Exxon Valdez Oil Spill
Restoration Project Annual Report

Pristane Monitoring in Mussels and Predators of Juvenile Pink Salmon & Herring

Restoration Project 00195
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

Jeffrey W. Short
Patricia M. Harris

Auke Bay Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
11305 Glacier Highway
Juneau, Alaska 99801-8626

July 2002

Pristane Monitoring in Mussels and Predators of Juvenile Pink Salmon & Herring

Restoration Project 00195
Annual Report

Study History: This project was initiated in FY96. This is the fifth annual report for the project. A similar demonstration project was conducted in FY94 and FY95 under Auke Bay Laboratory sponsorship which provided comparable data for those years.

Abstract: Pristane concentrations in mussels were monitored biweekly from April through early July at 40 stations in Prince William Sound (PWS) to evaluate inter-annual and geographic variability, and to examine whether these results may be related to the marine survival of pink salmon in PWS. Results show that pristane accumulation by mussels averaged across stations throughout PWS was less than half the average of the previous 5 years, indicating less favorable conditions for early marine survival of pink salmon and other zooplanktivores compared with the previous 5 years. The lower average accumulation of pristane by mussel in 2000 was because pristane concentrations declined earlier in the season at all stations. Stations where mussels accumulated the greatest concentrations of pristane clustered west of a line running from Montague Strait to Valdez Narrows, as in previous years. Returns of adult pink salmon to hatcheries were not consistent with predictions based on pristane monitoring and pink salmon survival data from previous years, casting considerable doubt on the utility of pristane monitoring as a forecasting method for predicting the early marine survival of hatchery-released pink salmon.

Key Words: *Exxon Valdez*, pristane, *Neocalanus spp.*, mussels, pink salmon, herring, Prince William Sound.

Project Data: (will be addressed in the final report)

Citation: Short, J. and P. Harris. 2002. Pristane monitoring in mussels and predators of juvenile pink salmon & herring, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 00195), Auke Bay Laboratory, Juneau, Alaska.

Table of Contents

List of Tables

List of Figures

Executive Summary

The purpose of this project is to assess marine feeding conditions during juvenile life stages of pink salmon and herring in Prince William Sound (PWS). In spring, the principal prey of these juveniles is the copepod *Neocalanus plumchrus*, and annual copepod abundances may vary considerably. Predators of these juvenile fish (such as adult pollock) may also prey on the copepods, and may possibly select copepods during years of high abundance. Variability of these feeding conditions may therefore modulate recruitment of these commercially exploited fishes, *e.g.* by alleviating predation pressure during years when conditions are favorable. This project indirectly assesses energy conversion from *Neocalanus* copepods to nearshore, juvenile fish during spring, by monitoring a surrogate measure of fish fecal production in mussels.

Copepods in the genera *Calanus* and *Neocalanus* are apparently unique in their ability to biosynthesize high concentrations of a hydrocarbon called pristane. Pristane is derived from chlorophyll ingested by the copepods, and concentrations of pristane approach 1% in these animals. As a terminally-branched alkane, pristane dissolves into lipids and resists catabolic

degradation, making it a tracer molecule for the lipids produced by these copepods. When these copepods are ingested by fish, some of the pristane is excreted in fecal material as a result of incomplete lipid absorption in the intestine. The fecal material may disperse in the water column, and then be accumulated by mussels as they filter seawater for food. Thus, pristane accumulation by mussels may indirectly indicate the extent of predation on *Calanus* and *Neocalanus* by nearby juvenile fish, with high pristane concentrations in mussels during spring indicating simultaneously high abundances of copepods and fish.

Pristane concentrations in mussels have been shown to increase by orders of magnitude during spring in PWS. The sharpest increases occur in early May, about 2 weeks following the peak of the copepod bloom. This project evaluates whether systematic monitoring of these concentration changes in mussels at fixed stations throughout PWS may be related to early marine survival and subsequent recruitment of pink salmon. Mussels were collected periodically from 40 stations (table1, figure 1) and analyzed for pristane to document seasonal concentration changes. In the laboratory, pristane is extracted from mussels with pentane and then isolated and measured by flame ionization gas-chromatography.

Results from 2000 indicate a dramatic departure from the trend of increasing pristane production throughout PWS noted for previous years of this study. Time-integrated pristane concentrations summarized by the PPI were 4.99×10^6 ng-d for 2000, less than half the 5-year average value of 10.4×10^6 for 1995 through 1999. These results suggest that early marine foraging conditions for pink salmon may have been considerably poorer in spring 2000, possibly leading to poorer marine survival of PWS pink salmon returning in fall 2001. As in previous years, the stations where pristane concentrations were greatest were located in the north and western parts of PWS.

Monitoring results of pristane in mussels collected from stations near hatcheries in PWS were compared with marine survivals of discrete release groups of hatchery-reared pink salmon over the past 6 years. This comparison indicated an insignificant association between pristane increases in mussels at stations near hatcheries following mass releases of juvenile pink salmon, and the survival of released juveniles. This lack of significance despite use of a more precise statistical analysis casts considerable doubt on the utility of pristane monitoring as a means for predicting the marine survival of hatchery-released pink salmon, in marked contrast with apparently significant relationships reported for previous years that were based on a less precise analysis.

Introduction

Pristane is a hydrocarbon biosynthesized from chlorophyll by herbivorous copepods in the genera *Calanus* and *Neocalanus*. These copepods are the only proven modern marine source of pristane (Avigan & Blumer 1968), and they typically contain concentrations that approach 1% dry weight (i.e. 10,000,000 ppb). As a branched alkane, pristane is highly lipophilic and resistant

to metabolic degradation, which suggests that it may be a useful "tracer" molecule that would quantitatively label fats in predators of these copepods (Blumer *et al.,* 1964). The low detection limit (about 100 ppb) of the inexpensive analytical method further suggests the utility of pristane as a natural indicator of energy flow from these copepods to higher trophic level predators.

Calanus and *Neocalanus* copepods are marine zooplankters about 3 - 8 mm in length, and are the dominant marine herbivores in Prince William Sound (PWS) during the spring phytoplankton bloom. They are important prey of many predator species. Direct predators of *Calanus* and *Neocalanus* copepods identified in PWS include storm petrels, herring, and juvenile pink salmon. In addition, pristane concentrations that range to 50,000 ppb (dry weight) are evident in filter feeding organisms such as mussels and some clams during spring. Experiments repeated at the Auke Bay Laboratory (ABL) and in the field in 1996 and in 1998 demonstrate that the route of pristane accumulation in these filter feeders is through ingestion of fecal material derived from predators of *Calanus* and *Neocalanus*, especially juvenile pink salmon. Pristane concentrations in PWS mussels may therefore reflect the timing and simultaneous abundance of *Calanus* and *Neocalanus* and their predators in seawater adjacent to sampled mussels.

A regular monitoring program for pristane in mussels during spring could provide a quantitative basis for comparing inter-annual energy flow through *Calanus* and *Neocalanus* to pink salmon. This may provide a relatively inexpensive indicator of survival through the early juvenile stages for these species. The monitoring program may also identify locations where this flow is consistently high, i.e. critical marine habitats. These approaches may elucidate some of the important natural factors that affect recruitment of juvenile salmon.

Objectives

This project has one objective given in the detailed project description:

1. Forecast marine survival of pink and chum salmon in PWS.

Methods

Mussel Collection

The seasonal variability of pristane concentrations in mussels (*Mytilus trossulus*) is based on collections from 40 stations in PWS (figure 1, table 1). Mussels were collected biweekly from most stations beginning early April through early July for a total of 7 collection periods and 274 mussel samples (collection of some samples was prevented by weather). Collected mussels were stored frozen and analyzed for whole-body pristane concentration.

Of the 40 stations monitored, 34 are sampled by ABL staff by small float-plane based out

of Cordova. Four stations are located near Prince William Sound Aquaculture Corporation (PWSAC) hatcheries, and two were sampled by students in Valdez and Chenega Bay as part of Youth Area Watch, an Exxon Valdez Oil Spill Trustee sponsored program.

Ten mussels are collected from selected mussel beds and placed into a plastic bag together with collection documentation (i.e. date, time, location, collector). Selected mussels are usually in the length range 20 - 45 mm.

Pristane Analysis

The chemical analysis of pristane involves pentane extraction of macerated tissues, lipid removal with silica gel, and separation and measurement of pristane by gas chromatography equipped with a flame ionization detector. Pristane concentrations are determined by the internal standard method, with deuterated hexadecane added to the pentane initially as the internal standard. Pristane identification is based on retention time relative to the internal standard. Quality control samples include method blanks, spiked method blanks, and reference sample analyzed with each batch of 20 samples to verify method accuracy, precision, and absence of laboratory introduced artifacts and interferences. Recovery of the internal standard is determined by adding a second internal standard prior to instrumental analysis. Method detection limits are assessed annually for the mussel tissue matrix. Based on previous performance, we anticipate accuracy of ± 15% of National Institute of Science and Technology (NIST)-certified values for the spiked blank and reference samples, precision of 95% of reference samples within ± 15% of sample means, and the frequency of laboratory artifacts above detection limits less than 1%. This level of analytical performance will insure that variability due to sample analysis is negligible compared with variability among replicate mussel samples.

Percent moisture is determined in samples so that results may be analyzed on dry weight basis. Dry weights will be determined by heating samples at 60 C to constant final weight.

Data Analysis

Pristane Accumulation Index

Quantitative comparisons of the amount of pristane accumulated by mussels across stations and through time are based on a pristane accumulation index (PAI), calculated as:

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

where $[P]_i$ is the pristane concentration measured in mussels collected at time t_i, for mussels

collected on I successive samplings throughout the collection season from the same station. 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 accommodate. 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.

Pristane Productivity Index

Interannual comparison of pristane accumulation by mussels averaged across stations is based on a pristane productivity index (Σ PAI), calculated as the PAIs summed across 25 selected stations. These 25 stations were selected because they are the most consistently sampled stations during the period 1995 through 2000.

Geographic Trends

Patterns in the geographic distribution of the PAI are evaluated by calculating the proportion of sampling years that the PAI at a station exceeds the average PAI for the respective year, and examining the geographic distribution of stations classified according to these proportions. That is, an average PAI may be calculated for each of the 6 sampling years 1995-2000, and stations with PAIs exceeding these averages are recorded. Stations that are consistently above-average in this sense are included in one classification, stations that are above-average in 5 of 6 years in another, etc., and the geographic distribution of stations in each class is examined. This procedure prevents differences in the average PAI among years from obscuring identification of stations where the PAI is relatively high (or low) most years.

Results

Pristane Concentrations in Mussels at Regular Monitoring Stations: Synopsis

The general geographic distribution of stations where high pristane concentrations were found in mussels is similar to that of previous years. West of a line running from Montague Strait to Valdez Narrows, pristane concentrations above 10,000 ppb (dry weight) were evident at several stations during early May (figures 2C & 2D). All of these stations either border or are down-current of the deep marine depression system of the northwestern sound. Concentrations in the eastern part of PWS remained low, usually below 1,000 ng/g and consistently below 3,000 ng/g.

Pristane concentrations tended to peak earlier in spring 2000 compared with previous survey years. The highest concentrations occurred during the early- and mid-May sampling

periods, with concentrations in early June comparable with those of mid-April (cf. figures 2B-2F). By mid-June concentrations were similar to those of early April (figures 2A and 2F). The highest concentration occurred at Payday Point at 69,000 ng/g during the early May sampling, and nearby stations at Chippy Point, Fairmont Island and West Eaglek Bay also had concentrations exceeding 20,000 ng/g. Concentrations declined markedly at these stations from early- to mid-May, when the highest concentration was only 14,000 ng/g at Payday Point. Other stations where concentrations were high were Point Eleanor, and stations near the AFK hatchery in the southwest, including the Foxfarm stations and Shelter Bay (figures 2C and 2D). Concentrations reached just over 10,700 ng/g at Point Eleanor in early May, declining to 3,680 ng/g by mid-May in concert with the more northern stations near Payday Point. In contrast, the stations at Foxfarm and Shelter Bay near the AFK hatchery remained high from early- through mid-May, remaining above 17,000 ng/g at 2 of these 4 stations (figures 2C and 2D).

Interannual Trends

Total pristane accumulation by mussels averaged across stations was markedly lower than results from previous years. Time-integrated pristane concentrations summarized by the PPI were 4.99×10^6 ng-d for 2000 (figure 3), less than half the 5-year average value of 10.4×10^6 for 1995 through 1999. The PPI varied little during the period 1995 through1999, ranging from a low of 8.7×10^6 in 1995 to a high of 12.7×10^6 in 1998 (figure 4). The value in 1999 was 12.6×10^6.

Geographic Trends

Pristane concentrations were consistently above annual averages only at Point Eleanor during the period 1995 through 2000 (figure 1). The Foxfarm 1 station was above annual averages during 5 of the 6 years, while Esther Island and Herring Point were above during 4 of the last 6 years. Three stations were variable, above the annual average during 3 of the last 6 years, including the AFK hatchery, Applegate Island and Point Pakenham.

In contrast, 9 stations were consistently below annual averages, and another 9 stations were below for 4 of the 6 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), and 2 stations on the Naked Island complex (Naked Island and Storey Island; see figure 1). These geographic trends are broadly similar with those of previous years (see previous annual reports).

Discussion

Inter-Annual Comparison

The results for 2000 contrast sharply with results from 1995 through 1999. The significance of inter-annual differences among PPI results has been estimated by calculating a least-significant-difference (LSD) criterion based on Monte Carlo re-sampling procedure described in the 1997 annual report for this project (Short and Harris, 1997). These results showed that an LSD of 22% is significant at the 95% confidence level. Application of this criteria to the PPI results from 1995 through 2000 indicates that the PPI for 2000 was significantly lower than for any previous year.

The initial increase of pristane concentrations noted at stations in western PWS in early May (cf. figures 2B and 2C) were not likely caused by releases of hatchery fish. The first release of hatchery-reared pink salmon occurred on May 4, 200 at the A. F. Koening hatchery (AFK) hatchery on Evans Island, and on May 9, 2000 at the W. H. Norenberg hatchery (WHN) on Esther Island. The first release was even later from the Cannery Creek hatchery in Unakwik Inlet, on May 20, 2000. Nearly all of the early-May stations were sampled on May 2 or 3, 2000. Previous work indicates a delay of at least 3 days between a mass-release of pink salmon and an increase of pristane in mussels nearby (Short and Harris 1998). Hence, there appear to be other nearshore predators of *Neocalanus* zooplankton that release pristane-rich fecal material, and that made a dominant contribution to the pristane signal in mussels at least in 2000. These may have included wild pink salmon, or other zooplanktivores such as sandlance, capelin, herring and pollock.

The temporal pattern of results in 2000 suggests that predation pressure on the *Neocalanus* zooplankton bloom may have been especially intense. Given that the increased pristane concentrations in mussels in early May were caused by zooplanktivores other than the hatchery-released pink salmon, the combined hatchery releases of 391 million juvenile pink salmon between May 4 - June 8 would likely have intensified predation on *Neocalanus*. Despite these releases, pristane concentrations generally declined in the northwestern sound. One scenario consistent with these results is the progressive exhaustion of the *Neocalanus* prey base for these zooplanktivores during May, at least near the deep marine trench in the northwestern sound where *Neocalanus* are thought to overwinter. The incorporation of high pristane concentrations by mussels at stations near the AFK hatchery in southwestern PWS was more protracted during May, which may have been a result of greater abundance of *Neocalanus* near those stations in relation to predation pressure.

Geographic Trends

Stations in the eastern sound had typically low PAI values as in previous years (figure 3). These results add another year of corroboration to the hypothesis that the deep marine depression

of the northwestern Sound provides overwintering habitat for diapausing *Neocalanus plumchrus/flemingerii*, and that copepodites produced by these diapausing adults in winter contribute substantially to the bulk of the zooplankton bloom during spring. This pattern is also consistent with the salmonid migration corridor from PWSAC hatcheries and streams in the western Sound.

Predicting Hatchery Survivals

The apparent association between pristane increases in mussels near PWSAC hatcheries immediately following mass releases of juvenile pink salmon, and the number of adults returning to the hatcheries 16 months later that was noted in the previous annual report is not confirmed by survival results of pink salmon that returned in 2000. Marine survivals for early May releases from the AFK hatchery were predicted to be quite high (>20%), based on the very high concentrations of pristane found in mussels at the Chenega Bay or at Foxfarm stations at least 5 days following the AFK releases in 1999. The actual survivals were about 5%. Low survivals were predicted for one large release group from the WHN, but the actual survival was near 8%. Compared with previous years, a more detailed statistical analysis was conducted that: (1) tracked predictive performance by individual release groups instead of combining several release groups as was done in previous reports, and (2) accounted for pristane depuration between sampling events. In spite of these improvements, the relationship between the maximum increase of pristane in mussels collected within 25 km of a hatchery, and the marine survival of pink salmon released by the hatchery at least 5 days prior to mussel collection was not even marginally significant. These results cast serious doubt on the utility of pristane monitoring as a predictive tool for marine survival of hatchery pink salmon at the scale of individual release groups.

The weakened relationship between pristane in mussels and the marine survival of juvenile pink salmon may be the result of a number of factors, possibly acting in concert. One is density dependence. The very high pristane concentrations found at stations near the A. F. Koening hatchery after the 1999 pink salmon releases there were accompanied by a bloom of *Chaetoceros*, which likely caused considerable mortality to the juveniles. This reduced survival may have occurred despite intense initial predation by juvenile pink salmon on *Neocalanus* copepods. More generally: the number of monitoring stations may not be sufficient to track the foraging migrations of released juvenile pink salmon adequately; analysis by release group may result in insufficient responses of pristane in mussels compared with other sources of pristane fecal material produced by other predators of *Neocalanus*; the early marine residence habits of pink salmon may include exploitation of feeding habitats away from the nearshore; the sizes of some release groups were probably too small to cause detectable increases in of pristane in mussels; and the marking and release strategies of the hatcheries is not consistent among hatcheries or among years. Also, pristane in mussels contributed by species other than pink salmon (as noted above) further confounds interpretation of the monitoring results. These factors may combine to obscure the relation between pristane in mussels and the marine survival of hatchery-produced juvenile pink salmon, even if the underlying uptake pathway of pristane from feces produced by juvenile pink salmon is correct.

In any case, the results from this year indicate that the utility of pristane monitoring as a means of predicting the early marine survival of hatchery-released pink salmon is doubtful. It remains to be determined whether the pristane monitoring results may be indicative of ecosystem dynamics regarding trophic energy transfer (i.e. from secondary to tertiary production) at a larger spatial scale, that of the sound as a whole. The much lower PPI observed this year would suggest less grazing on *Neocalanus* copepods throughout the sound compared with previous years, leading to reduced marine survival for hatchery pink salmon throughout the sound. The strength of returns of hatchery pink salmon next year will provide data to test this speculation.

Conclusions

1. Pristane accumulation by mussels has remained highest in western PWS, consistent with the extent of over-winter habitat for *Neocalanus* copepods provided by the deep marine depression of northwestern PWS.

2. The intensity of pristane accumulation by mussels averaged across PWS as a whole has declined sharply compared with the previous 5 years. The pristane production index (PPI) for 2000 was less than half the values of 1998 or 1999, and shows a decrease for the first time during the life of this monitoring project.

3. The utility of pristane monitoring for predicting the early marine survival of hatchery-released pink salmon now looks doubtful, owing to observed survivals of juveniles released in 1999 that were not consistent with predictions based on results from previous years.

Literature Cited

Avigan, J., and M. Blumer. 1968. On the origin of pristane in marine organisms. Journal of Lipid Research 9:350-352.

Blumer, M., M. M. Mullin, and D. W. Thomas. 1964. Pristane in the marine environment. Helgoländer Wissenschaftliche Meeresuntersuchungen 10:187-201.

Exxon Valdez oil spill of 1989: State/Federal trustee council hydrocarbon database, 1989-1995. Available from Bonita Nelson, Auke Bay Laboratory, 11305 Glacier Highway, Juneau, Alaska 99801-8626.

Short, J. and P. Harris. 1997. Pristane monitoring in mussels and predators of juvenile pink salmon & herring, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 97195), Auke Bay Laboratory, Juneau, Alaska.

Short, J. and P. Harris. 1998. Pristane monitoring in mussels and predators of juvenile pink salmon & herring, *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 98195), Auke Bay Laboratory, Juneau, Alaska.

Table 1. Locations and abbreviations of mussel collection stations sampled for this project in 2000. The abbreviations are also used in figure 1.

Station Abbreviation	Station Name	Latitude			Longitude		
		Deg N	Min	Sec	Deg W	Min	Sec
AFKHA	AFK Hatchery	60	3	8	148	3	30
APPLI	Applegate Island	60	37	30	148	8	10
BLIGI	Bligh Island	60	52	2	146	44	59
CANNC	Cannery Creek Hatchery	60	59	39	147	32	19
CHENB	Chenega Bay	60	3	47	148	1	10
CHENI	Chenega Island	60	23	11	148	0	4
CHIPP	Chippy Point	60	52	3	147	35	38
CONSH	Constantine Harbor	60	21	16	146	40	25
CULRP	Culross Passage	60	44	41	148	13	6
DAYVI	Dayville	61	5	13	146	16	40
DECIP	Decision Point	60	48	21	148	28	35
DIVIP	Division Point	60	28	55	148	17	13
EKNII	East Knight Island	60	20	49	147	38	32
ESTHI	Esther Island (WN Hatchery)	60	47	7	148	3	30
FAIRI	Fairmont Island	60	52	51	147	26	17
FLEMI	Fleming Island	60	10	29	148	2	3
FOXF1	Fox Farm 1	59	58	15	148	8	22
FOXF2	Fox Farm 2	59	58	7	148	6	36
FOXF3	Fox Farm 3	59	58	10	148	10	22
GRANB	Granite Bay	60	52	50	148	6	23
GREEI	Green Island	60	16	55	147	24	57
HERRP	Herring Point	60	28	28	147	47	27
HIDDB	Hidden Bay	60	42	57	148	6	12
ISLAB	Island Bay	60	48	4	147	59	27
KNIKL	Kniklik	60	50	51	147	37	46
LITTB	Little Bay	60	11	3	147	47	27
MAINB	Main Bay	60	32	0	148	3	30
NAKEI	Naked Island	60	39	3	147	26	24
OLSEN	Olsen Bay	60	44	30	146	11	58
PAYDP	Payday Point	60	54	46	147	29	39
PELEA	Point Eleanor	60	34	33	147	33	49
PERRI	Perry Island	60	40	40	147	54	50
PPAKE	Point Pakenham	60	0	23	148	5	7
ROCKB	Rocky Bay	60	20	14	147	7	32
SHELB	Shelter Bay	60	7	47	147	55	8
SNUGC	Snug Corner Cove	60	44	8	146	37	32
STORI	Storey Island	60	43	41	147	27	2
WEAGL	West Eaglek Bay	60	49	46	147	44	25
WINDB	Windy Bay	60	34	22	148	57	29
WTWIB	West Twin Bay	60	43	32	147	59	35

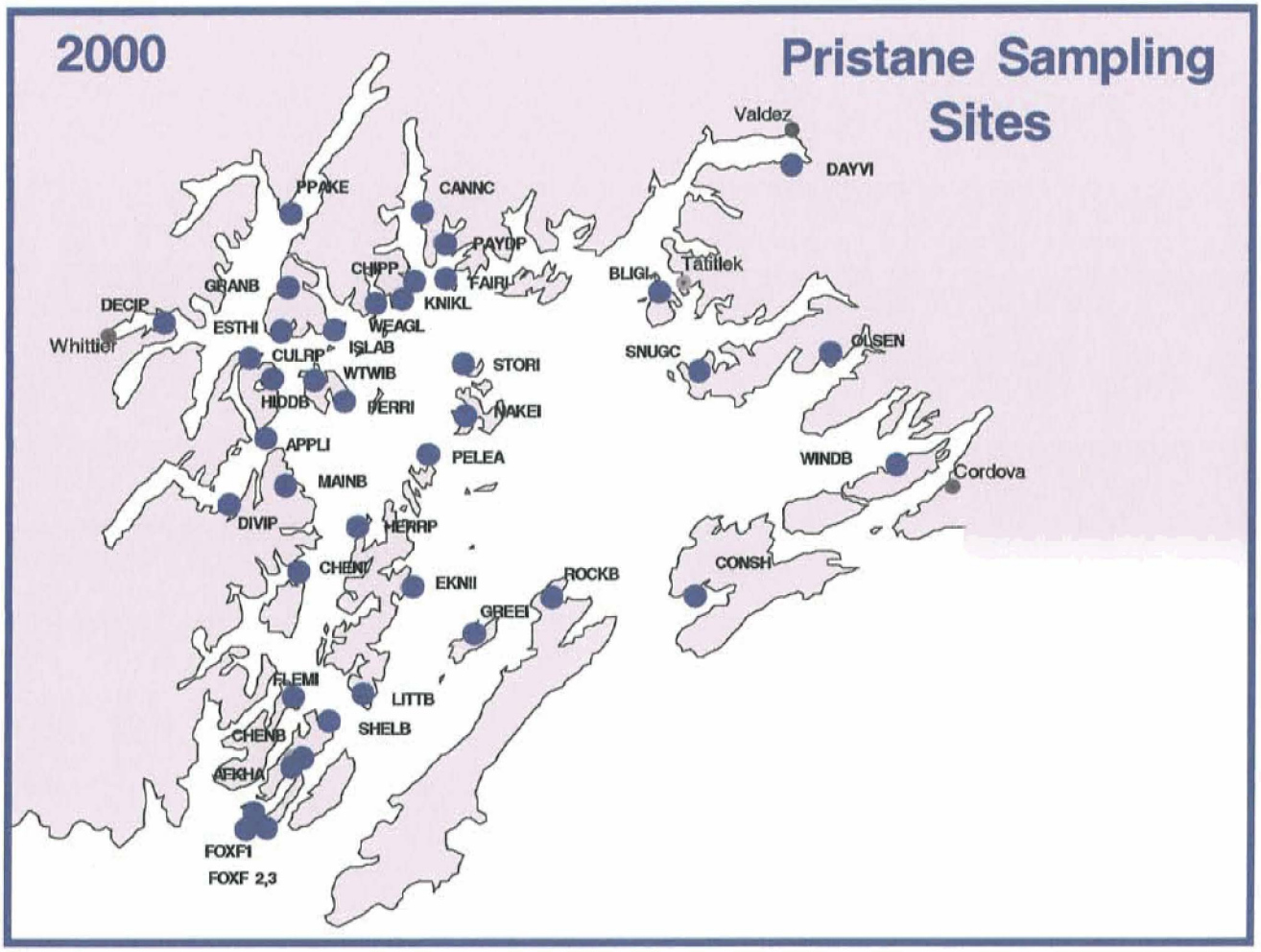
2000
Pristane Sampling Sites
Valdez
DAYVI
PPAKE
CANNC
PAYDP
CHIPP
FAIRI
BLIGI
Tatitlek
GRANB
KNIKL
DECIP
ESTHI
WEAGL
Whittier
ISLAB
SNUGC
OLSEN
CULRP
STORI
WTWIB
HIDDB
PERRI
NAKEI
APPLI
PELEA
WINDB
Cordova
MAINB
DIVIP
HERRP
CHEKI
EKNII
ROCKB
CONSH
GREEI
FLEMI
LITTB
SHELB
CHENB
AFKHA
FOXF1
FOXF 2,3

Figure 1.

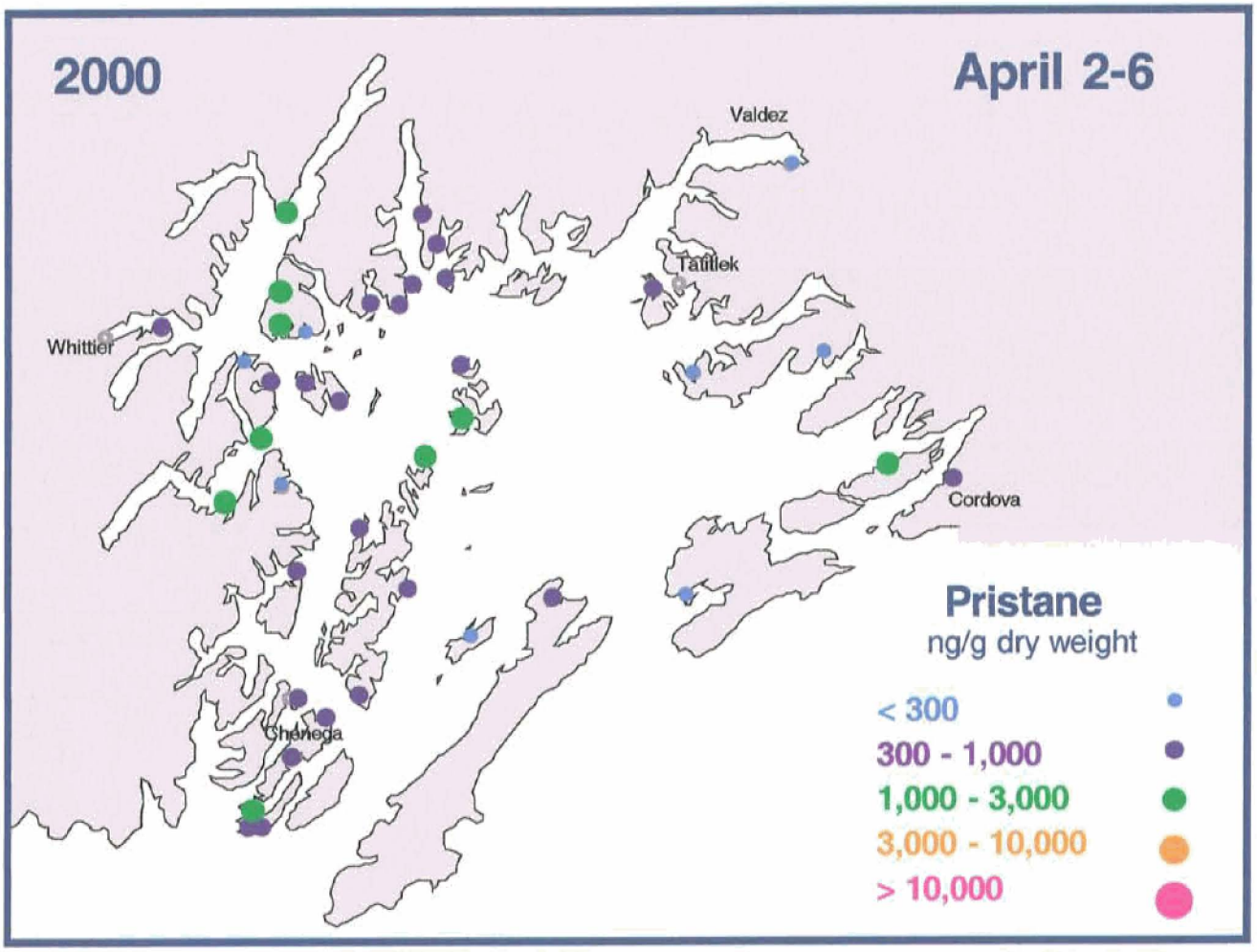
2000
April 2-6
Valdez
Tatitlek
Whittier
Cordova
Chenega
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2A.

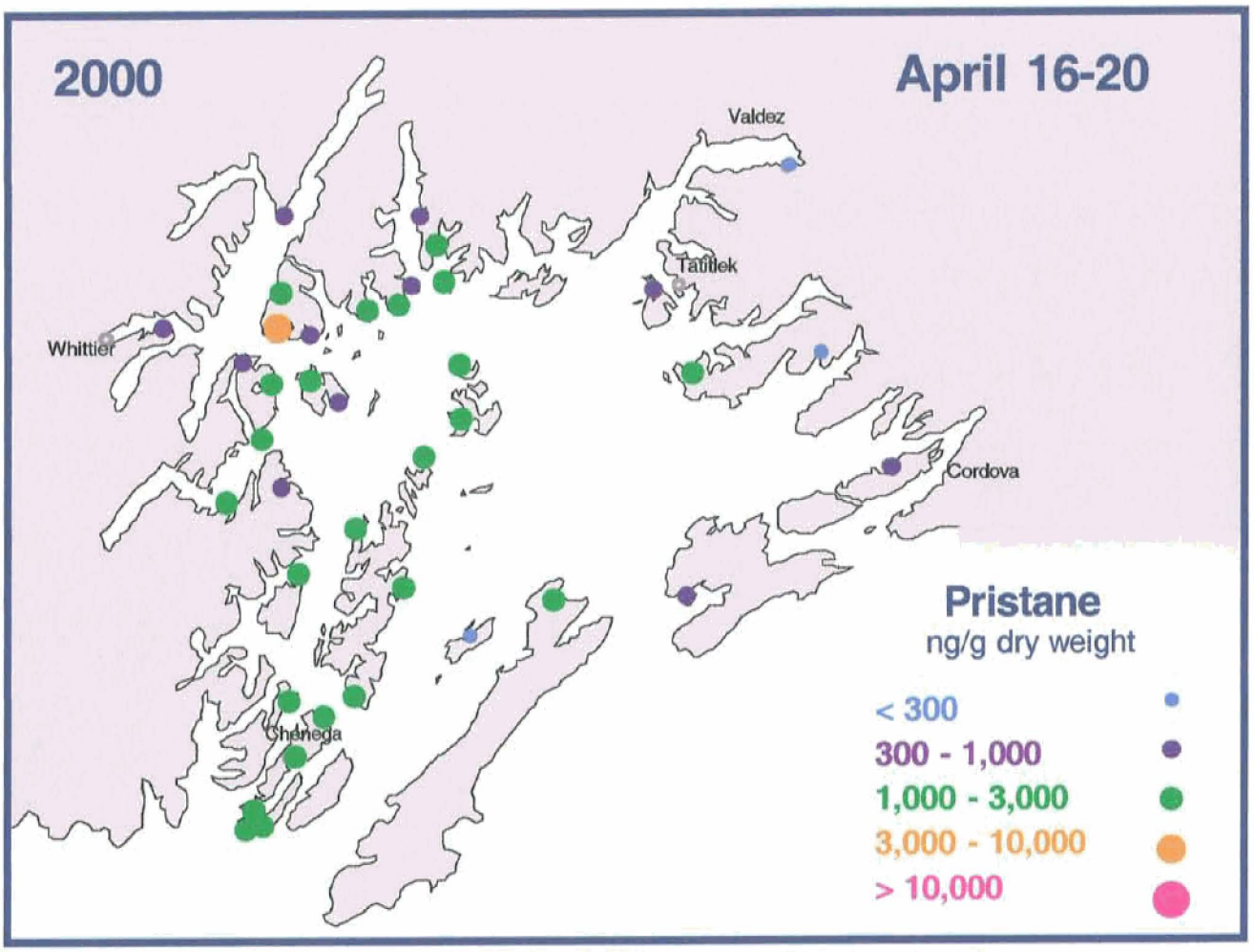
2000
April 16-20
Valdez
Tatitlek
Whittier
Cordova
Chenega
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2B.

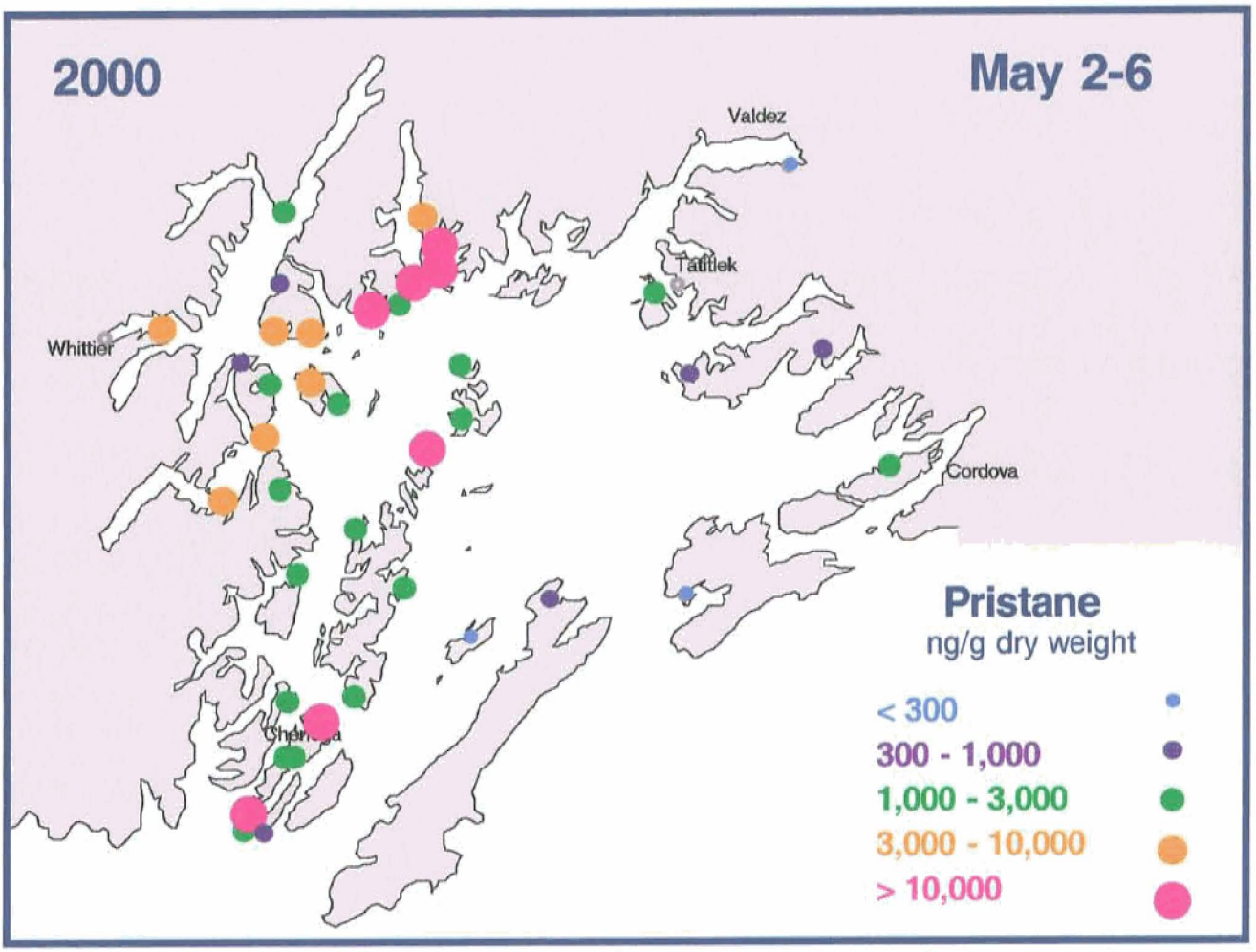
2000
May 2-6
Valdez
Tatitlek
Whittier
Cordova
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2C.

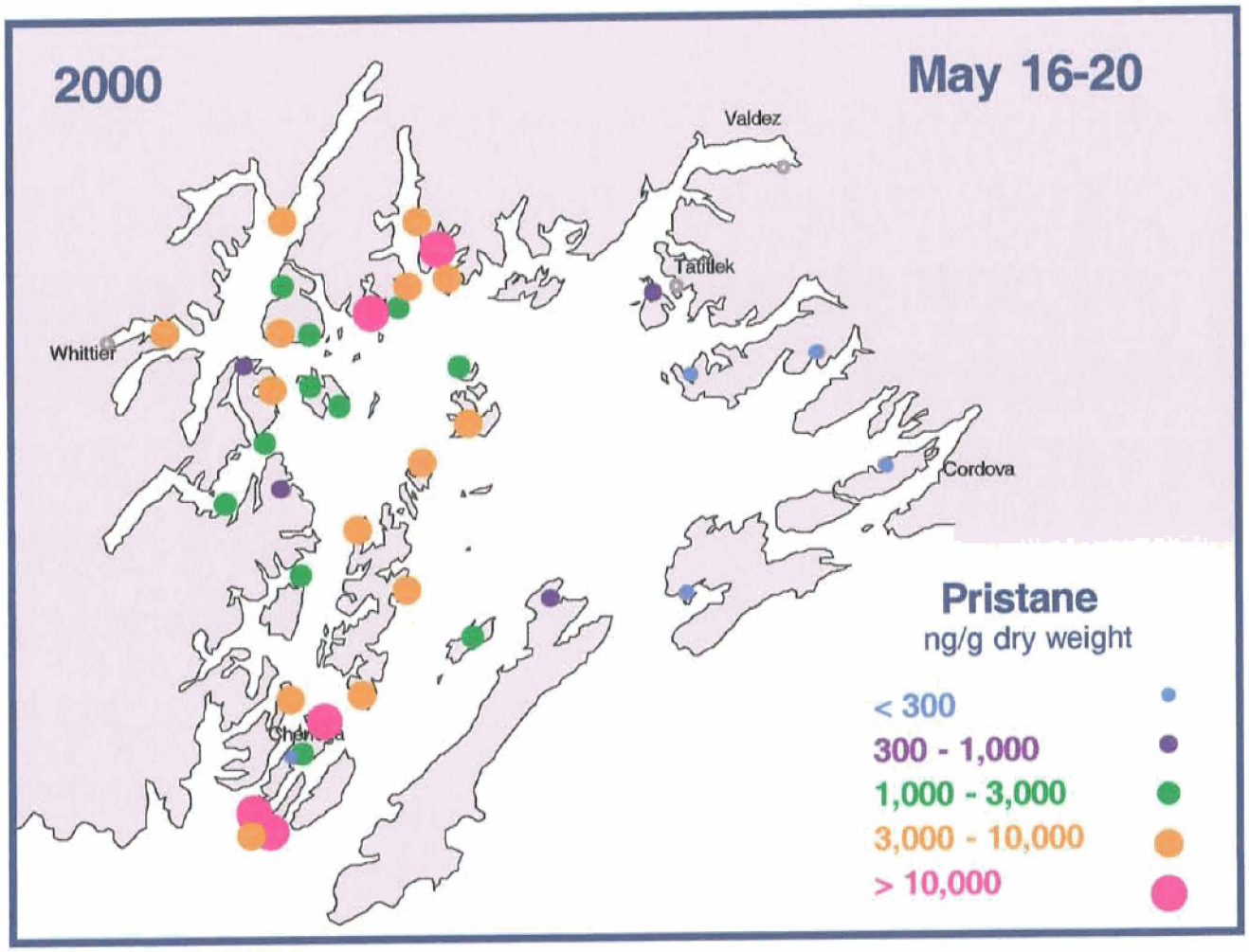
2000
May 16-20
Valdez
Tatitlek
Whittier
Cordova
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2D.

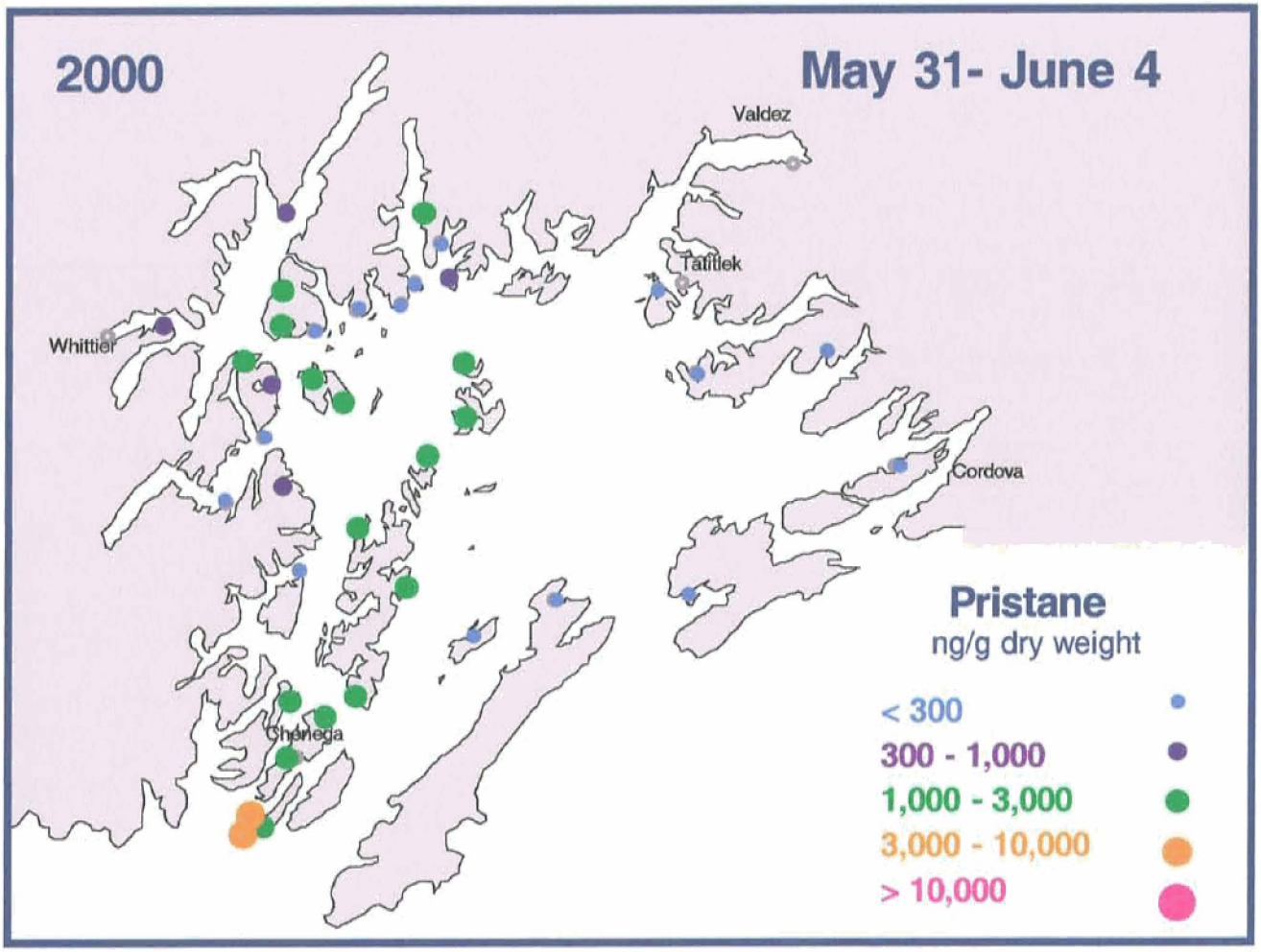
2000
May 31- June 4
Valdez
Tatitlek
Whittier
Cordova
Chenega
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2E.

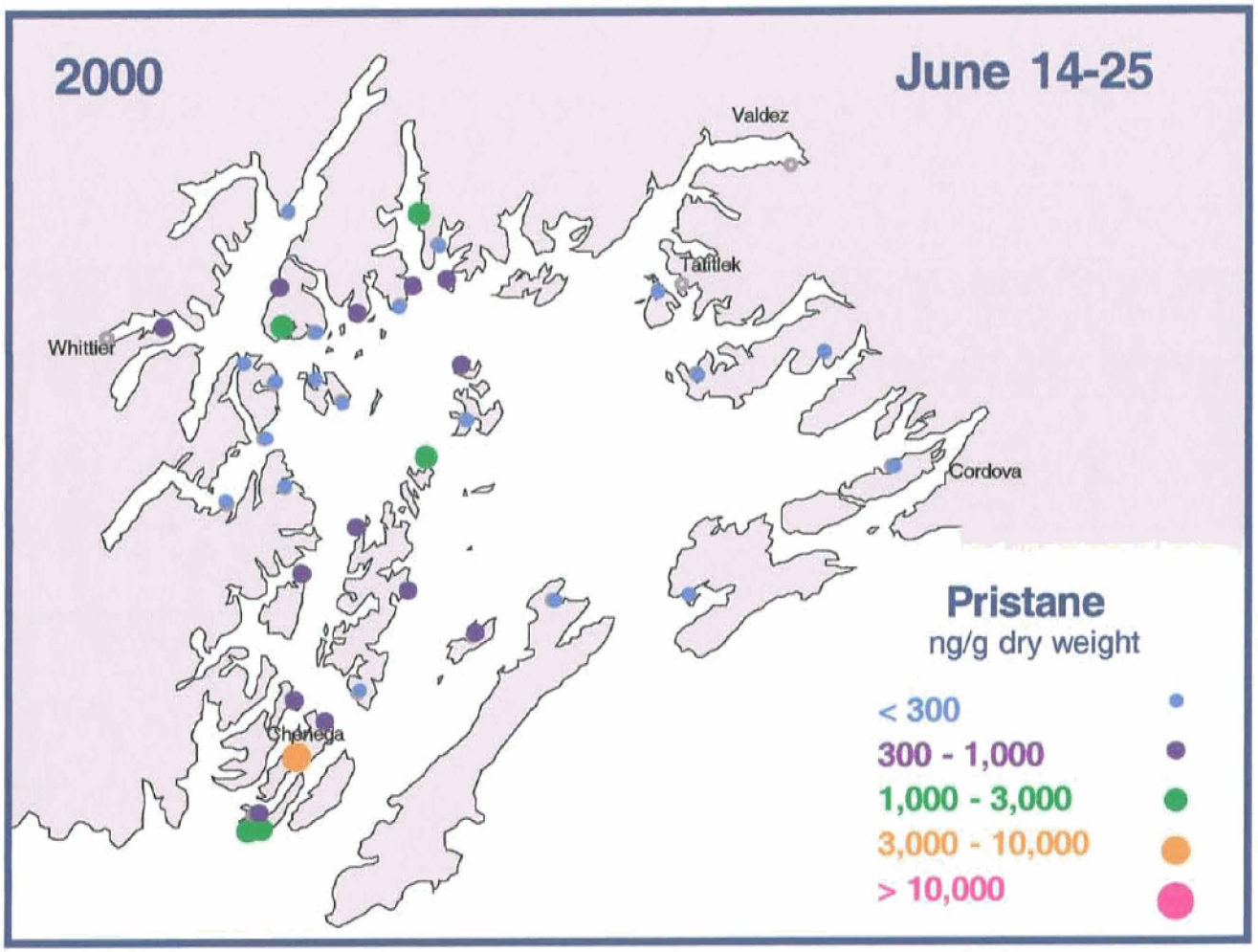
2000
June 14-25
Valdez
Tatitlek
Whittier
Cordova
Chenega
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2F.

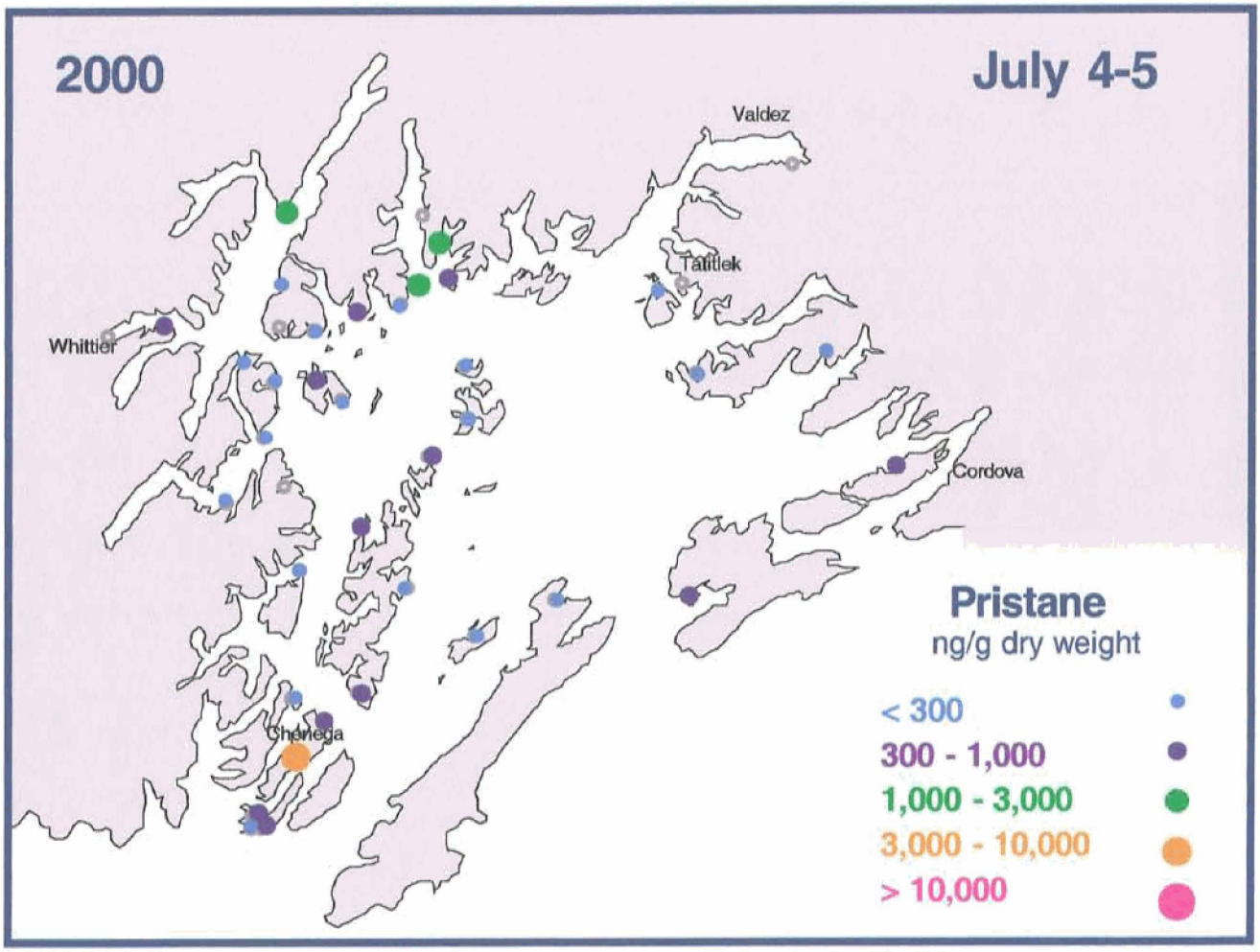
2000
July 4-5
Valdez
Tatitlek
Whittier
Cordova
Chenega
Pristane
ng/g dry weight
< 300
300 - 1,000
1,000 - 3,000
3,000 - 10,000
> 10,000

Figure 2G.

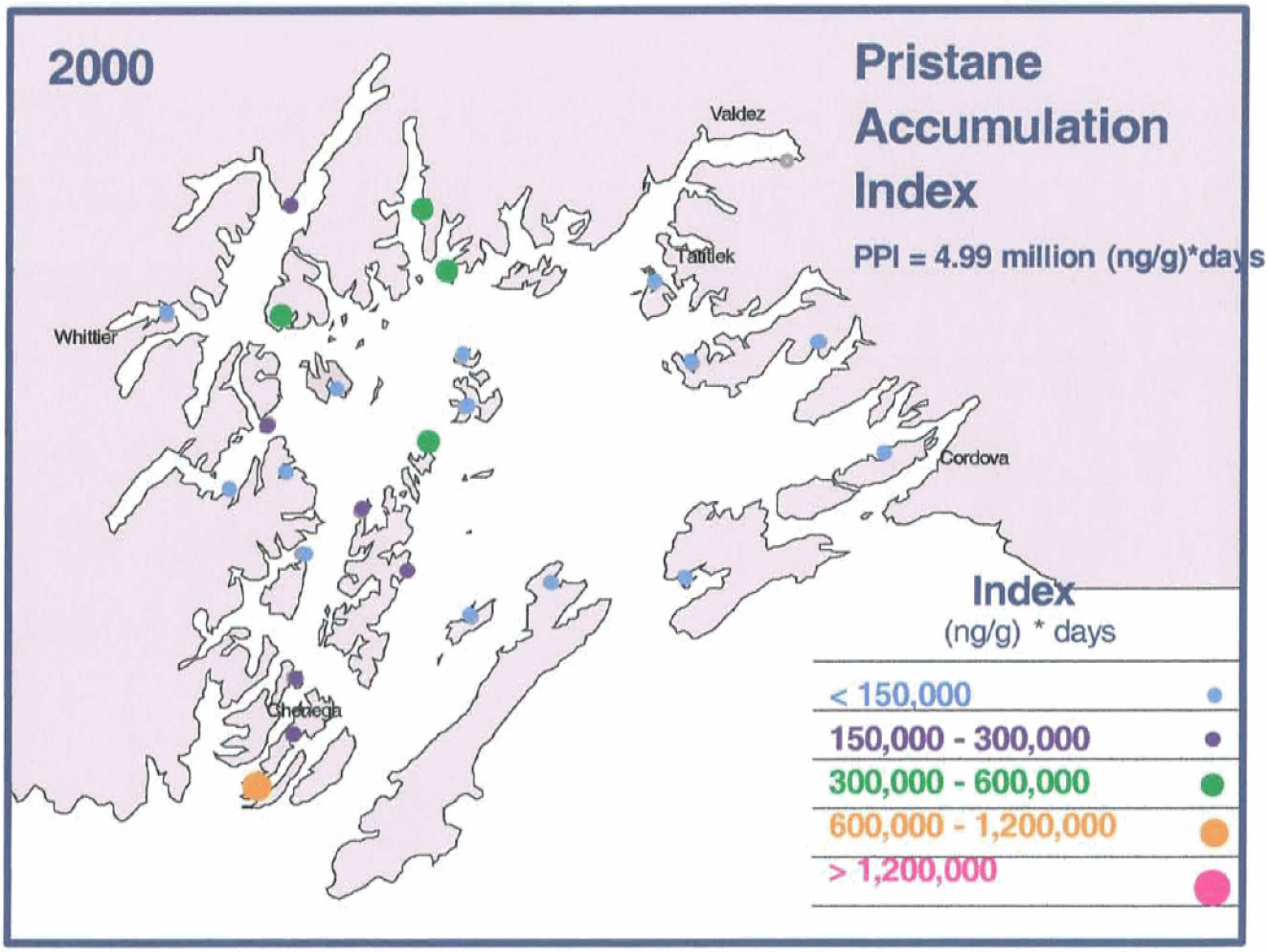
2000
Pristane
Accumulation
Index
PPI = 4.99 million (ng/g)*days
Valdez
Tatitlek
Whittier
Cordova
Chenega
Index
(ng/g) * days
< 150,000
150,000 - 300,000
300,000 - 600,000
600,000 - 1,200,000
> 1,200,000

Figure 3.

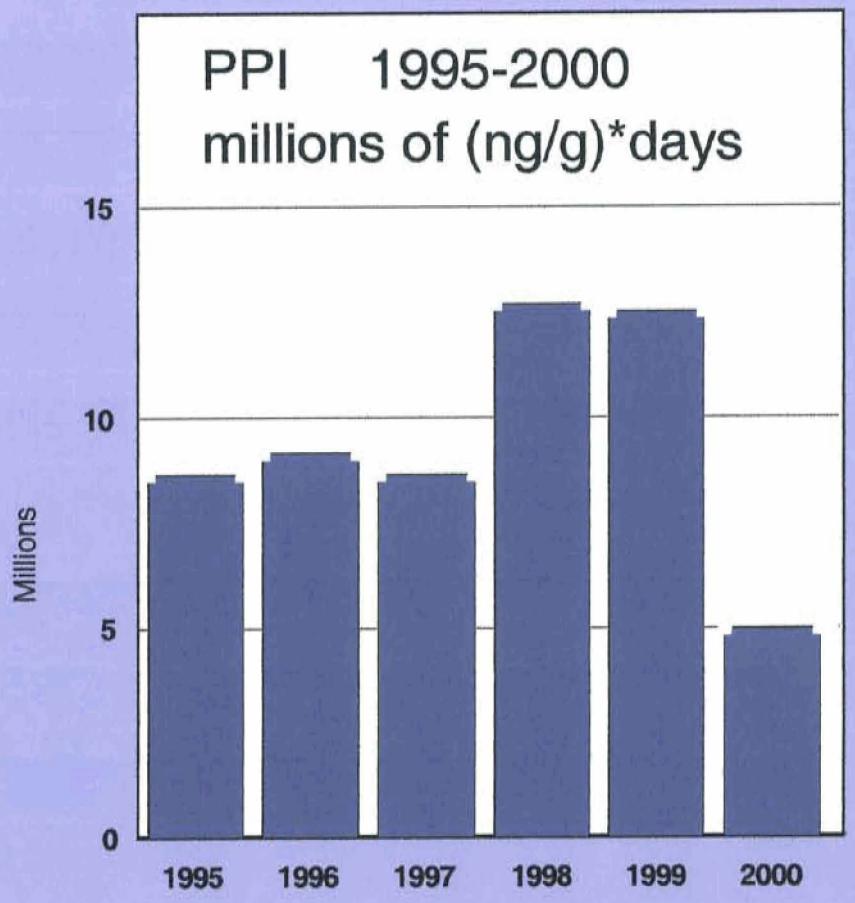
PPI 1995-2000
millions of (ng/g)*days
Millions
15
10
5
0
1995
1996
1997
1998
1999
2000

Figure 4.