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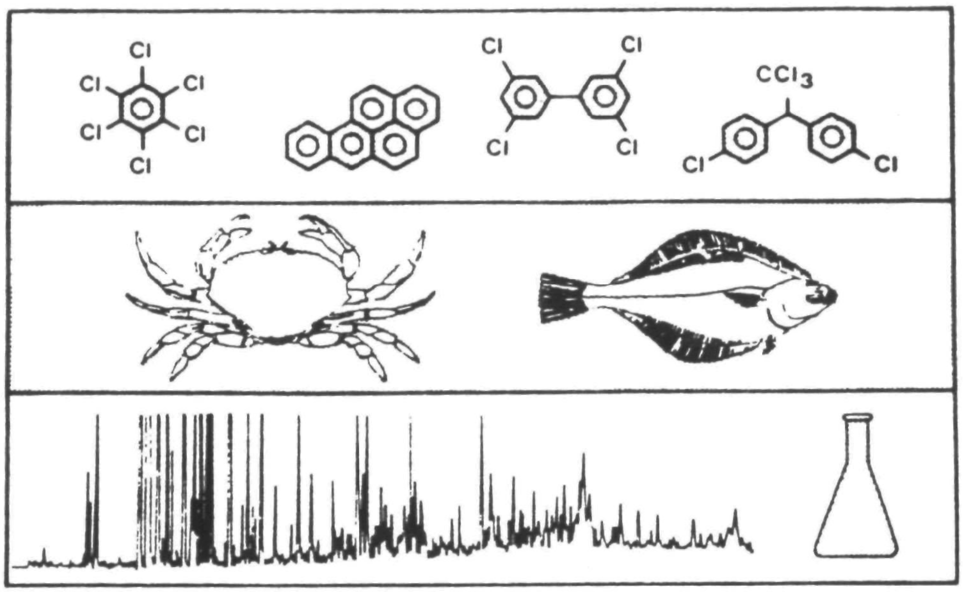
Bioaccumulation Monitoring Guidance: Selection of Target Species and Review of Available Data

Volume I



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Final Report

BIOACCUMULATION MONITORING GUIDANCE:

SELECTION OF TARGET SPECIES AND REVIEW OF AVAILABLE BIOACCUMULATION DATA

VOLUME I

for

U.S. Environmental Protection Agency
Office of Marine and Estuarine Protection
Washington, DC 20460

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by

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PREFACE

This manual has been prepared by the U.S. Environmental Protection Agency (EPA) Marine Operations Division, Office of Marine and Estuarine Protection in response to requests for guidance from U.S. EPA Regional Offices and coastal municipalities planning 301(h) monitoring programs for municipal discharges into the marine environment. The members of the 301(h) Task Force of EPA, which includes representatives for the EPA Regions I, II, III, IV, IX and X, the Office of Research and Development, and the Office of Water, are to be commended for their vital role in the development of this guidance by the technical support contractor, Tetra Tech, Inc. The guidance herein provides assistance in the selection of target species for bioaccumulation studies for several major coastal areas of the United States.

This guidance is produced in two volumes. Volume I provides a review of available information, selection methodology and specific guidance to ensure, to the degree possible, that there is regional consistency in selection of target species for bioaccumulation studies. Volume II contains a detailed compilation of available tissue chemistry data for the recommended target species.

The information provided herein will be useful to U.S. EPA monitoring program reviewers, permit writers, permittees, and other organizations involved in performing nearshore monitoring studies. Bioaccumulation monitoring has become increasingly important in assessing pollution effects, therefore this guidance should have broad applicability in the design and interpretation of marine and estuarine monitoring programs.

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ACKNOWLEDGMENTS

This document has been reviewed by the 301(h) Task Force of the Environmental Protection Agency, which includes representatives from the Water Management Divisions of U.S. EPA Regions I, II, III, IV, IX, and X; the Office of Research and Development - Environmental Research Laboratory - Narragansett (located in Narragansett, RI and Newport, OR), and the Marine Operations Division in the Office of Marine and Estuarine Protection, Office of Water.

This technical guidance document was produced for the U.S. Environmental Protection Agency under the 301(h) post-decision technical support contract No. 68-01-6938, Allison J. Duryee, Project Officer. This report was prepared by Tetra Tech, Inc., under the direction of Dr. Thomas C. Ginn. The primary authors were Dr. D. Scott Becker and Dr. Robert A. Pastorok. Ms. Marcy B. Brooks-McAuliffe performed technical editing and supervised report production.

INTRODUCTION

Monitoring the accumulation of toxic substances in tissues of marine organisms is useful for assessing environmental impacts of specific wastewater discharges or evaluating water quality from a regional perspective (e.g., Young et al. 1976, 1978a,b; Goldberg et al. 1983; Ladd et al. 1984). Under Section 301(h) of the Clean Water Act, periodic assessment of bioaccumulation in marine organisms is specified as part of the biological monitoring programs [40 CFR Part 125.62(b)(ii)]. Additionally, periodic assessment of the conditions and productivity of commercial or recreational fisheries may be required [40 CFR Part 125.63(b)(iv)]. Because the accumulation of toxic substances in tissue can result in restrictions being placed on a fishery, bioaccumulation can be used as one measure of the condition of a fishery. The choice of target species is a key element of any bioaccumulation monitoring program. Tissue concentrations of toxic substances in target species can serve as indicators of contamination throughout the biological system. At a minimum, the target species must be capable of accumulating toxic substances representative of the study area(s), abundant enough over time and space to allow adequate sampling, and large enough to provide adequate amounts of tissue for analysis.

The primary purpose of this report is to provide guidance for selecting target species for bioaccumulation monitoring studies to be conducted as part of the 301(h) sewage discharge program. Consistency among the monitoring programs for individual 301(h) discharges ultimately will allow the development of regional and national perspectives on the effects of sewage discharges on marine and estuarine environments. In addition to recommending target species for bioaccumulation monitoring, this report presents a compilation, evaluation, and summarization of recent data on concentrations of priority pollutants in those species. This data review should aid the interpretation of 301(h) monitoring results. For example, the data for a target species at a particular discharge site can be compared with historical data for that same species during different time periods and at various locations throughout the United States.

RECOMMENDED TARGET SPECIES

GENERAL APPROACH

The recommended target species include fishes and large macroinvertebrates[1]. These taxa were selected because 1) representatives are indigenous to most habitats affected by 301(h) discharges, 2) individuals generally are large enough to provide adequate tissue mass for bioaccumulation analyses, and 3) many of these taxa support commercial or recreational fisheries. A potential drawback in using these taxa is that all, except most bivalve molluscs, exhibit some degree of movement. Some spatial and temporal patterns of bioaccumulation could therefore be influenced by these movements.

Recommended fish and large macroinvertebrate species were selected on the basis of several criteria. In general, the major requisites for selection were that a species be relatively abundant near sewage outfalls and that its behavior create a substantial risk of bioaccumulation. To make the selection process as site specific as possible, candidate organisms were selected from data supplied in 301(h) applications from various municipalities. Information on fishes from Washington to California on the west coast and from Massachusetts to Virginia on the east coast was sufficiently quantitative to allow a detailed species selection analysis. In contrast to these quantitative data sets, fish data from Florida, Alaska, Puerto Rico, the Virgin Islands, and Hawaii, and all large macroinvertebrate data were qualitative. Several potential monitoring species were therefore recommended for fishes at each of these five areas and for large macroinvertebrates at all locations, with final selection to be made following quantitative site-specific surveys.

The detailed species selection analysis referred to above was based upon primary and secondary criteria. Primary selection criteria were concerned

[1]In this document, the term "large macroinvertebrate" refers to a species that is too large to be sampled adequately by a conventional bottom grab.

with ecological characteristics of organisms that would enhance their risk of bioaccumulation (i.e., habitat and prey type) or facilitate sampling and analytical procedures (i.e., geographic distribution, size, and abundance). Secondary selection criteria considered additional factors that would enhance the desirability of using particular species for monitoring purposes. These included economic importance and status as a recommended bioassay organism. Primary criteria were used to develop a list of the most desirable bioaccumulation candidates at each discharge site, whereas secondary criteria were used primarily to select a single recommended species from each group of candidates.

In addition to the primary and secondary selection criteria identified previously, two additional criteria were considered but rejected. The "ecological importance" of each species was considered a desirable criterion, but no means of objectively and unambiguously evaluating this criterion for each species was available. A second possible additional criterion was that a species was known to bioaccumulate contaminants based on historical studies. This second criterion was rejected because studies have not been conducted on most of the species considered.

FISHES

Ranking Procedure

The first step in ranking fishes for bioaccumulation monitoring was to develop a list of the most abundant species near individual municipalities applying for 301(h) modified permits. Adequate data sets were found for 28 localities (Table A-1), and evaluations were made for 115 species (Table A-2). Once each species list was developed, fishes were scored from 1 to 3 on the basis of each of five primary criteria. A score of 3 signified that a species was highly acceptable for bioaccumulation monitoring, whereas a score of 1 indicated that a species was marginal. A score of 2 was given to intermediate cases. After all species had been considered, the scores were summed across all five criteria. Fishes could then be ranked for acceptability as bioaccumulation monitoring species on the basis of their total scores. Species scoring 12 or greater out of the maximum of 15 were considered acceptable monitoring candidates and were evaluated further with respect to the secondary criteria discussed below (i.e., economic importance and status as a recommended bioassay species).

Site-specific abundances were based primarily on information collected using otter trawls, because most historical 301(h) studies used these devices and because most future 301(h) monitoring programs will use them to evaluate whether balanced indigenous populations (BIPs) of fishes exist near particular outfalls. It should be noted, however, that these otter trawls are biased to catch soft-bottom demersal fishes, rather than pelagic species or species that live near structures (e.g., rocks, coral). This bias was considered acceptable for the requirements of the present target species evaluation because fishes living near the bottom are better bioaccumulation candidates than are water-column species (see Habitat section under Primary Selection Criteria below) and because most 301(h) discharge sites are located in soft-bottom environments rather than in habitats having considerable amounts of structures. However, specific monitoring programs may require fishes to be collected from the water column or from the vicinity of structures. In such cases, sampling devices other than an otter trawl (e.g., midwater trawl, long-lines, hook and line, visual observations using divers or submersibles) will be required. Because of the site-specific nature of these objectives and sampling devices, guidance for the selection of target species and sampling methods is not given in this document. Characteristics of individual species, other than site-specific abundances, were based on information presented in general regional references of fish ecology and biology (i.e., Hildebrand and Schroeder 1927; Bigelow and Schroeder 1953; Miller and Lea 1972; Hart 1973; Allen 1982; Grosslein and Azarovitz 1982).

Primary Selection Criteria

Habitat--

It was assumed that fishes living in close contact with bottom sediments have a greater risk of bioaccumulation than fishes that spend a greater amount of time in the water column. The rationale for this assumption is that contaminant uptake through the skin or gills would be enhanced by close contact with sediments and interstitial waters. Accordingly, fishes that burrow or bury in sediments and those lacking swimbladders were given a score of 3. Fishes having swimbladders and known to spend considerable time near the bottom were scored 2. Pelagic fishes were scored 1.

Prey Type--

It was assumed that fishes feeding upon sedentary infaunal and small epifaunal organisms have a higher risk of bioaccumulation than fishes preying upon mobile, water-column organisms. The rationale for this assumption is that stationary prey near outfalls have a higher probability of being contaminated by toxic compounds in discharged effluent than do more mobile prey. Fishes preying almost exclusively upon infauna and small epifauna were therefore scored 3. Fishes preying upon mobile prey as well as infauna and small epifauna were scored 2. Fishes that preyed almost exclusively on mobile or water-column prey were scored 1.

Geographic Distribution--

Widespread species are more desirable for 301(h) monitoring programs than are locally restricted fishes. By using widespread species, within-species comparisons among dischargers are facilitated, and variations in the kinds and degrees of bioaccumulation can be evaluated. These comparisons will allow bioaccumulation to be evaluated from a regional perspective, without including the uncertainties inherent in comparing results collected from different species. Thus, fishes found to be abundant in three or more states were scored 3. Species found to be abundant in two states or only one state were scored 2 or 1, respectively. Note that California was subdivided into two regions (northern and southern) to coincide with the natural faunal break that occurs at Point Conception. Species occurring in both California regions were given a score of 2.

Size--

Larger species are more desirable for monitoring programs than are smaller species because adequate amounts of tissue for contaminant analyses can be obtained from single organisms or relatively few organisms pooled. Compositing of many organisms, and the uncertainties associated with it, can thereby be avoided. Length was used as the index of fish size, because that variable was reported more consistently in the regional references than was weight. Fishes with maximum (west coast) or common sizes (east coast) greater than 50 cm (20 in) were scored 3, those larger than or equal to 25 cm (10 in) but smaller than or equal to 50 cm (20 in) were scored 2, and those smaller than 25 cm (10 in) were scored 1.

Abundance--

Abundant species are more desirable for monitoring purposes than are rarer species. The probability of capturing adequate numbers of individuals for bioaccumulation analyses is enhanced by the use of abundant species. Whenever possible, the abundances used to rank species near specific outfalls were pooled across seasons and years to represent time-averaged, long-term patterns. Because the abundances of most species vary seasonally, individual monitoring programs should be designed to accommodate the seasonal patterns of individual target species. Fishes ranking in the top one-third of the most abundant species near each outfall were scored 3, and those in the middle third or lower third were scored 2 or 1, respectively.

Secondary Selection Criteria

Economic Importance--

Species having commercial or recreational importance were ranked higher than species having no economic importance. Because one objective of 301(h) monitoring is to assess commercial and recreational species near discharges, use of an economically important species for bioaccumulation monitoring will contribute simultaneously to two aspects of the monitoring program.

Bioassay Species--

Species recommended for use in bioassays by Peltier and Weber (1983) were ranked higher than species not recommended for these tests. Information regarding impacts on these species will thereby be maximized. However, this does not imply that results of the bioassays and bioaccumulation studies are related directly.

Recommended Target Fish Species

Results of the species selection analyses are presented in Appendix A, Table A-1. Scientific names of the 116 fishes considered during the species selection process are presented in Appendix A, Table A-2. A discussion of the results is provided below.

Candidate monitoring species identified by the detailed species-selection analysis are listed in Table 1. These species ranked highest (i.e., scores ≥12) on the basis of the primary selection criteria.

Inspection of Table 1 shows that certain fishes were candidate monitoring species at several sites within a larger geographic region. It is recommended that, as far as possible, these species be used for bioaccumulation monitoring at all outfalls within each region. This use of a regional monitoring species will allow valid comparisons among different discharge sites.

For Massachusetts and Rhode Island, winter flounder (*Pseudopleuronectes americanus*) is the recommended monitoring species. In addition to being the highest ranking species at every locality within this region, winter flounder is economically important and is a recommended EPA bioassay species.

For New Jersey and Virginia, spot (*Leiostomus xanthurus*) was the highest ranking species at all three localities considered. This species is also economically important and is a recommended EPA bioassay species. It is therefore recommended that this species be used for bioaccumulation monitoring within this region.

TABLE 1. HIGHEST RANKING CANDIDATE FISHES FOR USE AS 301(h) BIOACCUMULATION MONITORING SPECIES

State	Locality	Score	Species	Secondary Selection Criteria: Economic Importance	Secondary Selection Criteria: Bioassay Species
MASSACHUSETTS	Swampscott	13	Winter flounder	Yes	Yes
		13	Yellowtail flounder	Yes	Yes
		13	Ocean pout	No	No
		12	Windowpane	No	No
	Lynn	13	Winter flounder	Yes	Yes
		13	Yellowtail flounder	Yes	No
		13	Ocean pout	No	No
	South Essex	13	Winter flounder	Yes	Yes
		13	Yellowtail flounder	Yes	No
		13	Windowpane	No	No
		12	American eel	No	No
		12	Ocean pout	No	No
	Boston	13	Winter flounder	Yes	Yes
		13	Yellowtail flounder	Yes	No
		12	Ocean pout	No	No
		12	Windowpane	No	No
	Fall River	13	Winter flounder	Yes	Yes
		13	Windowpane	No	No
	New Bedford	13	Winter flounder	Yes	Yes
		12	Scup	Yes	No
		12	Summer flounder	Yes	Yes
RHODE ISLAND	Newport	13	Winter flounder	Yes	Yes
		12	Scup	Yes	No
		12	Weakfish	Yes	No
NEW YORK	Upper East River	13	Winter flounder	Yes	Yes
		13	Windowpane	No	No
		12	Weakfish	Yes	No
	Lower East River	13	Spot	Yes	Yes
		12	Scup	Yes	No
		12	American eel	No	No
	Lower Hudson River	13	Hogchoker	No	No
NEW JERSEY	Cape May	13	Spot	Yes	Yes
		12	Red hake	No	No
		12	Windowpane	No	No
		12	Summer flounder	Yes	Yes
VIRGINIA	Portsmouth	13	Spot	Yes	Yes
		13	Summer flounder	Yes	Yes
		12	Atlantic croaker	Yes	No
		12	Hogchoker	No	No
	Virginia Beach	13	Spot	Yes	Yes
		12	Red hake	No	No
		12	Summer flounder	Yes	Yes

TABLE 1. (Continued)

State	Locality	Score	Species	Secondary Selection Criteria: Economic Importance	Bioassay Species
CALIFORNIA (NORTHERN)	San Francisco	14	English sole	Yes	Yes
		12	Pacific sanddab	Yes	No
		12	Big Skate	No	No
	Oakland	15	English sole	Yes	Yes
		15	Starry flounder	Yes	No
		12	Pacific staghorn sculpin	No	No
	Monterey	13	English sole	Yes	Yes
		12	Curlfin sole	Yes	No
	Santa Cruz	12	English sole	Yes	Yes
	Watsonville	13	English sole	Yes	Yes
		12	Curlfin sole	Yes	No
CALIFORNIA (SOUTHERN)	Goleta	13	Dover sole	Yes	No
		12	Pacific sanddab	Yes	No
		12	Longspine combfish	No	No
		12	Spotted cusk-eel	No	No
	Santa Barbara	13	English sole	Yes	Yes
		12	Pacific sanddab	Yes	No
	L.A. County	13	Dover sole	Yes	No
		12	Curlfin sole	Yes	No
		12	English sole	Yes	Yes
	Orange County	15	Dover sole	Yes	No
		12	Pacific sanddab	Yes	No
		12	English sole	Yes	Yes
	Hyperion	14	Dover sole	Yes	No
	Oceanside	12	Longspine combfish	No	No
		12	Big skate	No	No
	Escondido	12	California skate	No	No
	San Elijo	15	Dover sole	Yes	No
		13	Blackbelly eelpout	No	No
		12	Pacific sanddab	Yes	No
		12	English sole	Yes	Yes
	San Diego	15	Dover sole	Yes	No
		13	English sole	Yes	Yes
		12	Pacific sanddab	Yes	No
		12	Longspine combfish	No	No
WASHINGTON	Central Puget Sound	14	English sole	Yes	Yes
		14	Dover sole	Yes	No
		14	Rock sole	Yes	No
		14	Spotted ratfish	No	No
		13	Rex sole	Yes	No
		12	C-O sole	Yes	No

Fish assemblages within the New York Harbor area were quite varied, and no species was found in the top-ranked group at more than one locality. However, winter flounder scored 11 in the Lower Hudson River and Lower East River, and spot scored 11 in the Upper East River. Because these two fishes are the recommended monitoring species for the regions north and south (respectively) of the New York Harbor area, it is recommended that either one be selected as a monitoring species for each locality within New York Harbor, depending upon site-specific availability.

For northern California, English sole (Parophrys vetulus) was the highest ranking species at all five localities considered. Because this species is also economically important, and is a recommended EPA bioassay species, it is recommended that this fish be used for bioaccumulation monitoring in northern California.

For southern California, Dover sole (Microstomus pacificus) was the highest ranking species at six of the nine localities considered. Because this species also is economically important, it is recommended that this fish be used as the primary bioaccumulation monitoring species for southern California. Because Pacific sanddab (Citharichthys sordidus) was ranked highly at five of the nine localities and because this species is economically important, it is recommended as an alternate bioaccumulation monitoring species, in case Dover sole cannot be sampled adequately.

At one of three southern California localities where Dover sole was not ranked highest (i.e., Santa Barbara), English sole was the highest ranking species. The fish assemblages at the remaining two localities (i.e., Escondido and Oceanside) were unique to the California area because neither Dover sole nor English sole were among the highest ranking fishes. Consequently, the highest ranking species at these sites [i.e., California skate (Raja inornata) and longspine combfish (Zaniolepis latipinnis), respectively] were also unique. Because English sole is the recommended monitoring species for northern California, it is recommended that this fish be used for that purpose off Santa Barbara. At Escondido and Oceanside, it is recommended that every effort be made to capture sufficient numbers of either English sole or Dover sole for bioaccumulation analyses. Possible strategies include increased number of hauls; sampling at dawn, dusk, or night; and sampling during different seasons.

For the Puget Sound area, both English sole and Dover sole were tied for the highest ranking with rock sole (Lepidopsetta bilineata) and spotted ratfish (Hydrolagus colliei). The spotted ratfish is not recommended because of its lack of economic importance. Because English sole and Dover sole are recommended monitoring species for California, it is recommended that they also be used for monitoring in Puget Sound. Determination of which of these two species to use at each locality should be based on site-specific availability.

As mentioned previously, fishes from Florida, Alaska, Puerto Rico, the Virgin Islands, and Hawaii could not be evaluated using the detailed species selection analysis. Therefore, a number of candidate monitoring species were tentatively recommended. Final selections should be made following quantitative site-specific surveys. For all of the above areas except Alaska, it is recommended that territorial chaetodontids (butterflyfishes and angelfishes) or pomacentrids (damselfishes) be used for bioaccumulation monitoring. Because these fishes live on reefs, they are frequently found near outfall pipes and associated armor. In addition, their territorial behavior should ensure that these fishes spend most of their time near sampling stations. Because many of these species are relatively small, compositing may be required. For Alaskan bioaccumulation studies, it is recommended that a pleuronectid (righteye flounder) be selected for monitoring purposes. Of the pleuronectids found in Alaska nearshore habitats, English sole is the preferred monitoring species because it is also a recommended monitoring species for Washington and northern California.

LARGE MACROINVERTEBRATES

As mentioned previously, historical 301(h) data regarding large macroinvertebrates has been largely qualitative. The main deterrent to collecting quantitative data has been use of an otter trawl for sampling. Although this device will efficiently capture many large soft-bottom macroinvertebrates, it will not adequately sample organisms associated with cover (e.g., kelp, eelgrass, rocks, coral) or organisms that reside below the sediment surface (e.g., burrowing molluscs). If sufficient numbers of these species cannot be captured using an otter trawl, alternate kinds of sampling gear should be used (e.g., traps, dredges).

Large macroinvertebrates considered as bioaccumulation monitoring candidates were either large bivalve molluscs or large decapod crustaceans, primarily because individuals generally are large enough to provide adequate tissue mass for bioaccumulation analysis and because many of these species are commercially or recreationally important. Bivalve molluscs are preferred over decapod crustaceans because they are relatively sedentary. However, because it was uncertain whether adequate abundances of large bivalves could be found at each discharge site, large decapod crustaceans were recommended as alternate monitoring species.

The recommended large macroinvertebrate species for each region are presented in Table 2. As with fishes, regional uniformity of target species is preferred. However, because many large macroinvertebrates exhibit a greater degree of site specificity than fishes, it is expected that various dischargers within a region may use different monitoring species. The species chosen by each discharger should be present near the zone of initial dilution (ZID), at the ZID boundary, at farfield stations, and in the reference areas. The abundance and distribution of potential monitoring species should be determined prior to monitoring, using sampling devices other than an otter trawl.

The use of small macroinvertebrates (e.g., polychaetes, amphipods, small molluscs) as bioaccumulation monitoring species is attractive because many of these species are relatively sedentary. However, use of small infauna presents several potential problems. Because these species are small, considerable effort and expense is required to sample enough tissue for laboratory analysis. Because the distributions of many of these species are strongly dependent on sediment characteristics, it is unlikely that the same species can be found in adequate abundances within the ZID, at the ZID boundary, at farfield stations, and in the reference areas. Thus, spatial patterns of bioaccumulation will probably be based on interspecific

TABLE 2. RECOMMENDED LARGE MACROINVERTEBRATE SPECIES FOR 301(h) BIOACCUMULATION MONITORING

Region	Recommended Species[a]
Massachusetts to Virginia	American lobster (*Homarus americanus*) Eastern rock crab (*Cancer irroratus*) Hard clam (*Mercenaria mercenaria*) Soft-shell clam (*Mya arenaria*) Ocean quahog (*Arctica islandica*) Surf clam (*Spisula solidissima*) Edible mussel (*Mytilus edulis*)
Alaska to California	Spiny lobster (*Panulirus interruptus*) Dungeness crab (*Cancer magister*) Rock crab (*Cancer antennarius*) Yellow crab (*Cancer anthonyi*) Red crab (*Cancer productus*) Edible mussel (*Mytilus edulis*) California mussel (*Mytilus californianus*)
Florida, Virgin Islands, and Puerto Rico	Spiny lobster (*Panulirus argus*)
Hawaii	Spiny lobster (*Panulirus penicillatus*)

[a] Additional species that may occur at specific discharge sites and are considered acceptable bioaccumulation monitoring species include the American oyster (*Crassostrea virginica*) and the Pacific oyster (*Crassostrea gigas*).

comparisons, which are very difficult to interpret. Finally, depuration, if required, will be difficult or impossible because many organisms will be injured or killed during the sieving and sorting processes.

If small macroinvertebrates will be used as monitoring species, it is recommended that the _Macoma_ spp. be considered as the primary candidates. These species are generally found in large abundances in organically enriched sediments and are consumed by a variety of fishes. In addition, because _Macoma_ spp. are deposit feeders, they have considerable potential for ingestion of sediment-associated contaminants.

ADDITIONAL SAMPLING CONSIDERATIONS

This section briefly discusses two important sampling variables for bioaccumulation monitoring that must be selected after the target species have been identified: the tissue(s) to analyze and the time(s) to collect the organisms. Because these variables are highly dependent on the objectives of individual monitoring programs, only general recommendations and guidance can be given.

TISSUE SELECTION

For fishes, it is recommended that edible muscle and/or liver tissue be analyzed for contaminants. Contaminants in edible muscle tissue represent the compounds that are retained by fishes in a form that allows transfer to humans and thereby results in possible restrictions being placed on commercial or recreational fisheries. Liver tissue is closely associated with regulation and storage of many toxic compounds (Fowler 1982). Contaminant concentrations in liver tissue can therefore be used to estimate the range of contaminants being assimilated by the fishes, and to evaluate the possible effects of those contaminants on the health of the fishes. Chemical analyses of liver tissue can also be used to establish links between bioaccumulation and histopathology data.

For crabs and lobsters, it is recommended that edible muscle and/or hepatopancreas tissue be analyzed for contaminants for purposes analagous to those described previously for fish muscle and liver tissue. For bivalve molluscs, contaminant analyses should be conducted on all soft-body tissues.

For whole-body analyses of bivalve molluscs, depuration may or may not be required, depending on the objectives of each particular monitoring study. If organisms are not depurated, contaminants in the gut contents that have not been incorporated into body tissue will be included in the results. Because most predators consume whole bivalves, including gut contents, results from undepurated organisms provide an accurate estimate of the total amount of contaminants available to most predators. Depuration is most appropriate for estimating the amount of contaminants that are retained in the tissue of a bivalve mollusc and may thereby pose a health threat to that organism. However, the depuration process must be conducted carefully to ensure that all individuals depurate completely and to avoid contaminating organisms during the process. From the standpoint of commercial and recreational fisheries, depuration is not always conducted before organisms are consumed by humans. Therefore, evaluation of undepurated organisms provides a conservative (i.e., worst-case) estimate of contaminant concentrations in economically important bivalves.

TIME OF SAMPLING

The reproductive cycles of marine organisms exert a major influence on the tissue levels of many contaminants (review in Phillips 1980). Thus, the time of sampling for bioaccumulation monitoring is an important consideration. Ideally, the target species should be sampled when tissue contaminant concentrations are expected to be at their highest levels, so that the worst-case conditions of bioaccumulation can be evaluated. An effort should therefore be made to coordinate the time of sampling with the reproductive cycle of each target species. If such an effort is made, the sampling period for each monitoring program will depend upon the species (fish and large macroinvertebrate) selected for analysis. Once a sampling period is chosen for a species, it should remain constant over time, so that valid interannual comparisons can be made.

HISTORICAL DATA FOR TARGET SPECIES

Historical data on priority pollutant concentrations in tissues of the recommended target species identified in the previous section are presented below. These data were compiled to assist the interpretation of 301(h) monitoring data. For example, the data for a target species at a particular discharge site can be compared with historical data for the same species during different time periods and at various locations throughout the United States. The following sections present the approach, data summaries, and data gaps for the compilation of historical data on priority pollutant concentrations in tissues of the recommended target species.

APPROACH

Relevant literature on priority pollutant concentrations in tissues was compiled by: 1) a manual search of Tetra Tech files and the University of Washington library system; 2) computerized searches of NTIS, Oceanic Abstracts, and Enviroline data bases; 3) examination of the bibliographies contained in recent reviews of bioaccumulation literature (e.g., Phillips 1980; annual marine pollution review articles in the Journal of the Water Pollution Control Federation); and 4) personal contacts with scientific investigators. Data in the 301(h) applications that were not also available in the published literature were judged to be of questionable quality (e.g., because of small sample sizes, lack of methods documentation, or inadequate QA/QC). Therefore, these limited data were not included in the data review. The literature search covered only January, 1974, through September, 1984. Earlier data were excluded because of the relatively primitive nature of analytical methods used to determine contaminant residues. The initial compilation of literature was limited to information on resident populations of target species from locations along the east and west coasts of the United States, from Hawaii, and from the Caribbean Islands. These are the locations of 301(h) sewage discharges. Tissue concentrations measured in laboratory exposures (e.g., bioassays) were not included in this review because such data are not directly comparable with field data.

After the initial literature compilation, each study was evaluated according to the criteria presented in Appendix B. Data were rejected for any of the following reasons:

- Inadequate documentation of sampling sites, dates, or methods
- Improper methods for sample collection, processing, or analysis
- Lack of analytical standards
- Lack of quality assurance/quality control specifications.

A total of 64 data sets were evaluated, and 34 of these were accepted for inclusion in the historical data base (Appendix C). Because of the large amount of acceptable mussel data, only representative data from recent studies were compiled (Appendix D). Major data gaps are described at the end of this section. Data for species recommended secondarily as target organisms (i.e., Macoma spp., Pacific oyster, American oyster, and Pacific sanddab) were not compiled. However, references to those data are presented in Appendix E.

Data were compiled for muscle tissue and liver tissue of target fish species, for muscle tissue of target macroinvertebrate species, and for whole-body tissue (soft tissue) of target bivalve species. Data for a specific body part (i.e., foot) of the ocean quahog and the surf clam were also included, because of the relatively small amount of data for whole-body analyses in these species. Initially, available data for all priority pollutants were compiled. Because only one study provided analyses for all volatile and acid-extractable priority pollutant compounds, the limited data for these pollutants were not included in the final Appendix tables. Data for these compounds are presented separately later in the text.

The data were compiled initially by study (Appendix D, Tables D-1 and D-2) and then sorted by species, tissue, and general sampling area (Appendix D, Table D-3 and D-4). Before examining the tissue concentration data, sampling locations were classified into two general sampling areas: 1) areas near known sources of contamination and 2) areas removed from known sources of contamination. The original authors' classifications for sampling locations were used whenever they were available. In most cases, sampling locations were classified by examining the authors' description of the sampling site relative to known locations of pollutant discharges. The data for each species were summarized by taking the median and overall range of the compiled data. The median was derived from whatever values were reported by the original authors (e.g., means, medians, and individual organism observations). Those original values appear in the "Value" columns of Tables D-3 and D-4 in Appendix D. The median was used rather than the mean because it is biased less by extreme values. Detection limits for "undetected" results were included in the determination of the median. The "overall range," which is presented in the results section below, is the range of observations in the "Value", "Minimum", and "Maximum" columns of Appendix D tables.

DATA SUMMARIES

The complete data compilations are shown in Appendix D, Tables D-1 through D-4, including data on all metals and 28 organic compounds on the priority pollutant list. The chemicals that have received the most attention in bioaccumulation studies of target species are metals, PCBs, DDT, and polynuclear aromatic hydrocarbons (PAH). Only a few studies (Malins et al. 1980; MacLeod et al. 1981; Ladd et al. 1984; Tetra Tech, 1985b) analyzed for a wide variety of organic priority pollutants.

A summary of results for each species and tissue type is provided in Tables 3-20. The general lack of a substantial difference in tissue contaminant concentrations between areas near and removed from known contaminant sources (Tables 3-20) is probably due to the subjective classification of sites by the original authors or the present reviewers, the wide range of reference conditions represented by samples collected from a broad geographic

TABLE 3. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF WINTER FLOUNDER (*Pseudopleuronectes americanus*)

Pollutant	Near Contaminant Sources: Median[a]	Range[b]		(n)[c]	Removed from Contaminant Sources: Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.005	< 0.001	< 0.100	29	0.085	< 0.070	< 0.100	6
Arsenic				0				0
Cadmium	0.002	< 0.001	0.180	29	0.085	< 0.070	< 0.100	6
Chromium	0.011	< 0.005	1.350	28	0.490	0.120	1.270	6
Copper	0.117	0.070	1.100	28	0.230	0.150	0.340	6
Mercury	0.060	0.030	0.120	5	0.040	0.023	0.106	5
Nickel	0.021	< 0.019	0.500	28	0.180	0.140	0.350	6
Lead	0.025	< 0.018	< 0.800	29	0.500	< 0.500	< 0.600	6
Selenium				0				0
Zinc	4.170	1.420	6.480	28	4.250	1.930	6.220	6
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	2.00	< 0.60	6.00	6	1.22	< 0.63	6.90	4
Anthracene	0.60	< 0.60	< 0.80	6	0.88	< 0.63	< 1.00	4
Phenanthrene	0.70	< 0.60	1.00	6	0.92	< 0.63	< 1.15	4
Fluorene				0				0
Fluoranthene	0.90	< 0.60	6.00	6	0.92	< 0.63	< 1.15	4
Benzo(a)anthracene	1.80	< 1.40	< 2.00	6	1.95	< 1.47	< 2.30	4
Benzo(a)pyrene	1.10	< 0.80	< 4.00	6	1.13	< 1.05	< 1.38	4
Chrysene	0.90	< 0.80	< 1.60	6	1.10	< 0.84	< 1.20	4
Pyrene	0.90	< 0.60	1.00	6	0.92	< 0.63	< 1.15	4
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.90	< 0.60	1.20	6	0.92	< 0.63	< 1.15	4
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	100.00	50.00	560.00	47	38.00	5.00	140.00	16
Aldrin	0.40	< 0.20	< 0.80	6	0.72	< 0.42	< 0.92	4
Dieldrin	0.90	< 0.80	4.00	6	1.13	< 0.84	< 1.38	4
Chlordane	7.00	6.00	8.00	6	1.08	0.84	1.68	4
DDT	2.00	< 1.40	4.00	6	1.64	< 1.05	< 2.07	4
ΣDDT, DDD, DDE	12.00	3.00	26.00	39	5.50	< 3.00	35.00	12
DDE	10.00	1.00	10.00	6	2.15	1.68	4.20	4
DDD				0				0
ΣEndosulfan				0				0
Endrin	0.40	< 0.20	< 0.80	6	0.72	< 0.42	< 0.92	4
Heptachlor	0.60	< 0.40	< 1.00	6	0.92	< 0.63	< 1.15	4
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	0.90	< 0.80	2.00	6	0.92	< 0.63	< 1.15	4

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 4. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN LIVER TISSUE OF WINTER FLOUNDER (*Pseudopleuronectes americanus*)

Pollutant	Near Contaminant Sources Median[a]	Range[b]		(n)[c]	Removed from Contaminant Source Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.175	0.042	0.800	30	0.101	0.050	0.265	6
Arsenic				0				0
Cadmium	0.168	< 0.010	< 0.300	29	0.082	0.052	0.233	6
Chromium	0.045	< 0.025	< 0.600	18	0.021	< 0.018	0.047	6
Copper	6.450	1.440	13.800	28	3.490	1.470	9.350	6
Mercury	0.065	< 0.030	0.170	10				0
Nickel	0.300	< 0.094	< 1.000	28	0.076	< 0.030	< 0.111	6
Lead	0.800	< 0.076	< 1.500	29	0.119	< 0.061	0.386	6
Selenium				0				0
Zinc	28.000	15.000	45.000	28	28.550	23.300	35.700	6
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	70.80	11.60	130.00	2				0
Anthracene	1.39	< 1.04	< 1.74	2				0
Phenanthrene	1.39	< 1.04	< 1.74	2				0
Fluorene				0				0
Fluoranthene	1.44	< 0.84	< 2.03	2				0
Benzo(a)anthracene	1.97	< 1.04	< 2.90	2				0
Benzo(a)pyrene	1.68	< 1.04	< 2.32	2				0
Chrysene	1.86	< 1.40	< 2.32	2				0
Pyrene	1.54	< 1.04	< 2.03	2				0
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	4.05	< 0.29	< 7.80	2				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	4550.00	400.00	10000.00	40	1200.00	250.00	4140.00	25
Aldrin	6.79	< 0.58	< 13.00	2				0
Dieldrin	6.79	< 0.58	< 13.00	2				0
Chlordane	15.20	13.00	17.40	2				0
DDT	27.30	< 2.60	< 52.00	2				0
ΣDDT, DDD, DDE	665.00	55.00	1600.00	38	305.00	100.00	650.00	12
DDE	247.44	< 0.87	494.00	2				0
DDD				0				0
ΣEndosulfan				0				0
Endrin	13.58	< 1.16	< 26.00	2				0
Heptachlor	6.94	< 0.87	< 13.00	2				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	13.58	< 1.16	< 26.00	2				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 5. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF SPOT (*Leiostomus xanthurus*)

Pollutant	Near Contaminant Sources			Removed from Contaminant Sources		
	Median[a]	Range[b]	(n)[c]	Median	Range	(n)
Metals (ppm wet wt.)						
Silver			0			0
Arsenic			0			0
Cadmium			0			0
Chromium			0			0
Copper			0			0
Mercury			0			0
Nickel			0			0
Lead			0			0
Selenium			0			0
Zinc			0			0
Organics (ppb wet wt.)						
Acenaphthene			0			0
Naphthalene			0			0
Anthracene			0			0
Phenanthrene			0			0
Fluorene			0			0
Fluoranthene			0			0
Benzo(a)anthracene			0			0
Benzo(a)pyrene			0			0
Chrysene			0			0
Pyrene			0			0
1,2,4-trichlorobenzene			0			0
Hexachlorobenzene			0			0
Dichlorobenzene			0			0
Hexachlorobutadiene			0			0
ΣPCB	240.00	240.00 290.00	1	30.00	30.00 30.00	1
Aldrin			0			0
Dieldrin			0			0
Chlordane			0			0
DDT			0			0
ΣDDT, DDD, DDE			0			0
DDE			0			0
DDD			0			0
ΣEndosulfan			0			0
Endrin			0			0
Heptachlor			0			0
Heptachlor epoxide			0			0
αBHC			0			0
βBHC			0			0
γBHC			0			0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 6. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF ENGLISH SOLE (*Parophrys vetulus*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0				0
Arsenic				0				0
Cadmium				0				0
Chromium				0				0
Copper				0				0
Mercury				0				0
Nickel				0				0
Lead				0				0
Selenium				0				0
Zinc				0				0
Organics (ppb wet wt.)								
Acenaphthene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Naphthalene	20.00	U 10.00	<1322.00	8	54.00	< 54.00	< 54.00	1
Anthracene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Phenanthrene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Fluorene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Fluoranthene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Benzo(a)anthracene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Benzo(a)pyrene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Chrysene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
Pyrene	10.00	U 10.00	U 10.00	8	10.00	U 10.00	U 10.00	1
1,2,4-trichlorobenzene	20.00	U 20.00	U 20.00	8	20.00	U 20.00	U 20.00	1
Hexachlorobenzene	10.00	U 10.00	< 15.00	8	10.00	U 10.00	U 10.00	1
Dichlorobenzene	40.00	U 40.00	U 42.00	8	40.00	U 40.00	U 40.00	1
Hexachlorobutadiene	40.00	U 40.00	< 41.00	8	40.00	U 40.00	U 40.00	1
ΣPCB	171.00	40.00	354.00	8	36.00	< 36.00	< 36.00	1
Aldrin	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
Dieldrin	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
Chlordane	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
DDT	50.00	U 50.00	U 95.00	8	50.00	50.00	50.00	1
ΣDDT, DDD, DDE				0				0
DDE	50.00	U 50.00	U 95.00	8	50.00	50.00	50.00	1
DDD	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
ΣEndosulfan	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
Endrin	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
Heptachlor	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1
Heptachlor epoxide	50.00	U 50.00	U 93.00	8	50.00	U 50.00	U 50.00	1
αBHC				0				0
βBHC				0				0
γBHC	50.00	U 50.00	U 95.00	8	50.00	U 50.00	U 50.00	1

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.
< = maximum value of mean shown; mean calculated using detection limits for undetected results.

TABLE 7. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN LIVER TISSUE OF ENGLISH SOLE (*Parophrys vetulus*)

Pollutant	Near Contaminant Sources Median[a]	Range[b]		(n)[c]	Removed from Contaminant Sources Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0				0
Arsenic				0				0
Cadmium	0.895	0.639	1.430	7	1.490	1.490	1.490	1
Chromium	0.775	0.459	1.090	2				0
Copper	5.450	3.510	12.600	7	3.060	3.060	3.060	1
Mercury				0				0
Nickel	0.924	0.637	1.210	2				0
Lead				0				0
Selenium				0				0
Zinc	34.600	29.400	38.900	7	28.400	28.400	28.400	1
Organics (ppb wet wt.)								
Acenaphthene	2.50	< 0.24	62.10	19	1.20	< 1.05	< 4.80	3
Naphthalene	12.50	2.00	< 81.60	18	1.20	< 1.05	< 16.80	3
Anthracene	4.20	< 0.23	14.40	19	1.40	< 1.26	< 7.20	3
Phenanthrene	2.23	< 1.00	18.40	8	1.13	< 1.05	< 1.20	2
Fluorene	2.50	< 0.80	14.40	19	1.20	< 1.05	< 4.80	3
Fluoranthene	7.20	< 0.24	< 45.60	19	1.40	< 1.26	< 33.60	3
Benzo(a)anthracene	9.20	< 0.48	52.80	19	4.00	< 2.10	< 14.40	3
Benzo(a)pyrene	5.00	< 0.24	< 170.40	19	2.00	< 1.89	< 7.20	3
Chrysene	4.60	< 0.24	36.00	19	1.80	< 1.68	< 7.20	3
Pyrene	4.60	< 1.00	264.00	19	7.20	< 1.40	10.50	3
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	4.60	0.92	888.00	19	2.10	2.00	28.80	3
Dichlorobenzene	2.30	< 0.24	< 7.20	19	2.00	0.81	< 2.40	3
Hexachlorobutadiene	2.40	0.40	2064.00	19	0.21	0.20	2.40	3
ΣPCB	2111.40	420.20	8054.60	19	592.00	331.80	1521.60	3
Aldrin	0.46	< 0.07	69.60	17	0.08	< 0.04	< 0.24	3
Dieldrin				0				0
Chlordane	7.20	0.96	20.70	19	2.00	0.24	2.10	3
DDT	21.60	2.50	144.90	19	6.30	2.40	12.00	3
ΣDDT, DDD, DDE				0				0
DDE	86.70	12.20	1382.40	19	20.00	12.60	79.20	3
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor	0.42	< 0.07	12.00	17	0.11	< 0.08	< 0.48	3
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	0.48	< 0.09	24.00	17	0.08	< 0.06	< 0.48	3

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 8. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF DOVER SOLE (*Microstomus pacificus*)

Pollutant	Near Contaminant Sources					Removed from Contaminant Sources				
	Median[a]	Range[b]			(n)[c]	Median	Range			(n)
Metals (ppm wet wt.)										
Silver	0.005	< 0.005		0.050	7	0.005	< 0.005		0.025	7
Arsenic					0					0
Cadmium	0.004	< 0.002	U	0.750	7	0.003	< 0.002	U	0.750	7
Chromium	0.013	< 0.008	U	0.050	7	0.012	0.009	U	0.050	7
Copper	0.084	0.058		0.150	7	0.074	0.052		0.130	7
Mercury	0.055	0.021		0.122	2	0.157	0.050		3.170	1
Nickel	0.036	< 0.026	U	0.500	7	0.043	< 0.037	U	0.500	7
Lead	0.073	< 0.069		0.330	7	0.078	< 0.070	U	0.330	7
Selenium					0					0
Zinc	2.150	1.900		9.850	7	1.980	1.720		9.500	7
Organics (ppb wet wt.)										
Acenaphthene					0					0
Naphthalene					0					0
Anthracene					0					0
Phenanthrene					0					0
Fluorene					0					0
Fluoranthene					0					0
Benzo(a)anthracene					0					0
Benzo(a)pyrene					0					0
Chrysene					0					0
Pyrene					0					0
1,2,4-trichlorobenzene					0					0
Hexachlorobenzene					0					0
Dichlorobenzene					0					0
Hexachlorobutadiene					0					0
ΣPCB	1100.00	37.00		6300.00	33	14.00	6.00		1400.00	15
Aldrin					0					0
Dieldrin					0					0
Chlordane					0					0
DDT					0					0
ΣDDT, DDD, DDE	10650.00	40.00		98000.00	40	37.00	13.00		2700.00	15
DDE					0					0
DDD					0					0
ΣEndosulfan					0					0
Endrin					0					0
Heptachlor					0					0
Heptachlor epoxide					0					0
αBHC					0					0
βBHC					0					0
γBHC					0					0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 9. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN LIVER TISSUE OF DOVER SOLE (*Microstomus pacificus*)

Pollutant	Near Contaminant Sources: Median[a]	Range[b]		(n)[c]	Removed from Contaminant Sources: Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.100	0.091	0.246	7	0.103	0.060	0.153	7
Arsenic	1.300	1.300	1.500	3	3.100	3.100	3.100	1
Cadmium	0.356	0.190	1.050	10	0.842	0.428	1.600	8
Chromium	0.204	0.100	0.582	7	0.051	< 0.034	0.126	7
Copper	3.295	1.900	8.270	10	2.300	1.580	2.970	8
Mercury	1.240	0.050	0.296	5	0.126	0.078	0.329	2
Nickel	0.080	< 0.050	0.650	7	0.200	< 0.130	0.350	7
Lead	0.152	< 0.044	1.300	7	0.438	< 0.098	1.300	7
Selenium	0.660	0.650	0.970	3	1.200	1.200	1.200	1
Zinc	26.100	23.000	40.200	10	24.600	16.500	43.600	8
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	20.00	20.00	20.00	1				0
Anthracene				0				0
Phenanthrene				0				0
Fluorene				0				0
Fluoranthene				0				0
Benzo(a)anthracene				0				0
Benzo(a)pyrene				0				0
Chrysene				0				0
Pyrene				0				0
1,2,4-trichlorobenzene	7.00	7.00	7.00	1				0
Hexachlorobenzene	6.00	6.00	6.00	1				0
Dichlorobenzene	27.00	27.00	27.00	1				0
Hexachlorobutadiene				0				0
ΣPCB	17000.00	760.00	56000.00	27	71.00	7.00	5600.00	7
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT	2600.00	168.00	46000.00	3	13000.00	13000.00	13000.00	1
ΣDDT, DDD, DDE	270000.00	29000.00	1100000.00	24	385.00	160.00	1100.00	12
DDE	19000.00	19000.00	19000.00	1				0
DDD	549.00	549.00	549.00	1				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor	3.00	3.00	3.00	1				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 10. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF AMERICAN LOBSTER (*Homarus americanus*)

Pollutant	Near Contaminant Sources Median[a]	Near Contaminant Sources Range[b]		(n)[c]	Removed from Contaminant Sources Median	Removed from Contaminant Sources Range		(n)
Metals (ppm wet wt.)								
Silver	0.390	0.100	0.730	6	0.555	0.500	0.610	2
Arsenic				0				0
Cadmium	0.020	0.011	0.360	36	0.014	0.010	0.120	12
Chromium	0.375	<0.100	0.520	6	0.380	0.260	0.500	2
Copper	4.725	2.270	9.460	6	11.475	7.470	15.480	2
Mercury	0.175	0.040	0.500	36	0.150	0.060	0.360	12
Nickel	0.175	0.080	0.460	6	0.260	0.250	0.270	2
Lead	0.350	0.200	0.600	6	0.400	0.300	< 0.500	2
Selenium				0				0
Zinc	13.950	5.750	18.030	6	16.845	14.440	19.250	2
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	6.45	< 0.64	9.20	6	7.20	< 0.88	9.50	6
Anthracene	0.92	< 0.51	< 1.47	6	1.35	< 0.76	< 3.60	6
Phenanthrene	1.28	< 0.69	5.10	6	1.25	< 0.76	< 3.60	6
Fluorene				0				0
Fluoranthene	3.30	< 1.10	23.00	6	1.44	< 0.76	< 3.60	6
Benzo(a)anthracene	2.07	< 1.36	< 4.20	6	3.80	< 1.90	< 9.00	6
Benzo(a)pyrene	1.15	< 1.02	< 2.10	6	1.64	< 0.95	< 5.40	6
Chrysene	1.24	< 0.68	< 2.10	6	1.64	< 0.95	< 5.40	6
Pyrene	4.95	< 1.10	46.00	6	1.53	< 1.10	< 3.60	6
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.63	< 0.04	1.15	6	0.02	< 0.02	0.08	6
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	165.00	40.00	410.00	36	40.00	1.00	200.00	19
Aldrin	0.08	< 0.02	< 0.10	6	0.04	< 0.02	< 0.04	6
Dieldrin	2.25	< 0.02	6.40	6	0.07	< 0.02	< 0.18	6
Chlordane	1.43	1.05	4.80	6	0.07	< 0.02	1.90	6
DDT	50.00	< 0.21	U 50.00	36	50.00	< 0.04	U 50.00	16
ΣDDT, DDD, DDE				0				0
DDE	8.00	6.30	13.20	6	6.81	0.22	15.20	6
DDD				0				0
ΣEndosulfan				0				0
Endrin	0.14	< 0.05	< 0.21	6	0.13	< 0.02	< 1.44	6
Heptachlor	0.19	< 0.02	0.80	6	0.06	< 0.02	< 0.09	6
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	0.09	< 0.02	0.23	6	0.07	< 0.02	< 0.09	6

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 11. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF EASTERN ROCK CRAB (*Cancer irroratus*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.270	0.160	0.790	9	0.250	0.140	0.810	8
Arsenic	1.900	1.900	1.900	1				0
Cadmium	0.100	< 0.060	1.000	9	0.080	< 0.070	< 0.270	8
Chromium	0.600	< 0.300	1.340	9	0.970	0.250	1.390	8
Copper	7.755	3.240	25.400	8	6.750	3.690	10.040	7
Mercury	0.180	0.160	0.190	3	0.155	0.150	0.160	2
Nickel	0.470	0.260	0.550	5	0.490	0.300	0.640	7
Lead	0.900	< 0.300	3.400	9	0.500	< 0.300	< 1.600	8
Selenium				0				0
Zinc	40.080	29.070	64.600	8	37.245	4.180	59.260	8
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	1.20	< 0.80	< 1.33	3	1.10	< 1.00	< 1.40	6
Anthracene	1.14	< 1.00	< 1.40	3	1.17	< 1.10	< 1.60	6
Phenanthrene	1.33	< 1.00	< 1.40	3	1.33	< 1.00	< 1.60	6
Fluorene				0				0
Fluoranthene	1.33	< 1.00	< 1.40	3	1.40	< 1.20	< 1.80	6
Benzo(a)anthracene	3.80	< 2.00	< 4.00	3	3.90	< 2.00	< 4.40	6
Benzo(a)pyrene	1.90	< 1.40	< 2.00	3	1.94	< 1.60	< 2.10	6
Chrysene	1.71	< 1.20	< 2.00	3	1.80	< 1.40	< 2.00	6
Pyrene	1.33	< 1.00	< 1.60	3	1.40	< 1.20	< 1.80	6
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.06	< 0.04	< 0.20	3	0.11	< 0.04	0.22	6
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	40.00	30.00	60.00	3	40.00	0.40	70.00	6
Aldrin	0.08	< 0.06	< 0.20	3	0.06	< 0.04	< 0.20	6
Dieldrin	0.06	< 0.04	< 0.08	3	0.04	< 0.04	< 0.20	6
Chlordane	0.57	< 0.20	1.80	3	0.82	< 0.06	1.10	6
DDT	0.40	< 0.19	1.20	3	1.10	< 0.22	1.60	6
ΣDDT, DDD, DDE				0				0
DDE	6.46	1.20	14.00	3	6.45	2.00	8.00	6
DDD				0				0
ΣEndosulfan				0				0
Endrin	0.20	< 0.19	< 0.40	3	0.21	< 0.09	< 0.60	6
Heptachlor	0.20	< 0.08	< 0.20	3	0.08	< 0.07	< 0.20	6
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	0.20	< 0.08	< 0.20	3	0.08	< 0.07	< 0.20	6

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 12. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF DUNGENESS CRAB (*Cancer magister*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0				0
Arsenic				0				0
Cadmium				0				0
Chromium				0				0
Copper				0				0
Mercury	0.230	0.230	0.230	1	0.050	0.050	0.050	1
Nickel				0				0
Lead				0				0
Selenium				0				0
Zinc				0				0
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene				0				0
Fluorene				0				0
Fluoranthene				0				0
Benzo(a)anthracene				0				0
Benzo(a)pyrene				0				0
Chrysene				0				0
Pyrene				0				0
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB				0				0
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE				0				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 13. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF YELLOW CRAB (*Cancer anthonyi*)

Pollutant	Near Contaminant Sources Median[a]	Near Contaminant Sources Range[b]		(n)[c]	Removed from Contaminant Sources Median	Removed from Contaminant Sources Range		(n)
Metals (ppm wet wt.)								
Silver	0.098	0.090	0.190	2	0.220	0.080	0.290	1
Arsenic				0				0
Cadmium	0.007	0.004	0.010	2	0.010	< 0.010	0.010	1
Chromium	0.080	0.050	0.090	2	0.040	< 0.020	0.060	1
Copper	7.840	7.840	7.840	1	13.000	3.600	15.000	1
Mercury	0.064	0.023	0.210	3	0.071	0.068	0.170	1
Nickel	0.260	0.220	0.510	2	0.040	< 0.040	< 0.050	1
Lead	0.140	0.030	0.450	2	0.150	< 0.150	< 0.160	1
Selenium				0				0
Zinc	25.200	25.200	25.200	1	97.000	34.000	210.000	1
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene				0				0
Fluorene				0				0
Fluoranthene				0				0
Benzo(a)anthracene				0				0
Benzo(a)pyrene				0				0
Chrysene				0				0
Pyrene				0				0
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	190.00	190.00	190.00	1				0
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE	1500.00	1500.00	1500.00	1				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 14. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN MUSCLE TISSUE OF SPINY LOBSTER (*Panulirus interruptus*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.050	< 0.010	0.060	1	0.015	< 0.010	0.030	2
Arsenic				0				0
Cadmium	0.020	< 0.010	0.040	1	0.010	< 0.010	0.030	2
Chromium	0.030	< 0.020	0.030	1	0.030	0.010	0.100	2
Copper				0				0
Mercury	0.280	0.210	0.480	1	0.265	0.092	0.380	2
Nickel	0.050	< 0.050	< 0.050	1	0.055	< 0.050	< 0.080	2
Lead	0.230	< 0.230	< 0.260	1	0.205	< 0.090	0.210	2
Selenium				0				0
Zinc				0				0
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene				0				0
Fluorene				0				0
Fluoranthene				0				0
Benzo(a)anthracene				0				0
Benzo(a)pyrene				0				0
Chrysene				0				0
Pyrene				0				0
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB				0				0
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE				0				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 15. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN WHOLE HARD CLAM (*Mercenaria mercenaria*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0				0
Arsenic				0				0
Cadmium	0.200	U 0.002	0.486	15	0.200	0.100	0.400	16
Chromium				0				0
Copper	2.800	1.120	5.780	15	1.900	1.000	2.600	16
Mercury				0				0
Nickel				0				0
Lead	0.321	U 0.002	1.480	1				0
Selenium				0				0
Zinc	19.500	0.326	53.300	15	14.550	7.500	29.300	16
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene				0	0.15	0.10	0.20	2
Fluorene				0				0
Fluoranthene				0	0.75	0.70	0.80	2
Benzo(a)anthracene				0	0.20	0.10	0.30	2
Benzo(a)pyrene				0				0
Chrysene				0				0
Pyrene				0	0.45	0.30	0.60	2
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB				0				0
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE				0				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 16. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN WHOLE SOFT-SHELL CLAM (*Mya arenaria*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0				0
Arsenic				0				0
Cadmium				0				0
Chromium				0				0
Copper				0				0
Mercury				0	0.100	0.100	0.100	1
Nickel				0				0
Lead				0				0
Selenium				0				0
Zinc				0				0
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene	155.40	144.40	162.30	6	10.50	9.40	17.40	5
Fluorene				0				0
Fluoranthene	114.85	89.90	121.10	6	10.20	7.70	14.20	6
Benzo(a)anthracene	30.25	25.30	71.50	6	2.75	2.00	4.50	6
Benzo(a)pyrene	8.25	7.40	11.40	6	3.30	2.30	5.50	6
Chrysene	25.15	21.50	38.90	6	7.90	5.90	8.90	6
Pyrene	54.90	47.30	98.80	6	6.15	5.30	7.90	6
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB				0				0
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE				0				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 17. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN OCEAN QUAHOG (*Arctica islandica*)

Pollutant	Near Contaminant Sources Median[a]	Range[b]		(n)[c]	Removed from Contaminant Sources Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0	1.410	0.580	2.620	6
Arsenic				0	2.825	2.410	3.900	6
Cadmium				0	0.390	< 0.060	0.900	15
Chromium				0	0.710	0.260	2.500	16
Copper				0	2.820	0.100	7.160	18
Mercury				0	0.100	< 0.060	1.170	15
Nickel				0	1.850	< 0.500	7.000	18
Lead				0	1.400	< 0.900	2.600	16
Selenium				0				0
Zinc				0	13.100	2.400	25.800	18
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene				0	1.00	U 1.00	9.10	25
Anthracene				0				0
Phenanthrene				0	1.80	U 1.00	4.00	25
Fluorene				0				0
Fluoranthene				0				0
Benzo(a)anthracene				0				0
Benzo(a)pyrene				0	1.00	U 1.00	6.00	25
Chrysene				0				0
Pyrene				0				0
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene				0				0
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB				0	11.00	1.50	26.80	25
Aldrin				0				0
Dieldrin				0				0
Chlordane				0				0
DDT				0				0
ΣDDT, DDD, DDE				0				0
DDE				0				0
DDD				0				0
ΣEndosulfan				0				0
Endrin				0				0
Heptachlor				0				0
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC				0				0

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 18. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN SURF CLAM (*Spisula solidissima*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver				0	0.725	0.190	1.630	10
Arsenic				0	2.170	1.460	2.630	10
Cadmium				0	0.130	< 0.110	0.150	10
Chromium				0	0.615	< 0.480	0.950	10
Copper				0	3.230	2.870	3.830	10
Mercury				0	0.075	< 0.050	< 0.080	10
Nickel				0	0.600	< 0.390	0.800	5
Lead				0	0.700	< 0.600	< 0.700	10
Selenium				0				0
Zinc				0	10.150	9.100	18.500	10
Organics (ppb wet wt.)								
Acenaphthene				0				0
Naphthalene	2.00	< 0.44	4.50	7	2.00	< 0.99	4.80	7
Anthracene	0.95	< 0.44	< 1.50	7	1.12	< 0.92	< 1.92	7
Phenanthrene	1.00	< 0.66	< 1.50	7	1.20	< 0.92	< 2.40	7
Fluorene				0				0
Fluoranthene	2.20	< 0.90	9.50	7	2.30	< 1.12	6.00	7
Benzo(a)anthracene	3.20	< 1.32	5.70	7	3.20	< 2.30	< 7.20	7
Benzo(a)pyrene	1.52	< 0.88	< 4.00	7	1.50	< 1.32	< 4.80	7
Chrysene	1.52	< 0.66	3.80	7	1.50	< 1.15	< 4.80	7
Pyrene	1.28	< 0.66	3.80	7	1.44	< 0.99	< 2.40	7
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.04	< 0.02	0.19	7	0.05	0.02	0.17	7
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	30.00	20.00	40.00	7	20.00	10.00	70.00	7
Aldrin	0.08	< 0.03	< 0.11	7	0.08	< 0.04	< 0.10	7
Dieldrin	0.08	< 0.02	0.88	7	0.15	< 0.05	3.20	7
Chlordane	0.45	0.16	1.14	7	0.30	< 0.06	0.92	7
DDT	0.45	< 0.15	3.80	7	0.60	< 0.30	1.68	7
ΣDDT, DDD, DDE				0				0
DDE	1.90	0.45	3.80	7	0.45	< 0.08	2.40	7
DDD				0				0
ΣEndosulfan				0				0
Endrin	0.16	< 0.05	< 0.19	7	0.15	< 0.10	< 0.24	7
Heptachlor	0.08	< 0.03	< 0.13	7	0.10	< 0.03	< 0.13	7
Heptachlor epoxide				0				0
αBHC				0				0
βBHC				0				0
γBHC	0.08	< 0.02	0.60	7	0.10	< 0.05	< 0.14	7

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 19. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN WHOLE EDIBLE MUSSEL (*Mytilus edulis*)

Pollutant	Near Contaminant Sources Median[a]	Range[b]		(n)[c]	Removed from Contaminant Sources Median	Range		(n)
<u>Metals (ppm wet wt.)</u>								
Silver	0.050	0.005	18.300	35	0.020	0.002	0.120	74
Arsenic	1.400	1.400	1.400	1	1.400	1.400	1.400	1
Cadmium	0.500	0.043	1.810	35	0.310	0.140	1.300	75
Chromium	0.345	0.170	0.760	9	0.410	0.410	0.410	1
Copper	1.420	0.790	3.290	35	1.200	0.600	6.000	75
Mercury	0.057	0.020	0.084	8	0.040	0.010	0.120	4
Nickel	0.310	0.070	0.740	26	0.310	< 0.050	1.660	73
Lead	0.470	0.090	11.000	35	0.480	< 0.030	2.690	74
Selenium	0.430	0.430	0.430	1	0.590	0.590	0.590	1
Zinc	22.000	9.000	60.000	35	17.400	8.000	55.200	75
<u>Organics (ppb wet wt.)</u>								
Acenaphthene				0				0
Naphthalene				0				0
Anthracene				0				0
Phenanthrene				0	156.10	45.90	284.30	28
Fluorene				0				0
Fluoranthene				0	65.80	10.70	242.20	28
Benzo(a)anthracene				0	44.55	7.00	154.30	28
Benzo(a)pyrene				0	1.65	0.80	33.10	28
Chrysene				0	92.05	47.60	137.60	12
Pyrene				0	28.50	15.40	142.30	28
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.10	< 0.09	0.16	6	0.09	< 0.09	0.81	5
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	145.00	44.00	886.00	23	42.50	U 1.70	240.00	6
Aldrin	0.09	U 0.09	U 0.09	6	0.09	U 0.09	0.84	5
Dieldrin	2.20	0.34	95.00	7	0.52	0.17	31.00	5
Chlordane	44.80	20.30	177.60	8	4.70	1.28	41.40	5
DDT	24.30	4.30	136.20	15	67.00	U 0.52	383.00	7
ΣDDT, DDD, DDE				0				0
DDE	150.30	60.00	708.60	15	80.00	2.80	530.00	7
DDD	34.00	10.20	260.30	15	65.00	2.10	420.90	7
αEndosulfan	0.17	U 0.17	U 0.17	6	45.00	U 0.17	259.00	7
Endrin	1.00	U 1.00	U 1.00	6	1.00	U 1.00	4.80	5
Heptachlor	0.44	U 0.10	2.60	6	0.10	U 0.10	0.34	5
Heptachlor epoxide				0				0
αBHC	0.46	0.43	0.72	6	0.53	0.33	0.71	5
βBHC	0.17	U 0.17	0.41	6	0.17	U 0.17	U 0.17	5
γBHC	0.41	0.17	0.83	6	0.15	U 0.05	0.22	5

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

TABLE 20. SUMMARY OF DATA ON PRIORITY POLLUTANT CONCENTRATIONS IN WHOLE CALIFORNIA MUSSEL (*Mytilus californianus*)

Pollutant	Near Contaminant Sources				Removed from Contaminant Sources			
	Median[a]	Range[b]		(n)[c]	Median	Range		(n)
Metals (ppm wet wt.)								
Silver	0.570	0.100	0.790	5	0.029	0.003	1.810	103
Arsenic	1.700	1.700	1.700	1	2.000	0.720	3.100	8
Cadmium	0.400	0.220	0.930	6	1.100	0.090	3.480	105
Chromium	0.590	0.590	0.590	1	0.280	0.067	0.797	15
Copper	1.500	0.590	1.900	6	1.100	0.430	2.400	104
Mercury	0.030	0.030	0.030	1	0.020	0.000	0.160	14
Nickel	0.380	0.100	0.600	5	0.430	0.210	1.300	89
Lead	1.200	0.620	1.400	5	0.185	< 0.030	4.500	104
Selenium	0.290	0.290	0.290	1	0.470	0.310	0.990	8
Zinc	30.900	20.700	48.300	6	23.850	10.000	47.000	104
Organics (ppb wet wt.)								
Acenaphthene				0	0.22	U 0.08	U 0.88	16
Naphthalene				0	0.32	U 0.11	10.90	16
Anthracene				0	1.20	U 0.22	10.30	16
Phenanthrene				0	5.05	U 0.11	65.50	16
Fluorene				0	0.22	U 0.11	5.79	16
Fluoranthene				0	4.36	U 0.11	65.60	16
Benzo(a)anthracene				0	2.87	U 0.22	25.20	16
Benzo(a)pyrene				0	0.22	U 0.11	9.54	16
Chrysene				0	3.08	U 0.22	30.00	16
Pyrene				0	7.17	0.97	23.40	16
1,2,4-trichlorobenzene				0				0
Hexachlorobenzene	0.09	U 0.09	0.76	4	0.09	U 0.09	0.55	28
Dichlorobenzene				0				0
Hexachlorobutadiene				0				0
ΣPCB	32.00	U 1.70	50.00	4	1.70	U 1.70	62.00	31
Aldrin	0.09	U 0.09	U 0.09	4	0.09	U 0.09	U 0.09	28
Dieldrin	1.05	0.33	1.90	4	1.20	0.21	4.00	28
Chlordane	3.60	2.24	6.03	4	1.28	0.05	6.55	28
DDT	1.47	U 0.52	4.14	4	0.52	U 0.52	14.00	26
ΣDDT, DDD, DDE				0				0
DDE	116.65	11.00	239.00	4	4.74	0.88	87.40	28
DDD	24.00	1.30	33.00	3	0.54	U 0.43	10.00	28
αEndosulfan	0.17	U 0.17	U 0.17	4	0.17	U 0.17	2.40	28
Endrin	1.00	U 1.00	U 1.00	4	1.00	U 1.00	U 1.00	16
Heptachlor	0.10	U 0.10	U 0.10	4	0.10	U 0.10	U 0.10	16
Heptachlor epoxide	0.17	U 0.16	0.17	2	0.16	U 0.16	0.24	23
αBHC	0.70	0.40	1.00	2	1.70	1.00	8.20	5
βBHC	0.17	U 0.17	U 0.17	2	0.17	U 0.17	U 0.17	5
γBHC	0.20	0.17	0.22	2	0.10	U 0.05	0.15	5

[a] Median of "Value" column for given species and tissue in Appendix Tables D-3 and D-4.

[b] Overall range of data in "Value," "Minimum," and "Maximum" columns in Appendix Tables D-3 and D-4.

[c] Number of values used to derive median.

NOTE: U = undetected at detection limit shown.

area, small numbers of samples, or movement of mobile organisms. Note that all data in the "Value" columns of Tables D-3 and D-4, including detection limits and "less-than" quantities, were included in the determination of median values presented in Tables 3-20, but that qualifiers are not shown in association with the medians.

The limitations of these data summaries should be kept in mind when monitoring data from a specific 301(h) site are compared with a "median" or "range" determined from historical data. First, different methods were used to collect, process, and analyze samples. The kinds of data reported by the original authors varied from values for tissue samples from individual organisms to means, medians, or ranges of values from composite samples consisting of a varying number of individuals. Therefore, the data are not strictly comparable among studies. Also, because the number of analyses available for a given species and tissue type generally is small, medians and ranges presented herein should be interpreted with caution.

Concentrations of volatile chemicals and acid-extractable organic compounds in target species from studies that passed the screening criteria are presented in Table 21. Based on these data, concentrations of acid-extractable and volatile organic priority pollutants are expected to be low in tissues of target species from most environments. Possible exceptions are trichlorophenol, pentachlorophenol, tetrachloroethylene, and benzene. None of the acid-extractable and volatile priority pollutants except pentachlorophenol are expected to persist in water or organism tissues, and most have a relatively low bioaccumulation potential (Tetra Tech 1985a). Nevertheless, data in Table 23 suggest that monitoring of priority pollutants in these compound classes should be continued to allow further evaluation of their significance based on a larger database.

Concentrations of detected volatile and acid-extractable organic compounds in samples from Commencement Bay and Carr Inlet (Puget Sound), as shown in Table 23, are maximum possible mean values calculated by using detection limits for "undetected" results from individual samples. It should also be noted that the frequency of detection for many of these substances in muscle tissue of individual organisms is relatively low, even near continuous

TABLE 21. CONCENTRATIONS OF ACID-EXTRACTABLE AND VOLATILE PRIORITY POLLUTANTS IN SELECTED TARGET SPECIES (ppb, wet weight)

Pollutant	Dover Sole-L[a] Palos Verdes Shelf	English Sole-M[b] Commencement Bay Waterways	English Sole-M[b] Carr Inlet	English Sole-LN[c] Commencement Bay Waterways	English Sole-LN[c] Carr Inlet	English Sole-LD[c] Commencement Bay Waterways	English Sole-LD[c] Carr Inlet	*Cancer* Crabs-M[d] Commencement Bay Waterways	*Cancer* Crabs-M[d] Carr Inlet
Acid Extractables									
Phenol	U 10	U 23	U 20	U 65	U 50	< 113	U 100	U 24	U 23
2,4,6-trichlorophenol	85	U 23	U 20	U 131	U 100	U 183	U 200	U 20	U 20
Pentachlorophenol	70	73	U 68	U 262	U 200	U 367	U 400	U 67	U 80
Volatiles									
Dichloroethane	U 0.3	U 15	U 15	NA	NA	NA	NA	NA	NA
1,1,1-trichloroethane	1.5	U 5	U 5	NA	NA	NA	NA	NA	NA
Chloroform	U 10	U 5	U 5	NA	NA	NA	NA	NA	NA
1,2-dichloroethylene	U 0.3	U 5	U 5	NA	NA	NA	NA	NA	NA
Trichloroethylene	4	U 5	U 5	NA	NA	NA	NA	NA	NA
Tetrachloroethylene	19	66	7	NA	NA	NA	NA	NA	NA
Vinyl chloride	U 0.3	U 10	U 10	NA	NA	NA	NA	NA	NA
Benzene	52	U 5	U 5	NA	NA	NA	NA	NA	NA
Ethyl benzene	0.3	15	U 5	NA	NA	NA	NA	NA	NA
Toluene	1	11	11	NA	NA	NA	NA	NA	NA

Key to abbreviations:

L = Liver (condition unspecified)
LN = Normal liver
LD = Diseased liver
M = Muscle
U = Undetected (detection limit shown)
NA = Not analyzed

[a] GC/MS (volatiles and phenol) or GC/EC (chlorinated phenols) analysis of 1-5 composite samples containing 1-10 livers from fish collected 6 km northwest of Whites Point sewage discharge site (Gossett et al. 1983).

[b] GC/MS analysis of acid extractables in 75 (Commencement Bay) or 10 (Carr Inlet) individual fish samples; GC/MS analysis of volatiles in 16 (Commencement Bay) or 4 (Carr Inlet) individual fish samples. Values are means calculated using detection limits for "undetected" results (Tetra Tech, 1985b).

[c] GC/MS analysis of composite liver samples, either normal condition (LN) or diseased (LD) (Tetra Tech, unpublished data). Values are means calculated using detection limits for "undetected" results. Number of composite samples per value is 13 for normal livers and 12 for diseased livers from waterways, and 2 for normal livers and 1 for diseased livers from Carr Inlet.

[d] GC/MS analysis of 19 (Commencement Bay) or 7 (Carr Inlet) individual crab samples (Tetra Tech, 1985b).

wastewater sources (Tetra Tech, 1985b). For English sole muscle in Commencement Bay (Table 23), for example, the detection frequency was 1 in 75 samples for pentachlorophenol and 3 in 16 samples for toluene. Tetrachloroethylene and toluene were each detected in one of four English sole muscle samples from Carr Inlet. Other acid-extractable and volatile priority pollutants not shown in Table 23 were undetected in the Commencement Bay and Carr Inlet samples (Tetra Tech, 1985b).

DATA GAPS

Relatively little data exist for concentrations of some priority pollutants in tissues of the recommended target species. In general, only the metals have been investigated adequately. Gaps in the historical database will preclude comparisons of 301(h) monitoring data with past conditions. The most important data gaps for contaminants and target species are as follows:

- Volatile compounds and phthalates in tissues of all target species

- Priority pollutants in tissues of selected target species from tropical waters [e.g., spiny lobster (*Panulirus* spp.), damselfishes (Pomacentridae), and angelfishes and butterflyfishes (Chaetodontidae)]

- Priority pollutants in liver and muscle tissue of spot (*Leiostomus xanthurus*), in muscle tissue of Dungeness crab (*Cancer magister*) and western rock crab (*Cancer antennarius*), and in ocean quahog (*Arctica islandica*) from areas near known sources of contamination

- PAH and pesticides other than DDTs in Dover sole (*Microstomus pacificus*) and winter flounder (*Pseudopleuronectes americanus*) (especially reference areas for the latter)

- Metals in English sole (*Parophrys vetulus*) muscle and in surf clams (*Spisula solidissima*) from areas near known sources of contamination

- Organic priority pollutants in hard clam (*Mercenaria mercenaria*) and in the spiny lobster (*Panulirus interruptus*)

- Metals, pesticides, and PCBs in soft-shell clams (*Mya arenaria*).

Data on metals in English sole muscle and liver are currently available (Tetra Tech, 1985b), but were not available in time for inclusion in this report.

SUMMARY OF RECOMMENDATIONS

At a minimum, a target species selected for 301(h) bioaccumulation monitoring must be capable of accumulating toxic substances representative of the study area(s), abundant enough over time and space to allow adequate sampling, and large enough to provide adequate amounts of tissue for analysis. As discussed earlier, detailed criteria that allow candidate target species to be ranked objectively include habitat, prey type, geographic distribution, size, and abundance. Secondary criteria which can be used to discriminate among the highest ranking candidate target species include economic importance and use of a species for other kinds of biological effects tests (e.g., bioassays).

The target species recommended for 301(h) bioaccumulation monitoring programs are shown in Figure 1. The species chosen for monitoring in the vicinity of each discharge will depend on the site-specific availability of the recommended species. To the extent possible, the same species should be monitored for all discharges within a region. In most cases, a benthic macroinvertebrate species and a demersal fish species should be chosen for the monitoring program. For most bioaccumulation studies, fish contaminant analyses should be conducted on edible muscle and/or liver tissue. Contaminant concentrations should be determined in muscle and/or hepatopancreas tissue of crustaceans (e.g., crabs, lobsters) and in all soft-body tissue of bivalve molluscs.

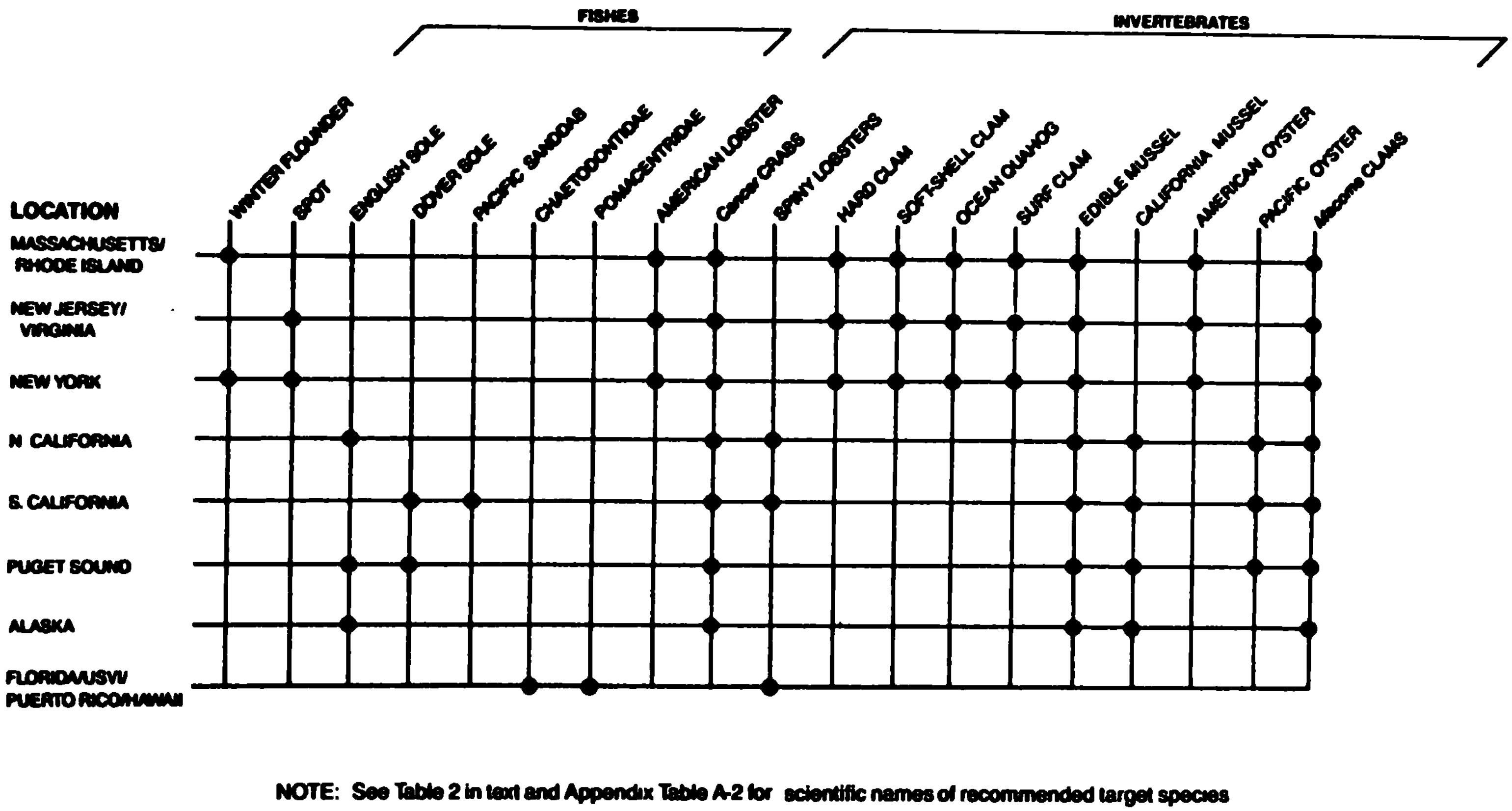

Figure 1. Summary of recommended target species.

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