.40	0.650	0.336
WINDB	05-Jun-01	5.03	0.780	0.182
WINDB	20-Jun-01	4.97	0.550	0.321
WINDB	07-Jul-01	5.09	0.407	0.000