**TABLE 4.3** Summary of the oral carcinogenicity bioassay of Kociba et al. (1978 a,b)

| Animal | Sex | Drug tested | Tumor type | Incidence |
|---|---|---|---|---|
| Sprague-Dawley rats | M | Control | Squamous cell carcinoma of the tongue, adenoma of the adrenal cortex, and squamous cell carcinoma of tyhe hard palate | 0/85 |
| | | 0.001 | Squamous cell carcinoma of the tongue | 1/50 |
| | | 0.01 | Squamous cell carcinoma of the tongue | 1/50 |
| | | | Squamous cell carcinoma of the adrenal cortex | 2/50 |
| | | 0.1 | Squamous cell carcinoma of the tongue | 3/50 |
| | | | Adenoma of the adrenal cortex | 5/50 |
| | | | Squamous cell carcinoma of the hard palate | 4/50 |
| | F | Control | Hepatocellular carcinoma | 1/86 |
| | | 0.001 | Hepatocellular carcinoma | 0/50 |
| | | 0.01 | Hepatocellular carcinoma | 2/50 |
| | | | Squamous cell carcinoma of the hard palate | 1/50 |
| | | 0.1 | Hepatocellular carcinoma | 11/49 |
| | | | Squamous cell carcinoma of the hard palate | 4/49 |
| | | | Squamous cell carcinoma of the lung | 7/49 |

Source: ATSDR, 1989.

TABLE 4.4 Other Oral Studies Supporting the Conclusion that 2,3,7,8-TCDD is an Animal Carcinogen

| Method of Exposure | Animal | Sex/number | Doses tested | Tumor type | References |
|---|---|---|---|---|---|
| Diet | Sprague-Dawley rats | M/10 | 0.01, 0.005, 0.05, 0.5, 1.0, or 5 ppb | Increase in total tumor incidence | Van Miller et al., 1977a,b |
| Gavage | Osborne-Mendel rats | M/50 | 0.01, 0.05, or 0.5 µg/kg/week | Follicular-cell adenomas and carcinomas of the liver | NTP, 1982b |
| | Osborne-Mendel rats | F/50 | 0.01, 0.05, or 0.5 µg/kg/week | Neoplastic nodules and hepatocellular carcinomas of the liver | NTP, 1982b |
| | B6C3Fl mice | M/50 | 0.01, 0.05, or 0.5 µg/kg/week | Hepatocellular carcinomas | NTP, 1982b |
| | B6C3Fl mice | F/50 | 0.01, 0.05, or 0.5 µg/kg/week | Hepatocellular carcinoma and follicular-cell adenomas of the thyroid | NTP, 1982b |
| | Swiss mice | M/44 | 0.007, 0.7, or 7.0 µg/kg/week | Hepatomas and hepatocellular carcinomas | Toth et al., 1979 |

Source: ATSDR, 1989.

limited number of cases, and the misclassification of soft-tissue sarcomas. A summary of the unit cancer risk values can be found in Table 4.9.

## 4.2 Toxicological Profile for 2,4-Dichlorophenoxyacetic Acid (2,4-D)

The purpose of this toxicological profile is to describe the known behavior of 2,4-D by using the most current and related information available. It is important to note that the n-butyl esters of 2,4-dichlorophenoxyacetic acid can hydrolyzed in biological and aquatic systems. Therefore, the behavior of the pure acid and their salts are pertinent and will be discussed in the following paragraphs along with studies on the esters when they are available (USAF, 1974).

### 4.2.1 Chemical Characteristics

2,4-Dichlorophenoxyacetic acid (2,4-D[9]) is a man-made chemical with no known natural sources. The chemical is produced by the interaction of 2,4-dichlorophenol, with the sodium salt of monochloroacetic acid, typically followed by an acid treatment to convert the 2,4-D salt to an acid (Sittig, 1980, 1986).

2,4-D is a systemic herbicide used for the control of broad leaf weeds in cereal crops, sugar cane, turf, pastures and other non-cropland (Weed Science Society of America, 1974). It is also used to control the ripening of bananas and citrus fruits (WHO, 1975). An estimated 27 million kg of 2,4-D acid equivalent, in the form of esters and salts, were used in the US in 1975 (IARC, 1977). 2,4-D was used as a jungle defoliant during the Vietnam War in the mid-1960's, where it was a component of "Agent Orange" (a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-trichlorophenoxyacetic acid). About 40 million liters of "Agent Orange" were sprayed

[9] 2,4-D refers to the acid derivative unless otherwise stated.

in South Vietnam between 1965-1971 (Committee on the Effects of Herbicides in Vietnam, 1974).

Various physical and chemical properties of 2,4-D are discussed in Section 4.5.

### 4.2.2 Pharmacokinetics

The differences in toxic effects caused by the various salts, amines and esters of 2,4-D can be explained on a pharmacometric basis. The concentrations of chemicals at the receptor sites in an organism depends on the absorption and distribution rates in relation to rates of metabolism and excretion. The rate of absorption in animals or plants is based on the route of entry and rate of membrane transport. Specific membrane transport rates depend upon the characteristics of the membrane in relation to the size, shape, polarity and lipid solubility of the particular molecule considered (USAF, 1974).

#### 4.2.2.1 Absorption

The most common route of exposure to herbicides in mammals is via ingestion, although exposure via inhalation and cutaneous routes is possible. The literature indicates that gastric absorption of 2,4-D, its amines and alkali salts occur readily as would be predicted from the Henderson-Hasselbalch relationships (USAF, 1974). The gastro-intestinal absorption of 2,4-D esters may be incomplete (Erne, 1966 as cited in USAF, 1974).

Frank et al. (1985) calculated that a maximum of 4.5% of the amount of 2,4-D deposited on the bare skin of a person directly sprayed with 2,4-D was absorbed. Among those occupationally exposed, dermal exposure appears to be the most important route of absorption.

#### 4.2.2.2 Distribution

After oral administration of 2,4-D to sheep and cattle, analyses of muscle, fat, liver and kidney showed the presence of 2,4-dichlorophenol (Clark et al., 1975 as cited in USDIFWS, 1978). There are no data concerning distribution after other relevant routes of administration.

#### 4.2.2.3 Metabolism

Most studies indicate that 2,4-D is rapidly eliminated via the kidneys by active tubular secretion into the urine. Cattle and rabbits excrete 2,4-D in their urine mostly unchanged (USAF, 1974). Erne (1966) as cited in USAF (1974), found that 2,4-D had a half-life from three to twelve hours and that urinary excretion was the primary route of elimination in the rat, rabbit, calf and chicken. Berndt and Koschier (1973), as cited in USAF (1974), concluded that renal tubular transport by the organic anion mechanism may account for the relatively rapid disappearance of 2,4-D and that might account for 2,4-D's low toxicity.

#### 4.2.2.4 Excretion

In a study on the kinetics of 2,4-D, five male volunteers were administered a dose of 5 mg/kg bw. Absorption was nearly complete, as indicated by the recovery of 88-100% of the dose in the urine within 144 h. Approximately 80% of the 2,4-D was excreted unchanged in the urine. The additional 20% was excreted as an acid-labile conjugate (Sauerhoff et al., 1977a). Extensive and rapid gastrointestinal absorption of 2,4-D was also observed by Kohli et al. (1974b).

Maximum concentrations of 2,4-D were detected in urine three days after dermal exposure (Feldman and Maibach, 1974).

### 4.2.3 Toxicity

Toxicity data for humans are difficult to obtain because people are rarely exposed to pure 2,4-D. Most occupational exposure studies are difficult to evaluate because of the combined exposures of many workers to more than one herbicide or greater than one derivative of a single herbicide.

#### 4.2.3.1 Noncancer Toxicity

Most of the data derived from acute toxicity studies indicate that 2,4-D has low toxicity. In the rat, the single dose $LD_{50}$ is 620 mg/kg for the butyl ester derivative of 2,4-D and 100 mg/kg for the dog in the 2,4-D acid derivative (Rowe et al., 1954; Edson et al., 1964 as cited in USAF, 1974).

Groups of 3 male and 3 female beagle dogs were fed 10, 50, 100, or 500 mg/kg of diet 2,4-D for 2 years, beginning at 6-8 months of age. Twenty-eight dogs survived the 2 year period and were clinically normal. No adverse effects related to 2,4-D were observed (Hansen et al., 1971).

Results of teratological studies are variable; teratogenic effects are observed with doses close to maternal toxicity. In a study by Bjorklund and Erne (1966), Sprague-Dawley rats were given 1000 mg/l 2,4-D ( 50 mg/kg) in the drinking water during pregnancy and for an additional 10 months after that, and 2,4-D was administered to the second generation for up to 2-years. Pregnancy and parturition were normal, the litter size was not significantly reduced, and no malformations were noted in the young. Except for retarded growth and increased mortality in the second generation, no clinical or morphological changes were seen.

In a three-generation study, Osborne-Mendel rats were orally administered 100 or 500 µg/kg (4 µg/kg or 20 µg/kg) of diet 2,4-D. No adverse effects were observed.

Diets containing 1500 µg/kg (60 µg/kg) 2,4-D significantly reduced the percentage of pups surviving to weaning and their weights (Hansen et al., 1971).

No significant increases in embryonic effects were noted when 2,4-D was orally administered to hamsters at doses up to 100 mg/kg on days 6-10 of gestation (Collins and Williams, 1971).

An Oral Reference Dose (Oral $R_fD$), of 0.01 mg/kg/day has been set by EPA (IRIS, 1991). This is based on data from Dow Chemical Co. (1983). Hematologic, hepatic and renal toxicity were demonstrated in Fisher 344 rats during a subchronic feeding. 2,4-D was fed to the rats for 91 days at doses calculated to be 0, 1, 5, 15, or 45 mg/kg/day. There were a total of 200 animals in the study. Criteria examined to determine toxicity were survival, daily examination for clinical symptomology, weekly change in body weights and clinical, gross and histopathologic alterations. The results demonstrated statistically significant reductions in mean hemoglobin (both sexes), mean hematocrit and red blood cell levels (both sexes), and mean reticulocyte levels (males only) at the 5 mg/kg/day dose or higher after 7 weeks. There were also significant reductions in liver enzymes LDH, SGOT, SGPT, and alkaline phosphatase at week 14 in animals treated at the 15 mg/kg/day or higher doses. Kidney weights (absolute and relative) showed significant increases in all animals at the 15 mg/kg/day dose or higher at the end of the experimental protocol. Histopathologic examinations correlated well with kidney organ weight changes showing cortical and subcortical pathology. The dose used to derive the $R_fD_0$ was 1 mg/kg/day (IRIS, 1991). The $R_fD_0$ was set at 0.01 mg/kg bw/day by using a total uncertainty factor of 100 to account for uncertainty in the interspecies and interhuman variability in the toxicity of 2,4-D in regard to these specific data (IRIS, 1991). Because the analysis of the 90-day and a follow up 1-year interim study, results suggest that the NOAEL would also be relevant for the full 2-year duration. Inclusion of the subchronic-to-chronic uncertainty factor is not warranted (IRIS, 1991). The EPA has medium confidence (tending towards high) in this oral $R_fD$ (IRIS, 1991). Confidence in the study is medium because of a reasonable number of animals were used of both sex, the four doses were given, and a generous number of parameters were examined (IRIS, 1991). Confidence in the data base is medium because several studies support both the observation of critical toxic effects and the levels at which they occur (IRIS, 1991).

Critical noncarcinogenic toxicity values for 2,4-D are discussed in Section 4.5.

#### 4.2.3.2 Carcinogenicity

Osborne-Mendel rats were orally administered 5, 25, 125, 625, or 1250 mg/kg (0.2, 1.0, 5.0, 25.0, or 50 mg/kg) 2,4-D for 2 years. A significant increase in tumors was seen only in the highest dose group, but tumors were randomly distributed and were typical of those found in aging rats of this strain (Hansen et al., 1971). Because of the limitations of this study (including the small number of animals used) no evaluation of carcinogenicity could be made based on the available studies (IARC, 1987).

IARC (1987 and 1977) state that the evidence for carcinogenicity in animals is inadequate for 2,4-D.

#### 4.2.3.3 Additional Data

The genotoxicity data for 2,4-D have yielded fairly inconsistent results overall. Many *in vitro* studies have given positive results in absence of metabolic activation, but a few negative results have been noted. The results of these studies can be found in Tables 4.5 (*in vitro* data) and 4.6 (*in vivo* data).

TABLE 4.5 Genotoxicity of 2,4-D *in vitro*

| End point | Species (test system) | Results | References |
|---|---|---|---|
| Gene Mutation | *Salmonella typhimurium* (reverse mutation) | -/-[a] | Nishimura et al., 1982 Mortelmans et al., 1984 |
| | *S. typhimurium* (reverse mutation) | 0[b]/- | Anderson and Styles, 1978 |
| | *S. typhimurium* (reverse mutation) | -/0 | Zetterberg et al., 1977 Anderson et al., 1972 |
| | *Saccharomyces cerevisiae* (reverse mutation) | +/0 | Zetterberg, 1978 |
| Cytogenetic | *S. cerevisiae* (gene conversion) | +/0 | Zetterberg et al., 1977 |
| | *S. cerevisiae* (gene conversion) | (+)[c]/0 | Siebert and Lemperle, 1974 |
| | Chinese hamster cells (sister chromatid exchange) | -/- | Linnainmaa, 1984 |
| | Human lymphocytes (sister chromatic exchange) | +/0 | Korte and Jalal, 1982 |
| | Human lymphocytes (chromosomal aberration) | +/0 | Pilinskaya, 1974 Mustonen et al., 1986 |

[a] In presence of metabolic activation/absence of metabolic activation
[b] Not tested
[c] Weakly positive

Source: IARC, 1987.

TABLE 4.6 **Genotoxicity of 2,4-D *in vivo***

| End point | Species (test system) | Results | References |
|---|---|---|---|
| Gene mutation | *Drosophila melanogaster* (sex-linked recessive lethal) | - | Vogel and Chandley, 1974<br>Zimmering et al., 1985 |
| | *Drosophila melanogaster* (sex-linked recessive lethal) | + | Magnusson et al., 1977 |
| Cytogenetic | *Drosophila melanogaster* (somatic mutation/ recombination) | + | Rasmuson and Svahlin, 1978 |
| | *Drosophila melanogaster* (aneuploidy) | - | Ramel and Magnusson, 1979<br>Magnusson et al., 1977<br>Woodruff et al., 1983 |
| | Mouse (micronucleus test) | - | Seiler, 1978<br>Jenssen and Renberg, 1976 |
| | Mouse (dominant lethal test) | - | Epstein et al., 1972 |
| | Human lymphocytes (sister chromatid exchange) | - | Linnainmaa, 1983 |
| | Human lymphocytes (sister chromatid exchange) | (+)[a] | Crossen et al., 1978 |
| | Human lymphocytes (chromosome aberration) | - | Mustonen et al., 1986 |
| | Human lymphocytes (chromosome aberration) | (-)[b] | Hoegstedt et al., 1980 |

[a] Weakly positive
[b] Weakly negative

Source: IARC, 1987.

## 4.3 Toxicological Profile for 2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T)

The purpose of this toxicological profile is to describe the known behavior of 2,4,5-T by using the most current and related information available. It is important to note that the n-butyl esters of 2,4,5-trichlorophenoxyacetic acid can be hydrolyzed in biological and aquatic systems. Therefore, the behavior of the pure acid and their salts are pertinent and will be discussed along with studies on the esters when they are available (USDAF, 1974).

### 4.3.1 Chemical Characteristics

2,4,5-Trichlorophenoxyacetic acid (2,4,5-T[10]) is a man-made chemical with no known natural sources. The chemical is currently produced by the reaction of 2,4,5-trichlorophenol with the sodium salt of monochloroacetic acid, typically followed by an acid treatment to convert the 2,4,5-T salt to an acid (Sittig, 1980).

2,4,5-T was used as a jungle defoliant during the Vietnam War in the mid-1960s, where it was a component of "Agent Orange" (a 50:50 mixture of the n-butyl esters of 2,4,5-T and 2,4-dichlorophenoxyacetic acid). About 40 million liters of "Agent Orange" were sprayed in South Vietnam between 1965-1971 (Committee on the Effects of Herbicides in Vietnam, 1974).

Various physical and chemical properties of 2,4,5-T are discussed in Section 4.5.

[10] 2,4,5-T refers to the acid derivative unless otherwise stated.

### 4.3.2 Pharmacokinetics

The differences in toxic effects caused by the various salts, amines and esters of 2,4,5-T can be explained on a pharmacometric level. The concentrations of chemicals at the receptor sites in an organism depends upon the absorption and distribution rates in relation to rates of metabolism and excretion. The rate of absorption in animals or plants is dependent on the route of entry and the rate of membrane transport. Specific membrane transport rates depend upon the characteristics of the membrane in relation to the size, shape, polarity and lipid solubility of the particular molecule considered (USDAF, 1974).

#### 4.3.2.1 Absorption

The most common route of exposure to herbicides in mammals is via ingestion, although exposure via inhalation and cutaneous routes is possible. The literature indicates that gastric absorption of 2,4,5-T and its amines and alkali salts occur readily as would be predicted from the Henderson-Hasselbalch relationships (USDAF, 1974). There is no information in the available literature about the absorption of 2,4,5-T via the skin or inhalation.

#### 4.3.2.2 Distribution

There was no available information on the distribution of 2,4,5-T.

#### 4.3.2.3 Metabolism and Excretion

Most studies indicate that animals rapidly eliminate 2,4,5-T via the kidney by active tubular secretion into the urine. Cattle and rabbits excrete 2,4,5-T in their urine mostly unchanged (USDAF, 1974). Erne (1966), as cited in USDAF (1974), found that 2,4,5-T had a half-life from three to twelve hours and that urinary excretion was the primary route of elimination in the rat, rabbit, calf and chicken. Berndt and Koschier (1973), as cited in USDAF (1974), concluded that renal tubular transport by the organic anion mechanism may account for the relatively rapid disappearance of 2,4,5-T, which may account for 2,4,5-T's low toxicity.

[1-$^{14}$C]2,4,5-T was administered to pregnant and non-pregnant rats by stomach tube in a study by Fang et al. (1973), as cited in USDIFWS (1978). The rate of elimination for both groups was the same. Ninety to 95% of the label was eliminated in the form of unchanged 2,4,5-T in the urine. In addition, two non-polar and one water soluble metabolite were observed. Acid hydrolysis of the water soluble metabolite produced 2,4,5-T suggests potential ester formation.

Studies in humans confirm the results observed in animals. Gerring et al. (1973) orally administered 2,4,5-T directly or in milk in 5 human male volunteers. An average of 88% of the dose was excreted in the urine within 96 hours of administration, and renal clearance was 180 to 260 ml/min. The ingested 2,4,5-T was eliminated unchanged into the urine (USDAF, 1974). There was no free trichlorophenol detected in the urine. Clearance from the plasma and excretion both followed first-order kinetics with a half-life of 23 hours. Fecal excretion was <1% of the dose (Gerring et al., 1973).

In a similar study, 2,4,5-T was administered orally at 2, 3, or 5 mg/kg bw. Maximum plasma concentrations were detected 7 to 24 hours after administration. Following the 5 mg/kg bw dose, the half-life averaged 19 hours. For all of the doses examined, an average of 63 to 79% of the dose was recovered in the urine within 96 h of administration (Kohli et al., 1974a).

### 4.3.3 Toxicity

Toxicity data for humans are difficult to obtain because people are rarely exposed to pure 2,4,5-T. In the majority of cases, the available data do not distinguish between the possible effects of exposure to 2,4,5-T and those of exposure to associated chemicals or more toxic contaminants such as TCDD.

#### 4.3.3.1 Noncancer Toxicity

Most of the data derived form acute toxicity studies indicate that 2,4,5-T has low toxicity. In the mice, the single dose $LD_{50}$ was 940 mg/kg for the butyl ester derivative for 2,4,5-T and 500 mg/kg in the rat for the 2,4,5-T acid derivative (Rowe and Hymas, 1954 as cited in USDAF, 1974).

Dogs fed 2,4,5-T 5 times a week for 90 days at a dosage level of 2, 5, or 10 mg/kg bw exhibited no adverse effects. Daily doses of 20 mg/kg bw resulted in deaths 11-75 days after the first dosing (Drill and Hiratzka, 1953).

Results of teratology studies in animals are variable. 2,4,5-T (containing less than 0.02 mg/kg TCDD) orally administered on days 6-15 of gestation was embryotoxic to NMRI mice. The frequency of cleft palate was significantly increased when doses of greater than 20 mg/kg bw were administered. Reductions in fetal weight were found with doses of 10-15 mg/kg bw, but there was no increase in embryolethality over controls. Cleft palates were produced following a single oral dose of 150-300 mg/kg bw. 2,4,5-T butyl ester was found to have similar embryopathic effects as 2,4,5-T following administration on days 6-15 of gestation (Neubert and Dillmann, 1972).

To the contrary, 2,4,5-T (containing 0.5 mg/kg TCDD) was neither teratogenic or fetotoxic when orally administered to CD rats at doses ranging from 1-80 mg/kg bw (Courtney and Moore, 1971), or in Sprague-Dawley rats at doses ranging from 1-24 mg/kg bw (Emerson et al., 1971) on days 6-15 of gestation. The butyl ester of 2,4,5-T had no effect when orally dosed at 50 or 150 mg/kg bw in Wistar rats, but 2,4,5-T (containing less than 0.5 mg/kg) did induce skeletal anomalies following single daily doses of 100-150 mg/kg bw on days 6-15 of gestation (Khera and McKinley, 1972).

Sjoden and Soderberg (1977), reported that prenatal exposure to 2,4,5-T may lead to behavioral abnormalities and changes in thyroid activity as well as brain serotonin levels in the progeny. Crampton and Rogers (1983) reported that prenatal exposure to 2,4,5-T has long-term effects on behavior in rats. After exposure to a single dose of 2,4,5-T (6 mg/kg) on day 8 of gestation, abnormalities were observed in tests for novelty responses.

An oral Reference Dose (oral $R_fD$), of 0.01 mg/kg/day has been set by EPA (IRIS, 1991). This is based on data from two well conducted studies (Kociba et al., 1979; Smith et al., 1981). Kociba et al. (1979) maintained Sprague-Dawley rats (50/sex) on diets supplying 0, 3, 10, or 30 mg 2,4,5-T/kg bw/day for 2 years. Toxicological endpoints measured were body weight, food consumption, tumorigenicity, hematology, urinalysis, serum chemistry, and histopathology. No effects were seen at 3 mg/kg/day. An increase in urinary excretion of coproporphyrin (at 4 months only) was reported for males at 10 and 30 mg/kg/day and for females at the 30 mg/kg bw dose level. A mild dose-related increase in the incidence of mineralized deposits in the renal pelvis was reported for females after 2 years. Smith et al. (1981) conducted a three generation reproduction study. Rats were fed levels of 2,4,5-T corresponding to 0, 3, 10, or 30 mg 2,4,5-T/kg bw/day. No effects were observed at the lower doses. Reduced neonatal survival was observed at both higher doses. The dose used to derive the $R_fD_o$ was 3 mg/kg/day (IRIS, 1991). The $R_fD_o$ was set at 0.01 mg/kg bw/day by using a total uncertainty factor of 300 to account for uncertainty in the extrapolation of dose levels from laboratory animals to humans

(10), uncertainty in the threshold for sensitive humans (10), and uncertainty because of deficiencies in the chronic toxicity data base (3) (IRIS, 1991). The EPA has medium confidence (tending towards high) in this oral $R_fD$ (IRIS, 1991). There is high confidence in the studies used to determine the $R_fD_o$ because of the completeness of the studies and the data base is supportive of the magnitude of the reproductive effect. The relative weakness of the chronic toxicity data base precludes a higher overall confidence level (IRIS, 1991).

Critical noncarcinogenic toxicity values for 2,4,5-T are discussed in Section 4.5.

#### 4.3.3.2 Carcinogenicity

2,4,5-T has been tested in mice by oral administration. In a study by Mutanyi-Kjovacs et al. (1976), 20 male and 19 female 6-week old inbred XVBII/G mice were given 100 mg/l (5 mg/kg) 2,4,5-T (containing less than 0.05 mg/kg chlorinated dibenzodioxins) in the drinking water for 2 months. Subsequently, 2,4,5-T was fed orally at a concentration of 80 mg/kg (3.2 mg/kg) of diet for lifespan. No significant increase was noted in the incidence of tumors. In a similar study by the same authors, C3HF mice were treated in the same manner. The treated female mice showed a significant increase in the total number of tumors. Although an increased incidence of tumors at various sites were observed in this study, no evaluation of carcinogenicity of 2,4,5-T could be made because of the limitations of this study (small number of animals used) (IARC, 1987).

IARC (1987, 1977) state that the evidence for carcinogenicity in animals is inadequate for 2,4,5-T.

#### 4.3.3.3 Additional Data

The genotoxicity data suggest that 2,4,5-T is not likely to effect genetic material. Most studies have given negative results, while the positive studies had only weak responses. The results of these studies can be found in Tables 4.7 (*in vitro* data) and 4.8 (*in vivo* data).

**TABLE 4.7 Genotoxicity of 2,4,5-T *in vitro***

| End point | Species (test system) | Results | References |
|---|---|---|---|
| Gene mutation | *Salmonella typhimurium* (reverse mutation) | -/-[a] | Herbold et al., 1982<br>Nishimura et al., 1982<br>Mortelmans et al., 1984 |
| | *Salmonella typhimurium* (reverse mutation) | 0[b]/- | Anderson and Styles, 1978 |
| | *Salmonella typhimurium* (reverse mutation) | -/0 | Andersen et al., 1972 |
| | *Saccharomyces cerevisiae* (reverse mutation) | +/0 | Zetterberg, 1978 |

[a] In presence of metabolic activation/absence of metabolic activation
[b] Not tested

Source: IARC, 1987.

TABLE 4.8 Genotoxicity of 2,4,5-T *in vivo*

| End point | Species (test system) | Results | References |
|---|---|---|---|
| Gene mutation | *Drosophila melanogaster* (sex-linked recessive lethal) | + | Majumdar and Golia, 1974 |
| | *Drosophila melanogaster* (sex-linked recessive lethal) | (+)[a] | Magnusson et al., 1977 |
| | *Drosophila melanogaster* (sex-linked recessive lethal) | - | Zimmering et al., 1985 |
| Cytogenetic | *Drosophila melanogaster* (somatic mutation/recombination) | - | Rasmuson and Svahlin, 1978 |
| | *Drosophila melanogaster* (aneuploidy) | - | Ramel and Magnusson, 1979<br>Magnusson et al., 1977 |
| | Mouse (micronucleus test) | - | Jenssen and Renberg, 1976 |
| | Mouse (dominant lethal test) | - | Buselmaier et al., 1972 |
| | Rat (dominant lethal test) | - | Herbold et al., 1982 |
| | Human lymphocytes (sister chromatid exchange) | (+) | Crossen et al., 1978 |

[a] Weakly positive

Source: IARC, 1987.

## 4.4 Toxicity Profile for the Mixtures of 2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T), 2,4-Dichlorophenoxyacetic Acid (2,4-D), and 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) as Chlorophenoxy Herbicides

### 4.4.1 Toxicity

Toxicity data for humans are difficult to obtain because people are rarely exposed to pure 2,4,5-T, 2,4-D or TCDD. Most occupational exposure studies are difficult to evaluate because of the combined exposures of many workers to more than one herbicide or greater than one derivative of a single herbicide. In the majority of cases, the available data do not distinguish between the possible effects of exposure to 2,4,5-T or 2,4-D and the exposure to associated chemicals such as TCDD. Many studies involve the occupational exposure to the general category of chlorophenoxy herbicides.

### 4.4.2 Noncancer Toxicity

#### 4.4.2.1 Chloracne

In a reaction incident with exposure to 2,4,5-T and its contaminant TCDD in 1949, workers were who were exposed were followed for 4 years. Directly after exposure, workers had complaints including chloracne and respiratory tract, liver and nervous system disorders. By 1953, liver and nervous system problems subsided, but chloracne still persisted in some cases (Suskind, 1985).

#### 4.4.2.2 Reproduction and Prenatal Toxicity

Effects on reproduction and prenatal toxicity have been addressed in several studies in humans. A study in Arkansas, USA, divided the state into low, medium and high 2,4,5-T use areas on the basis of rice acreage. No significant differences in rates of facial cleft were found among the different areas between 1943 and 1974 (Nelson et al., 1979). The USEPA investigated spontaneous abortion rates in areas of Oregon, USA, in relation to 2,4,5-T spray rates between 1972 and 1977. Significantly higher spontaneous abortion rates were noted in areas in which 2,4,5-T was used. IARC (1986) noted that some of the methods in the study were inadequate.

A study of the pregnancy outcomes of wives of professional herbicide (2,4,5-T) sprayers was conducted in New Zealand (Smith et al., 1981). There were a total of 1172 births among families in the exposed group (1969-1979 for spraying of 2,4,5-T; 1960-1979 for spraying of any pesticide) and 1122 births in a control group. Major congenital defects were reported in 2% (24) of births to applicator families and 1.6% (18) of births to the control group; the difference was not significant. Similar rates were observed for the two groups for stillbirths and miscarriages. In further analysis, the pregnancy outcomes associated with spraying of 2,4,5-T by the father in the same year or in the previous year of the birth were selected and compared to the control group. The relative risk for congenital defects in children of exposed fathers was 1.19 and for miscarriages 0.89 (Smith et al., 1982b). These results were not statistically significant.

### 4.4.3 Cancer

#### 4.4.3.1 Case-Control Studies

##### 4.4.3.1.1 Soft-Tissue Sarcomas

Hardell and Sandstrom (1979), conducted a case-control study of 52 male patients with soft-tissue sarcoma and 220 matched controls. A person was classified as being exposed if he had at least one full day of exposure more than 5 years before a tumor was diagnosed. Of the 52 cases, 13 cases were exposed to chlorophenoxy herbicides (12 had been exposed to 2,4,5-T or 2,4-D, and one to 4-chloro-2-methylphenoxy acetic acid (MCPA) alone; combined exposure to 2,4,5-T and 2,4-D was reported in 9 cases). A significant association was observed (odds ratio = 5.3; 95% CI, 2.4 to 11.5) with prior exclusion of exposure cases to chlorophenol. Latency from first exposure was 10 to 20 years. The average duration of exposure was three to four months (range, 2 days to 49 months).

Eriksson et al. (1981) undertook a case-control study with 110 cases with soft-tissue sarcomas and 220 matched controls in an area of Sweden where MCPA and 2,4-D had been widely used in agriculture. A significant association was observed (odds ration = 8.5) for exposure to chlorophenoxy herbicides alone for more than 30 days (7 cases), and 5.7 for exposures of less than or equal to 30 days (7 cases). The odds ratio for exposure to chlorophenoxy herbicides other than 2,4,5-T was 4.2 (95% CI, 1.3 to 15.8).

An initial analysis of occupations recorded with the National New Zealand Center Registry between 1976 and 1980 did not find and excess of soft-tissue sarcoma cases in agricultural and forestry workers (Smith et al., 1982). After this preliminary analysis, nearly 90% of the cases (or next of kin) were interviewed regarding past occupations and actual exposure to chlorophenoxy herbicides. A significant association was observed (odds ratio = 1.6; 90% CI, 0.7 to 3.3) was calculated for those who had probably or definitely been exposed for more than one day greater than 5 years prior to the diagnosis of the tumor. None of the cases was of a professional applicator. The possibility of recall bias based on the previous study was noted.

In a study by Smith et al. (1984) 82 persons with soft-tissue sarcomas and 92 controls (with other types of cancers) were interviewed for a case-control study. For those potentially exposed to phenoxyherbicides for more than one day not in the 5 years prior to cancer diagnosis, no significant association was observed (odds ratio = 1.3; 90% CI, 0.6 to 2.5). In addition, no significant association was observed for chlorophenol exposure (odds ratio = 1.5; 90% CI. 0.5 to 4.5). The authors concluded that further studies were needed to clarify whether human exposure to these chemicals increase the risk of soft-tissue sarcoma.

4.4.3.1.2 Malignant Lymphomas

A case-control study of 169 cases of malignant lymphoma was undertaken with 338 matched controls (Hardell et al., 1981). The study design, including determination of exposure, was similar to the Swedish soft-tissue sarcoma studies (see Hardell and Sandstorm, 1979). A significant association (odds ratio = 4.8; 95% CI, 2.9 to 8.1) was obtained for exposure to chlorophenoxy herbicides, excluding cases and controls exposed to chlorophenols. Stratifying by duration of exposure, the relative risk estimate was 4.3 for less than 90 days and 7.0 for 90 days or more exposure to chlorophenoxy herbicides. The majority of chlorophenoxy herbicide-exposed cases reported exposure to both 2,4,5-T and 2,4-D (25 cases), two reported exposure to 2,4,5-T, 2,4-D and MCPA, seven to 2,4-D alone and 5 to MCPA alone (Hardell, 1981a).

An analysis of reported occupations appearing on the New Zealand Cancer Registry indicated an excess of malignant lymphoma and multiple myeloma among men in agricultural occupations during 1977-1981. The main findings of a subsequent case-control study concerned 88 cases of malignant lymphoma (covering non-Hodgkin's lymphoma other than lymphosarcoma and reticulosarcoma), classified as ICD 202, and 352 matched controls. A subsequent study with 83 cases of ICD 202 suggested that exposure to chlorophenoxy herbicides was not associated, since the odds ratio of 1.3 (90% CI. 0.7 to 2.5) was obtained when controls were people with other cancers were used, and an odds ratio of 1.0 (90% CI. 0.5 to 2.1) when the controls were the general population (Pearce et al., 1986).

#### 4.4.3.1.3 Nasal and Nasopharyngeal Cancer

Hardell et al. (1982), described an odds ratio of 2.1 (95% CI, 0.9 to 4.7) for exposure to chlorophenoxy herbicides.

### 4.5 Conclusion and Summary

There is limited evidence that occupational exposures to chlorophenoxy herbicides are carcinogenic to humans (IARC, 1986). Benchmark values for all relevant toxicological indicators, carcinogenic and noncarcinogenic, are presented in Tables 4.9 and 4.10, respectively.

## TABLE 4.9
**Critical Carcinogenic Toxicity Values for Indicator Chemicals**
Herbicide Orange Storage Area
Johnston Island, Johnston Atoll

| Chemical Name | Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$ | Weight of Evidence Classification | Type of Cancer | SF Basis/ SF Source |
|---|---|---|---|---|
| Oral Route | | | | |
| 2,3,7,8-Tetrachloro-dibenzo-p-Dioxin[a] | $1.56 \times 10^5$ | B1[a] | Lung, liver, hard palate, nasal turbinates | Food/ATSDR (June 1989) |
| 2,4-Dichlorophenoxy acetic acid[b] (n-butyl ester) | No data | No data | No data | No data |
| 2,4,5-Trichlorophenoxy acetic acid[b] (n-butyl ester) | No data | No data | No data | No data |
| 2,4,5-Trichlorophenoxy acetic acid[b] (Iso-octyl ester) | No data | No data | No data | No data |
| Inhalation Rate | No data | No data | No data | No data |

[a] When associated with phenoxy herbicides and/or chlorophenols, B2 when considered alone.

**TABLE 4.10**
**Critical Noncarcinogenic Toxicity Values for Indicator Chemicals**
Herbicide Orange Storage Area
Johnston Island, Johnston Atoll

| Chemical Name | Chronic $R_fD$ (mg/kg-day) | Confidence Level[a] | Critical Effect | $R_fD$ Basis/ $R_fD$ Source | Uncertainty and Modifying Factors[b] |
|---|---|---|---|---|---|
| Oral Route | | | | | |
| 2,3,7,8-Tetrachloro-dibenzo-p-Dioxin | $1 \times 10^{-9}$ | No data | Primary: Fetal survival<br>Secondary: Renal | No data/ ATSDR | UF=100 for A, L<br>MF=10 |
| 2,4-Dichlorophenoxy acetic acid (n-butyl ester) | $1 \times 10^{-2}$[c] | Medium | Primary: Renal<br>Secondary: Hematologic, hepatic | Food/ IRIS | UF=100 for H, A<br>MF=1 |
| 2,4,5-Trichlorophenoxy acetic acid (n-butyl ester) | $1 \times 10^{-2}$[d] | Medium | Primary: Neonatal survival<br>Secondary: Increased urinary coproporphyrin | Food/ IRIS | IF=300 for H, A, D<br>MF=1 |

| | | | | | |
|---|---|---|---|---|---|
| Inhalation Route | No data | No data | No data | No data | No data |

[a] Confidence level from IRIS, either high, medium, or low.
[b] Uncertainty adjustments: H=variation in human sensitivity; A=animal to human extrapolation; and D=deficiencies in toxicity data.
[c] $R_fD$ value for acid, n-butyl ester value not available.
[d] $R_fD$ value for acid, n-butyl ester and iso-octyl ester values not available.

## 5.0 *Risk Characterization*

Characterization of risk is based on the results of the exposure assessment (as summarized in Table 3.12) and the benchmark toxicity values (presented in Table 4.10). The basic algorithm for calculation of risk for carcinogenicity is:

$$Risk = Lifetime\ Average\ Daily\ Dose\ (mg/kg/day) \times unit\ cancer\ risk\ (mg/kg/day) \quad (5\text{-}8)$$

and for systemic toxicity (as the hazard quotient) is:

$$Noncancer\ hazard\ quotient = \frac{Average\ Daily\ Dose\ (ADD)}{Reference\ Dose\ (RfD)} \quad (5\text{-}9)$$

Among the chemicals of concern, TCDD is the only known carcinogen. The Unit Cancer Risk (UCR) on which risk was calculated is $1.56 \times 10^5$. TCDD, 2,4-D, and 2,4,5-T are all systemic toxicants. It is important to note that, in the case of systemic toxicity, hazard quotients are *not* additive for different chemicals where their respective $R_fD$'s are based on different target organs. $R_fD$'s and their bases are listed in Table 4.10 as the primary effect on which each chemical's $R_fD$ is based. For TCDD the primary effect is fetotoxicity; for 2,4-D it is renal toxicity; and for 2,4,5-T it is reduced neonatal survival. As a result, hazard quotients are presented separately for all three chemicals and are not added into a single hazard index.

The noncancer hazard quotient assumes that there is a level of exposure (i.e., $R_fD$) below which it is unlikely for even sensitive populations to experience adverse health effects. If the exposure level (i.e., average daily intake) exceeds this threshold (i.e., if the hazard quotient exceeds unity), there may be concern for potential noncancer effects. It is important to note that the level of concern does not increase linearly as the $R_fD$ is approached or exceeded because $R_fD$s do not have equal accuracy or precision and are not based on the same severity or toxic effects. Thus, the slopes of the dose response curve in excess of the $R_fD$ can range widely depending on the substance (EPA, 1989c).

For all three compounds (i.e., TCDD, 2,4-D, and 2,4,5-T) inhalation, only oral $R_fD$s were available, and only an oral cancer potency factor (or UCR) was available for TCDD. Therefore, it was necessary to adjust these toxicity benchmark values, which were based on exposure (administered) dose to account for absorption. This route-to-route extrapolation method as been described by EPA (1989c) and is used to express the toxicity expected from an absorbed dose. Additionally, these adjusted toxicity benchmark values must then be used with inhalation exposure values which have also been adjusted to estimate absorbed dose. The uncertainties associated with this method include the fact that "point-of-entry" toxicity (i.e., in the lungs) cannot be estimated from oral toxicity data. Furthermore, unlike orally administered compounds, inhaled chemicals would not be subjected to first-pass hepatic metabolism before reaching the systemic circulation. Therefore, a toxic effect attributable to an active metabolite might be more pronounced if the compound was administered orally. Conversely, the pulmonary absorption of a toxic parent compound that undergoes little or no first-pass metabolism may result in a greater dose of the toxic moiety entering the systemic circulation than if the compound was absorbed orally.

## 5.1 Quantitative Assessment of Risk

All parameters used in calculations leading to the expression of carcinogenic and systemic toxicity risks are presented in Table 5.1 for the current scenario and Table 5.2 for the two future use scenarios. Although all media were considered in the analysis, lack of or inadequate monitoring data on water and marine biota reduced multimedia considerations to air only. For this medium, both vapor phase and chemical-bound particulate were factored into the calculations.

For the *current scenario*, the cancer risk from exposure to TCDD is $3 \times 10^{-5}$ for the TMEI and $3 \times 10^{-5}$ for the AMEI. The hazard quotient from exposure to TCDD is 0.76 for the TMEI and 0.76 for the AMEI. The hazard quotient from exposure to 2,4-D is 0.0014 for the TMEI and 0.00051 for the AMEI. The hazard quotient from exposure to 2,4,5-T is 0.0015 for the TMEI and 0.00095 for the AMEI.

For the *future-use scenario involving excavation (Scenario 1)*, the cancer risk from exposure to TCDD is $8 \times 10^{-7}$ for the TMEI and $8 \times 10^{-7}$ for the AMEI. The hazard quotient from exposure to TCDD is 0.52 for the TMEI and 0.52 for the AMEI. The hazard quotient from exposure to 2,4-D is 0.00090 for the TMEI and 0.00034 for the AMEI. The hazard quotient from exposure to 2,4,5-T is 0.0010 for the TMEI and 0.00063 for the AMEI.

For the *future-use scenario involving paving (Scenario 2)*, the cancer risk from exposure to TCDD is $2 \times 10^{-7}$ for the TMEI and $2 \times 10^{-7}$ for the AMEI. The hazard quotient from exposure to TCDD is 0.25 for the TMEI and 0.25 for the AMEI. The hazard quotient from exposure to 2,4-D is 0.00045 for the TMEI and 0.00017 for the

Table. 5.1

Estimated Lifetime Average Daily Absorbed Dose a.1
Average Daily Absorbed Dose and Subsequent Risk from Inhalation of Vapor-Phase
TCDD, 2,4-D, and 2,4,5-T within the Impact Zone of the Existing Herbicide Orange Site.

| Compound | Ambient Air Conc (mg/m^3) (1hr avg) | Inhalation Rate (m^3/hr) | Exposure time (hr/d) | Exposure Freq (d/yr) | Exposure Duration (yr) | Absorption Fraction (vapor) | Body Weight (kg) | Avg. Time (d) | ABS. DOSE (mg/kg/day) | CANCER RISK | CHRONIC RfD (Adjusted) (mg/kg/day) | HAZARD RATIO (DOSE/RfD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMEI | | | | | | | | | | | | |
| TCDD-c | 1.01E-08 | 2.1 | 1 | 250 | 25 | 0.75 | 70 | 25550 | 5.55E-11 | 2.89E-05 | | |
| TCDD-nc | 1.01E-08 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 2.27E-10 | | 3.00E-10 | 7.56E-01 |
| 2,4-D | 1.81E-04 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 4.06E-06 | | 3.00E-03 | 1.35E-03 |
| 2,4,5-T | 2.00E-04 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 4.51E-06 | | 3.00E-03 | 1.50E-03 |
| AMEI | | | | | | | | | | | | |
| TCDD-c | 1.01E-08 | 2.1 | 1 | 250 | 25 | 0.75 | 70 | 25550 | 5.55E-11 | 2.89E-05 | | |
| TCDD-nc | 1.01E-08 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 2.27E-10 | | 3.00E-10 | 7.56E-01 |
| 2,4-D | 6.79E-05 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 1.53E-06 | | 3.00E-03 | 5.09E-04 |
| 2,4,5-T | 1.27E-04 | 2.1 | 1 | 250 | 1 | 0.75 | 70 | 250 | 2.85E-06 | | 3.00E-03 | 9.50E-04 |

Table. 5.2 Estimated Lifetime Average Daily Absorbed Dose and Average Daily Absorbed Dose and Subsequent Risk from Inhalation of Vapor-Phase and Particle-Associated TCDD, 2,4-D, and 2,4,5-T within the Impact Zone During either Excavation or Construction of a Cement Cover.

SCENARIO 1: Excavation

| Compound | Ambient Air Conc (mg/m^3) (1hr avg; adjusted for absorption) | Inhalation Rate (m^3/hr) | Exposure time (hr/d) | Exposure Freq (d/yr) | Exposure Duration (yr) | Absorption Fraction | Body Weight (kg) | Avg. Time (d) | ABS DOSE (mg/kg/day) | CANCER RISK | CHRONIC RfD (Adjusted) (mg/kg/day) | HAZARD RATIO (DOSE/RfD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMEI | | | | | | | | | | | | |
| TCDD-c | 7.80E-09 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 25550 | 1.48E-12 | 7.70E-07 | | |
| TCDD-nc | 7.80E-09 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 243 | 1.56E-10 | | 3.00E-10 | 5.19E-01 |
| 2,4-D | 1.35E-04 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 243 | 2.70E-06 | | 3.00E-03 | 9.01E-04 |
| 2,4,5-T | 1.50E-04 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 243 | 3.00E-06 | | 3.00E-03 | 1.00E-03 |
| AMEI | | | | | | | | | | | | |
| TCDD-c | 7.80E-09 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 25550 | 1.48E-12 | 7.70E-07 | | |
| TCDD-nc | 7.80E-09 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 243 | 1.56E-10 | | 3.00E-10 | 5.19E-01 |
| 2,4-D | 5.09E-05 | 2.1 | 1 | 243 | 0.67 | 1 | 70 | 243 | 1.02E-06 | | 3.00E-03 | 3.39E-04 |
| 2,4,5-T | 9.5E-05 | 2.1 | 1 | 243 | 0.6658 | 1 | 70 | 243 | 1.9E-06 | | 3.00E-03 | 6.33E-04 |



SCENARIO 2: Construction of Cement Cover

| Compoun | Ambient Air Conc (mg/m^3) (1hr avg; adjusted for absorption) | Inhalation Rate (m^3/hr) | Exposure time (hr/d) | Exposure Freq (d/yr) | Exposure Duration (yr) | Absorption Fraction | Body Weight (kg) | Avg. Time (d) | ABS DOSE (mg/kg/day) | CANCER RISK | CHRONIC RfD (Adjusted) (mg/kg/day) | HAZARD RATIO (DOSE/RfD) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TMEI | | | | | | | | | | | | |
| TCDD-c | 7.58E-09 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 25550 | 3.51E-13 | 1.83E-07 | | |
| TCDD-nc | 7.58E-09 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 7.48E-11 | | 3.00E-10 | 2.49E-01 |
| 2,4-D | 1.35E-04 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 1.34E-06 | | 3.00E-03 | 4.45E-04 |
| 2,4,5-T | 1.50E-04 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 1.48E-06 | | 3.00E-03 | 4.94E-04 |
| AMEI | | | | | | | | | | | | |
| TCDD-c | 7.58E-09 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 25550 | 3.51E-13 | 1.83E-07 | | |
| TCDD-nc | 7.58E-09 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 7.48E-11 | | 3.00E-10 | 2.49E-01 |
| 2,4-D | 5.09E-05 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 5.02E-07 | | 3.00E-03 | 1.67E-04 |
| 2,4,5-T | 9.50E-05 | 2.1 | 1 | 120 | 0.33 | 1 | 70 | 120 | 9.37E-07 | | 3.00E-03 | 3.12E-04 |

AMEI. The hazard quotient from exposure to 2,4,5-T is 0.00049 for the TMEI and 0.00031 for the AMEI.

## 5.2 Uncertainties

As in exposure assessment (see Section 3.4), there are uncertainties associated with the dose-response component of risk assessment. The EPA is now considering new evidence to suggest that TCDD may be a threshold carcinogen dependent on receptor-mediated (aryl hydroxylase) binding into a ligand-receptor complex for all dioxin-induced effects, and that this binding is rate-limiting. Furthermore, the complex must undergo activation and translocation into the nucleus as a prerequisite for effect. The Agency is now considering lowering the slope factor by two-fold, which would have an impact on the ultimate expression of risk. At this time of report preparation, the IRIS file on TCDD has been pulled while deliberations are underway on this issue.

As recorded in Table 4.10, the level of confidence in the studies used to develop RfD's for all three chemicals can be highly variable for a great variety of reasons having to do with the quality of available science. No level of confidence is presented for TCDD; levels of confidence for 2,4-D and 2,4,5-T are described as medium, creating a margin of uncertainty.

Susceptibility to chemical toxicity among potential human receptors can also be highly variable due to preexisting general morbidity of residents on the Island, particular sensitivities among individuals (e.g., pregnant women), and such other factor as genetic predisposition to cancer.

Determination of carcinogenic risk from exposure to TCDD is typically amortized over a lifetime of 70 years. While exposure for the current scenario was assumed to have a maximum duration of 25 years (based on first exposure in 1972 and paving, excavation, or some other modification to the site in 1997), for some individuals, lifetime may be fewer or greater than 70 years, creating an element of uncertainty in the risk calculation.

Section 4.0 included a discussion on the toxicity of HO as a mixture. However there is insufficient evidence to formulate either a composite $R_fD$ or additive hazard quotients. As a result, any synergistic, potentiative, or antagonistic effects posed by exposure to the three chemicals in combination could alter the benchmark values used to calculate risk. These toxicological phenomena could not be accounted for in this analysis.

Finally, the uncertainties posed by dose-response data and the toxicity benchmark values derived from them for the determination of risk are compounded on top of the uncertainties associated with exposure assessment, as expressed in Section 3.4. Together they may result in a risk determination that can be off by as many as two orders of magnitude.

## 6.0 *Ecological Effects*

Johnston Island is a coral atoll occupying 626 acres in the Pacific Ocean, 717 nautical miles southwest of Honolulu. The island was expanded from an area of 60 acres by the deposition of local dredged material in 1942. The marine ecosystem in the waters surrounding the Johnston Atoll is typical of a diverse tropical Indo-Pacific reef community. One hundred ninety-three fish species and 164 invertebrate species have been identified (Amerson and Shelton, 1976). The terrestrial fauna at the Johnston Atoll comprises about 40 species of birds, many of which brood on the nearby Sand Island. Relative to the marine community, the terrestrial ecosystem is less diverse since the island is arid, only seven feet above sea level, and has no tropical forest. No information was available on other terrestrial fauna and flora. Most of the land on the island is taken up by a 9,000 foot runway and military buildings associated with the chemical agent disposal system and, therefore, would provide poor habitat for most species.

As part of the investigation of contaminant effects at JI, this section describes the sampling and analysis of TCDD in sediments and biota, analyzes possible exposure of ecological receptors (fish, invertebrates, and birds) to dioxin, and assesses risks. Risks to the ecological community resulting from exposure to 2,4-D and 2,4,5-T have not been assessed because these substances were not monitored in the present study.

## 6.1 Sampling Data

From 1985 through 1988, sediments were sampled from four areas of JI. Areas 1 through 3 are near the inner reef in the vicinity of the HO site, while Area 4 is on the opposite side of the Island (Figure 1). While a total of 38 samples were collected (Table 1), only 26 were identified by sampling area. In Area 1, dioxin was detected in one of 11 samples at a concentration of 160 parts per trillion (ppt). In Area 2, dioxin was detected in one of seven samples at a concentration of 190 ppt. Dioxin was not detected in the four Area 3 samples or the two Area 4 samples.

Samples were collected from a variety of fish, invertebrate, and bird species from 1984 through 1989 (Table 2). A total of 199 tissue samples (44 fish species, 13 invertebrate species, 2 bird species) were analyzed for dioxin. Samples of aquatic species were collected from Areas 1 through 4, Area 5 (inner reef), and Area 6 (outer reef) (see Figure 1). Samples of birds were collected on land near the Formal HO Storage Area.

A total of 32/199 tissue samples contained detectable concentrations of dioxin. Frequency of detection for the fish, invertebrate, and bird samples from each area is listed in Table 2.1. Analysis of the fish and invertebrate tissue data is complicated by the use of different organs (liver, muscle, and unspecified organs) for various samples. In addition, differences in habitat and feeding strategies are likely to result in variable uptake. Nevertheless, for the purpose of summarizing the data, all fish (whole body, muscle, or unspecified), crab, snail, octopus, and sea cucumber data have been summarized for each area.

A total of three bird samples were analyzed. TCDD was not detected in any of the samples which included one liver sample and two unspecified organ samples.

## 6.2 Toxicological Profile for TCDD

The toxicity of dioxin to fish and wildlife was reviewed by Eisler (1986). Dioxin is toxic to fish at low and sub-ng/L levels which makes it one of the most toxic compounds tested in aquatic organisms. Mehrle et al. (1988) reported significant increases in mortality and decreases in growth in rainbow trout (*Oncorhynchus mykiss*) exposed for 28 days to 0.038 ng/L followed by a 28-day observation period. Recently, Wisk and Cooper (1990) exposed Japanese medaka (*Oryzias latipes*) embryos to dioxin beginning on the day of fertilization and continuing until hatch (11 to 14 days). A statistically significant increase in the incidence of lesions occurred at 0.4 ng/L. Eisler's (1986) review stated that the highest tested concentration that did not produce adverse effects was 0.01 ng/L.

Due to its low water solubility, estimated at less than 20 ng/L (Marple et al., 1986), releases of dioxin to the aquatic environment tend to result in accumulations in sediments and biota (Eisler, 1986). Eisler (1986) cited studies in which higher levels of dioxin were found in bottom-feeding versus top-feeding fish, indicating the likely importance of sediments as a source. Dietary uptake may also contribute to body burdens as substantial levels of dioxin were measured in fish gut contents (Young and Cockerham, 1985; as cited in Eisler, 1986). Mehrle et al. (1988) estimated a bioconcentration factor (steady state fish muscle concentration divided by water concentration) of 39,000. Monitoring studies have identified measurable levels of dioxin in field samples of fish and crab tissues (e.g., Belton et al., 1985; Ryan et al., 1984). Studies in New Jersey have resulted in closure of the Passaic River to the harvesting of fish and shellfish because dioxin was frequently found in fish and crabs at concentrations exceeding the FDA levels of concern (Belton et al., 1985).

Several studies were found linking tissue residues with toxic effects. The Mehrle et al. (1988) study, which reported increased mortality and decreased growth, measured mean whole body dioxin concentrations of 0.74 ng/g (=740 ppt). Branson et. al. (1985) exposed rainbow trout to 0.107 ng/L dioxin for 6 hours and monitored elimination over 139 days. Dioxin body burdens at the end of the study were 650 ppt in whole fish, 260 ppt in muscle, and 2710 in liver. In these fish, there was reduced growth relative to controls and evidence of fin rot. The embryo exposure study of Wisk and Cooper (1990) reported that lesions were reported in embryos containing 240 ppt dioxin.

Dioxin is known to bioaccumulate in fish-eating birds (reviewed by Walker, 1990). Braune and Norstrom (1989) measured dioxin concentrations in herring gulls (*Larus argentatus*) and alewife, which comprise a major portion of their diet, from Lake Ontario. Mean whole body dioxin concentrations were 127 ppt in gulls and 4 ppt in fish. A biomagnification factor (whole body bird/whole body alewife concentration) of 32 was calculated. Egg levels may be similar to whole body levels; mean dioxin levels in herring gull eggs and whole body tissues were 83 and 127 ppt, respectively.

Elliott et al. (1989) reported that population declines in great blue herons (*Ardea herodias*) in British Columbia coincided with a tripling of dioxin levels in eggs from 66 to 210 ppb. These researchers cited studies in which colonial waterbird population declines occurred when dioxin levels exceeded 2000 ppt and began to recover when levels decreased to below 500 ppt. These field studies have not established causal relationships; controlled laboratory studies are required. Eisler (1986) cited a laboratory study in which chick edema disease (pericardial, subcutaneous, and peritoneal edema accompanied by liver enlargement and necrosis) occurred in domestic chickens fed dioxin at 1 or 10 ppb for 21 days. This disease was frequently lethal.

## 6.3 Risk Assessment

Releases of HO have exposed fish and invertebrates and possibly birds to dioxin. Only a rough estimate of risk is possible given the limitations of the data. When possible, risks were assessed by comparing body burdens with levels associated with toxic effects.

### 6.3.1 Aquatic life

The highest concentration of dioxin was reported in the crown squirrelfish. Squirrelfishes tend to remain close to the bottom and do not travel long distances (Migdalski and Fichter, 1976). These behaviors may increase their exposure to localized sources of dioxin in sediments. Out of four samples (three Area 1; one Area 2), TCDD was detected in one sample from Area 1 at 352 ppt and in one sample from Area 2 at 472 ppt. These concentrations exceed the 260 ppt measured in rainbow trout muscle that was associated with decreased growth and fin lesions (Branson et al., 1985).

The only other fish species with concentrations exceeding 100 ppt was the yellowfin goatfish. Three samples were collected in Area 1, where concentrations were 11, 85, and 102 ppt. TCDD was not detected in single samples of this species from Areas 2 and 5. Goatfishes are bottom feeders (Migdalski and Fichter, 1976), which may account for their enhanced body burdens. The maximum reported concentration is nearly one-half the 260 ppt reported as toxic by Branson et al. (1985).

Several invertebrate samples were detected at levels between 14 and 28 ppt. The only invertebrate sample detected at greater than 100 ppt was a "snails" sample from Area 2 measured at 120 ppt. No data linking tissue concentrations with effects in snails could be located.

Uncertainties in the analysis result from the collection of a small number (usually less than five) samples of each species in each area. In addition, in some samples either the species or organ that was analyzed or the collection site was not reported.

### 6.3.2 Birds

In three samples of birds, there were no detectable concentrations of dioxin. Further sampling is recommended to more adequately characterize risks.

## 6.4 Regulatory Concentrations

EPA has not issued ambient water quality criteria for the protection of aquatic life from exposure to dioxin (F. Gostomski, EPA, personal communication, January 22, 1991). FDA advisory levels are for the protection of human health rather than aquatic species. No sediment quality criteria have been published or proposed for dioxin.

## *7.0 Data Requirements Assessment*

The EPA (1989) recommends that the data needs for the RI/FS be addressed at the site scoping meetings. Developing a comprehensive sampling and analysis plan (SAP) during the scoping meeting allows all of the data needs for the RI/FS, including the risk assessment, to be met. The data needs are identified by determining the type and duration of possible exposures (e.g., acute, chronic), potential exposure routes (e.g., fish ingestion, dust inhalation), and key exposure points (e.g., work areas) for each medium. These same types of considerations are also important for the ecological risk assessment. Data needs may have to be addressed before a more comprehensive risk assessment can be performed.

While there is always a need for better empirical data on toxicity, dispersion modeling, and general methodologies for expressing risk, monitoring data is usually site-specific and can be tailored to specific features of the site. There has not been a systematic effort in collecting the needed monitoring data at the HO site. To date, the most definitive data-collection activity has been the soil characterization study by Crockett et al. (1986). Data that can be obtained to convert this risk assessment into a more realistic multimedia approach are presented below. Many of these needs were presented in the trip report for the site visit (Appendix C). Although the indicated supplemental data collection would provide the complete range of information needed for a full baseline risk assessment, there are some pieces of information that are more important than others, so that the individual needs may need to be ranked in priority order. This may preclude the necessity of having to perform all recommended procedures.

## 7.1 Air Sampling

The risk assessment used estimated values for the particulate and vapor phase emissions from the site. Air sampling would characterize the particulates and vapors coming from the site. Particle size distribution will enable determination of the percentage of respirable dust. To determine the wind erosion around the site several Hi-Vol samplers, equipped with particulate traps, could be placed downwind around the fence line. At the southwestern fenceline the odor of 2,4-D was detectable during the site visit, indicating that there may be significant vapor emissions from the site. Organic vapor phase samplers capable of collecting dioxins, 2,4-D, and 2,4,5-T can be placed around the site to characterize ambient air concentrations. There are other potential sources of dioxin on JI, including JACADS, the burn pit, and the fire training area. Sampling would permit source apportionment of dioxin from each of these sites.

## 7.2 Soil Sampling

The characteristics of the soil can have an influence on the bioavailability of dioxins and the other chemicals. Soil moisture content, organic content, and particle size distribution are missing elements that are important for lowering the uncertainty in the soil exposure calculations. It was originally planned to vertically sample the TCDD hot spots, but sample results were not available in time to accomplish this, and, therefore, some hot spots were missed in the vertical soil sampling. These hot spots could now be sampled vertically for all three compounds, TCDD, 2,4-D, and 2,4,5-T. Only 15 plots were sampled for 2,4-D and 2,4,5-T, presenting a spacial distribution for these compounds inadequate for risk assessment. More plots could be sampled for these two compounds. One method that can be used to accomplish this is to revisit the 48 plots that were originally vertically sampled. These 48 plots could be sampled for all three chemicals of concern. This sample design would have two benefits: (1) better knowledge of the spacial distribution for 2,4-D and 2,4,5-T; and (2) knowledge of the fate of these chemicals over time.

## 7.3 Sediment Sampling

Channell and Stoddart (1984) found positive sediment samples near the western shore, prior to construction of the seawall in that area. This area could be revisited to determine if the seawall is performing according to its intended function. More sediment samples are needed to better characterize the spacial pattern of contamination. A grid pattern similar to the soil sampling protocol would help to characterize the spacial contamination pattern. These samples should include areas close to the shoreline.

## 7.4 Water Sampling

### 7.4.1 Seawater Sampling

No seawater sampling has been conducted off the former HO site. The U.S. Fish and Wildlife (1987) report that TCDD levels of 38 pg/l are toxic to fish. Toxic endpoints include severe adverse effects on survival, growth, and behavioral responses. With this potency, seawater sampling may be important.

### 7.4.2 Groundwater Sampling

The groundwater under the former HO site has never been sampled and may be a vital link in any discovery of HO site-related fish contamination. Groundwater sampling could proceed as described in Appendix C.

## 7.5 Biological Sampling

More sampling can to be performed within Site 3 to determine if contaminated fish are in this area. No biological samples have been analyzed for 2,4-D or 2,4,5-T. It is not possible to assess the potential impact from fish ingestion for these two chemicals if this analysis is not performed. Walsh III (1984) and Randall (1961) demonstrated that several adult fish species can have large movements. A study could be performed to ascertain if these migratory fish species are moving from the waters adjacent to the former HO site into fishing waters (e.g., Zones 5 and 10 in Figure 3.1). Sampling and analysis of fishermen's catches can be easily used to determine if humans are consuming contaminated fish. This is the only study that would demonstrate if the fish being consumed are contaminated.

## 7.6 Ecological Risk Sampling Recommendations

Further field investigations may be needed to adequately characterize the ecological risks at JI. Any additional research should be coordinated with the work underway by Dr. John Labelle of the Woods Hole Oceanographic Institute in support of the JACADS monitoring program. Additional sampling programs could be designed so that statistical comparisons can be made between concentrations in the different areas. In such an investigation sediment sampling would be expanded to allow better characterization of the spatial pattern of contamination. Biota samples would be focussed on species whose behavior may lead to greater levels of contamination (e.g., bottom feeding resident species). Organisms that are important parts of marine food chains (e.g., small invertebrates such as marine worms) would be sampled. Based on the available data, the crown squirrelfish, yellowfin goatfish, snails, and crabs are good candidates for further sampling. Increased sampling of birds may be required to determine whether populations are at risk due to consumption of contaminated prey (e.g., fish and snails). Sampling could focus on one or two bird species that tend to be localized on the Island.

Although the contaminant studies should remain focussed on dioxin, it would be useful to examine several fish samples for 2,4-D. This compound has been measured at levels as high as 281 ppm in soil samples on the Island (Crockett et al. 1986). Although it is not bioaccumulated to the same extent as dioxin, measurable residues have been reported in fish from lakes treated with the compound (Frank et al. 1987) and toxicity data are available (e.g., Cope et al., 1970).

## 8.0 *Summary*

*Scope of the study and physical setting.* This report contains the results of a screening-level risk assessment conducted for the Air Force Occupational and Environmental Health Laboratory concerning the Herbicide Orange (HO) storage site at Johnston Island (JI). The risk assessment is part of the remedial investigation and feasibility study (RI/FS) process established by the U.S. EPA for characterizing the nature and extent of risks posed by hazardous waste sites and for developing and evaluating remedial options. This process is being conducted in the context of the U.S. Department of Defense (DoD) Installation Restoration Program (IRP).

JI is currently used for three purposes:

1. In the late 1950's and early 1960's, the island was used to launch missiles for atmospheric testing of nuclear weapons. During 1962, three missile aborts caused transuranic contamination on parts of the island. Launch and support facilities at JI are maintained in a caretaker status in case testing is deemed necessary for national defense.

2. JI has been designated as a chemical warfare destruction site and the Department of the Army maintains the Johnston Atoll Chemical Agent Disposal System (JACADS) on the Island. JACADS is involved in active thermal destruction of CW agents.

3. Johnston Atoll, including JI, is a National Bird Refuge, largely because of bird populations on nearby Sand Island. Among the few species of animal life swimming in waters off JI is the green sea turtle, currently classified as an endangered species. The Island is also used as a chemical munitions storage site.

The Island is inhabited with military personnel and civilian employees of DoD support contractors. The tour of duty for military personnel has generally run 1 to 2 years. Civilian personnel have generally been on the Island for longer periods of time (5 years but as many as 15 years or more). No children reside on the Island, although there is a potential for fetal exposures.

*Site characterization.* During the period from 1972 to 1977, JI was also used for temporary storage of Herbicide Orange (HO). A total of 1.37 million gallons of HO in 26,300 fifty-five gallon drums were transferred to JI from South Vietnam in 1972. The drums were stored on a 4-acre site on the northwest corner of the Island. The HO was successfully incinerated at sea in 1977. Corrosion of drums while in storage resulted in HO leakage at a rate of approximately 20 to 70 drums per week. Approximately 49,000 pounds of HO are estimated to have escaped into the environment annually during the storage period. The site is now contaminated with the active ingredients of HO: 2,3,7,8-tetrachloro-dibenzodioxin (TCDD); the n-butyl ester of 2,4-dichlorophenoxy acetic acid (2,4-D); and the n-butyl ester of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T).

For this risk assessment, the chemicals of primary concern are TCDD, 2,4-D, and 2,4,5-T. The site is bounded by a seawall to the west-northwest, an open area and storage area to the east-southeast, a roadway to the south, and several limited-use operations to the west: a transformer, beacon building, Hi-Vol sampler associated with JACADS, fire training area, and burn pit. Access to the site itself is restricted by a fence on all landlocked sides. Soil on the site is contaminated with the three chemicals of concern. Soil samples taken in 1986 contained surface residues of TCDD (nondetect at 0.1 ppb to 163 ppb), 2,4-D (2.5 to 281,330 ppb), and 2,4,5-T (53 to 237,155 ppb). Soil samples also contained subsurface residues of TCDD (nondetect to 510 ppb), 2,4-D (nondetect to 365,202 ppb), and 2,4,5-T (nondetect to 682,247 ppb). Measurement of these substances in air, groundwater, seawater, and sediments have not been conducted. Analysis of marine biota for TCDD has revealed residues ranging from nondetect to 472 ppb. Subsurface soil and marine biota samples were limited to the point of greatly confining the scope of the exposure and risk assessments.

*Exposure assessment.* The potential for exposure to TCDD, 2,4-D, and 2,4,5-T for persons engaged in activities proximal to the HO site is dependent on numerous factors including the physical setting of the site (i.e., climate, vegetation, soil type, and hydrology), as well as features of the potentially exposed populations. The frequency and duration of potential exposure depends on population demographics and human activities patterns associated with land-use around the site.

The site is currently not in use, is dormant, and has limited access by a surrounding fence. However, potential avenues of human exposure include volatilization of the contaminants into the air, suspension of particle-associated compounds into the air due to wind erosion, and consumption of edible marine life that have become contaminated in the waters adjacent to the site. For purposes of assessing current or "baseline" risk from exposures related to the HO site, only the air pathway was evaluated. Wind erosion was judged to be non-significant for the undisturbed site, whereas, ingestion of contaminated marine biota, while considered plausible, could not be performed to due the lack of sufficient data.

For exposure through the air medium, important human activities include, but are not necessarily limited to, occupational operations associated with the seawall, the electrical transformer, the Hi-Vol sampler, the beacon building in the immediate area, the fire training area, the rip-rap area used as a boat-launch site, and the burn pit at an intermediate distance.

Two future scenarios that would alter exposure potential from that presented by current land conditions which were considered in this report are: (1) remediation through excavation; and (2) covering of the site with cement. For purposes of assessing potential inhalation exposures due to the release of particle-associated compounds resulting from future-use activities, emission rates were estimated for each activity (i.e., unloading and loading of contaminated soil, vehicular traffic, wind erosion) within each scenario (i.e., excavation or cement cover construction).

For both vapor-phase inhalation potentially occurring during the current scenario, as well as vapor-phase and particle-associated inhalation potentially occurring during the two future-use scenarios, exposure was estimated for the Theoretical Most Exposed Individual (TMEI), as well as an Alternate Most Exposed Individual (AMEI). The TMEI was assumed to have access to the entire perimeter of the HO site; whereas, the AMEI has access to only the fenceline (southern side of the site).

To estimate the air concentrations ($g/m^3$) of both vapor-phase and particle-associated TCDD, 2,4-D, and 2,4,5-T, a screening-level atmospheric dispersion modeling analysis was conducted to estimate one-hour, eight-hour, and annual average concentrations of these compounds around the perimeter of the HO site. These predicted air concentrations were then used to estimate inhalation exposures and lifetime average and average daily absorbed doses to the TMEI and the AMEI. The estimated absorbed doses where then used to assess cancer and noncancer risks, respectively.

*Toxicity assessment.* For noncarcinogenic toxic endpoints, TCDD appears to be approximately seven orders of magnitude more potent than either 2,4-D or 2,4,5-T, with oral $R_fD$'s of $1 \times 10^{-9}$, $1 \times 10^{-2}$, and $1 \times 10^{-2}$, respectively. The primary critical effect seen for TCDD was fetal survival and the secondary critical effect seen was renal damage. The primary critical effect seen for 2,4-D was renal damage and the secondary critical seen was hematologic and hepatic effects. The $R_fD$ for 2,4-D was based on studies producing a medium level of confidence. For 2,4,5-T the primary critical effect was neonatal survival, and the secondary critical effect was increased urinary coproporphyrin excretion. The $R_fD$ for this chemical was based on studies producing a medium level of confidence.

For both 2,4-D and 2,4,5-T an evaluation of their carcinogenicity cannot be made on the limited animal data available. TCDD is classified as a B1 carcinogen when associated with phenoxy herbicides and/or chlorophenols. In animal studies TCDD has been shown to be a potent carcinogen with an oral slope factor of $1.56 \times 10^5$ $(mg/kg/day)^{-1}$. Increased incidences of cancer have been observed in lungs, liver, hard palate, and nasal turbinates. Epidemiological studies have produced only a potential correlation of an increased risk of soft-tissue sarcomas for chemicals contaminated with TCDD.

*Human health risk assessment.* Characterization of risk based on the results of the exposure assessment for inhalation of vapor-phase TCDD revealed that current or baseline lifetime excess cancer risk associated with the undisturbed HO site was approximately $3 \times 10^{-5}$ for both the TMEI and the AMEI. This is equivalent to 3 excess cancer cases occurring among 10,000 individuals exposed for a period of 25 years during their lifetime. TCDD-associated estimated cancer risks resulting from excavation and cement cover construction activities were 8 x $10^{-7}$ and 2 x $10^{-7}$, respectively, for both the TMEI and the AMEI. The magnitude of these cancer risk estimates are within the Superfund site remediation goals (i.e., cancer risk range of $10^{-4}$ to $10^{-7}$); however, it is plausible that additional lifetime excess cancer risk may be present due to ingestion of contaminated marine biota. This exposure pathway has not been adequately characterized and was not included in the risk characterization.

For the current scenario, noncancer risks, as measured by hazard quotients from exposure of the TMEI to TCDD, 2,4-D, and 2,4,5-T, were 0.76, 0.0014, and 0.0015, respectively; whereas, the hazard quotients from exposure of the AMEI to TCDD, 2,4-D, and 2,4,5-T were 0.76, 0.00051, and 0.00095, respectively.

For the future excavation scenario, noncancer risks, as measured by the hazard quotients from exposure of the TMEI to TCDD, 2,4-D, and 2,4,5-T, were 0.52, 0.00090, and 0.0010, respectively; whereas, the hazard quotients from exposure of the AMEI to TCDD, 2,4-D, and 2,4,5-T were 0.52, 0.00034, and 0.00063, respectively.

For the future cement cover construction scenario, noncancer risks, as measured by the hazard quotients from exposure of the TMEI to TCDD, 2,4-D, and 2,4,5-T, were 0.25, 0.00045, and 0.00049, respectively; whereas the hazard quotients from exposure of the AMEI to TCDD, 2,4-D, and 2,4,5-T were 0.25, 0.00017, and 0.00031, respectively.

Similar to the cancer risk estimates for TCDD, these noncancer hazard quotients are within the Superfund site remediation goals (i.e., less than 1.0). However, noncancer risk resulting from ingestion of contaminated marine biota has not been evaluated.

*Uncertainties associated with this analysis.* There are several significant uncertainties associated with soil characterization, exposure assessment, and risk characterization. The two future-use scenarios, remedial excavation or surfacing with unknown pretreatment, are hypothetical and not necessarily reflective of actual future use. Many empirical and site-specific assumptions were made in the exposure assessment, including body weight, inhalation rate, pulmonary deposition rate, construction vehicle weight, number of wheels rolling over the site, duration of excavation, duration of the soil covering activity, physicochemical features of the soil, threshold wind velocity, diffusion and air-soil partition coefficients, and spatial distribution of 2,4-D and 2,4,5-T on the surface and in vertical profiles. In addition, other variables were unaccounted for in the analysis. They include population transience, male/female differences in exposure, presence of other isomers of dioxin and other chemicals on the Island and prior or concurrent exposures to them, atmospheric transformation and soil photodegradation of the chemicals of concern, groundwater contamination, and potential concurrent exposures from JACADS.

With regard to toxicity and dose-response parameters associated with the risk calculation, uncertainties include what is currently a rethinking of the mechanism of toxicity of TCDD in the scientific community (which would affect the benchmark toxicity value used in the risk calculation), medium levels of confidence in the $R_fD$ values used, and the potential for sensitive individuals and those with preexisting morbidity to be exposed to chemicals at the HO site. In addition, the assumed periods of maximum exposure (25 years) and lifetime risk (70 years) may be incorrect. Lastly, synergistic or other toxicological phenomena caused by chemical interaction are unknown.

*Ecological risk.* A limited data base permitted only a preliminary ecological risk assessment. Sediment sampling indicates several locations of dioxin contamination. Among resident fish species sampled at the site, the crown squirrelfish had the highest dioxin levels in several samples (352 and 472 ppb).

These concentrations exceed levels reported to be associated with toxic effects in the rainbow trout. Further sampling of fish, invertebrates, birds, and sediments is needed to characterize the spatial pattern of contamination and to assess ecological risks.

*Needs assessment.* There is a fairly large uncertainty associated with the calculation of human health and ecological risks for the HO site because of a consistent lack of appropriate scientific information. It is recommended that uncertainty reduction be given a high priority in any future activities concerning HO site closure. With specific regard to the air component of the risk assessment, it is recommended that particulate and vapor-phase concentrations of TCDD, 2,4-D, and 2,4,5-T be conducted. Since ambient air concentrations of these chemicals is dependent on soil characteristics, it is recommended that additional soil sampling be performed to characterize soil moisture and organic content, particle size distribution, and spacial distributions of the chemical contaminants. Sediment and water sampling is recommended to determine which medium or media contain the potential source of the fish contamination. Further biological sampling is recommended to better characterize the potential for human exposure to contaminated fish, and (as a National Bird Sanctuary) the risks to the avian populations on the Atoll.

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# *Appendix A*

# JOHNSTON ATOLL RESOURCE SURVEY
# FINAL REPORT - PHASE SIX
# (21 JUL 89 - 20 JUL 90)

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JOHNSTON ATOLL RESOURCE SURVEY
FINAL REPORT - PHASE SIX
(21 JUL 89 - 20 JUL 90)

## INTRODUCTION

Construction of the Johnston Atoll Chemical Agent Disposal System (JACADS) project has been completed, and operations began in June 1990. The potential for adverse environmental effects is a concern, which has been addressed in environmental impact statements (U.S. Army Corps of Engineers 1983, 1985). This concern has led to a number of studies of the atoll's surrounding environment and biota (Applied Eco-Tech Services, Inc. 1983; Balazs 1984; Irons et al. 1984; Lobel 1984, 1985; Agegian and Abbott 1985; Dee et al. 1985; Keating 1985; Randall et al. 1985; Irons et al. 1986; Irons et al. 1987, 1988, 1989). There have been several previous studies of elements of the Johnston Atoll lagoon flora and fauna (Smith and Swain 1882; Edmondson et al. 1925; Fowler and Ball 1925; Clark 1949; Schultz et al. 1953; Halstead and Bunker 1954; Gosline 1955; Banner and Helfrich 1964; Moul 1964; Brock et al. 1965, 1966; Buggeln and Tsuda 1966; Jones 1968; Brock 1972, 1982; Bailey-Brock 1975; Amerson and Shelton 1976; Jokiel 1976; Maragos and Jokiel 1986). A systematic survey of the nature and distribution of the living aquatic resources is of particular concern because of the status of Johnston Atoll as a National Wildlife Refuge.

The first portion of the initial study (Irons et al. 1984) was designed to characterize, describe and evaluate the shallow-water ecosystem of the atoll as a whole, in an attempt to better assess its environment and resources. This included identifying the zones or "ecotypes" (Fig. 10), based on physical and biological similarities, that appeared distinctive within the atoll ecosystem (Irons et al. 1984).

The second portion of the initial study (Dee et al. 1985) had two distinct but related objectives: 1) detailed resource measurement and status monitoring, and 2) assessment of the nature and level of harvest. Subsequent work during Phase Two (Irons et al. 1986), Phase Three (Irons et al. 1987), Phase Four (Irons et al. 1988), Phase Five (Irons et al. 1989), and the present phase (Phase Six) have continued with the same objectives. The detailed resource measurement and status monitoring is intended to obtain more complete and quantitative abundance, distribution, and population characteristic data for the non-cryptic macrofauna within a representative set of long-term monitoring stations. Using standardized methods, the resources at the long-term stations have been monitored periodically to detect differences in the resource populations as JACADS progresses.

To the extent that spatial patterns of fishing/collecting activity permit, it is desirable to maintain a pair of physically and ecologically similar stations, one with a fairly high present level of harvest and one with a low level. Differences over time in the unharvested monitoring station will reflect changes unrelated to harvest - either natural variability or changes abundance and distribution of cryptic species, such as soldierfish and bigeyes. These were conducted by searching all possible hiding places where cryptic species may be found throughout two areas of 900 $m^2$ each, within a station.

The overall area characterization consisted of a quantitative estimate of percent algal and coral cover (corals by species), invertebrate abundances, and physical characteristics of the station area. Overall characterization methods were basically as in Irons et al. (1984) except that a numerical value was assigned for bottom coverage of most sessile forms (Appendix A).

To assess the fishery at Johnston Atoll, two methods were used: 1) fishermen's catch reporting, and 2) creel census. The catch reporting program was started in February 1984, and has been ongoing throughout the project whenever fishing was permitted. Boxes containing catch report forms (Appendix B, Fig. 1) were placed at the six most frequently fished locations on Johnston Island: port control, Hama point, Hashi's shack, the east and west ends of the main pier, and the boathouse (between port control and the main pier) (Fig. 1). Catch reports provided information on species and numbers of animals caught and/or collected: date, time, and location caught/collected; amount and types of gear used; hours spent fishing; and identity of fishermen. A catch report was requested each time anyone did any kind of fishing and/or collecting, even if there was no catch. The catch report format was designed and the report boxes were located and maintained so as to make the reporting process as simple and painless as possible for all fishermen. Consistent and accurate catch reporting was constantly stressed by Unit project staff. Serious declines in voluntary catch reporting during the report year ending 1987 resulted in the implementation of a new form (Appendix B, Fig. 2) combining recreational boat sign-out procedures with a mandatory catch report to be filled out upon the fisherman's return. A serious decline in JI shoreline catch reporting during the report year ending 1989 made this shoreline information unusable. Subsequently, Unit personnel and Island management personnel have been unable to determine a satisfactory method of enforcing mandatory reporting of JI shore catch. As a result, no data for JI shore catch will be reported. However, Unit personnel continue to encourage JI shore catch reporting and continue to collect the completed JI shore catch forms.

Creel census was performed by the Unit project staff on catches made by fishermen. It consisted of recording pertinent data, such as numbers of each species caught, weights, lengths, and sex (if discernible) of specimens, date, gear used, and the names of fishermen. Catches involving the use of boats were censused at the boathouse. Due to the work schedule of Johnston Atoll people, approximately 70% of all fishing occurs on Sundays. For this reason creel census was routinely conducted only on Sundays. This allowed a significant portion of the harvest to be examined with minimum time and effort.

considerably reduced the negative trend in "mean total number per census" (Table 3). By extension, variability of recruitment occurring for a good many species might contribute heavily to the overall population pattern observed.

All the community analyses combined showed no clear seasonal variations in the fish communities at the monitoring stations. However, there were differences in the fish communities between stations. Stations P3 and P7, which are both located in different habitat types from Stations P1, P5, and P6, have very different fish communities. Station P3 has a significantly lower mean number (as determined by paired t-tests) of total individuals observed on the fish transect censuses when compared to Stations P1, P5, and P6. In some previous phases of this study and in the present phase, Station P7 has had a significantly higher number (as determined by paired t-tests) of Ctenochaetus strigosus and Acanthurus nigroris juveniles than any other station. Station P5 showed no significant differences from Stations P1 and P6 in the t-tests and dendrograms, but it is the only place where the whitecheek surgeonfish (Acanthurus glaucopareius) is seen.

In addition, paired t-tests were performed on some species that are often important in the catch (i.e., Myripristis amaenus, the doublebar goatfish (Pseudupeneus bifasciatus), the manybar goatfish (P. multifasciatus), the blue goatfish (P. cyclostomus), the Samoan goatfish (Mulloides flavolineatus), the rudderfish (Kyphosus vaigiensis), the blue jack (Caranx melampygus), the spectacled parrotfish (Scarus perspicillatus), and Acanthurus triostegus) seen at Stations P5 and P6. These results also showed no significant differences between these two stations. The lack of significant differences between these stations, with similar habitats and substantially different fishing effort, is consistent with the harvest assessment results in suggesting that there is no significant impact on the fish communities at Johnston Atoll from the present level of fishing.

## THE FISHERY

### General Characteristics

All fishing at Johnston Atoll (JA) is supposedly for recreational purposes. The majority of the fishing activity and a very large fraction of the finfish catch is due to long-term "residents" - almost all employees of Holmes and Narver, the prime contractor for JA operations. These fishermen fish mostly for enjoyment, to add fresh fish to their diet, and to accumulate fish to freeze and carry home when they take home leave from JA at infrequent intervals. The remainder of the catch is due to "transients" - personnel stationed for one to two years at JA, such as military personnel, and the employees of various JACADS contractors. As a rough estimate, 330 boxes of frozen fish are "exported" annually for home leave. During years of good deep-sea fishing conditions, a majority of these boxes may contain deep sea fish, primarily wahoo (Acanthocybium solandri). Most of the "exported" fish terminates in Honolulu. There is no definite information as to how it is disposed of. While there are no subsistence implications to the consumption of fish locally at JA, eating fresh caught fish is clearly an important recreational and social activity for a number of residents. There is apparently little waste of the total fish catch. Many fishermen give fish to nonfishermen to take home on leave. There is no monitoring or control of "export". Coral and gastropods are taken by both residents and transients. Disposition of these and most other invertebrate species appears to be for personal collections, or they are used as gifts for family and friends. The following is a brief description of the nature of the fishery for some of the species (fish and invertebrates) that were major items in the catch when the study began.

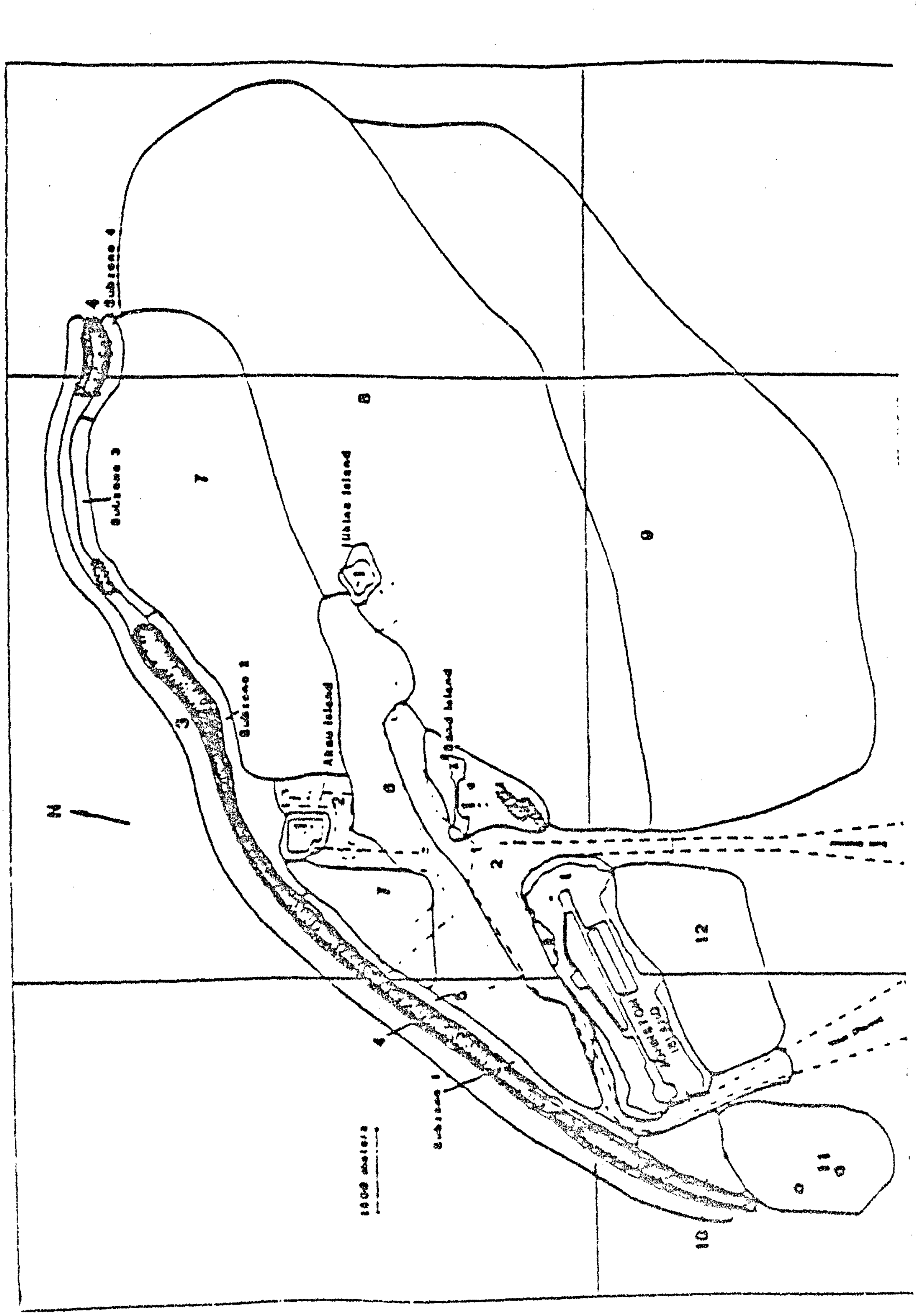
*Myripristis amaenus*, the most common of the "menpachi", constitutes the largest catch in numbers of all fish species at JA. Large numbers of this soldierfish are taken by fishermen throughout the year. Prime areas for nighttime line fishing for menpachi include Hama point and Red Hat seawall on Johnston Island (JI), as well as at the Sand Island pier (Fig. 1). During the day, large numbers of menpachi are taken by spear throughout Zones 5 and 10 (Fig. 10), with most taken in the vicinity of Station P5. No menpachi are taken by net. Menpachi fishing, like most fishing at JA, is done almost exclusively by residents. Most menpachi taken is used for local get-togethers, or is frozen by fishermen for home leave export.

*Priacanthus cruentatus* or "aweoweo" is one of the most prized fish species at JA. Bigeyes are taken at night by line from several locations on Johnston Island - main pier, Hama point, Red Hat seawall - as well as from the Sand Island pier. During the day, they are occasionally taken by spear throughout Zone 5, with most of these taken in the vicinity of Station P5. No aweoweo are taken by net. Aweoweo fishing is done almost exclusively by residents. They are taken in small numbers most of the year. Occasionally (only a few times a year, usually in January and February), they are taken in large numbers. When this occurs, many fishermen go to the main pier at night to fish exclusively for aweoweo, which usually bite heavily for one or two days. Aweoweo are usually frozen for home leave export.

*Kuhlia marginata* or "aholehole" and *Chaenomugil leuciscus* or "uouoa" are taken almost exclusively by throw net. Schools of these flagtail and mullet frequent the shallow rubble flats around the shorelines of Akau, Hikina, and Sand Islands, and occasionally Johnston Island. There are a few regular throw net fishermen (all residents) who take these species in large numbers. Thus small changes in the fishing activity of these fishermen can produce wide fluctuations in the annual catch figures for these species. They are either eaten locally, given to others, or frozen for home leave export.

*Kyphosus vaigiensis* or "nenue" are taken by line and spear mostly from JI. Rudderfish taken by residents are usually consumed; those taken by transients are considered incidental catch and are either used as bait or are returned alive.

*Mulloides flavolineatus* or "weke" are taken using all three gear types - line, spear, and net - from shallows around all islands and occasionally from Zone 5. During the summer months,



N
Subzone 1
Subzone 2
Subzone 3
Subzone 4
Akau Island
Sand Island
Hikina Island
1000 meters

juvenile weke or "oama" are taken in large numbers by throw net from the shallows around the islands. Approximately 50% of all weke taken are oama. Residents, mostly throw netters, take the majority of weke, with transients taking small numbers by line fishing. This goatfish is eaten locally or given away for home leave export. Juveniles are often collected for use as bait.

*Pseudupeneus bifasciatus* or "moano papa" is a prized fish species at JA and is taken almost exclusively by residents by line fishing or spearing. Line fishing for moano papa is done by boat along the channel edges, primarily the north edge of the main channel. This goatfish is taken by spear throughout Zones 5 and 10, mostly from the vicinity of Station P5. Moano papa are usually frozen by fishermen for their own home leave export.

*Pseudupeneus cyclostomus* or "moano kea" are highly prized at JA. A large part of the catch is taken by residents using lines or spears. Most moano kea are taken along the edges of the main channel; many are also taken from rubble shoreline areas around Johnston Island. This goatfish is speared throughout Zones 5 and 10, with most taken in the vicinity of Station P5. Moano kea are usually frozen for home leave export.

*Pseudupeneus multifasciatus* or "moano" are taken almost exclusively by residents, by line fishing along the channel edges, with some also taken from Johnston and Sand Island shorelines. This goatfish is speared throughout Zones 5 and 10, with most taken in the vicinity of Station P5. Most moano are frozen for home leave export.

*Caranx melampygus* and Forskal's jack (*Carangoides orthogrammus*), known locally as "papio" (those under 10 lbs.) or "ulua" (those over 10 lbs.), are taken mostly by residents and some transients by line fishing along channel edges, or from several locations on Johnston Island, as well as from Sand and East Island piers. These jacks are only occasionally taken by spear, usually in the vicinity of Station P5. Most papio are frozen for home leave export.

*Scarus perspicillatus* or "uhu" are taken predominantly by residents using spears. This parrotfish is speared throughout Zones 5 and 10, with some also taken around Sand and Johnston Island shorelines. Uhu are prized by fishermen and are usually frozen for home leave export.

*Acanthurus triostegus* or "manini" are taken exclusively by residents using throw nets, or spears. About 40% of the total catch is taken by throw nets around the shallows of all islands. Spearing, which accounts for the remaining 60% of the total catch, is done throughout Zones 5 and 10, with most fish taken in the vicinity of Station P5. This surgeonfish is usually eaten at local get-togethers or given to others for home leave export.

*Ctenochaetus strigosus* or "kole" are taken almost exclusively by residents. Practically all are taken by spear from Zones 5 and 10, primarily in the vicinity of Station P5. This surgeonfish is also eaten locally or is given to others to freeze for home leave export.

*Acropora cytherea* or "tabletop coral" is frequently collected by hand by both residents and transients. Most *A. cytherea* colonies collected are ~15-30 cm in diameter. This coral is commonly used for making coral trophy boxes. Most *A.*

cytherea is taken in the vicinity of Station P5, but it is also taken from other locations throughout the lagoon. Other species of coral, including Pocillopora sp. and Millepora are taken in much smaller numbers for similar purposes.

The red coral (Distichopora sp.) is prized by collectors and is primarily used for decorative purposes such as coral boxes. It is taken by hand throughout Zone 4 by both residents and transients. It is somewhat scarce in various sections of Zone 4, especially from Station P5 northward toward Station P6 (Irons et al. 1984), but is abundant in areas inaccessible to collectors (outside the barrier reef).

The mushroom coral (Fungia [P.] scutaria), the sea urchin (Echinothrix calamaris/diadema), and various gastropods such as augers, cones and small cowries occur in Zone 5 and other locations throughout the lagoon. These are collected by hand by both residents and transients, and are used for decorative purposes.

The tiger cowrie (Cypraea tigris) is prized by residents and transients and is used for decorative purposes. C. tigris is taken by hand throughout Zone 4, mostly from the reef-top around and between Stations P5 and P6. It is somewhat scarce and scattered throughout Zone 4.

Octopus sp. or "tako" are prized by residents and are occasionally found in the rubble of shallows along the shorelines of all four islands. Tako are speared or hand collected and are usually eaten locally.

The spiny lobster (Panulirus penicillatus) is taken by hand exclusively from Zone 4 and is highly prized by both residents and transients. Any P. penicillatus taken are usually eaten locally.

The crab (Grapsus sp.) is collected by hand and eaten exclusively by residents. It is found along stretches of all the island shorelines. Only a few people occasionally collect this crab.

Many other fish and some invertebrate species produce small catches of some minor recreational value.

## Correction for Underreporting of Catch

The basic quantitative data used to estimate catch came from fishermen's catch reports. There was substantial underreporting, and adjustments were made in an attempt to obtain a reasonable approximation of the annual catch. Fishing involving use of boats includes all fishing done on and around Akau, Hikina, and Sand Island, as well as all fishing done directly from boats. Underreporting of fishing done by boat was estimated by counting the catch report forms that were turned in not completed by fishermen who used boats. (Catch reports are now located on the back of the boathouse "boat check-out" records (Appendix B, Fig. 2) that are filled out for the recreation department each time a boat is used). Since it is mandatory for everyone who checks out a boat to fill out the catch form on the back, a single estimate of underreporting was calculated for all species caught using boats. During the current report year, 77% of all boats that were checked out for fishing reported on catch. Thus, we estimated that 77% of the catch of each species was reported. Catch data recorded from JI shore fishing were neither analyzed nor reported because there is no means for estimating underreporting, which is known to be substantial.

## Annual Catch and Effort

The total boat catch of each species, for the period Jun 89 to May 90 (year ending 1990), corrected for underreporting, is shown in Table 5, including major gear types used and primary location(s) of catch. The first 13 species listed were those that initially provided the largest catches. For historical reasons, this group continues to be referred to as the "major catch species", and most of these species have provided important landings in most years of the study. In the last few years, catches of Kyphosus vaigiensis have been very low (zero by boat in the current year), and catches of Carangoides orthogrammus, Selar crumenophthalmus, and Decapterus macarellus have been as high as many of the "major catch species".

Table 5. Estimated total annual boat catch of all species reported in the JA fishery, including major types of fishing gear and locations of catch, for Jun 89 - May 90.

| FISH SPECIES[1] | TOTAL NUMBER CAUGHT | MAJOR GEAR TYPE[2] | PRIMARY LOCATION(S)[3] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AI | HI | SI | P1 | P5 | 26 | 210 | CX | LA |
| Myripristis amaena | 3362 | LI SP | | HI | | 227 | 2047 | | 690 | | 375 |
| Ctenochaetus strigosus | 1201 | SP | 594 | HI | | P1 | | | 161 | | 385 |
| Acanthurus triostegus | 828 | SP NT | 112 | 521 | | | | | 172 | | LA |
| Chaenomugil leuciscus | 509 | NT | 112 | 392 | | | | | | | |
| Kuhlia marginata | 225 | LI NT | 65 | 160 | | | | | | | |
| Caranx melampygus | 186 | LI SP | 26 | 110 | SI | | | | | CX | LA |
| Pseudupeneus cyclostomus | 129 | LI SP | AI | 73 | SI | | | | | CX | |
| Mulloides flavolineatus | 123 | LI SP NT | 56 | 69 | SI | | | | | | |
| Scarus perspicillatus | 83 | SP | 36 | 18 | | | | | 210 | | 18 |
| Priacanthus cruentatus | 79 | SP | 20 | | | | | | 52 | | LA |
| Pseudupeneus bifasciatus | 66 | LI SP | 34 | | | | | | 210 | CX | LA |
| Pseudupeneus multifasciatus | 38 | LI SP | AI | HI | SI | | | | | CX | LA |
| Kyphosus vaigiensis | 0 | - | | | | | | | | | |
| | | | | | | | | | | | |
| Selar crumenophthalmus | 595 | LI NT | 31 | 564 | | | | | | | |
| Carangoides orthogrammus | 157 | LI SP | 30 | 102 | SI | | | | | CX | LA |
| Acanthurus mata | 26 | LI | | HI | | | | | | | |
| Acanthurus nigroris | 16 | SP | AI | | | | | | | | |
| Balistes sp. | 13 | LI | | | | | | | | | LA |
| Aphareus furca | 5 | LI | | HI | | | | | | | |
| Aulostomus chinensis | 2 | NT | | HI | | | | | | | |
| Carcharhinus amblyrhynchos | 2 | LI | | HI | | | | | | | |
| Scomberoides lysan | 2 | LI | | HI | | | | | | | |

Table 5 (continued).

| BENTHIC SPECIES[1] | TOTAL NUMBER CAUGHT | MAJOR GEAR TYPE[2] | PRIMARY LOCATION(S)[3] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | AI | HI | SI | P1 | P5 | Z4 | Z10 | CH | LA |
| Corals | | | | | | | | | | | |
| Acropora cytherea | 456 | HC | | | | | P5 | | | | |
| Distichopora sp. | 402 | HC | | | | | | Z4 | | | |
| Fungia scutaria | 135 | HC | AI | | | | | | | | LA |
| Acropora valida | 108 | HC | | | | | P5 | | | | |
| Millepora tenera | 4 | HC | | | | | | | Z10 | | |
| Non-sessile invertebrates | | | | | | | | | | | |
| Octopus sp. | 121 | SP HC | AI | HI | | | | | Z10 | | |
| Panulirus penicillatus | 74 | HC | | | | | | Z4 | | | |
| Linckia sp. | 14 | HC | | | | | | | | | LA |
| Grapsus sp. | 8 | HC | AI | | | | | | | | |
| Cypraea tigris | 57 | HC | | | | | | Z4 | | | |
| Terebra sp. | 36 | HC | AI | | SI | | | | | | |
| Conus sp. | 8 | HC | | | | | | Z4 | | | |
| Charonia tritonis | 7 | HC | | | | | | Z4 | Z10 | | |
| Cypraea sp. | 5 | HC | | | | | | | | | LA |

1 See Appendix H for common names.

2 Gear abbreviations:

- LI : Line
- SP : Pole spear
- HC : Hand collected
- NT : Throw net

3 Location abbreviations:

- AI : Shoreline and/or shallow waters around Akau Island
- HI : Shoreline and/or shallow waters around Hikina Island
- SI : Shoreline and/or shallow waters around Sand Island
- P1 : Long-term Station P1 and adjacent similar areas
- P5 : Long-term Station P5 and adjacent similar areas
- Z4 : Zone 4
- Z10: Zone 10
- CH : All channels
- LA : Elsewhere in JA lagoon within the shallow platform atoll area.
- Note : For species with a substantial total number caught in more than one location, the number caught in each major location is shown.

Some fishing and collecting have occurred throughout all areas of the lagoon where boat use is permitted and at all the islands of JA. However, there are a number of locations that are fished much more than others.

Trolling and bottom fishing are done in all the channels. About 95% occurs along the north edge of the main channel and turning basin from Hama point around JI to the garbage chute. Catch from the channels consists primarily of _Caranx melampygus_, _Carangoides orthogrammus_, _Pseudupeneus multifasciatus_, _P. cyclostomus_, and _P. bifasciatus_. There are only a few fishermen who fish this area once and occasionally twice a week.

Another location that receives considerable fishing pressure from spearfishermen and coral collectors is the area between the north edge of Akau Island and the barrier reef, extending from Station P5 west to the NW corner of Akau Island. Very little line fishing occurs in this area. Major catch species are _Myripristis amaenus_, _Ctenochaetus strigosus_, _Pseudupeneus multifasciatus_, _P. bifasciatus_, _Acanthurus triostegus_, and _Priacanthus cruentatus_. _Acropora cytherea_, _Cypraea tigris_, and _Panulirus penicillatus_ are the primary hand collected species from this area.

The area in Zone 10 between the west edge of the main channel and the barrier reef, extending past the west camera stand to the SW end of the barrier reef, receives a moderate amount of fishing pressure. Major catch species taken are _Ctenochaetus strigosus_, _Pseudupeneus bifasciatus_, _P. multifasciatus_, _P. cyclostomus_, _Acanthurus triostegus_, and _Scarus perspicillatus_. Most are speared, but some are taken with lines from the channel edge near Station P3. The reef flat immediately adjacent to the west camera stand is regularly visited by fishermen looking for octopus.

The area around and containing Station P1 is occasionally visited by spearfishermen and collectors. Major catch species from this area are _Myripristis amaenus_, _Priacanthus cruentatus_, _Ctenochaetus strigosus_, and _Scarus perspicillatus_. Less fishing occurs here during winter months due to strong surge and currents resulting from large surf breaking just outside the reef. The region of Zone 5 extending from Station P5 to P6 and Donovan's Reef is occasionally visited by spearfishermen and collectors. Major catch species from this area are _Ctenochaetus strigosus_ and _Myripristis amaenus_. Hand collected species are _Cypraea tigris_, _Panulirus penicillatus_, and _Distichopora_ sp.

Various locations around Johnston Island receive a considerable amount of fishing pressure. The main pier is line fished for _Caranx melampygus_, _Carangoides orthogrammus_, _Pseudupeneus cyclostomus_, and _Priacanthus cruentatus_ when barge traffic allows. The port control pier, which formerly was line fished for _Myripristis amaenus_, is now off limits to fishing. During the day, _Pseudupeneus cyclostomus_, _P. multifasciatus_, and occasionally _Octopus_ sp. are taken primarily by line along the shoreline from the Point house to the southeast corner of JI. _Myripristis amaenus_ and _Priacanthus cruentatus_ are taken by line and are the major catch species from Hama point. Throw nets are occasionally used along the shoreline from Hama point to the West point to take _Acanthurus triostegus_ and _Chaenomugil leuciscus_.

At night the Red Hat seawall is line fished for Myripristis amaenus, the big-scale soldierfish (Myripristis berndti), and Priacanthus cruentatus. Hashi's shack is line fished for the needlefish (Platybelone argalus) and Scarus perspicillatus. The grey reef shark (Carcharhinus amblyrhynchos) is also occasionally taken by military personnel using handlines from Hashi's shack and Hama point. The white-tipped reef shark (Triaenodon obesus), which was formerly caught at these sites, is now protected by an FCJ regulation. The garbage chute, formerly a popular fishing site, has been condemned due to structural damage by a storm. Fishing previously done at the garbage chute is now done at nearby Hashi's shack on the west wharf. However, some shark fishermen have been frequenting the garbage chute again.

Sand Island also receives some line and net fishing pressure. At night the pier is line fished for Myripristis amaenus and Priacanthus cruentatus. Caranx melampygus and Carangoides orthogrammus are occasionally taken there also. During the day, throw netters take Acanthurus triostegus, Kuhlia marginata, and Chaenomugil leuciscus from the shorelines around the east part of Sand Island.

Akau and Hikina Islands are frequented by throw netters taking Acanthurus triostegus, Chaenomugil leuciscus, Kuhlia marginata, and Mulloides flavolineatus. Pseudupeneus cyclostomus, Caranx melampygus, and Carangoides orthogrammus were also taken by line from the Hikina Island pier. These islands are off limits for all human visitation most of the year due to the large numbers of nesting seabirds there.

Weather permitting, all the locations above are easily accessible to fishermen. Locations in Zone 5 are somewhat less accessible due to occasional strong currents and surge. The areas around Stations P1, P3, P5 and P6 are visited primarily by divers spearing and/or hand collecting. Very little, if any, line fishing occurs at or near these areas. The channel areas are fished almost exclusively using lines, with some spearing occurring along the channel edge near Station P3. Line fishing from shore on JI is done at all the locations mentioned above. There is a low level of throw netting on JI done by a handful of regular fishermen.

A more detailed breakdown for annual catch of the 13 "major catch species" is presented in Table 6. Catch was separated by gear types. Catch, effort, and catch per unit effort (CPUE) were calculated for each situation.

Table 6. Estimated annual boat [1] catch, effort, and catch per unit effort (CPUE) of the 13 "major catch species" in the JA fishery for the period Jun 89 - May 90, broken down by gear type.

| SPECIES | LINE | SPEAR | THROW NET | TOTAL |
|---|---|---|---|---|
| | GEAR TYPE | | | |
| *Myripristis amaenus* (Brick soldierfish) | | | | |
| CATCH[2] | 65 | 3297 | | 3362 |
| EFFORT[3] | 29 | 737 | | |
| CPUE[4] | 2.24 | 4.47 | | |
| *Priacanthus cruentatus* (Bigeye) | | | | |
| CATCH | | 79 | | 79 |
| EFFORT | | 194 | | |
| CPUE | | 0.41 | | |
| *Kuhlia marginata* (Hawaiian flagtail) | | | | |
| CATCH | 38 | | 187 | 225 |
| EFFORT | 28.5 | | 30 | |
| CPUE | 1.33 | | 6.23 | |
| *Kyphosus vaigiensis* (Rudderfish) | | | | |
| CATCH | | | | 0 |
| EFFORT | | | | |
| CPUE | | | | |
| *Mulloides flavolineatus* (Samoan goatfish) | | | | |
| CATCH | 35 | 29 | 64 | 128 |
| EFFORT | 98 | 82.5 | 21 | |
| CPUE | 0.36 | 0.35 | 3.05 | |
| *Pseudupeneus bifasciatus* (Doublebar goatfish) | | | | |
| CATCH | 4 | 60 | | 64 |
| EFFORT | 26 | 131 | | |
| CPUE | 0.15 | 0.46 | | |
| *Pseudupeneus cyclostomus* (Blue goatfish) | | | | |
| CATCH | 124 | 5 | | 129 |
| EFFORT | 429 | 18 | | |
| CPUE | 0.29 | 0.28 | | |
| *Pseudupeneus multifasciatus* (Manybar goatfish) | | | | |
| CATCH | 31 | 7 | | 38 |
| EFFORT | 226 | 10.5 | | |
| CPUE | 0.14 | 0.67 | | |

Table 6 (continued).

| SPECIES | GEAR TYPE LINE | SPEAR | THROW NET | TOTAL |
|---|---|---|---|---|
| Caranx melampygus (Blue jack) | | | | |
| CATCH[2] | 177 | 9 | | 186 |
| EFFORT[3] | 506 | 41 | | |
| CPUE[4] | 0.35 | 0.22 | | |
| Chaenomugil leuciscus (Chaptall's mullet) | | | | |
| CATCH | | | 509 | 509 |
| EFFORT | | | 81 | |
| CPUE | | | 6.28 | |
| Scarus perspicillatus (Spectacled parrotfish) | | | | |
| CATCH | | 74 | 9 | 83 |
| EFFORT | | 145 | 15 | |
| CPUE | | 0.51 | 0.60 | |
| Acanthurus triostegus (Convict surgeonfish) | | | | |
| CATCH | | 480 | 348 | 828 |
| EFFORT | | 222.5 | 45.5 | |
| CPUE | | 2.16 | 7.65 | |
| Ctenochaetus strigosus (Yellow eyed surgeonfish) | | | | |
| CATCH | | 1201 | | 1201 |
| EFFORT | | 359 | | |
| CPUE | | 3.34 | | |
| GRAND TOTAL FOR MAJOR SPECIES IN CATCH | | | | |
| CATCH | 474 | 5241 | 1117 | 6832 |
| EFFORT | 1342.5 | 1940.5 | 192.5 | |
| CPUE | 0.35 | 2.70 | 5.80 | |

1 Any fishing from shores of islands other than JI involved the use of boats and is reported here.
2 Catch in number of individuals.
3 Effort units:
Line : line-hours
Spearing : spear-hours
Throw netting : throw net-hours
4 Catch per unit effort:
Line : number of fish per line-hour
Spearing : number of fish per spear-hour
Throw netting : number of fish per throw net-hour

Catch and effort were highly variable among species, and for most species, they were highly variable over time. Most of the CPUE values for individual species from the year ending 1990 were generally within the range of the corresponding values from the previous years of the study (Table 7). However, all the CPUE values were highly variable with no clear trends between the years.

Total catch has varied considerably over the 6 years of the study (Table 7) as well as the subtotals by each type of gear (Fig. 11-13). No particular temporal pattern is recognizable. However, for most of the total time series for each gear type, the pattern of fishing effort corresponds rather closely with that of catch. Therefore, CPUE, which is sometimes used as an indicator of fish abundance, is much less variable than catch. CPUE for each gear type is considerably more stable for all species combined than for most single species. It shows no meaningful temporal trend for any of the gear types. CPUE's for spearing and netting (Fig. 11-12) seem to vary randomly above and below their initial values. The CPUE for line fishing (Fig. 13) decreases irregularly. These temporal patterns and the limited range of CPUE values for each gear type suggest that the year-to-year fluctuations in catch primarily reflect fluctuations in effort.

Effort and CPUE may have been noticeably affected by some observable shifts in the fishermen's fishing patterns in recent years. Several of the "resident" fishermen have retired and left JA in the past two years. Other "resident" fishermen have stated that they have been "taking a break" from fishing and have only gone fishing a few times in the past two years. Competition by increasing numbers of "transient" SCUBA divers (who seem to catch little) for the use of the limited supply of boats at JA appears to have reduced the amount of productive effort by experienced, skilled fishermen. Other fishermen new to JA have been replacing the older "resident" fishermen in the fishery, but these new fishermen do not seem to catch as much as the "resident" fishermen did. A decrease in CPUE may have resulted, especially where consistent line fisherman have left JA for good. The "resident" fishery has been shifting to mostly a few groups of spear fishermen. Consequently, some of the species previously caught mostly by line fishing were collected in low numbers this report year, while some of the spear catches were high. Overall, there are now fewer fisherman who catch a high volume of fish. Inconsistent reporting of catch and effort, months of bad weather (especially in the years ending 1985 and 1986), as well as the home leaves, travel and work schedules of "resident" fishermen all can have significant effects on this small fishery.

Clearly there are some unresolved anomalies in the catch and effort data. However, all the catch and effort data together do not produce any consistent trends that would indicate any major change in abundance of the resident fished populations.

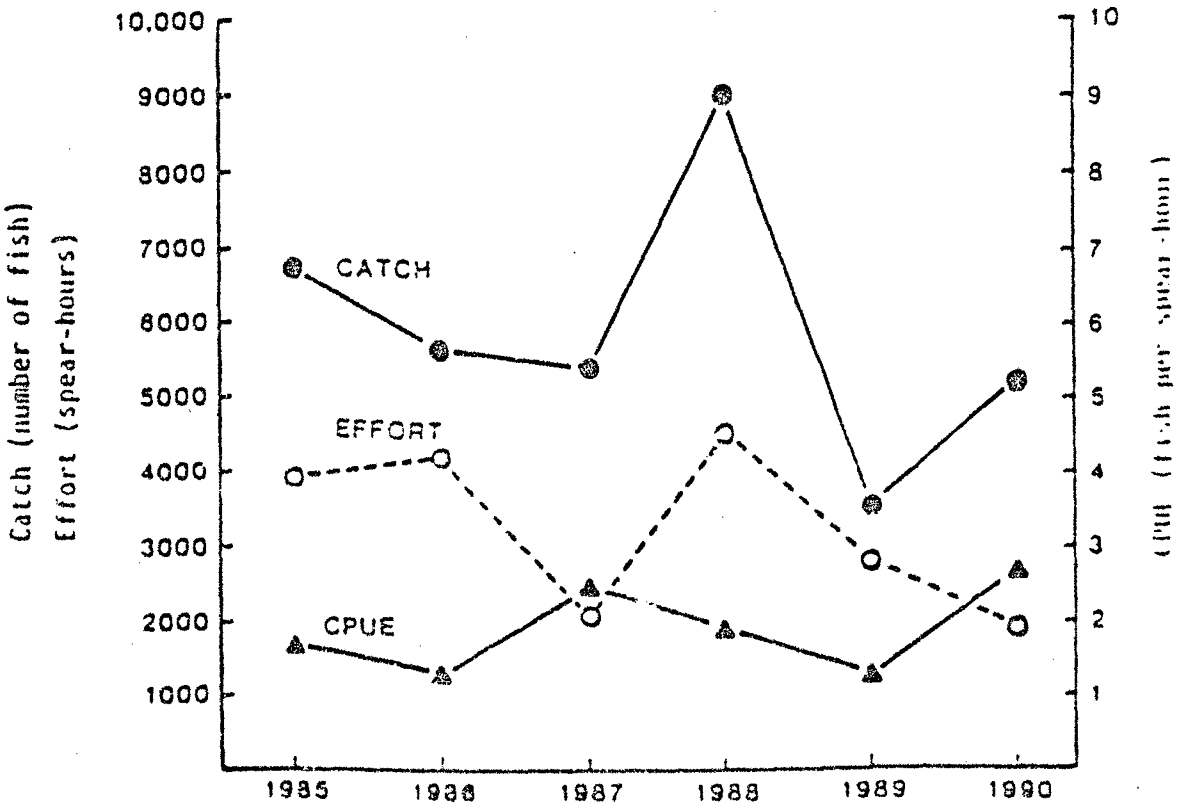



Figure 11. History of catch, effort and catch per unit effort (CPUE) of all species caught by spear fishing (using boats) over the full course of the study.

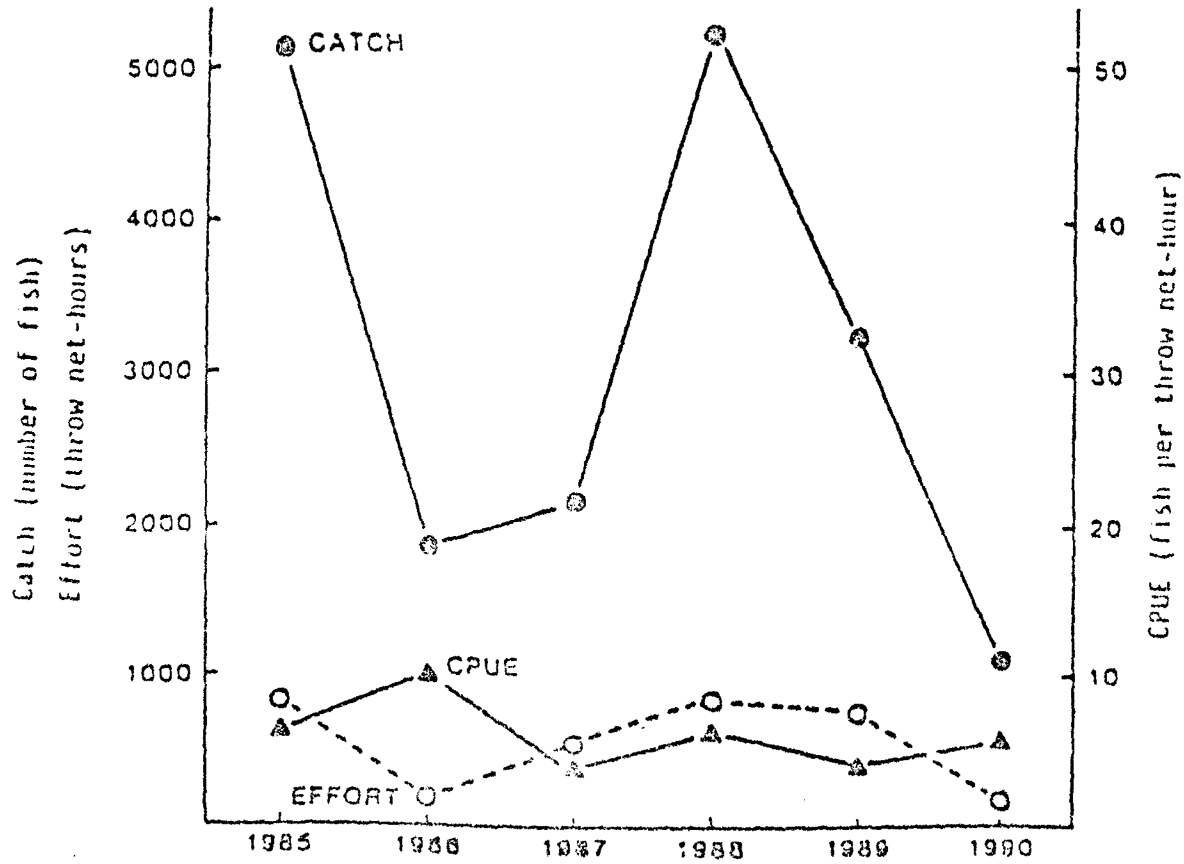



Figure 12. History of catch, effort and catch per unit effort (CPUE) of all species caught by throw net fishing (using boats) over the full course of the study.

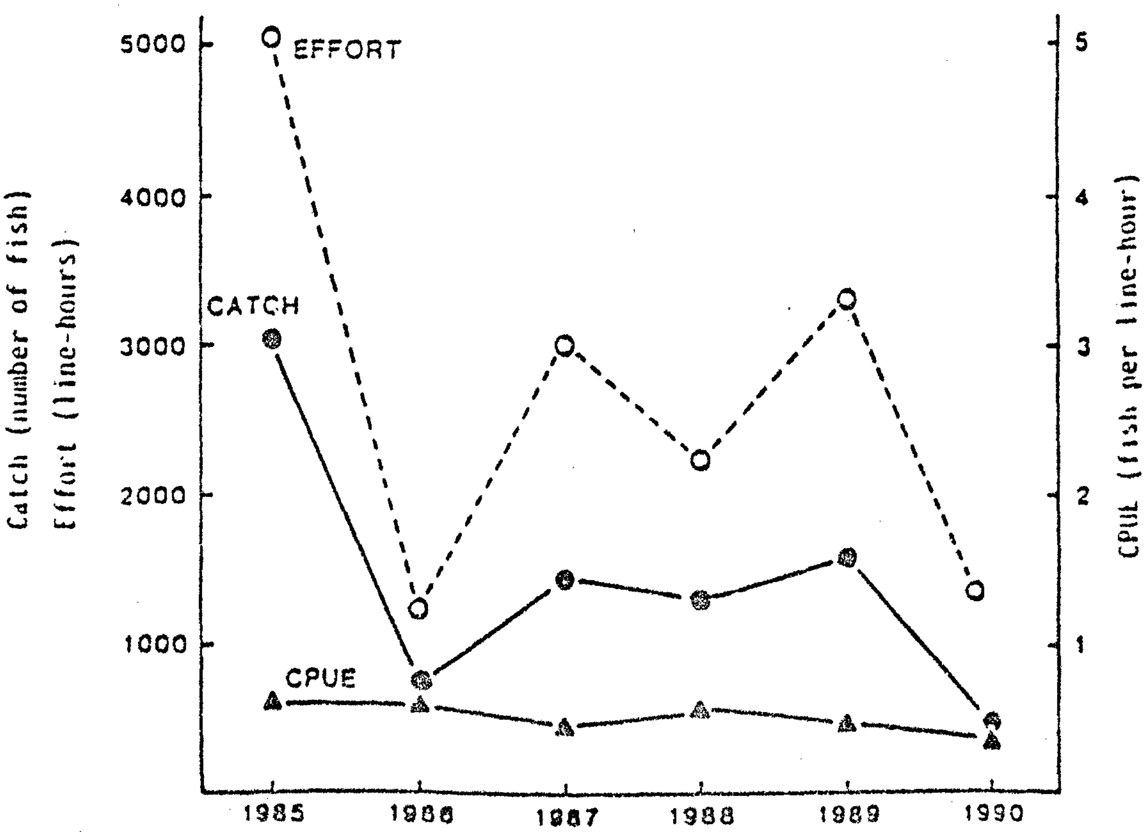



Figure 13. History of catch, effort and catch per unit effort (CPUE) of all species caught by line fishing (using boats) over the full course of the study.

Table 7. Boat catch and effort data for six successive phases of the project for the "major catch species". Resu include the total estimated annual catch, and for the major gear type, the total effort and the catch per unit ef

| Species | Estimated Annual Boat Catch (all gear combined), for year ending: 1990 | 1989 | 1988 | 1987 | 1986 | 19 |
|---|---|---|---|---|---|---|
| Myripristis amaenus | 3362 | 1799 | 4474 | 4206 | 2039 | 30 |
| Priacanthus cruentatus | 79 | 49 | 63 | 94 | 95 | '1 |
| Kuhlia marginata | 225 | 240 | 555 | 75 | 293 | 1: |
| Kyphosus vaigiensis | 0 | 19 | 78 | 28 | 48 | |
| Mulloides flavolineatus | 128 | 903 | 396 | 269 | 265 | 3 |
| Pseudupeneus bifasciatus | 64 | 144 | 370 | 207 | 358 | 3 |
| Pseudupeneus cyclostomus | 129 | 435 | 322 | 282 | 239 | 5 |
| Pseudupeneus multifasciatus | 38 | 338 | 289 | 288 | 198 | - |
| Caranx melampygus | 186 | 310 | 405 | 362 | 552 | 5 |
| Chaenomugil leuciscus | 509 | 1201 | 3772 | 769 | 557 | '8 |
| Scarus perspicillatus | 83 | 315 | 353 | 185 | 289 | ' |
| Acanthurus triostegus | 828 | 1657 | 2940 | 1222 | 1162 | 24 |
| Ctenochaetus strigosus | 1201 | 936 | 1609 | 1066 | 2188 | 31 |
| Total | 6,832 | 8,396 | 15,652 | 9,051 | 8,274 | 14,9 |

Effort and Catch per Unit Effort by major gear type for year ending:

| Species | Major Gear Type | 1990 Effort | 1990 CPUE | 1989 Effort | 1989 CPUE | 1988 Effort | 1988 CPUE | 1987 Effort | 1987 CPUE | 1986 Effort | 1986 CPUE | 19 Effort |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M. amaenus | spear | 737 | 4.47 | 631 | 2.12 | 999 | 4.35 | 359 | 6.78 | 574 | 3.40 | 346 |
| P. cruentatus | spear | 196 | 0.41 | 74 | 0.40 | 406 | 0.13 | 198 | 0.38 | 276 | 0.27 | 326 |
| K. marginata | net | 30 | 6.23 | 46 | 4.97 | 33 | 16.03 | 63 | 1.23 | 30 | 9.93 | 136 |
| K. vaigiensis | line | 0 | 0 | 0 | 0 | 39 | 1.03 | 70 | 0.03 | 0 | 0 | 326 |
| M. flavolineatus | net | 21 | 3.05 | 166 | 4.44 | 60 | 3.92 | 59 | 4.16 | 27 | 6.23 | 63 |
| P. bifasciatus | spear | 131 | 0.46 | 259 | 0.28 | 505 | 0.43 | 117 | 0.62 | 556 | 0.57 | 440 |
| P. cyclostomus | line | 479 | 0.27 | 1227 | 0.28 | 766 | 0.39 | 492 | 0.55 | 362 | 0.43 | 1072 |
| P. multifasciatus | line | 225 | 0.14 | 737 | 0.38 | 745 | 0.38 | 348 | 0.63 | 207 | 0.62 | 890 |
| C. melampygus | line | 506 | 0.35 | 576 | 0.56 | 201 | 1.78 | 1063 | 0.32 | 472 | 0.41 | 1334 |
| C. leuciscus | net | 81 | 6.28 | 281 | 4.28 | 353 | 10.69 | 268 | 2.87 | 51 | 10.47 | 265 |
| S. perspicillatus | spear | 145 | 0.51 | 626 | 0.50 | 591 | 0.56 | 352 | 0.54 | 618 | 0.47 | 370 |
| A. triostegus | net | 46 | 7.63 | 264 | 4.40 | 344 | 1.99 | 167 | 7.49 | 53 | 11.40 | 327 |
| C. strigosus | spear | 357 | 3.34 | 491 | 2.01 | 826 | 1.95 | 391 | 2.72 | 566 | 3.30 | 689 |

## Fish Population Characteristics Based on Creel Census

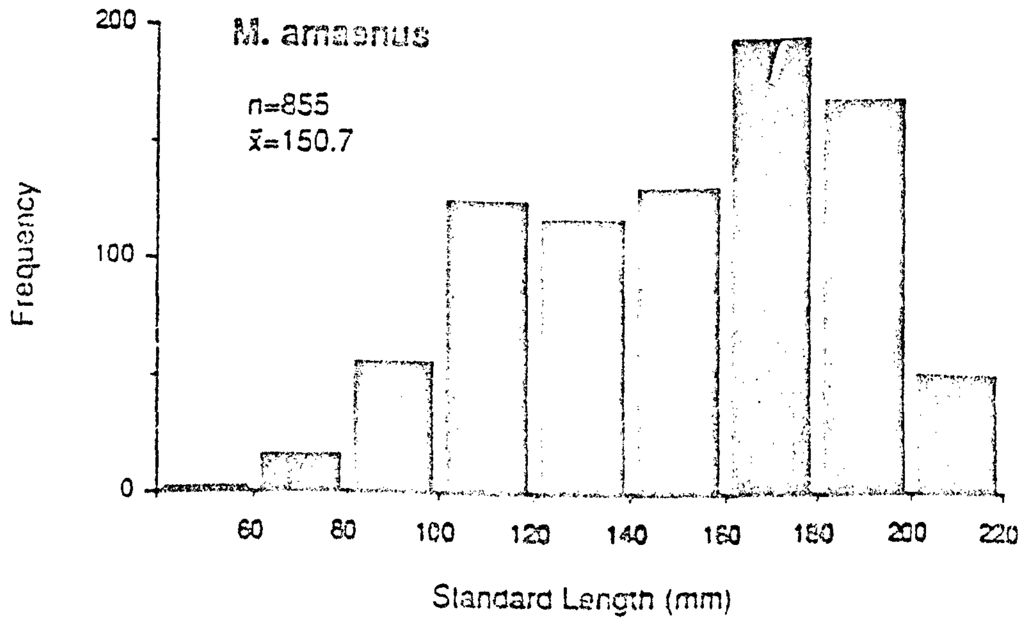
Some basic descriptive statistics for 11 of the "major catch species" were calculated from the creel census size data using SAS (version 5.16) on the University of Hawaii's mainframe IBM 3081 computer (Table 8). Only species with 70 or more specimens examined in creel census (from Feb 84 to May 90) were analyzed. Table 8 shows a summary of the data, as well as length-weight regression equations generated for each species, and the size at first reproduction for some of the species. Figures 14-24 are histograms of the standard lengths (SL) and weights of the individuals examined from Feb 84 to May 90. Appendix G contains frequency tables of SL and weights for the species shown in these histograms.

Most of the catch was of a fairly large size. The absence of very small individuals and the presence of several ascending size classes below the mode probably reflect selection for larger individuals by the gear and fishing techniques. However, very small individuals of any species were rarely seen in censuses or surveys. At body sizes above the mode, strong selection by fishermen for larger individuals of M. amaenus appears to produce a distribution that may be much different from the natural population at large (Fig. 14). For some species, the descending limb of the distribution curve (to the right of the mode) is rough (perhaps because of limited sample size). However, there seems to be no reason to believe that this portion of the distributions is far from representative of the natural populations in most cases. A cluster of large outliers of C. melampygus (Fig. 19) is produced by the efforts of a few fishermen specifically targetting large size classes.

Few cases of multiple modes appear clearly in any of the histograms. None of the data sets in their present condition appear promising for detecting cohorts for age or mortality estimation. No adequate data for size frequency are available from areas with low fishing effort for comparison with these data (which came primarily from the more heavily fished areas).

The sizes at first reproduction (SFR) for six of the 11 species shown in Table 8 were taken from the results of other investigators working in the Hawaiian Islands. No estimates were available for the SFR of Priacanthus cruentatus, Carangoides orthogrammus, Scarus perspicillatus, Ctenochaetus strigosus, and Chaenomugil leuciscus. No data were available from JA for the SFR of any species except Myripristis amaenus (Dee 1986), but it seems unlikely that any are greatly different from Hawaiian populations.

The number of fish caught and examined in creel census was inadequate to do many types of fishery analyses. The results presented here are thus somewhat limited, but they are adequate in light of the low level of catch. Since there has been no sustained and significant increase in fishing effort since the beginning of the project, all the basic descriptive data taken to date will serve as a useful baseline for comparison with samples taken after any future major changes in fishing effort. The frequency distributions of the catch species will be especially useful if fishing pressure significantly increases at JA.



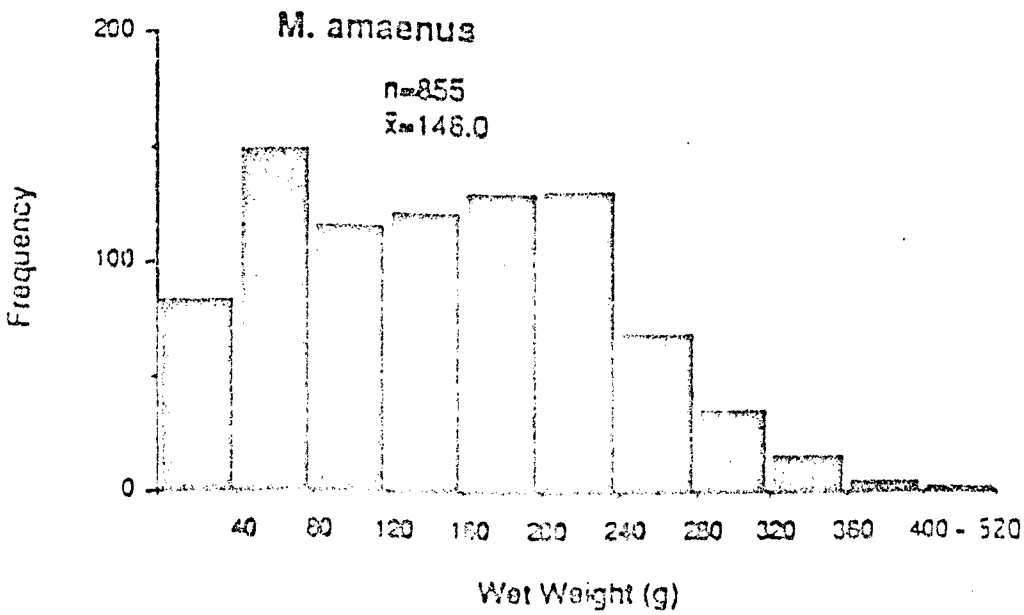
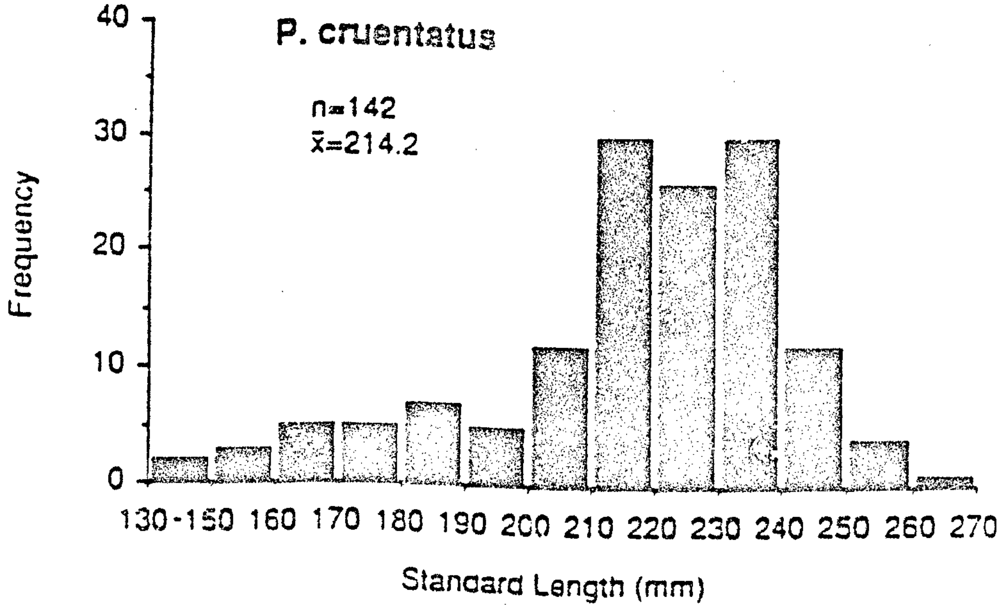




Fig. 14. Frequency histograms of standard lengths (mm) and wet weights (g) of M. amaenus creel censused between Feb 84 and May 90. The means (x̄) represent the arithmetic average of all data taken during this period.



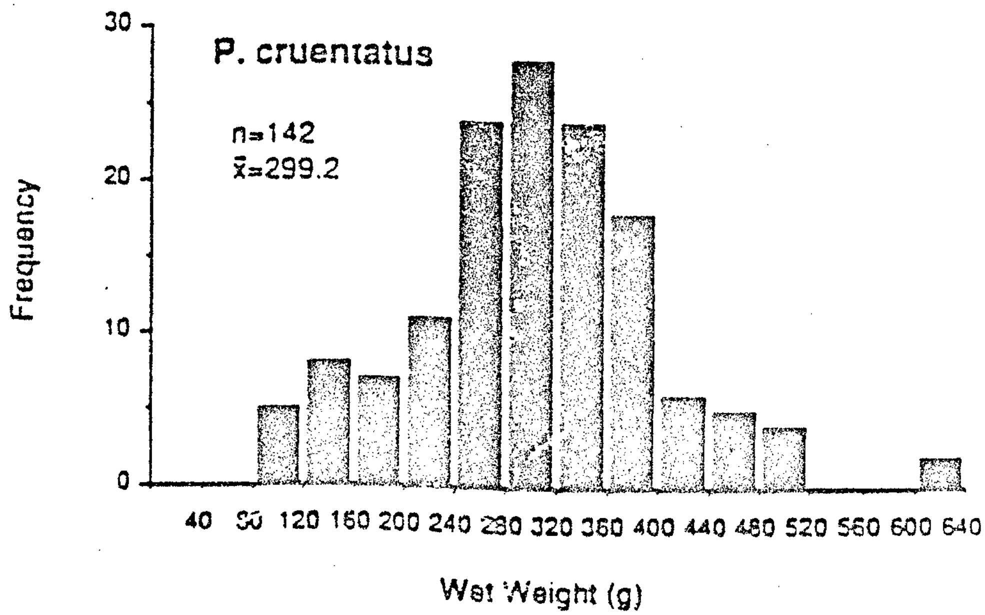




Fig. 15. Frequency histograms of standard lengths (mm) and wet weights (g) of _P. cruentatus_ creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

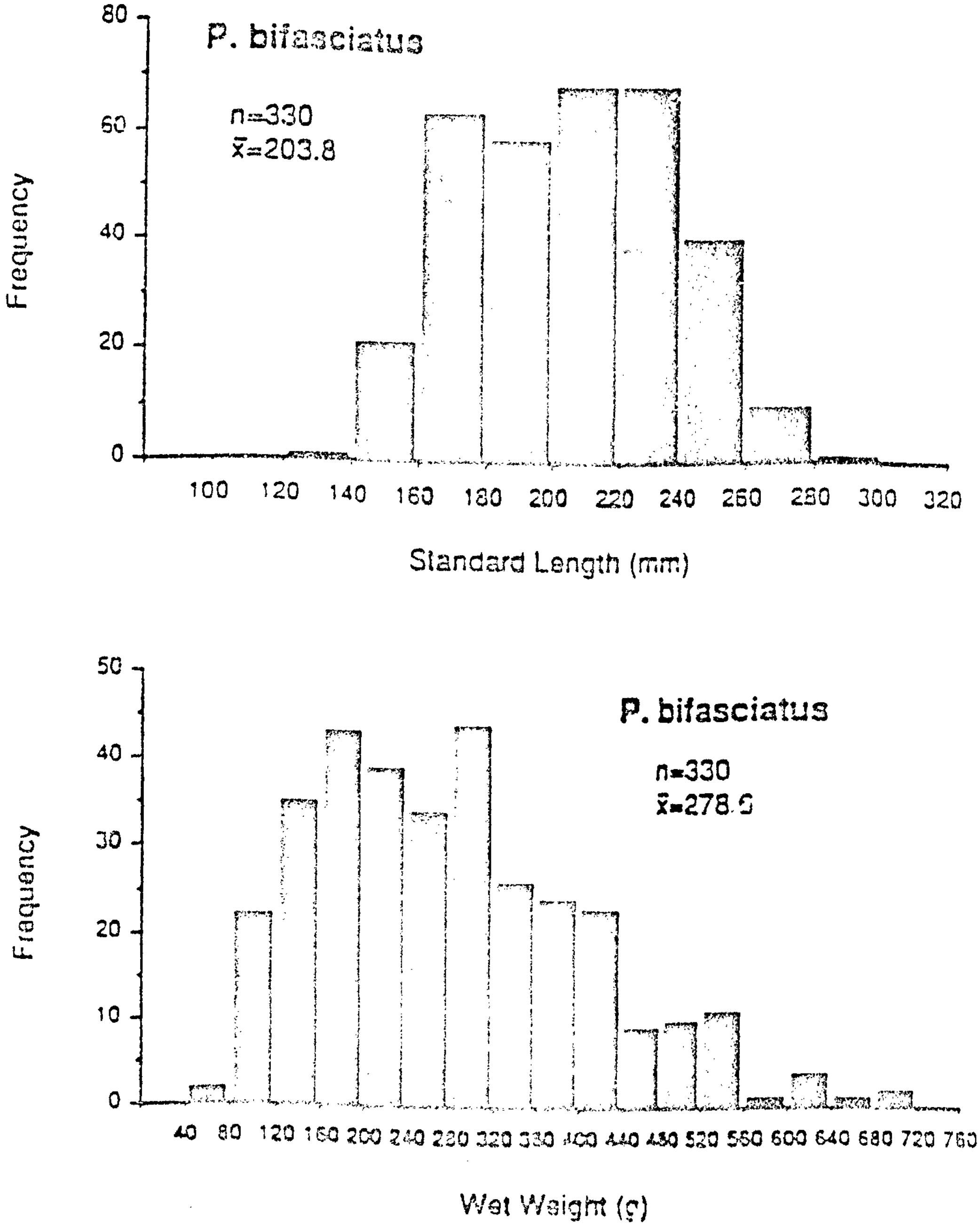



Fig. 16. Frequency histograms of standard lengths (mm) and wet weights (g) of P. bifasciatus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

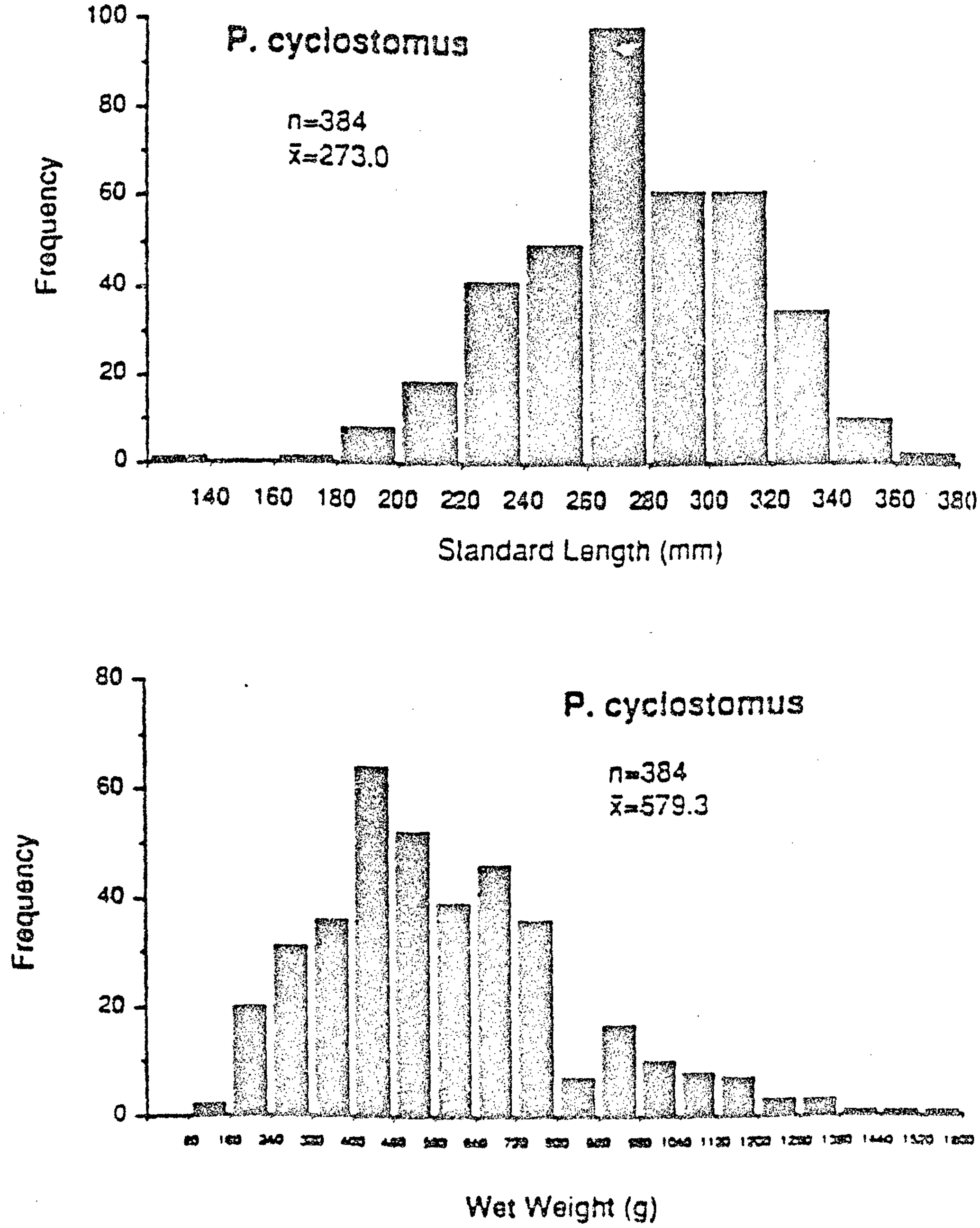



Fig. 17. Frequency histograms of standard lengths (mm) and wet weights (g) of P. cyclostomus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

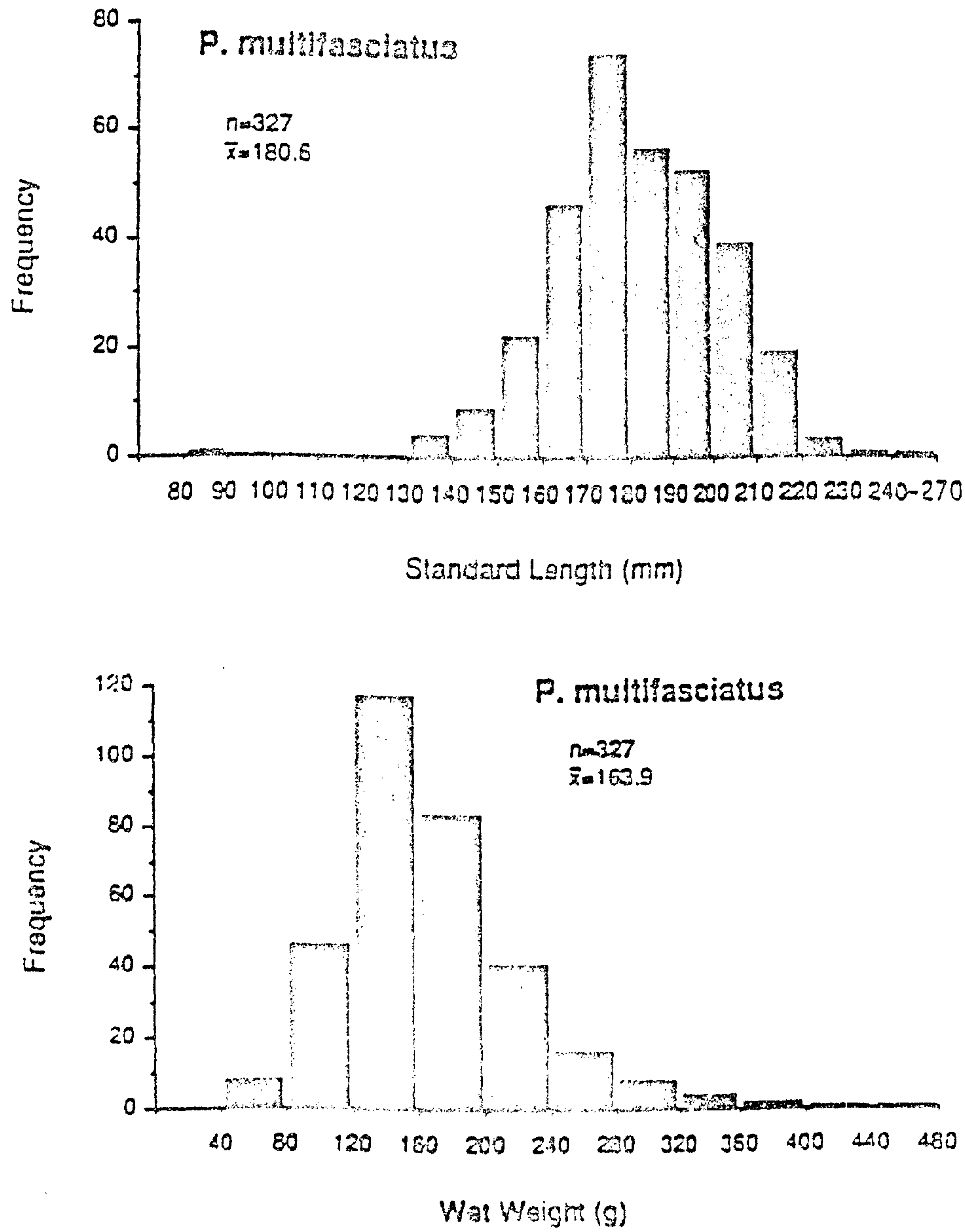
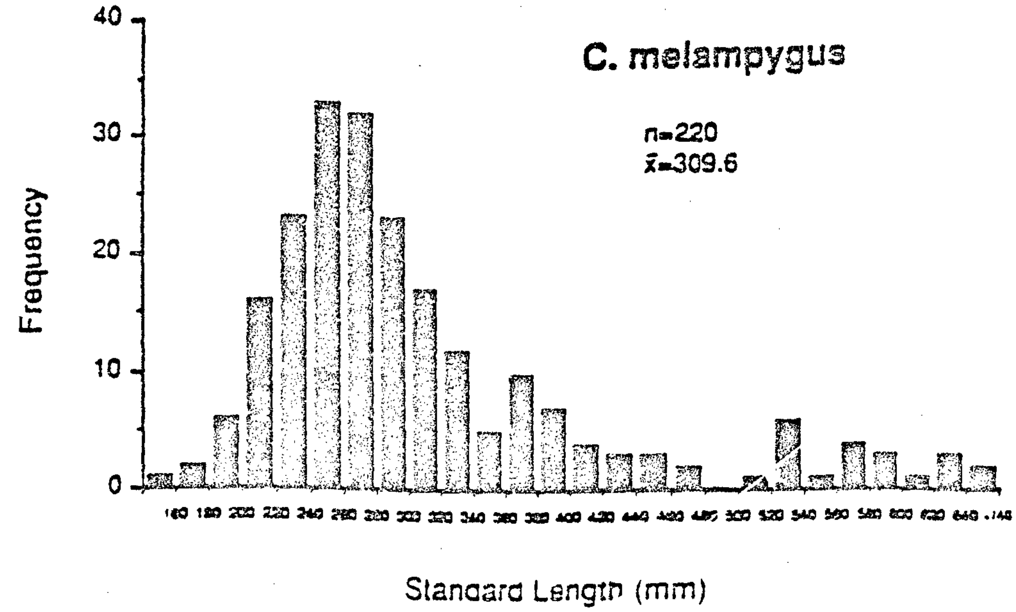



Fig. 18. Frequency histograms of standard lengths (mm) and wet weights (g) of P. multifasciatus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.



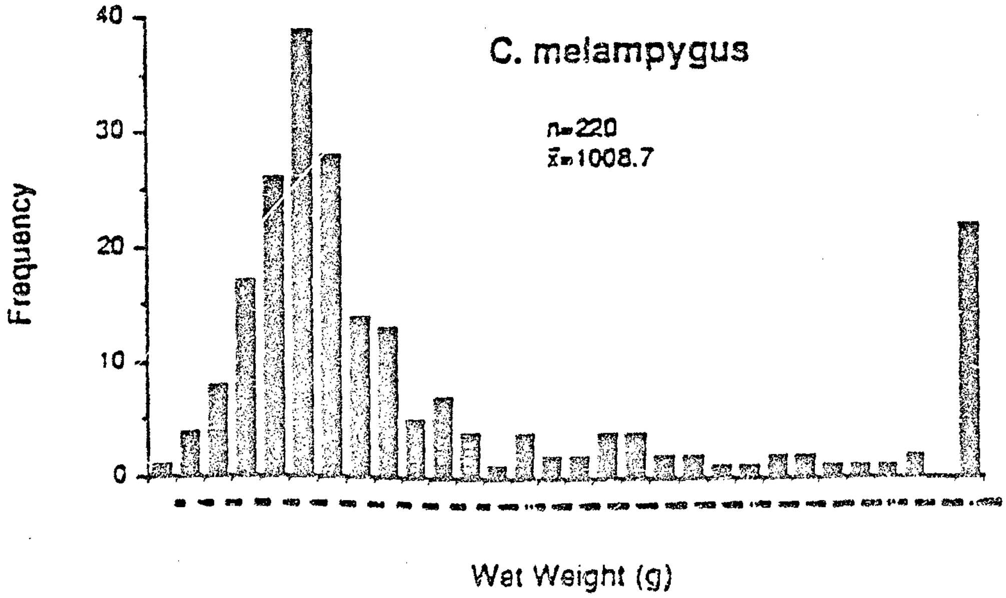
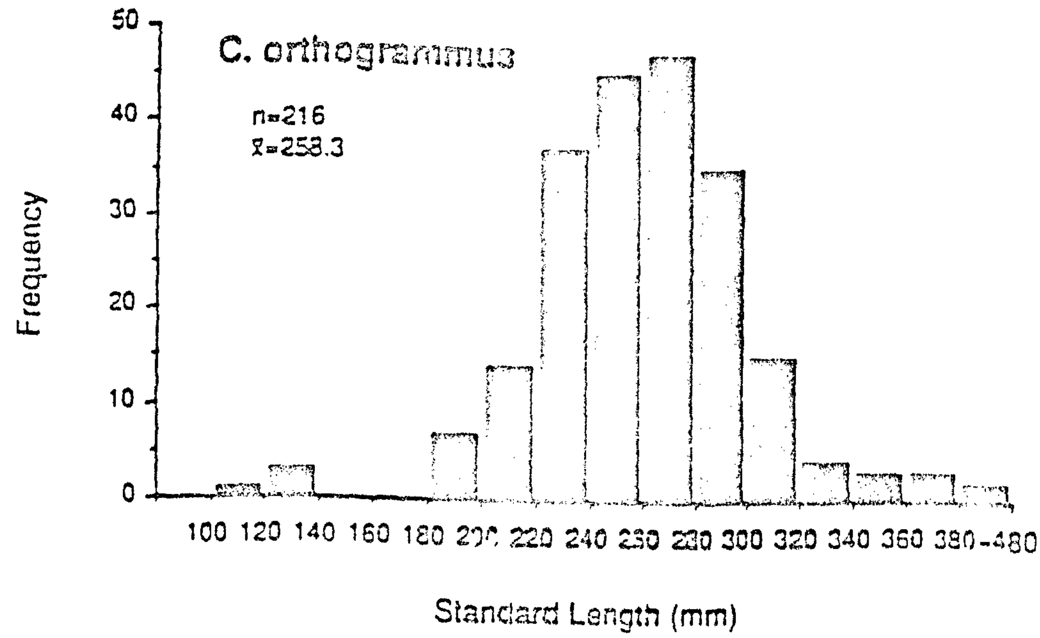




Fig. 19. Frequency histograms of standard lengths (mm) and wet weights (g) of _C. melampygus_ creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.



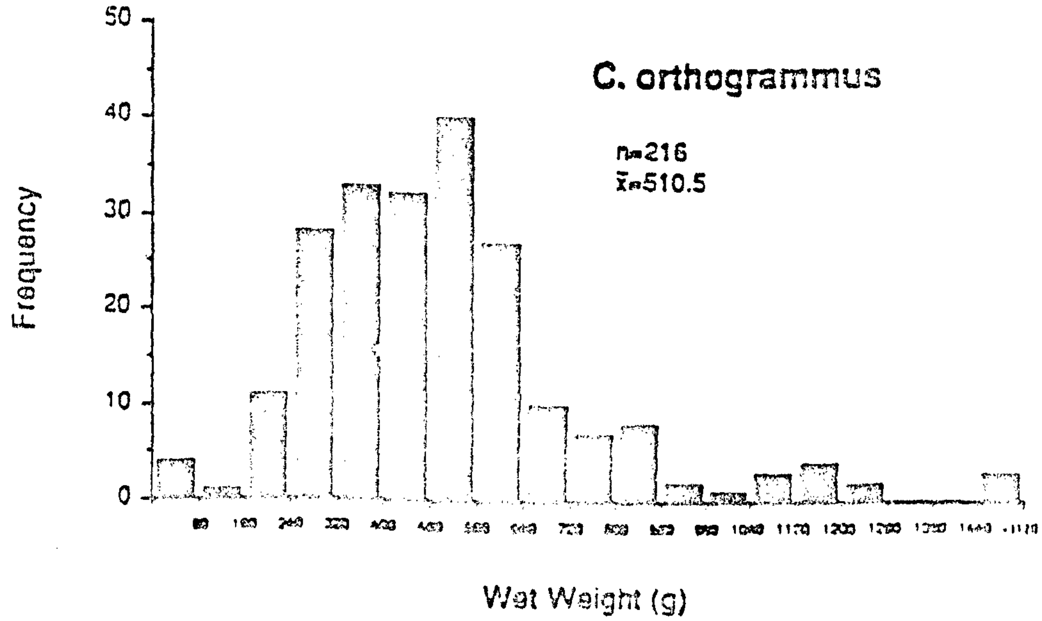




Fig. 20. Frequency histograms of standard lengths (mm) and wet weights (g) of *C. orthogrammus* creel censused between Feb 84 and May 90. The means (x̄) represent the arithmetic average of all data taken during this period.

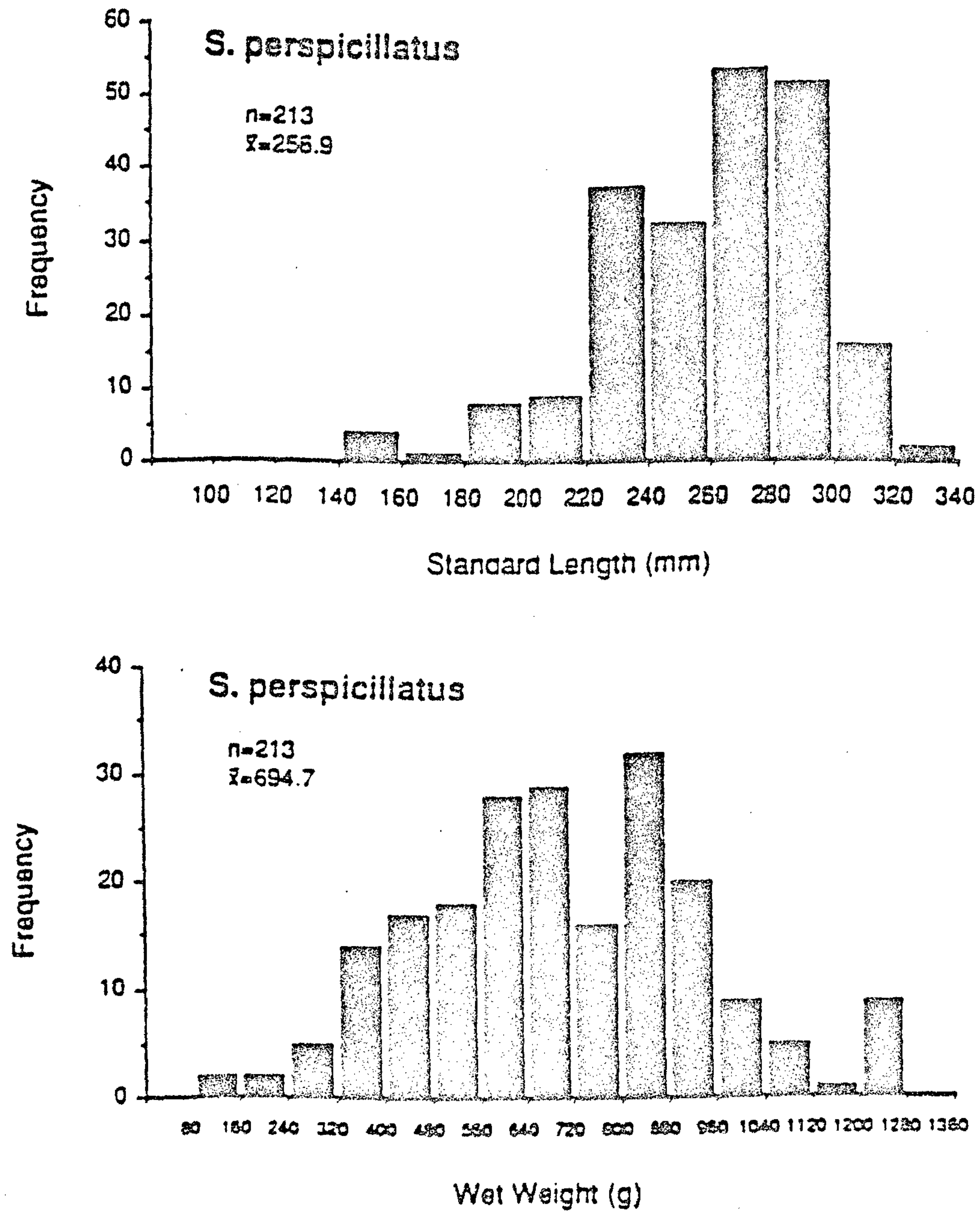
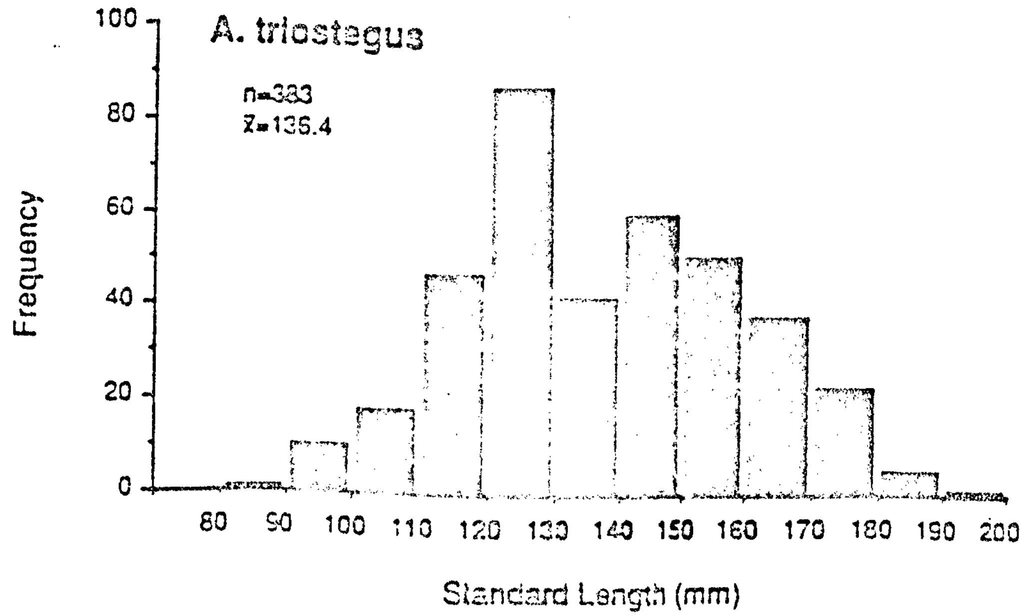



Fig. 21. Frequency histograms of standard lengths (mm) and wet weights (g) of S. perspicillatus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent th arithmetic average of all data taken during this period.



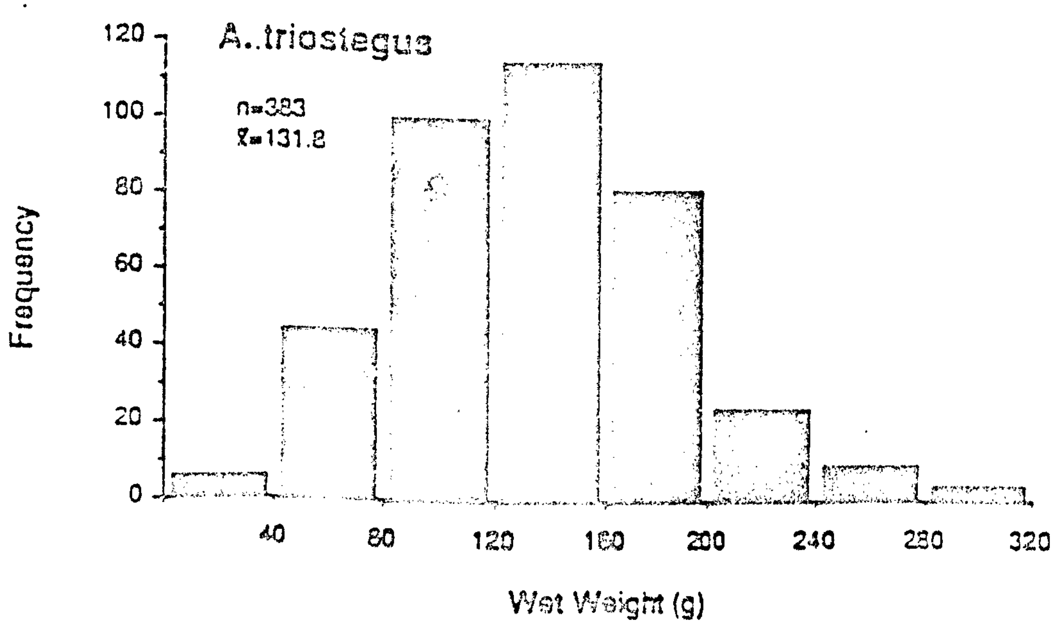




Fig. 22. Frequency histograms of standard lengths (mm) and wet weights (g) of A. triostegus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

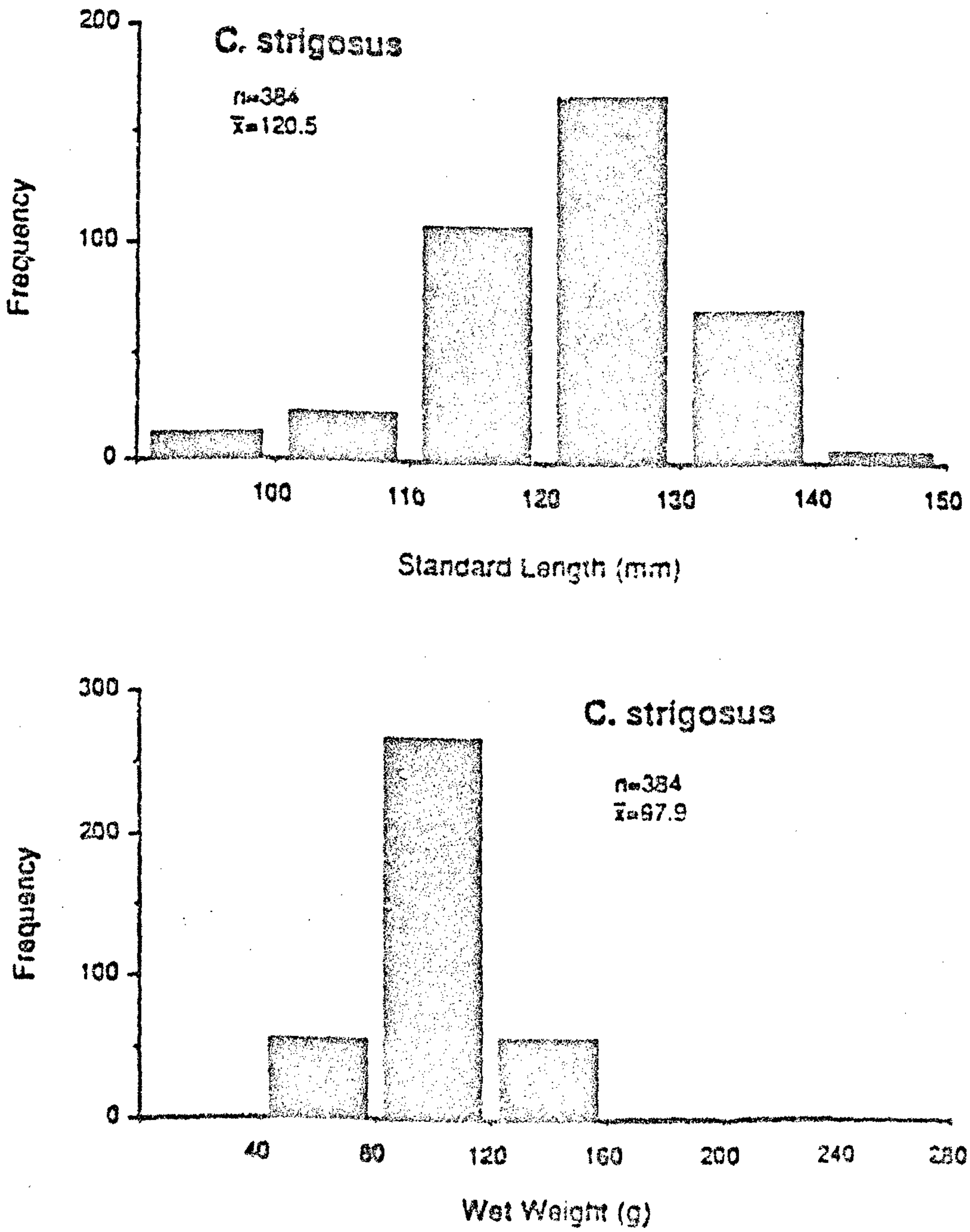



Fig. 23. Frequency histograms of standard lengths (mm) and wet weights (g) of C. strigosus creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

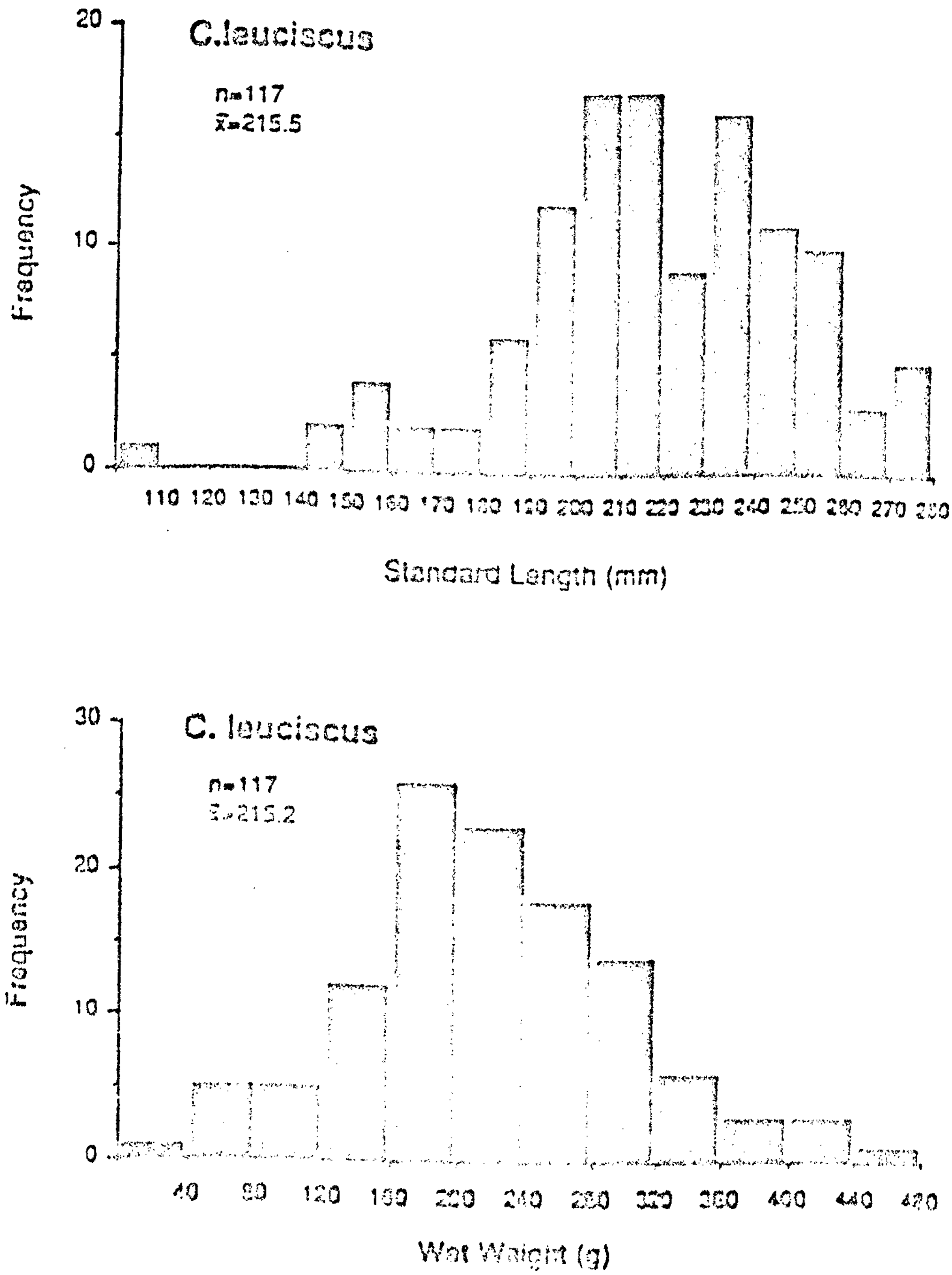



Fig. 24. Frequency histograms of standard lengths (mm) and wet weights (g) of *C. leuciscus* creel censused between Feb 84 and May 90. The means ($\bar{x}$) represent the arithmetic average of all data taken during this period.

Table 8. Summary size data for 11 important catch species, based on creel census.

| Catch species | Mean Standard Length, SL (mm) | Mean Weight, W (g) | Range of Weight (g) | Regression Equation $W = a(SL)^b$: a | b | $r^2$ | n | Size at Fir Reproductio |
|---|---|---|---|---|---|---|---|---|
| | Creel Census Data[1] | | | | | | | |
| Myripristis amaenus | 150.7 | 146.0 | 2.8-480.0 | $7.00 \times 10^{-5}$ | 2.87 | 0.97 | 855 | F 153-156 mm |
| | | | | | | | | M 149-156 mm |
| Priacanthus cruentatus | 214.2 | 299.2 | 80.0-600.0 | $5.41 \times 10^{-5}$ | 2.89 | 0.88 | 142 | - |
| Pseudupeneus bifasciatus | 203.8 | 278.6 | 72.0-700.0 | $5.96 \times 10^{-5}$ | 2.88 | 0.86 | 330 | -181 mm |
| Pseudupeneus cyclostomus | 273.1 | 579.2 | 130.0-1560.0 | $5.33 \times 10^{-5}$ | 2.83 | 0.82 | 384 | -181 mm |
| Pseudupeneus multifasciatus | 180.6 | 163.9 | 40.0-440.0 | $1.35 \times 10^{-4}$ | 2.69 | 0.76 | 327 | F < 115 mm |
| | | | | | | | | M 164-200 mm |
| Caranx melampygus | 309.6[2] | 1008.7[2] | 60.0-9000.0 | $7.35 \times 10^{-5}$ | 2.81 | 0.96 | 220 | F 325-375 mm |
| Carangoides orthogrammus | 258.3 | 310.5 | 30.0-3100.0 | $1.92 \times 10^{-5}$ | 3.06 | 0.91 | 216 | - |
| Scarus perspicillatus | 256.9 | 694.7 | 140.0-1265.0 | $1.07 \times 10^{-3}$ | 2.41 | 0.85 | 213 | - |
| Acanthurus triostegus | 136.4 | 131.8 | 20.0-310.0 | $5.51 \times 10^{-4}$ | 2.51 | 0.83 | 383 | F 101 mm |
| | | | | | | | | M 97 mm |
| Ctenochaetus strigosus | 120.5 | 97.9 | 40.0-200.0 | $1.79 \times 10^{-3}$ | 2.27 | 0.63 | 384 | - |
| Chaenomugil leuciscus | 215.5 | 215.3 | 20.0-470.0 | $2.93 \times 10^{-5}$ | 2.87 | 0.83 | 117 | - |

[1] Data only for species with 70 or more specimens examined from Feb 86 - May 90.

[2] There was one large outlier of SL = 736.6 mm and W = 9000.0 g that was excluded from the means.

[3] From Hayes et al. (1982) unless otherwise specified. (F = female, M = male).

[4] From Moffitt (1979) for Pseudupeneus porphyreus.

[5] From Suckeus (1984).

[6] From Dee ([illegible]).

## ATOLL-WIDE ESTIMATES OF FISH POPULATIONS AND CATCHES

Rough atoll-wide population estimates for 10 of the 13 "major catch species" are presented in Table 9, column 1 (Dee et al. 1985). (For the remaining three "major catch species", data were insufficient to arrive at reasonable atoll-wide estimates.) Using these population estimates, the percent of the species population caught annually for the year ending 1990 was calculated and compared to that for the years ending 1989, 1988, 1987, 1986 and 1985 (Table 9, column 3).

Table 9. Estimated percents of species populations caught annually from boats for the years ending 1990 (Jun 89 - May 90), 1989 (Jun 88 - May 89), 1988 (Jun 87 - May 88), 1987 (Jun 86 - May 87), 1986 (Jun 85 - May 86), and 1985 (Feb 84 - May 85).

| SPECIES | 1<br>ESTIMATED<br>ATOLL POPULATION | 2<br>ESTIMATED TOTAL<br>1990 BOAT CATCH | 3<br>ANNUAL CATCH/POPULATION (%)<br>1990 | 1989 | 1988 | 1987 | 1986 | 1985 |
|---|---|---|---|---|---|---|---|---|
| Ctenochaetus strigosus | 1,650,300 | 1201 | <0.1 | <0.1 | <0.1 | <0.1 | 0.1 | 0.2 |
| Acanthurus triostegus | 599,600 | 823 | 0.1 | 0.3 | 0.5 | 0.2 | 0.2 | 0.4 |
| Myripristis amaenus | 383,400* | 3362 | 0.9* | 0.5* | 1.2* | 1.0* | 0.5* | 0.8* |
| Mulloides flavolineatus | 128,900 | 123 | <0.1 | 0.5 | 0.2 | 0.1 | 0.1 | 0.2 |
| Pseudupeneus multifasciatus | 61,850 | 38 | <0.1 | 0.5 | 0.5 | 0.5 | 0.3 | 1.3 |
| Pseudupeneus bifasciatus | 43,000 | 66 | 0.1 | 0.3 | 0.8 | 0.4 | 0.7 | 0.8 |
| Scarus perspicillatus | 29,450 | 83 | 0.3 | 1.1 | 1.2 | 0.6 | 1.0 | 0.6 |
| Pseudupeneus cyclostomus | 27,600 | 129 | 0.5 | 1.6 | 1.2 | 1.0 | 0.9 | 2.0 |
| Caranx melampygus | 26,500 | 186 | 0.7 | 1.1 | 1.5 | 1.4 | 2.1 | 1.9 |
| Kyphosus vaigiensis | 22,350 | 0 | 0 | 0.1 | 0.3 | 0.1 | 0.2 | 0.2 |

* The atoll population estimate is probably a considerable underestimate because of its cryptic habits.

# STATUS OF STOCKS

## Harvested Species

The harvest assessment shows that few species were taken in sizable numbers and that the annual catches this past year, as in previous years, were insignificant compared to the estimated standing stocks of the respective species (Table 9).

More Myripristis amaenus are caught than any other species at JA. However, this catch estimate is quite small compared to the total population figure (Table 9, which is undoubtedly an underestimate for this cryptic species). In the year ending 1985, of the 193 measured specimens caught from shore by lines, approximately 93% were below the maximum SFR (Dee et al. 1985). No individuals caught by line fishing from shore were examined in the years ending 1986, 1988, 1989 and 1990. In the year ending 1987, of the 30 measured individuals caught from shore by lines, 90% were below the maximum SFR. Among measured specimens in the speared catch, about 22% of the individuals were below the maximum SFR in the years ending 1985 (n=233), 1986 (n=54), and 1987 (n=100); about 14% were below in 1988; about 25% in 1989, and none were below in 1990. This result is consistent with visual observations of individual size ranges at the long-term stations. Since the taking of individuals from the lagoon below the maximum SFR has apparently not increased much over the period of the study, the total atoll population should not be reduced by the present level of harvest.

There are no population size estimates for Kuhlia marginata or Chaenomugil leuciscus because of the nature of their habitat. These two species frequent the island shorelines to feed. These areas are the only places where they are seen and caught. Under completely natural conditions, these species would probably make similar use of shoreline habitat. No quantitative surveys or censuses were done in these habitats to provide population estimates. Net fishing for these species occurred less frequently this year than during the previous three years. In the absence of other data, little can be said about the status of these stocks except that the absolute catch values do not seem extremely high for an area of the general size of JA.

No information on SFR is available for Kyphosus vaigiensis, Mulloides flavolineatus, Scarus perspicillatus, or Ctenochaetus strigosus. All their catches are insignificant compared to their respective populations.

Based on the available Hawaiian values for SFR, our data suggest that approximately 30% of Pseudupeneus bifasciatus*, 1% of P. cyclostomus*, and 3% of Acanthurus triostegus are caught at sizes below their respective maximum SFR (based on data for all six years combined).

The total number of Pseudupeneus multifasciatus caught annually is not significant compared to the estimated standing stock (Table 9). Only one of the P. multifasciatus caught was below the SFR for females, but the male SFR falls in the range of sizes caught most frequently. Approximately 87% of the P. multifasciatus catch is below the maximum male SFR value.

About 82% of the Caranx melampygus catch is below the maximum SFR value. However, most of the individuals seen at the monitoring stations were much larger than the SFR. This seems to be due to the occasional presence of small schools of small individuals feeding near the piers of the islands where they are especially vulnerable to catch. The annual catch is very small compared to the standing stock.

When the 13 "major catch species" are considered as a group, the small size at capture of some species seems to offer some potential for concern if the catch levels were to increase greatly. In agreement with the results of the five previous phases, at present levels of effort, there appears to be very little impact on atoll fish populations as a result of fishing pressure.

The mandatory catch reporting system incorporated during the 1988 report year has resulted in higher reporting rates (compared with those of previous years) of invertebrates that previously went largely unreported. The catches of most species of coral and of total coral declined from last year, but comparisons with years prior to that would be misleading due to the substantial reduction in underreporting of boat catches that has resulted from the mandatory reporting system. However, the relatively small portion of the atoll accessible to coral collectors as well as the abundance of Acropora corals make it unlikely that the populations of these species will be threatened. A large majority of the coral populations (especially Distichopora sp., which is found primarily in the restricted area outside the barrier reef) lie outside the areas where recreational diving is permitted. In addition, the diurnally cryptic habits of most mollusks popular with shell collectors are sufficient to prevent overcollection at the present low levels of fishing pressure. In

*Estimated from SFR for Pseudupeneus porphyreus.

spite of higher levels of reported catches compared with report years 1985-87, the major invertebrate catch species (coral, cephalopods, gastropods, crustaceans, and echinoderms) continue to be collected in insignificant numbers compared to their respective abundances.

Protected Species

Protected species occurring at JA are the threatened green sea turtle (*Chelonia mydas*) and the endangered Hawaiian monk seal (*Monachus schauinslandi*). Turtles are most often found in the vicinity of Zones 11 and 12. This is the area where their major food source, the algae (*Caulerpa* spp.), occurs in abundance. Turtles are also seen occasionally throughout the lagoon and channel areas. One turtle was censused in April 1986 at Station P5. Hawaiian monk seals have been seen occasionally by residents at various locations throughout JA over the past several years. In November 1984, nine male monk seals were brought to JA from Laysan Island. At last report, none of these monk seals appears to have remained at JA; the last reported sighting was in the summer of 1986. Most of the other monk seals have not been seen since shortly after their arrival.

## DEEP SEA FISHING

Although the scope of this project and report focuses on the lagoon and shallow platform waters, a brief discussion of the fishery for pelagic species of the deep waters surrounding the atoll as a whole will complete the picture of atoll fisheries. Deep sea fishing at JA is done from several landing craft ~13 m long (known locally as "Mike boats"), operated by port control personnel. All deep sea fishing is for recreational purposes and is done on weekends only. One or two "Mike boats" with five to seven residents and/or transient personnel each, go out Saturday and Sunday (weather permitting) for three to four hours. Table 10 presents rough annual catch estimates for the fish species occurring in the deep sea catch during Jun 89 - May 90 (1990), Jun 88 - May 89 (1989), Jun 87 - May 88 (1988), Jun 86 - May 87 (1987), Jun 85 - May 86 (1986), and Feb 84 - May 85 (1985), based on catch reports and creel census. Little time and effort was spent collecting catch data for these trips. The data set is small, and no underreporting estimate was made for these deep sea catches. Although there is a broad decreasing trend in the estimated deep-sea catch over the period of Table 10, in the absence of effort data, little can be said about changes in the local abundance of these species. The deep sea catch at JA is essentially independent of the lagoon and its fishing activity. There is probably little or nothing that JA resource management can do that will affect these species significantly.

Table 10. Estimate of annual catch of deep sea species (uncorrected for underreporting).

| SPECIES | ESTIMATED NO. CAUGHT | | | | | |
|---|---|---|---|---|---|---|
| | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 |
| Acanthocybium solandri (wahoo) | 136 | 149 | 120 | 175 | 201 | 201 |
| Thunnus albacares (yellowfin tuna) | 70 | 65 | 110 | 120 | 135 | 111 |
| Sphyraena barracuda (great barracuda) | 28 | 8 | 15 | 10 | 12 | - |
| Katsuwonus pelamis (skipjack tuna) | 23 | 29 | 60 | 50 | 90 | 134 |
| Elagatis bipinnulatus (rainbow runner) | 13 | 15 | 20 | 15 | 15 | 6 |
| Coryphaena hippurus (dolphin) | 5 | 6 | 10 | 6 | 8 | 5 |

## SUMMARY

Environmental studies in the lagoon at Johnston Atoll continued through the project year in an attempt to detect any effects of JACADS activities (including any increase in recreational fishing) on the marine ecosystem. Established, long-term stations were monitored by visual, underwater censuses of fish and invertebrates. Catch and effort of the recreational fishery were monitored by use of catch reports completed by fishermen and by direct observation of fishing activity. Samples of the catch were examined to determine species and size composition.

Of the five stations censused, the three that appeared visually to provide similar habitat (Stations P1, P5, and P6) had similar fish communities, even though Station P5 was much more heavily fished than the physically very similar Station P6. Stations P3 and P7, which appeared visually different in habitat from each other and from the preceding stations, had distinctly different fish communities. Results of analyses by both similarity index and paired t-tests indicated these results. Similarity index analysis indicated relatively high levels of similarity within each station over the six years of the study, suggesting that activities related to JACADS development had not made a detectable change in these fish communities. The time series of population size as estimated by census was analyzed for temporal trends by two methods of correlation/regression. It seems likely that there has been a decreasing trend in the total number of fish and in the numbers of a good many species over the six years of the study. The changes do not seem associated with fishing, and there is no evidence to link them with any other human activity. It seems likely that this is a natural phenomenon, perhaps related to variability in recruitment. The available data on this apparently natural variability provide a valuable baseline for comparison with changes in fish populations that may occur in the future.

Fourteen fish species, octopus, and a few species of decorative coral made up the bulk of the recreational fishery. A

few decorative shelled mollusc species, lobsters, and occasional other invertebrates were also collected, as well as a few individuals of many other fish species. Comparing years was difficult because of variable underreporting of catch and effort. However, there seemed to be no evidence of significant or consistent increase in either total catch or effort over the six years of the study (despite a more than three-fold increase in JA human population at maximum). Most transient changes in catch seem to be explained by corresponding changes in effort. For all the major fish species caught, the total annual catch was small compared to the estimated size of the species population. Continued fishing at levels observed during the study is unlikely to affect the fish populations seriously. Increases reported in the 1989 catch of several invertebrates (e.g., corals, shelled molluscs, octopus) may reflect an artifact of reporting by fishermen. Catches of most of these species declined somewhat in the present year, but the trend will bear watching in future years.

The serious problem with compliance by boat fishermen with the catch reporting system during the year ending 1987 has largely been remedied. Mandatory catch reporting was incorporated into the sign-out/return procedure for recreational boat use in the year ending 1988, and the requirement for reporting all types of animals caught was stressed. Catch estimates for the past two years based on boat catch reports are believed to be reasonably accurate; the loss of data from previous years is irreparable and will continue to hamper analysis and interpretation of temporal trends. It is essential that compliance with reporting requirements for all catch be maintained high in order that the studies on the fishery can produce meaningful results. This issue must receive the necessary attention and continuing effective supervision by JA management if the project is to succeed.

During the project year, it became clear that compliance with reporting of shoreline catch and effort had deteriorated to the point that the data were not reliable for making the main quantitative estimates useful for management decisions. Compliance by fishermen cannot be enforced by project staff, and it is not feasible for project staff to collect the data directly. In response to our report of this status, JA administration indicated that they would not enforce compliance nor apply other means to secure shoreline catch and/or effort data. The attempt to use such data for quantitative analysis in the project has therefore been abandoned, and the effects of shoreline fishing on the fish stocks will remain unknown.

As of the end of the project year, the JACADS facility was just beginning operation, so monitoring of any environmental effects due to operation is still to come. A good baseline has been acquired, and no effects of construction have been detected. Lack of effects on the fishery may be due to a lack of increased fishing effort; it is not clear what the trend of human population and fishing effort will be in the future. However, if the effects of any future changes due to plant operation or fishing are to be detected, the study program presented here must be continued using much the same sampling methods and analyses.

# *Appendix B*

**TABLE B-1.** Estimated 1-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site.

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.10869E-05 |
| 0.000 | 6.096 | 0.71606E-06 |
| 0.000 | 12.192 | 0.15821E-05 |
| 0.000 | 18.288 | 0.92511E-06 |
| 0.000 | 24.384 | 0.13211E-05 |
| 0.000 | 30.480 | 0.11776E-05 |
| 0.000 | 36.576 | 0.17014E-05 |
| 0.000 | 42.672 | 0.89331E-06 |
| 0.000 | 48.768 | 0.12986E-05 |
| 0.000 | 54.864 | 0.10935E-05 |
| 0.000 | 60.960 | 0.10394E-05 |
| 0.000 | 67.056 | 0.23507E-05 |
| 0.000 | 73.152 | 0.72389E-05 |
| 0.000 | 79.248 | 0.25512E-05 |
| 0.000 | 85.344 | 0.66881E-05 |
| 0.000 | 91.440 | 0.23620E-05 |
| 0.000 | 97.536 | 0.19368E-05 |
| 0.000 | 103.632 | 0.17130E-05 |
| 0.000 | 109.728 | 0.19697E-05 |
| 0.000 | 115.824 | 0.12683E-05 |
| 0.000 | 121.920 | 0.12411E-05 |
| 6.096 | 121.920 | 0.82771E-06 |
| 12.192 | 121.920 | 0.17928E-05 |
| 18.288 | 121.920 | 0.25317E-05 |
| 24.384 | 121.920 | 0.13754E-05 |
| 30.480 | 121.920 | 0.33187E-05 |
| 36.576 | 121.920 | 0.65311E-05 |
| 42.672 | 121.920 | 0.70387E-05 |
| 48.768 | 121.920 | 0.41036E-05 |
| 54.864 | 121.920 | 0.33110E-05 |
| 60.960 | 121.920 | 0.42264E-05 |
| 67.056 | 121.920 | 0.64511E-05 |
| 73.152 | 121.920 | 0.58638E-05 |
| 79.248 | 121.920 | 0.34911E-05 |
| 85.344 | 121.920 | 0.46393E-05 |
| 91.440 | 121.920 | 0.28861E-05 |
| 97.536 | 121.920 | 0.66784E-05 |

**TABLE B-1.** Estimated 1-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (Continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.27536E-05 |
| 109.728 | 121.920 | 0.67676E-05 |
| 115.824 | 121.920 | 0.27149E-05 |
| 121.920 | 121.920 | 0.54310E-05 |
| 128.016 | 121.920 | 0.22306E-05 |
| 134.112 | 121.920 | 0.52685E-05 |
| 140.208 | 121.920 | 0.20922E-05 |
| 146.304 | 121.920 | 0.47859E-05 |
| 152.400 | 121.920 | 0.16793E-05 |
| 158.496 | 121.920 | 0.40241E-05 |
| 164.592 | 121.920 | 0.23911E-05 |
| 170.688 | 121.920 | 0.73955E-05 |
| 176.784 | 121.920 | 0.26016E-05 |
| 182.880 | 121.920 | 0.77590E-05 |
| 188.976 | 121.920 | 0.27115E-05 |
| 195.072 | 121.920 | 0.10147E-05 |
| 195.072 | 115.824 | 0.29191E-05 |
| 195.072 | 109.728 | 0.84478E-05 |
| 195.072 | 103.632 | 0.32479E-05 |
| 195.072 | 97.536 | 0.81633E-05 |
| 195.072 | 91.440 | 0.27307E-05 |
| 195.072 | 85.344 | 0.51753E-05 |
| 195.072 | 79.248 | 0.21901E-05 |
| 195.072 | 73.152 | 0.52978E-05 |
| 195.072 | 67.056 | 0.18375E-05 |
| 195.072 | 60.960 | 0.10187E-05 |
| 188.976 | 60.960 | 0.20641E-05 |
| 182.880 | 60.960 | 0.48878E-05 |
| 176.784 | 60.960 | 0.17248E-05 |
| 170.688 | 60.960 | 0.45996E-05 |
| 164.592 | 60.960 | 0.37120E-05 |
| 158.496 | 60.960 | 0.93241E-05 |
| 152.400 | 60.960 | 0.36129E-05 |
| 146.304 | 60.960 | 0.93482E-05 |
| 146.304 | 54.864 | 0.33913E-05 |
| 146.304 | 48.768 | 0.34357E-05 |

**TABLE B-1.** Estimated 1-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (Continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.14158E-05 |
| 146.304 | 36.576 | 0.34726E-05 |
| 146.304 | 30.480 | 0.24876E-05 |
| 146.304 | 24.384 | 0.24098E-05 |
| 146.304 | 18.288 | 0.14316E-05 |
| 146.304 | 12.192 | 0.20872E-05 |
| 146.304 | 6.096 | 0.27877E-05 |
| 146.304 | 0.000 | 0.32758E-05 |
| 140.208 | 0.000 | 0.35537E-05 |
| 134.112 | 0.000 | 0.10083E-04 |
| 128.016 | 0.000 | 0.39054E-05 |
| 121.920 | 0.000 | 0.85703E-05 |
| 115.824 | 0.000 | 0.31626E-05 |
| 109.728 | 0.000 | 0.71679E-05 |
| 103.632 | 0.000 | 0.28354E-05 |
| 97.536 | 0.000 | 0.78186E-05 |
| 91.440 | 0.000 | 0.32782E-05 |
| 85.344 | 0.000 | 0.67743E-05 |
| 79.248 | 0.000 | 0.26083E-05 |
| 73.152 | 0.000 | 0.73547E-05 |
| 67.056 | 0.000 | 0.27275E-05 |
| 60.096 | 0.000 | 0.62408E-05 |
| 54.864 | 0.000 | 0.22823E-05 |
| 48.768 | 0.000 | 0.19447E-05 |
| 42.672 | 0.000 | 0.15307E-05 |
| 36.576 | 0.000 | 0.40823E-05 |
| 30.480 | 0.000 | 0.17803E-05 |
| 24.384 | 0.000 | 0.45009E-05 |
| 18.288 | 0.000 | 0.19206E-05 |
| 12.192 | 0.000 | 0.13845E-05 |
| 6.096 | 0.000 | 0.80730E-06 |

**TABLE B-2.** Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site.

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.19477E-02 |
| 0.000 | 6.096 | 0.39631E-02 |
| 0.000 | 12.192 | 0.26655E-02 |
| 0.000 | 18.288 | 0.97173E-02 |
| 0.000 | 24.384 | 0.70420E-02 |
| 0.000 | 30.480 | 0.25542E-01 |
| 0.000 | 36.576 | 0.67856E-01 |
| 0.000 | 42.672 | 0.26382E-01 |
| 0.000 | 48.768 | 0.67592E-01 |
| 0.000 | 54.864 | 0.25488E-01 |
| 0.000 | 60.960 | 0.69852E-02 |
| 0.000 | 67.056 | 0.96678E-02 |
| 0.000 | 73.152 | 0.26252E-02 |
| 0.000 | 79.248 | 0.46039E-02 |
| 0.000 | 85.344 | 0.19071E-02 |
| 0.000 | 91.440 | 0.55104E-02 |
| 0.000 | 97.536 | 0.33685E-02 |
| 0.000 | 103.632 | 0.40676E-02 |
| 0.000 | 109.728 | 0.60926E-02 |
| 0.000 | 115.824 | 0.21389E-02 |
| 0.000 | 121.920 | 0.61288E-02 |
| 6.096 | 121.920 | 0.60058E-02 |
| 12.192 | 121.920 | 0.49756E-02 |
| 18.288 | 121.920 | 0.30086E-02 |
| 24.384 | 121.920 | 0.67717E-02 |
| 30.480 | 121.920 | 0.25632E-01 |
| 36.576 | 121.920 | 0.18519E-01 |
| 42.672 | 121.920 | 0.67457E-01 |
| 48.768 | 121.920 | 0.18052E+00 |
| 54.864 | 121.920 | 0.67357E-01 |
| 60.960 | 121.920 | 0.17853E+00 |
| 67.056 | 121.920 | 0.67358E-01 |
| 73.152 | 121.920 | 0.18427E-01 |
| 79.248 | 121.920 | 0.25561E-01 |
| 85.344 | 121.920 | 0.66975E-02 |
| 91.440 | 121.920 | 0.29347E-02 |
| 97.536 | 121.920 | 0.49055E-02 |

TABLE B-2. Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.59388E-02 |
| 109.728 | 121.920 | 0.60642E-02 |
| 115.824 | 121.920 | 0.56506E-02 |
| 121.920 | 121.920 | 0.50112E-02 |
| 128.016 | 121.920 | 0.43326E-02 |
| 134.112 | 121.920 | 0.37016E-02 |
| 140.208 | 121.920 | 0.31521E-02 |
| 146.304 | 121.920 | 0.26377E-02 |
| 152.400 | 121.920 | 0.23038E-02 |
| 158.496 | 121.920 | 0.40571E-02 |
| 164.592 | 121.920 | 0.20113E-02 |
| 170.688 | 121.920 | 0.24965E-02 |
| 176.784 | 121.920 | 0.13524E-02 |
| 182.880 | 121.920 | 0.16639E-02 |
| 188.976 | 121.920 | 0.19454E-02 |
| 195.072 | 121.920 | 0.19422E-02 |
| 195.072 | 115.824 | 0.15801E-02 |
| 195.072 | 109.728 | 0.15036E-02 |
| 195.072 | 103.632 | 0.19604E-02 |
| 195.072 | 97.536 | 0.21416E-02 |
| 195.072 | 91.440 | 0.17412E-02 |
| 195.072 | 85.344 | 0.13755E-02 |
| 195.072 | 79.248 | 0.14653E-02 |
| 195.072 | 73.152 | 0.25189E-02 |
| 195.072 | 67.056 | 0.13646E-02 |
| 195.072 | 60.960 | 0.14306E-02 |
| 188.976 | 60.960 | 0.12030E-02 |
| 182.880 | 60.960 | 0.14390E-02 |
| 176.784 | 60.960 | 0.20232E-02 |
| 170.688 | 60.960 | 0.18035E-02 |
| 164.592 | 60.960 | 0.22019E-02 |
| 158.496 | 60.960 | 0.33033E-02 |
| 152.400 | 60.960 | 0.47735E-02 |
| 146.304 | 60.960 | 0.58437E-02 |
| 146.304 | 54.864 | 0.21440E-02 |
| 146.304 | 48.768 | 0.63571E-02 |

TABLE B-2. Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.14449E-02 |
| 146.304 | 36.576 | 0.63571E-02 |
| 146.304 | 30.480 | 0.17778E-02 |
| 146.304 | 24.384 | 0.58435E-02 |
| 146.304 | 18.288 | 0.12571E-02 |
| 146.304 | 12.192 | 0.50959E-02 |
| 146.304 | 6.096 | 0.18491E-02 |
| 146.304 | 0.000 | 0.26943E-02 |
| 140.208 | 0.000 | 0.52016E-02 |
| 134.112 | 0.000 | 0.29861E-02 |
| 128.016 | 0.000 | 0.19225E-02 |
| 121.920 | 0.000 | 0.86733E-02 |
| 115.824 | 0.000 | 0.20161E-02 |
| 109.728 | 0.000 | 0.90958E-02 |
| 103.632 | 0.000 | 0.28467E-02 |
| 97.536 | 0.000 | 0.93074E-02 |
| 91.440 | 0.000 | 0.12760E-01 |
| 85.344 | 0.000 | 0.62689E-02 |
| 79.248 | 0.000 | 0.32600E-02 |
| 73.152 | 0.000 | 0.62469E-02 |
| 67.056 | 0.000 | 0.11686E-01 |
| 60.096 | 0.000 | 0.91177E-02 |
| 54.864 | 0.000 | 0.28482E-02 |
| 48.768 | 0.000 | 0.90952E-02 |
| 42.672 | 0.000 | 0.22583E-02 |
| 36.576 | 0.000 | 0.86766E-02 |
| 30.480 | 0.000 | 0.19236E-02 |
| 24.384 | 0.000 | 0.30140E-02 |
| 18.288 | 0.000 | 0.52274E-02 |
| 12.192 | 0.000 | 0.27159E-02 |
| 6.096 | 0.000 | 0.17363E-02 |

TABLE E-3. Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site.

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.40998E-02 |
| 0.000 | 6.096 | 0.30514E-02 |
| 0.000 | 12.192 | 0.51275E-02 |
| 0.000 | 18.288 | 0.18139E-01 |
| 0.000 | 24.384 | 0.13190E-01 |
| 0.000 | 30.480 | 0.47588E-01 |
| 0.000 | 36.576 | 0.12670E+00 |
| 0.000 | 42.672 | 0.48208E-01 |
| 0.000 | 48.768 | 0.12590E+00 |
| 0.000 | 54.864 | 0.47446E-01 |
| 0.000 | 60.960 | 0.13036E-01 |
| 0.000 | 67.056 | 0.18007E-01 |
| 0.000 | 73.152 | 0.50186E-02 |
| 0.000 | 79.248 | 0.53689E-02 |
| 0.000 | 85.344 | 0.39782E-02 |
| 0.000 | 91.440 | 0.60774E-02 |
| 0.000 | 97.536 | 0.44624E-02 |
| 0.000 | 103.632 | 0.45234E-02 |
| 0.000 | 109.728 | 0.68376E-02 |
| 0.000 | 115.824 | 0.33081E-02 |
| 0.000 | 121.920 | 0.69038E-02 |
| 6.096 | 121.920 | 0.67646E-02 |
| 12.192 | 121.920 | 0.56497E-02 |
| 18.288 | 121.920 | 0.35287E-02 |
| 24.384 | 121.920 | 0.77137E-02 |
| 30.480 | 121.920 | 0.27982E-01 |
| 36.576 | 121.920 | 0.20313E-01 |
| 42.672 | 121.920 | 0.73438E-01 |
| 48.768 | 121.920 | 0.20046E+00 |
| 54.864 | 121.920 | 0.73290E-01 |
| 60.960 | 121.920 | 0.19416E+00 |
| 67.056 | 121.920 | 0.73231E-01 |
| 73.152 | 121.920 | 0.20133E-01 |
| 79.248 | 121.920 | 0.27832E-01 |
| 85.344 | 121.920 | 0.11522E-01 |
| 91.440 | 121.920 | 0.40237E-02 |
| 97.536 | 121.920 | 0.55060E-02 |

TABLE B-3. Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration (g/m³) |
|---|---|---|
| 103.632 | 121.920 | 0.66277E-02 |
| 109.728 | 121.920 | 0.67720E-02 |
| 115.824 | 121.920 | 0.63372E-02 |
| 121.920 | 121.920 | 0.56586E-02 |
| 128.016 | 121.920 | 0.49383E-02 |
| 134.112 | 121.920 | 0.42681E-02 |
| 140.208 | 121.920 | 0.36863E-02 |
| 146.304 | 121.920 | 0.43281E-02 |
| 152.400 | 121.920 | 0.27947E-02 |
| 158.496 | 121.920 | 0.58916E-02 |
| 164.592 | 121.920 | 0.22107E-02 |
| 170.688 | 121.920 | 0.47877E-02 |
| 176.784 | 121.920 | 0.22674E-02 |
| 182.880 | 121.920 | 0.17181E-02 |
| 188.976 | 121.920 | 0.18273E-02 |
| 195.072 | 121.920 | 0.17304E-02 |
| 195.072 | 115.824 | 0.13019E-02 |
| 195.072 | 109.728 | 0.12953E-02 |
| 195.072 | 103.632 | 0.18293E-02 |
| 195.072 | 97.536 | 0.18026E-02 |
| 195.072 | 91.440 | 0.16046E-02 |
| 195.072 | 85.344 | 0.10864E-02 |
| 195.072 | 79.248 | 0.19185E-02 |
| 195.072 | 73.152 | 0.20209E-02 |
| 195.072 | 67.056 | 0.12299E-02 |
| 195.072 | 60.960 | 0.13806E-02 |
| 188.976 | 60.960 | 0.13524E-02 |
| 182.880 | 60.960 | 0.15511E-02 |
| 176.784 | 60.960 | 0.32245E-02 |
| 170.688 | 60.960 | 0.37882E-02 |
| 164.592 | 60.960 | 0.35080E-02 |
| 158.496 | 60.960 | 0.38885E-02 |
| 152.400 | 60.960 | 0.37995E-02 |
| 146.304 | 60.960 | 0.44871E-02 |
| 146.304 | 54.864 | 0.29576E-02 |
| 146.304 | 48.768 | 0.49692E-02 |

**TABLE B-3.** Estimated 1-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.22117E-02 |
| 146.304 | 36.576 | 0.49690E-02 |
| 146.304 | 30.480 | 0.29834E-02 |
| 146.304 | 24.384 | 0.61789E-02 |
| 146.304 | 18.288 | 0.17737E-02 |
| 146.304 | 12.192 | 0.45863E-02 |
| 146.304 | 6.096 | 0.16218E-02 |
| 146.304 | 0.000 | 0.41072E-02 |
| 140.208 | 0.000 | 0.39609E-02 |
| 134.112 | 0.000 | 0.41424E-02 |
| 128.016 | 0.000 | 0.17067E-02 |
| 121.920 | 0.000 | 0.88917E-02 |
| 115.824 | 0.000 | 0.19144E-02 |
| 109.728 | 0.000 | 0.67356E-02 |
| 103.632 | 0.000 | 0.28113E-02 |
| 97.536 | 0.000 | 0.66454E-02 |
| 91.440 | 0.000 | 0.95679E-02 |
| 85.344 | 0.000 | 0.46037E-02 |
| 79.248 | 0.000 | 0.34387E-02 |
| 73.152 | 0.000 | 0.45487E-02 |
| 67.056 | 0.000 | 0.81558E-02 |
| 60.096 | 0.000 | 0.64398E-02 |
| 54.864 | 0.000 | 0.26765E-02 |
| 48.768 | 0.000 | 0.78736E-02 |
| 42.672 | 0.000 | 0.33379E-02 |
| 36.576 | 0.000 | 0.89007E-02 |
| 30.480 | 0.000 | 0.16248E-02 |
| 24.384 | 0.000 | 0.50808E-02 |
| 18.233 | 0.000 | 0.66992E-02 |
| 12.192 | 0.000 | 0.40998E-02 |
| 6.096 | 0.000 | 0.24769E-02 |

TABLE B-4. Estimated 8-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.76103E-06 |
| 0.000 | 6.096 | 0.50137E-06 |
| 0.000 | 12.192 | 0.11078E-05 |
| 0.000 | 18.288 | 0.64774E-06 |
| 0.000 | 24.384 | 0.92498E-06 |
| 0.000 | 30.480 | 0.82454E-06 |
| 0.000 | 36.576 | 0.11913E-05 |
| 0.000 | 42.672 | 0.62548E-06 |
| 0.000 | 48.768 | 0.90928E-06 |
| 0.000 | 54.864 | 0.76562E-06 |
| 0.000 | 60.960 | 0.72775E-06 |
| 0.000 | 67.056 | 0.16459E-05 |
| 0.000 | 73.152 | 0.50685E-05 |
| 0.000 | 79.248 | 0.17863E-05 |
| 0.000 | 85.344 | 0.46829E-05 |
| 0.000 | 91.440 | 0.16538E-05 |
| 0.000 | 97.536 | 0.13561E-05 |
| 0.000 | 103.632 | 0.11994E-05 |
| 0.000 | 109.728 | 0.13791E-05 |
| 0.000 | 115.824 | 0.88805E-06 |
| 0.000 | 121.920 | 0.86897E-06 |
| 6.096 | 121.920 | 0.57955E-06 |
| 12.192 | 121.920 | 0.12553E-05 |
| 18.288 | 121.920 | 0.17726E-05 |
| 24.384 | 121.920 | 0.96304E-06 |
| 30.480 | 121.920 | 0.23237E-05 |
| 36.576 | 121.920 | 0.45730E-05 |
| 42.672 | 121.920 | 0.49284E-05 |
| 48.768 | 121.920 | 0.28733E-05 |
| 54.864 | 121.920 | 0.23183E-05 |
| 60.960 | 121.920 | 0.29592E-05 |
| 67.056 | 121.920 | 0.45170E-05 |
| 73.152 | 121.920 | 0.41092E-05 |
| 79.248 | 121.920 | 0.24444E-05 |
| 85.344 | 121.920 | 0.32833E-05 |
| 91.440 | 121.920 | 0.20208E-05 |
| 97.536 | 121.920 | 0.46761E-05 |

TABLE B-4. Estimated 8-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.19280E-05 |
| 109.728 | 121.920 | 0.47386E-05 |
| 115.824 | 121.920 | 0.19009E-05 |
| 121.920 | 121.920 | 0.38027E-05 |
| 128.016 | 121.920 | 0.15618E-05 |
| 134.112 | 121.920 | 0.36889E-05 |
| 140.208 | 121.920 | 0.14649E-05 |
| 146.304 | 121.920 | 0.33510E-05 |
| 152.400 | 121.920 | 0.11758E-05 |
| 158.496 | 121.920 | 0.28176E-05 |
| 164.592 | 121.920 | 0.16742E-05 |
| 170.688 | 121.920 | 0.51782E-05 |
| 176.784 | 121.920 | 0.18216E-05 |
| 182.880 | 121.920 | 0.54327E-05 |
| 188.976 | 121.920 | 0.18986E-05 |
| 195.072 | 121.920 | 0.71046E-06 |
| 195.072 | 115.824 | 0.20439E-05 |
| 195.072 | 109.728 | 0.59150E-05 |
| 195.072 | 103.632 | 0.22741E-05 |
| 195.072 | 97.536 | 0.57158E-05 |
| 195.072 | 91.440 | 0.19120E-05 |
| 195.072 | 85.344 | 0.36238E-05 |
| 195.072 | 79.248 | 0.15334E-05 |
| 195.072 | 73.152 | 0.37094E-05 |
| 195.072 | 67.056 | 0.12866E-05 |
| 195.072 | 60.960 | 0.71327E-06 |
| 188.976 | 60.960 | 0.14452E-05 |
| 182.880 | 60.960 | 0.34224E-05 |
| 176.784 | 60.960 | 0.12077E-05 |
| 170.688 | 60.960 | 0.32206E-05 |
| 164.592 | 60.960 | 0.25990E-05 |
| 158.496 | 60.960 | 0.65285E-05 |
| 152.400 | 60.960 | 0.25297E-05 |
| 146.304 | 60.960 | 0.65454E-05 |
| 146.304 | 54.864 | 0.23745E-05 |
| 146.304 | 48.768 | 0.24056E-05 |

**TABLE B-4.** Estimated 8-Hour Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.99130E-06 |
| 146.304 | 36.576 | 0.24315E-05 |
| 146.304 | 30.480 | 0.17418E-05 |
| 146.304 | 24.384 | 0.16873E-05 |
| 146.304 | 18.288 | 0.10024E-05 |
| 146.304 | 12.192 | 0.14614E-05 |
| 146.304 | 6.096 | 0.19519E-05 |
| 146.304 | 0.000 | 0.22937E-05 |
| 140.208 | 0.000 | 0.24882E-05 |
| 134.112 | 0.000 | 0.70600E-05 |
| 128.016 | 0.000 | 0.27345E-05 |
| 121.920 | 0.000 | 0.60008E-05 |
| 115.824 | 0.000 | 0.22144E-05 |
| 109.728 | 0.000 | 0.50188E-05 |
| 103.632 | 0.000 | 0.19853E-05 |
| 97.536 | 0.000 | 0.54744E-05 |
| 91.440 | 0.000 | 0.22953E-05 |
| 85.344 | 0.000 | 0.47432E-05 |
| 79.248 | 0.000 | 0.18263E-05 |
| 73.152 | 0.000 | 0.51496E-05 |
| 67.056 | 0.000 | 0.19097E-05 |
| 60.096 | 0.000 | 0.43697E-05 |
| 54.864 | 0.000 | 0.15980E-05 |
| 48.768 | 0.000 | 0.13617E-05 |
| 42.672 | 0.000 | 0.10718E-05 |
| 36.576 | 0.000 | 0.28584E-05 |
| 30.480 | 0.000 | 0.12465E-05 |
| 24.384 | 0.000 | 0.31514E-05 |
| 18.288 | 0.000 | 0.13448E-05 |
| 12.192 | 0.000 | 0.96941E-06 |
| 6.096 | 0.000 | 0.56525E-06 |

**TABLE B-5.** Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site.

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.13637E-02 |
| 0.000 | 6.096 | 0.27748E-02 |
| 0.000 | 12.192 | 0.18663E-02 |
| 0.000 | 18.288 | 0.68037E-02 |
| 0.000 | 24.384 | 0.49306E-02 |
| 0.000 | 30.480 | 0.17884E-01 |
| 0.000 | 36.576 | 0.47511E-01 |
| 0.000 | 42.672 | 0.18472E-01 |
| 0.000 | 48.768 | 0.47326E-01 |
| 0.000 | 54.864 | 0.17846E-01 |
| 0.000 | 60.960 | 0.48908E-02 |
| 0.000 | 67.056 | 0.67691E-02 |
| 0.000 | 73.152 | 0.18381E-02 |
| 0.000 | 79.248 | 0.32235E-02 |
| 0.000 | 85.344 | 0.13353E-02 |
| 0.000 | 91.440 | 0.38582E-02 |
| 0.000 | 97.536 | 0.23585E-02 |
| 0.000 | 103.632 | 0.28480E-02 |
| 0.000 | 109.728 | 0.42659E-02 |
| 0.000 | 115.824 | 0.14976E-02 |
| 0.000 | 121.920 | 0.42912E-02 |
| 6.096 | 121.920 | 0.42051E-02 |
| 12.192 | 121.920 | 0.34838E-02 |
| 18.288 | 121.920 | 0.21065E-02 |
| 24.384 | 121.920 | 0.47413E-02 |
| 30.480 | 121.920 | 0.17947E-01 |
| 36.576 | 121.920 | 0.12966E-01 |
| 42.672 | 121.920 | 0.47231E-01 |
| 48.768 | 121.920 | 0.12640E+00 |
| 54.864 | 121.920 | 0.47161E-01 |
| 60.960 | 121.920 | 0.12500E+00 |
| 67.056 | 121.920 | 0.47162E-01 |
| 73.152 | 121.920 | 0.12902E-01 |
| 79.248 | 121.920 | 0.17897E-01 |
| 85.344 | 121.920 | 0.46894E-02 |
| 91.440 | 121.920 | 0.20548E-02 |
| 97.536 | 121.920 | 0.34347E-02 |

**TABLE B-5.** Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.41582E-02 |
| 109.728 | 121.920 | 0.42460E-02 |
| 115.824 | 121.920 | 0.39563E-02 |
| 121.920 | 121.920 | 0.35087E-02 |
| 128.016 | 121.920 | 0.30336E-02 |
| 134.112 | 121.920 | 0.25918E-02 |
| 140.208 | 121.920 | 0.22070E-02 |
| 146.304 | 121.920 | 0.18819E-02 |
| 152.400 | 121.920 | 0.16131E-02 |
| 158.496 | 121.920 | 0.28406E-02 |
| 164.592 | 121.920 | 0.14082E-02 |
| 170.688 | 121.920 | 0.17480E-02 |
| 176.784 | 121.920 | 0.94689E-03 |
| 182.880 | 121.920 | 0.11650E-02 |
| 188.976 | 121.920 | 0.13621E-02 |
| 195.072 | 121.920 | 0.13599E-02 |
| 195.072 | 115.824 | 0.11063E-02 |
| 195.072 | 109.728 | 0.10528E-02 |
| 195.072 | 103.632 | 0.13726E-02 |
| 195.072 | 97.536 | 0.14995E-02 |
| 195.072 | 91.440 | 0.12191E-02 |
| 195.072 | 85.344 | 0.96305E-03 |
| 195.072 | 79.248 | 0.10260E-02 |
| 195.072 | 73.152 | 0.17636E-02 |
| 195.072 | 67.056 | 0.95543E-03 |
| 195.072 | 60.960 | 0.10017E-02 |
| 188.976 | 60.960 | 0.84227E-03 |
| 182.880 | 60.960 | 0.10075E-02 |
| 176.784 | 60.960 | 0.14166E-02 |
| 170.688 | 60.960 | 0.12627E-02 |
| 164.592 | 60.960 | 0.15417E-02 |
| 158.496 | 60.960 | 0.23129E-02 |
| 152.400 | 60.960 | 0.33423E-02 |
| 146.304 | 60.960 | 0.40916E-02 |
| 146.304 | 54.864 | 0.15012E-02 |
| 146.304 | 48.768 | 0.44511E-02 |

TABLE B-5. Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site. (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.10117E-02 |
| 146.304 | 36.576 | 0.44510E-02 |
| 146.304 | 30.480 | 0.12448E-02 |
| 146.304 | 24.384 | 0.40915E-02 |
| 146.304 | 18.288 | 0.88019E-03 |
| 146.304 | 12.192 | 0.35660E-02 |
| 146.304 | 6.096 | 0.12946E-02 |
| 146.304 | 0.000 | 0.18865E-02 |
| 140.208 | 0.000 | 0.36420E-02 |
| 134.112 | 0.000 | 0.20908E-02 |
| 128.016 | 0.000 | 0.13461E-02 |
| 121.920 | 0.000 | 0.60728E-02 |
| 115.824 | 0.000 | 0.14116E-02 |
| 109.728 | 0.000 | 0.63686E-02 |
| 103.632 | 0.000 | 0.19931E-02 |
| 97.536 | 0.000 | 0.65167E-02 |
| 91.440 | 0.000 | 0.89339E-02 |
| 85.344 | 0.000 | 0.43893E-02 |
| 79.248 | 0.000 | 0.22826E-02 |
| 73.152 | 0.000 | 0.43739E-02 |
| 67.056 | 0.000 | 0.81820E-02 |
| 60.096 | 0.000 | 0.63839E-02 |
| 54.864 | 0.000 | 0.19942E-02 |
| 48.768 | 0.000 | 0.63682E-02 |
| 42.672 | 0.000 | 0.15812E-02 |
| 36.576 | 0.000 | 0.60751E-02 |
| 30.480 | 0.000 | 0.13468E-02 |
| 24.384 | 0.000 | 0.21103E-02 |
| 18.288 | 0.000 | 0.36601E-02 |
| 12.192 | 0.000 | 0.19016E-02 |
| 6.096 | 0.000 | 0.12157E-02 |

TABLE B-6. Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.28706E-02 |
| 0.000 | 6.096 | 0.21365E-02 |
| 0.000 | 12.192 | 0.35901E-02 |
| 0.000 | 18.288 | 0.12700E-01 |
| 0.000 | 24.384 | 0.92349E-02 |
| 0.000 | 30.480 | 0.33319E-01 |
| 0.000 | 36.576 | 0.88714E-01 |
| 0.000 | 42.672 | 0.33753E-01 |
| 0.000 | 48.768 | 0.88149E-01 |
| 0.000 | 54.864 | 0.33220E-01 |
| 0.000 | 60.960 | 0.91275E-02 |
| 0.000 | 67.056 | 0.12608E-01 |
| 0.000 | 73.152 | 0.35139E-02 |
| 0.000 | 79.248 | 0.37591E-02 |
| 0.000 | 85.344 | 0.27854E-02 |
| 0.000 | 91.440 | 0.42552E-02 |
| 0.000 | 97.536 | 0.31244E-02 |
| 0.000 | 103.632 | 0.31671E-02 |
| 0.000 | 109.728 | 0.47875E-02 |
| 0.000 | 115.824 | 0.23162E-02 |
| 0.000 | 121.920 | 0.48338E-02 |
| 6.096 | 121.920 | 0.47363E-02 |
| 12.192 | 121.920 | 0.39557E-02 |
| 18.288 | 121.920 | 0.24707E-02 |
| 24.384 | 121.920 | 0.54009E-02 |
| 30.480 | 121.920 | 0.19592E-01 |
| 36.576 | 121.920 | 0.14222E-01 |
| 42.672 | 121.920 | 0.51419E-01 |
| 48.768 | 121.920 | 0.14036E+00 |
| 54.864 | 121.920 | 0.51315E-01 |
| 60.960 | 121.920 | 0.13595E+00 |
| 67.056 | 121.920 | 0.51274E-01 |
| 73.152 | 121.920 | 0.14097E-01 |
| 79.248 | 121.920 | 0.19487E-01 |
| 85.344 | 121.920 | 0.80671E-02 |
| 91.440 | 121.920 | 0.28173E-02 |
| 97.536 | 121.920 | 0.38551E-02 |

TABLE B-6. Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.46405E-02 |
| 109.728 | 121.920 | 0.47415E-02 |
| 115.824 | 121.920 | 0.44371E-02 |
| 121.920 | 121.920 | 0.39620E-02 |
| 128.016 | 121.920 | 0.34576E-02 |
| 134.112 | 121.920 | 0.29884E-02 |
| 140.208 | 121.920 | 0.25810E-02 |
| 146.304 | 121.920 | 0.30304E-02 |
| 152.400 | 121.920 | 0.19568E-02 |
| 158.496 | 121.920 | 0.41251E-02 |
| 164.592 | 121.920 | 0.15478E-02 |
| 170.688 | 121.920 | 0.33522E-02 |
| 176.784 | 121.920 | 0.15876E-02 |
| 182.880 | 121.920 | 0.12029E-02 |
| 188.976 | 121.920 | 0.12794E-02 |
| 195.072 | 121.920 | 0.12116E-02 |
| 195.072 | 115.824 | 0.91155E-03 |
| 195.072 | 109.728 | 0.90693E-03 |
| 195.072 | 103.632 | 0.12808E-02 |
| 195.072 | 97.536 | 0.12621E-02 |
| 195.072 | 91.440 | 0.11235E-02 |
| 195.072 | 85.344 | 0.76067E-03 |
| 195.072 | 79.248 | 0.13433E-02 |
| 195.072 | 73.152 | 0.14150E-02 |
| 195.072 | 67.056 | 0.86112E-03 |
| 195.072 | 60.960 | 0.96662E-03 |
| 188.976 | 60.960 | 0.94691E-03 |
| 182.880 | 60.960 | 0.10860E-02 |
| 176.784 | 60.960 | 0.22577E-02 |
| 170.688 | 60.960 | 0.26523E-02 |
| 164.592 | 60.960 | 0.24562E-02 |
| 158.496 | 60.960 | 0.27226E-02 |
| 152.400 | 60.960 | 0.26603E-02 |
| 146.304 | 60.960 | 0.31417E-02 |
| 146.304 | 54.864 | 0.20708E-02 |
| 146.304 | 48.768 | 0.34792E-02 |

**TABLE B-6.** Estimated 8-Hour Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.15485E-02 |
| 146.304 | 36.576 | 0.34791E-02 |
| 146.304 | 30.480 | 0.20889E-02 |
| 146.304 | 24.384 | 0.43263E-02 |
| 146.304 | 18.288 | 0.12419E-02 |
| 146.304 | 12.192 | 0.32112E-02 |
| 146.304 | 6.096 | 0.11355E-02 |
| 146.304 | 0.000 | 0.28757E-02 |
| 140.208 | 0.000 | 0.27733E-02 |
| 134.112 | 0.000 | 0.29004E-02 |
| 128.016 | 0.000 | 0.11950E-02 |
| 121.920 | 0.000 | 0.62257E-02 |
| 115.824 | 0.000 | 0.13404E-02 |
| 109.728 | 0.000 | 0.47161E-02 |
| 103.632 | 0.000 | 0.19684E-02 |
| 97.536 | 0.000 | 0.46529E-02 |
| 91.440 | 0.000 | 0.66992E-02 |
| 85.344 | 0.000 | 0.32234E-02 |
| 79.248 | 0.000 | 0.24077E-02 |
| 73.152 | 0.000 | 0.31848E-02 |
| 67.056 | 0.000 | 0.57105E-02 |
| 60.096 | 0.000 | 0.45089E-02 |
| 54.864 | 0.000 | 0.18740E-02 |
| 48.768 | 0.000 | 0.55128E-02 |
| 42.672 | 0.000 | 0.23371E-02 |
| 36.576 | 0.000 | 0.62320E-02 |
| 30.480 | 0.000 | 0.11376E-02 |
| 24.384 | 0.000 | 0.35574E-02 |
| 18.288 | 0.000 | 0.46905E-02 |
| 12.192 | 0.000 | 0.28706E-02 |
| 6.096 | 0.000 | 0.17343E-02 |

**TABLE B-7.** Estimated Annual Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration (g/m$^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.27181E-07 |
| 0.000 | 6.096 | 0.17907E-07 |
| 0.000 | 12.192 | 0.39565E-07 |
| 0.000 | 18.288 | 0.23135E-07 |
| 0.000 | 24.384 | 0.33036E-07 |
| 0.000 | 30.480 | 0.29449E-07 |
| 0.000 | 36.576 | 0.42548E-07 |
| 0.000 | 42.672 | 0.22340E-07 |
| 0.000 | 48.768 | 0.32476E-07 |
| 0.000 | 54.864 | 0.27345E-07 |
| 0.000 | 60.960 | 0.25992E-07 |
| 0.000 | 67.056 | 0.58786E-07 |
| 0.000 | 73.152 | 0.18103E-06 |
| 0.000 | 79.248 | 0.63799E-07 |
| 0.000 | 85.344 | 0.16725E-06 |
| 0.000 | 91.440 | 0.59067E-07 |
| 0.000 | 97.536 | 0.48434E-07 |
| 0.000 | 103.632 | 0.42838E-07 |
| 0.000 | 109.728 | 0.49257E-07 |
| 0.000 | 115.824 | 0.31717E-07 |
| 0.000 | 121.920 | 0.31036E-07 |
| 6.096 | 121.920 | 0.20699E-07 |
| 12.192 | 121.920 | 0.44833E-07 |
| 18.288 | 121.920 | 0.63311E-07 |
| 24.384 | 121.920 | 0.34396E-07 |
| 30.480 | 121.920 | 0.82992E-07 |
| 36.576 | 121.920 | 0.16333E-06 |
| 42.672 | 121.920 | 0.17602E-06 |
| 48.768 | 121.920 | 0.10262E-06 |
| 54.864 | 121.920 | 0.82799E-07 |
| 60.960 | 121.920 | 0.10569E-06 |
| 67.056 | 121.920 | 0.16133E-06 |
| 73.152 | 121.920 | 0.14676E-06 |
| 79.248 | 121.920 | 0.87302E-07 |
| 85.344 | 121.920 | 0.11727E-06 |
| 91.440 | 121.920 | 0.72175E-07 |
| 97.536 | 121.920 | 0.16701E-06 |

TABLE B-7. Estimated Annual Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.68860E-07 |
| 109.728 | 121.920 | 0.16924E-06 |
| 115.824 | 121.920 | 0.67892E-07 |
| 121.920 | 121.920 | 0.13581E-06 |
| 128.016 | 121.920 | 0.55781E-07 |
| 134.112 | 121.920 | 0.13175E-06 |
| 140.208 | 121.920 | 0.52321E-07 |
| 146.304 | 121.920 | 0.11968E-06 |
| 152.400 | 121.920 | 0.41996E-07 |
| 158.496 | 121.920 | 0.10063E-06 |
| 164.592 | 121.920 | 0.59795E-07 |
| 170.688 | 121.920 | 0.18494E-06 |
| 176.784 | 121.920 | 0.65060E-07 |
| 182.880 | 121.920 | 0.19403E-06 |
| 188.976 | 121.920 | 0.67809E-07 |
| 195.072 | 121.920 | 0.25374E-07 |
| 195.072 | 115.824 | 0.72998E-07 |
| 195.072 | 109.728 | 0.21126E-06 |
| 195.072 | 103.632 | 0.81222E-07 |
| 195.072 | 97.536 | 0.20414E-06 |
| 195.072 | 91.440 | 0.68287E-07 |
| 195.072 | 85.344 | 0.12942E-06 |
| 195.072 | 79.248 | 0.54768E-07 |
| 195.072 | 73.152 | 0.13249E-06 |
| 195.072 | 67.056 | 0.45951E-07 |
| 195.072 | 60.960 | 0.25475E-07 |
| 188.976 | 60.960 | 0.51618E-07 |
| 182.880 | 60.960 | 0.12223E-06 |
| 176.784 | 60.960 | 0.43134E-07 |
| 170.688 | 60.960 | 0.11503E-06 |
| 164.592 | 60.960 | 0.92827E-07 |
| 158.496 | 60.960 | 0.23317E-06 |
| 152.400 | 60.960 | 0.90349E-07 |
| 146.304 | 60.960 | 0.23377E-06 |
| 146.304 | 54.864 | 0.84808E-07 |
| 146.304 | 48.768 | 0.85918E-07 |

TABLE B-7. Estimated Annual Average Concentrations of Vapor-Phase TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration (g/m$^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.35405E-07 |
| 146.304 | 36.576 | 0.86842E-07 |
| 146.304 | 30.480 | 0.62209E-07 |
| 146.304 | 24.384 | 0.60264E-07 |
| 146.304 | 18.288 | 0.35802E-07 |
| 146.304 | 12.192 | 0.52195E-07 |
| 146.304 | 6.096 | 0.69714E-07 |
| 146.304 | 0.000 | 0.81921E-07 |
| 140.208 | 0.000 | 0.88869E-07 |
| 134.112 | 0.000 | 0.25215E-06 |
| 128.016 | 0.000 | 0.97365E-07 |
| 121.920 | 0.000 | 0.21432E-06 |
| 115.824 | 0.000 | 0.79088E-07 |
| 109.728 | 0.000 | 0.17925E-06 |
| 103.632 | 0.000 | 0.70906E-07 |
| 97.536 | 0.000 | 0.19552E-06 |
| 91.440 | 0.000 | 0.81979E-07 |
| 85.344 | 0.000 | 0.16941E-06 |
| 79.248 | 0.000 | 0.65227E-07 |
| 73.152 | 0.000 | 0.18392E-06 |
| 67.056 | 0.000 | 0.68207E-07 |
| 60.096 | 0.000 | 0.15607E-06 |
| 54.864 | 0.000 | 0.57075E-07 |
| 48.768 | 0.000 | 0.48633E-07 |
| 42.672 | 0.000 | 0.38279E-07 |
| 36.576 | 0.000 | 0.10209E-06 |
| 30.480 | 0.000 | 0.44520E-07 |
| 24.384 | 0.000 | 0.11256E-06 |
| 18.288 | 0.000 | 0.48030E-07 |
| 12.192 | 0.000 | 0.34623E-07 |
| 6.096 | 0.000 | 0.20188E-07 |

TABLE B-8. Estimated Annual Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.48697E-04 |
| 0.000 | 6.096 | 0.99089E-04 |
| 0.000 | 12.192 | 0.66645E-04 |
| 0.000 | 18.288 | 0.24296E-03 |
| 0.000 | 24.384 | 0.17607E-03 |
| 0.000 | 30.480 | 0.63862E-03 |
| 0.000 | 36.576 | 0.16966E-02 |
| 0.000 | 42.672 | 0.65962E-03 |
| 0.000 | 48.768 | 0.16900E-02 |
| 0.000 | 54.864 | 0.63726E-03 |
| 0.000 | 60.960 | 0.17465E-03 |
| 0.000 | 67.056 | 0.24172E-03 |
| 0.000 | 73.152 | 0.65633E-04 |
| 0.000 | 79.248 | 0.11511E-03 |
| 0.000 | 85.344 | 0.47684E-04 |
| 0.000 | 91.440 | 0.13777E-03 |
| 0.000 | 97.536 | 0.84221E-04 |
| 0.000 | 103.632 | 0.10170E-03 |
| 0.000 | 109.728 | 0.15233E-03 |
| 0.000 | 115.824 | 0.53477E-04 |
| 0.000 | 121.920 | 0.15324E-03 |
| 6.096 | 121.920 | 0.15016E-03 |
| 12.192 | 121.920 | 0.12440E-03 |
| 18.288 | 121.920 | 0.75222E-04 |
| 24.384 | 121.920 | 0.16931E-03 |
| 30.480 | 121.920 | 0.64088E-03 |
| 36.576 | 121.920 | 0.46302E-03 |
| 42.672 | 121.920 | 0.16866E-02 |
| 48.768 | 121.920 | 0.45136E-02 |
| 54.864 | 121.920 | 0.16841E-02 |
| 60.960 | 121.920 | 0.44637E-02 |
| 67.056 | 121.920 | 0.16842E-02 |
| 73.152 | 121.920 | 0.46073E-03 |
| 79.248 | 121.920 | 0.63910E-03 |
| 85.344 | 121.920 | 0.16746E-03 |
| 91.440 | 121.920 | 0.73376E-04 |
| 97.536 | 121.920 | 0.12265E-03 |

TABLE B-8. Estimated Annual Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.14849E-03 |
| 109.728 | 121.920 | 0.15162E-03 |
| 115.824 | 121.920 | 0.14128E-03 |
| 121.920 | 121.920 | 0.12530E-03 |
| 128.016 | 121.920 | 0.10833E-03 |
| 134.112 | 121.920 | 0.92551E-04 |
| 140.208 | 121.920 | 0.78812E-04 |
| 146.304 | 121.920 | 0.67201E-04 |
| 152.400 | 121.920 | 0.57602E-04 |
| 158.496 | 121.920 | 0.10144E-03 |
| 164.592 | 121.920 | 0.50288E-04 |
| 170.688 | 121.920 | 0.62420E-04 |
| 176.784 | 121.920 | 0.33813E-04 |
| 182.880 | 121.920 | 0.41601E-04 |
| 188.976 | 121.920 | 0.48641E-04 |
| 195.072 | 121.920 | 0.48562E-04 |
| 195.072 | 115.824 | 0.39507E-04 |
| 195.072 | 109.728 | 0.37595E-04 |
| 195.072 | 103.632 | 0.49014E-04 |
| 195.072 | 97.536 | 0.53545E-04 |
| 195.072 | 91.440 | 0.43535E-04 |
| 195.072 | 85.344 | 0.34390E-04 |
| 195.072 | 79.248 | 0.36637E-04 |
| 195.072 | 73.152 | 0.62979E-04 |
| 195.072 | 67.056 | 0.34118E-04 |
| 195.072 | 60.960 | 0.35770E-04 |
| 188.976 | 60.960 | 0.30077E-04 |
| 182.880 | 60.960 | 0.35979E-04 |
| 176.784 | 60.960 | 0.50585E-04 |
| 170.688 | 60.960 | 0.45091E-04 |
| 164.592 | 60.960 | 0.55053E-04 |
| 158.496 | 60.960 | 0.82593E-04 |
| 152.400 | 60.960 | 0.11935E-03 |
| 146.304 | 60.960 | 0.14611E-03 |
| 146.304 | 54.864 | 0.53606E-04 |
| 146.304 | 48.768 | 0.15895E-03 |

TABLE B-8. Estimated Annual Average Concentrations of Vapor-Phase 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.36126E-04 |
| 146.304 | 36.576 | 0.15895E-03 |
| 146.304 | 30.480 | 0.44450E-04 |
| 146.304 | 24.384 | 0.14610E-03 |
| 146.304 | 18.288 | 0.31431E-04 |
| 146.304 | 12.192 | 0.12741E-03 |
| 146.304 | 6.096 | 0.46232E-04 |
| 146.304 | 0.000 | 0.67366E-04 |
| 140.208 | 0.000 | 0.13006E-03 |
| 134.112 | 0.000 | 0.74662E-04 |
| 128.016 | 0.000 | 0.48068E-04 |
| 121.920 | 0.000 | 0.21686E-03 |
| 115.824 | 0.000 | 0.50407E-04 |
| 109.728 | 0.000 | 0.22742E-03 |
| 103.632 | 0.000 | 0.71174E-04 |
| 97.536 | 0.000 | 0.23271E-03 |
| 91.440 | 0.000 | 0.31903E-03 |
| 85.344 | 0.000 | 0.15674E-03 |
| 79.248 | 0.000 | 0.81509E-04 |
| 73.152 | 0.000 | 0.15619E-03 |
| 67.056 | 0.000 | 0.29218E-03 |
| 60.096 | 0.000 | 0.22797E-03 |
| 54.864 | 0.000 | 0.71213E-04 |
| 48.768 | 0.000 | 0.22741E-03 |
| 42.672 | 0.000 | 0.56405E-04 |
| 36.576 | 0.000 | 0.21694E-03 |
| 30.480 | 0.000 | 0.48095E-04 |
| 24.384 | 0.000 | 0.75358E-04 |
| 18.288 | 0.000 | 0.13070E-03 |
| 12.192 | 0.000 | 0.67904E-04 |
| 6.096 | 0.000 | 0.43413E-04 |

TABLE B-9. Estimated Annual Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.10251E-03 |
| 0.000 | 6.096 | 0.76294E-04 |
| 0.000 | 12.192 | 0.12820E-03 |
| 0.000 | 18.288 | 0.45352E-03 |
| 0.000 | 24.384 | 0.32978E-03 |
| 0.000 | 30.480 | 0.11898E-02 |
| 0.000 | 36.576 | 0.31679E-02 |
| 0.000 | 42.672 | 0.12053E-02 |
| 0.000 | 48.768 | 0.31478E-02 |
| 0.000 | 54.864 | 0.11863E-02 |
| 0.000 | 60.960 | 0.32594E-03 |
| 0.000 | 67.056 | 0.45022E-03 |
| 0.000 | 73.152 | 0.12548E-03 |
| 0.000 | 79.248 | 0.13424E-03 |
| 0.000 | 85.344 | 0.99465E-04 |
| 0.000 | 91.440 | 0.15195E-03 |
| 0.000 | 97.536 | 0.11157E-03 |
| 0.000 | 103.632 | 0.11310E-03 |
| 0.000 | 109.728 | 0.17096E-03 |
| 0.000 | 115.824 | 0.82712E-04 |
| 0.000 | 121.920 | 0.17261E-03 |
| 6.096 | 121.920 | 0.16913E-03 |
| 12.192 | 121.920 | 0.14126E-03 |
| 18.288 | 121.920 | 0.88228E-04 |
| 24.384 | 121.920 | 0.19286E-03 |
| 30.480 | 121.920 | 0.69962E-03 |
| 36.576 | 121.920 | 0.50783E-03 |
| 42.672 | 121.920 | 0.18362E-02 |
| 48.768 | 121.920 | 0.50121E-02 |
| 54.864 | 121.920 | 0.18325E-02 |
| 60.960 | 121.920 | 0.48547E-02 |
| 67.056 | 121.920 | 0.18310E-02 |
| 73.152 | 121.920 | 0.50338E-03 |
| 79.248 | 121.920 | 0.69537E-03 |
| 85.344 | 121.920 | 0.28607E-03 |
| 91.440 | 121.920 | 0.10060E-03 |
| 97.536 | 121.920 | 0.13767E-03 |

**TABLE B-9.** Estimated Annual Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.16571E-03 |
| 109.728 | 121.920 | 0.16932E-03 |
| 115.824 | 121.920 | 0.15845E-03 |
| 121.920 | 121.920 | 0.14148E-03 |
| 128.016 | 121.920 | 0.12347E-03 |
| 134.112 | 121.920 | 0.10672E-03 |
| 140.208 | 121.920 | 0.92168E-04 |
| 146.304 | 121.920 | 0.10821E-03 |
| 152.400 | 121.920 | 0.69877E-04 |
| 158.496 | 121.920 | 0.14731E-03 |
| 164.592 | 121.920 | 0.55273E-04 |
| 170.688 | 121.920 | 0.11970E-03 |
| 176.784 | 121.920 | 0.56691E-04 |
| 182.880 | 121.920 | 0.42956E-04 |
| 188.976 | 121.920 | 0.45687E-04 |
| 195.072 | 121.920 | 0.43265E-04 |
| 195.072 | 115.824 | 0.32551E-04 |
| 195.072 | 109.728 | 0.32386E-04 |
| 195.072 | 103.632 | 0.45736E-04 |
| 195.072 | 97.536 | 0.45069E-04 |
| 195.072 | 91.440 | 0.40119E-04 |
| 195.072 | 85.344 | 0.27163E-04 |
| 195.072 | 79.248 | 0.47968E-04 |
| 195.072 | 73.152 | 0.50529E-04 |
| 195.072 | 67.056 | 0.30750E-04 |
| 195.072 | 60.960 | 0.34518E-04 |
| 188.976 | 60.960 | 0.33814E-04 |
| 182.880 | 60.960 | 0.38783E-04 |
| 176.784 | 60.960 | 0.80621E-04 |
| 170.688 | 60.960 | 0.94715E-04 |
| 164.592 | 60.960 | 0.87710E-04 |
| 158.496 | 60.960 | 0.97224E-04 |
| 152.400 | 60.960 | 0.94999E-04 |
| 146.304 | 60.960 | 0.11219E-03 |
| 146.304 | 54.864 | 0.73949E-04 |
| 146.304 | 48.768 | 0.12424E-03 |

TABLE B-9. Estimated Annual Average Concentrations of Vapor-Phase 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.55298E-04 |
| 146.304 | 36.576 | 0.12424E-03 |
| 146.304 | 30.480 | 0.74594E-04 |
| 146.304 | 24.384 | 0.15449E-03 |
| 146.304 | 18.288 | 0.44348E-04 |
| 146.304 | 12.192 | 0.11467E-03 |
| 146.304 | 6.096 | 0.40550E-04 |
| 146.304 | 0.000 | 0.10269E-03 |
| 140.208 | 0.000 | 0.99033E-04 |
| 134.112 | 0.000 | 0.10357E-03 |
| 128.016 | 0.000 | 0.42672E-04 |
| 121.920 | 0.000 | 0.22232E-03 |
| 115.824 | 0.000 | 0.47864E-04 |
| 109.728 | 0.000 | 0.16841E-03 |
| 103.632 | 0.000 | 0.70291E-04 |
| 97.536 | 0.000 | 0.16615E-03 |
| 91.440 | 0.000 | 0.23923E-03 |
| 85.344 | 0.000 | 0.11511E-03 |
| 79.248 | 0.000 | 0.85978E-04 |
| 73.152 | 0.000 | 0.11373E-03 |
| 67.056 | 0.000 | 0.20392E-03 |
| 60.096 | 0.000 | 0.16101E-03 |
| 54.864 | 0.000 | 0.66920E-04 |
| 48.768 | 0.000 | 0.19686E-03 |
| 42.672 | 0.000 | 0.83456E-04 |
| 36.576 | 0.000 | 0.22254E-03 |
| 30.480 | 0.000 | 0.40624E-04 |
| 24.384 | 0.000 | 0.12703E-03 |
| 18.288 | 0.000 | 0.16750E-03 |
| 12.192 | 0.000 | 0.10251E-03 |
| 6.096 | 0.000 | 0.61930E-04 |

**TABLE B-10.** Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.79800E-07 |
| 0.000 | 6.096 | 0.51560E-06 |
| 0.000 | 12.192 | 0.64930E-06 |
| 0.000 | 18.288 | 0.10700E-06 |
| 0.000 | 24.384 | 0.69100E-06 |
| 0.000 | 30.480 | 0.54920E-06 |
| 0.000 | 36.576 | 0.33510E-06 |
| 0.000 | 42.672 | 0.91270E-06 |
| 0.000 | 48.768 | 0.17620E-06 |
| 0.000 | 54.864 | 0.10329E-05 |
| 0.000 | 60.960 | 0.11560E-06 |
| 0.000 | 67.056 | 0.10329E-05 |
| 0.000 | 73.152 | 0.17630E-06 |
| 0.000 | 79.248 | 0.91270E-06 |
| 0.000 | 85.344 | 0.33530E-06 |
| 0.000 | 91.440 | 0.54920E-06 |
| 0.000 | 97.536 | 0.69120E-06 |
| 0.000 | 103.632 | 0.10700E-06 |
| 0.000 | 109.728 | 0.64920E-06 |
| 0.000 | 115.824 | 0.51560E-06 |
| 0.000 | 121.920 | 0.79800E-07 |
| 6.096 | 121.920 | 0.36670E-06 |
| 12.192 | 121.920 | 0.78420E-06 |
| 18.288 | 121.920 | 0.38060E-06 |
| 24.384 | 121.920 | 0.28400E-06 |
| 30.480 | 121.920 | 0.10137E-05 |
| 36.576 | 121.920 | 0.26380E-06 |
| 42.672 | 121.920 | 0.95500E-06 |
| 48.768 | 121.920 | 0.52050E-06 |
| 54.864 | 121.920 | 0.10385E-05 |
| 60.960 | 121.920 | 0.43080E-06 |
| 67.056 | 121.920 | 0.13628E-05 |
| 73.152 | 121.920 | 0.16800E-06 |
| 79.248 | 121.920 | 0.13630E-05 |
| 85.344 | 121.920 | 0.43080E-06 |
| 91.440 | 121.920 | 0.10389E-05 |
| 97.536 | 121.920 | 0.52050E-06 |

**TABLE B-10.** Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.95530E-06 |
| 109.728 | 121.920 | 0.26360E-06 |
| 115.824 | 121.920 | 0.10137E-05 |
| 121.920 | 121.920 | 0.28420E-06 |
| 128.016 | 121.920 | 0.38040E-06 |
| 134.112 | 121.920 | 0.78420E-06 |
| 140.208 | 121.920 | 0.36680E-06 |
| 146.304 | 121.920 | 0.79800E-07 |
| 152.400 | 121.920 | 0.33040E-06 |
| 158.496 | 121.920 | 0.54250E-06 |
| 164.592 | 121.920 | 0.43790E-06 |
| 170.688 | 121.920 | 0.20460E-06 |
| 176.784 | 121.920 | 0.62800E-07 |
| 182.880 | 121.920 | 0.85300E-07 |
| 188.976 | 121.920 | 0.18310E-06 |
| 195.072 | 121.920 | 0.27900E-06 |
| 195.072 | 115.824 | 0.34480E-06 |
| 195.072 | 109.728 | 0.14160E-06 |
| 195.072 | 103.632 | 0.66800E-07 |
| 195.072 | 97.536 | 0.30220E-06 |
| 195.072 | 91.440 | 0.37230E-06 |
| 195.072 | 85.344 | 0.11370E-06 |
| 195.072 | 79.248 | 0.12900E-06 |
| 195.072 | 73.152 | 0.40520E-06 |
| 195.072 | 67.056 | 0.27770E-06 |
| 195.072 | 60.960 | 0.40000E-07 |
| 188.976 | 60.960 | 0.44500E-07 |
| 182.880 | 60.960 | 0.49900E-07 |
| 176.784 | 60.960 | 0.56200E-07 |
| 170.688 | 60.960 | 0.63700E-07 |
| 164.592 | 60.960 | 0.72900E-07 |
| 158.496 | 60.960 | 0.84000E-07 |
| 152.400 | 60.960 | 0.98000E-07 |
| 146.304 | 60.960 | 0.11550E-06 |
| 146.304 | 54.864 | 0.10330E-05 |
| 146.304 | 48.768 | 0.17620E-06 |

**TABLE B-10.** Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.91280E-06 |
| 146.304 | 36.576 | 0.33520E-06 |
| 146.304 | 30.480 | 0.54940E-06 |
| 146.304 | 24.384 | 0.69110E-06 |
| 146.304 | 18.288 | 0.10700E-06 |
| 146.304 | 12.192 | 0.64930E-06 |
| 146.304 | 6.096 | 0.51550E-06 |
| 146.304 | 0.000 | 0.79800E-07 |
| 140.208 | 0.000 | 0.36680E-06 |
| 134.112 | 0.000 | 0.78420E-06 |
| 128.016 | 0.000 | 0.38040E-06 |
| 121.920 | 0.000 | 0.28420E-06 |
| 115.824 | 0.000 | 0.10137E-05 |
| 109.728 | 0.000 | 0.26360E-06 |
| 103.632 | 0.000 | 0.95520E-06 |
| 97.536 | 0.000 | 0.52030E-06 |
| 91.440 | 0.000 | 0.10387E-05 |
| 85.344 | 0.000 | 0.43060E-06 |
| 79.248 | 0.000 | 0.13629E-05 |
| 73.152 | 0.000 | 0.16810E-06 |
| 67.056 | 0.000 | 0.13629E-05 |
| 60.096 | 0.000 | 0.43090E-06 |
| 54.864 | 0.000 | 0.10387E-05 |
| 48.768 | 0.000 | 0.52060E-06 |
| 42.672 | 0.000 | 0.95520E-06 |
| 36.576 | 0.000 | 0.26360E-06 |
| 30.480 | 0.000 | 0.10137E-05 |
| 24.384 | 0.000 | 0.28410E-06 |
| 18.288 | 0.000 | 0.38040E-06 |
| 12.192 | 0.000 | 0.78420E-06 |
| 6.096 | 0.000 | 0.36680E-06 |

TABLE B-11. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.48800E-05 |
| 0.000 | 6.096 | 0.31510E-04 |
| 0.000 | 12.192 | 0.39680E-04 |
| 0.000 | 18.288 | 0.65400E-05 |
| 0.000 | 24.384 | 0.42230E-04 |
| 0.000 | 30.480 | 0.33560E-04 |
| 0.000 | 36.576 | 0.20480E-04 |
| 0.000 | 42.672 | 0.55780E-04 |
| 0.000 | 48.768 | 0.10770E-04 |
| 0.000 | 54.864 | 0.63120E-04 |
| 0.000 | 60.960 | 0.70600E-05 |
| 0.000 | 67.056 | 0.63120E-04 |
| 0.000 | 73.152 | 0.10770E-04 |
| 0.000 | 79.248 | 0.55780E-04 |
| 0.000 | 85.344 | 0.20490E-04 |
| 0.000 | 91.440 | 0.33560E-04 |
| 0.000 | 97.536 | 0.42240E-04 |
| 0.000 | 103.632 | 0.65400E-05 |
| 0.000 | 109.728 | 0.39680E-04 |
| 0.000 | 115.824 | 0.31510E-04 |
| 0.000 | 121.920 | 0.48800E-05 |
| 6.096 | 121.920 | 0.22410E-04 |
| 12.192 | 121.920 | 0.47920E-04 |
| 18.288 | 121.920 | 0.23260E-04 |
| 24.384 | 121.920 | 0.17360E-04 |
| 30.480 | 121.920 | 0.61950E-04 |
| 36.576 | 121.920 | 0.16120E-04 |
| 42.672 | 121.920 | 0.58360E-04 |
| 48.768 | 121.920 | 0.31810E-04 |
| 54.864 | 121.920 | 0.63460E-04 |
| 60.960 | 121.920 | 0.26330E-04 |
| 67.056 | 121.920 | 0.83280E-04 |
| 73.152 | 121.920 | 0.10260E-04 |
| 79.248 | 121.920 | 0.83300E-04 |
| 85.344 | 121.920 | 0.26330E-04 |
| 91.440 | 121.920 | 0.63490E-04 |
| 97.536 | 121.920 | 0.31810E-04 |

**TABLE B-11.** Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.58380E-04 |
| 109.728 | 121.920 | 0.16110E-04 |
| 115.824 | 121.920 | 0.61950E-04 |
| 121.920 | 121.920 | 0.17370E-04 |
| 128.016 | 121.920 | 0.23250E-04 |
| 134.112 | 121.920 | 0.47920E-04 |
| 140.208 | 121.920 | 0.22420E-04 |
| 146.304 | 121.920 | 0.48800E-05 |
| 152.400 | 121.920 | 0.20190E-04 |
| 158.496 | 121.920 | 0.33160E-04 |
| 164.592 | 121.920 | 0.26760E-04 |
| 170.688 | 121.920 | 0.12510E-04 |
| 176.784 | 121.920 | 0.38400E-05 |
| 182.880 | 121.920 | 0.52100E-05 |
| 188.976 | 121.920 | 0.11190E-04 |
| 195.072 | 121.920 | 0.17050E-04 |
| 195.072 | 115.824 | 0.21070E-04 |
| 195.072 | 109.728 | 0.86500E-05 |
| 195.072 | 103.632 | 0.40800E-05 |
| 195.072 | 97.536 | 0.18470E-04 |
| 195.072 | 91.440 | 0.22750E-04 |
| 195.072 | 85.344 | 0.69500E-05 |
| 195.072 | 79.248 | 0.78800E-05 |
| 195.072 | 73.152 | 0.24760E-04 |
| 195.072 | 67.056 | 0.16970E-04 |
| 195.072 | 60.960 | 0.24500E-05 |
| 188.976 | 60.960 | 0.27200E-05 |
| 182.880 | 60.960 | 0.30500E-05 |
| 176.784 | 60.960 | 0.34300E-05 |
| 170.688 | 60.960 | 0.38900E-05 |
| 164.592 | 60.960 | 0.44500E-05 |
| 158.496 | 60.960 | 0.51400E-05 |
| 152.400 | 60.960 | 0.59900E-05 |
| 146.304 | 60.960 | 0.70600E-05 |
| 146.304 | 54.864 | 0.63130E-04 |
| 146.304 | 48.768 | 0.10770E-04 |

TABLE B-11. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.55780E-04 |
| 146.304 | 36.576 | 0.20490E-04 |
| 146.304 | 30.480 | 0.33570E-04 |
| 146.304 | 24.384 | 0.42230E-04 |
| 146.304 | 18.288 | 0.65400E-05 |
| 146.304 | 12.192 | 0.39680E-04 |
| 146.304 | 6.096 | 0.31500E-04 |
| 146.304 | 0.000 | 0.48800E-05 |
| 140.208 | 0.000 | 0.22420E-04 |
| 134.112 | 0.000 | 0.47920E-04 |
| 128.016 | 0.000 | 0.23250E-04 |
| 121.920 | 0.000 | 0.17370E-04 |
| 115.824 | 0.000 | 0.61950E-04 |
| 109.728 | 0.000 | 0.16110E-04 |
| 103.632 | 0.000 | 0.58370E-04 |
| 97.536 | 0.000 | 0.31800E-04 |
| 91.440 | 0.000 | 0.63480E-04 |
| 85.344 | 0.000 | 0.26310E-04 |
| 79.248 | 0.000 | 0.83290E-04 |
| 73.152 | 0.000 | 0.10270E-04 |
| 67.056 | 0.000 | 0.83290E-04 |
| 60.096 | 0.000 | 0.26330E-04 |
| 54.864 | 0.000 | 0.63480E-04 |
| 48.768 | 0.000 | 0.31820E-04 |
| 42.672 | 0.000 | 0.58370E-04 |
| 36.576 | 0.000 | 0.16110E-04 |
| 30.480 | 0.000 | 0.61950E-04 |
| 24.384 | 0.000 | 0.17360E-04 |
| 18.288 | 0.000 | 0.23250E-04 |
| 12.192 | 0.000 | 0.47920E-04 |
| 6.096 | 0.000 | 0.22420E-04 |

**TABLE B-12.** Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 1 Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.17290E-04 |
| 0.000 | 6.096 | 0.11171E-03 |
| 0.000 | 12.192 | 0.14069E-03 |
| 0.000 | 18.288 | 0.23180E-04 |
| 0.000 | 24.384 | 0.14972E-03 |
| 0.000 | 30.480 | 0.11900E-03 |
| 0.000 | 36.576 | 0.72610E-04 |
| 0.000 | 42.672 | 0.19775E-03 |
| 0.000 | 48.768 | 0.38170E-04 |
| 0.000 | 54.864 | 0.22380E-03 |
| 0.000 | 60.960 | 0.25040E-04 |
| 0.000 | 67.056 | 0.22380E-03 |
| 0.000 | 73.152 | 0.38200E-04 |
| 0.000 | 79.248 | 0.19775E-03 |
| 0.000 | 85.344 | 0.72660E-04 |
| 0.000 | 91.440 | 0.11900E-03 |
| 0.000 | 97.536 | 0.14976E-03 |
| 0.000 | 103.632 | 0.23180E-04 |
| 0.000 | 109.728 | 0.14067E-03 |
| 0.000 | 115.824 | 0.11171E-03 |
| 0.000 | 121.920 | 0.17300E-04 |
| 6.096 | 121.920 | 0.79450E-04 |
| 12.192 | 121.920 | 0.16991E-03 |
| 18.288 | 121.920 | 0.82450E-04 |
| 24.384 | 121.920 | 0.61540E-04 |
| 30.480 | 121.920 | 0.21963E-03 |
| 36.576 | 121.920 | 0.57150E-04 |
| 42.672 | 121.920 | 0.20692E-03 |
| 48.768 | 121.920 | 0.11278E-03 |
| 54.864 | 121.920 | 0.22501E-03 |
| 60.960 | 121.920 | 0.93340E-04 |
| 67.056 | 121.920 | 0.29528E-03 |
| 73.152 | 121.920 | 0.36390E-04 |
| 79.248 | 121.920 | 0.29532E-03 |
| 85.344 | 121.920 | 0.93340E-04 |
| 91.440 | 121.920 | 0.22510E-03 |
| 97.536 | 121.920 | 0.11278E-03 |

TABLE B-12. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration (g/m$^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.20698E-03 |
| 109.728 | 121.920 | 0.57110E-04 |
| 115.824 | 121.920 | 0.21963E-03 |
| 121.920 | 121.920 | 0.61570E-04 |
| 128.016 | 121.920 | 0.82420E-04 |
| 134.112 | 121.920 | 0.16991E-03 |
| 140.208 | 121.920 | 0.79480E-04 |
| 146.304 | 121.920 | 0.17290E-04 |
| 152.400 | 121.920 | 0.71590E-04 |
| 158.496 | 121.920 | 0.11755E-03 |
| 164.592 | 121.920 | 0.94880E-04 |
| 170.688 | 121.920 | 0.44340E-04 |
| 176.784 | 121.920 | 0.13610E-04 |
| 182.880 | 121.920 | 0.18480E-04 |
| 188.976 | 121.920 | 0.39660E-04 |
| 195.072 | 121.920 | 0.60440E-04 |
| 195.072 | 115.824 | 0.74710E-04 |
| 195.072 | 109.728 | 0.30680E-04 |
| 195.072 | 103.632 | 0.14470E-04 |
| 195.072 | 97.536 | 0.65480E-04 |
| 195.072 | 91.440 | 0.80670E-04 |
| 195.072 | 85.344 | 0.24640E-04 |
| 195.072 | 79.248 | 0.27940E-04 |
| 195.072 | 73.152 | 0.87790E-04 |
| 195.072 | 67.056 | 0.60170E-04 |
| 195.072 | 60.960 | 0.86700E-05 |
| 188.976 | 60.960 | 0.96500E-05 |
| 182.880 | 60.960 | 0.10810E-04 |
| 176.784 | 60.960 | 0.12170E-04 |
| 170.688 | 60.960 | 0.13810E-04 |
| 164.592 | 60.960 | 0.15730E-04 |
| 158.496 | 60.960 | 0.18210E-04 |
| 152.400 | 60.960 | 0.21230E-04 |
| 146.304 | 60.960 | 0.25030E-04 |
| 146.304 | 54.864 | 0.22381E-03 |
| 146.304 | 48.768 | 0.38180E-04 |

TABLE B-12. Estimated 1-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | Annual Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.19777E-03 |
| 146.304 | 36.576 | 0.72630E-04 |
| 146.304 | 30.480 | 0.11903E-03 |
| 146.304 | 24.384 | 0.14973E-03 |
| 146.304 | 18.288 | 0.23190E-04 |
| 146.304 | 12.192 | 0.14069E-03 |
| 146.304 | 6.096 | 0.11169E-03 |
| 146.304 | 0.000 | 0.17290E-04 |
| 140.208 | 0.000 | 0.79480E-04 |
| 134.112 | 0.000 | 0.16991E-03 |
| 128.016 | 0.000 | 0.82420E-04 |
| 121.920 | 0.000 | 0.61570E-04 |
| 115.824 | 0.000 | 0.21963E-03 |
| 109.728 | 0.000 | 0.57110E-04 |
| 103.632 | 0.000 | 0.20696E-03 |
| 97.536 | 0.000 | 0.11273E-03 |
| 91.440 | 0.000 | 0.22506E-03 |
| 85.344 | 0.000 | 0.93290E-04 |
| 79.248 | 0.000 | 0.29530E-03 |
| 73.152 | 0.000 | 0.36410E-04 |
| 67.056 | 0.000 | 0.29530E-03 |
| 60.096 | 0.000 | 0.93370E-04 |
| 54.864 | 0.000 | 0.22506E-03 |
| 48.768 | 0.000 | 0.11280E-03 |
| 42.672 | 0.000 | 0.20696E-03 |
| 36.576 | 0.000 | 0.57110E-04 |
| 30.480 | 0.000 | 0.21963E-03 |
| 24.384 | 0.000 | 0.61570E-04 |
| 18.288 | 0.000 | 0.82420E-04 |
| 12.192 | 0.000 | 0.16991E-03 |
| 6.096 | 0.000 | 0.79480E-04 |

**TABLE B-13.** Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.55860E-07 |
| 0.000 | 6.096 | 0.36092E-06 |
| 0.000 | 12.192 | 0.45451E-06 |
| 0.000 | 18.288 | 0.74900E-07 |
| 0.000 | 24.384 | 0.48370E-06 |
| 0.000 | 30.480 | 0.38444E-06 |
| 0.000 | 36.576 | 0.23457E-06 |
| 0.000 | 42.672 | 0.63889E-06 |
| 0.000 | 48.768 | 0.12334E-06 |
| 0.000 | 54.864 | 0.72303E-06 |
| 0.000 | 60.960 | 0.80920E-07 |
| 0.000 | 67.056 | 0.72303E-06 |
| 0.000 | 73.152 | 0.12341E-06 |
| 0.000 | 79.248 | 0.63889E-06 |
| 0.000 | 85.344 | 0.23471E-06 |
| 0.000 | 91.440 | 0.38444E-06 |
| 0.000 | 97.536 | 0.48384E-06 |
| 0.000 | 103.632 | 0.74900E-07 |
| 0.000 | 109.728 | 0.45444E-06 |
| 0.000 | 115.824 | 0.36092E-06 |
| 0.000 | 121.920 | 0.55860E-07 |
| 6.096 | 121.920 | 0.25669E-06 |
| 12.192 | 121.920 | 0.54894E-06 |
| 18.288 | 121.920 | 0.26642E-06 |
| 24.384 | 121.920 | 0.19880E-06 |
| 30.480 | 121.920 | 0.70959E-06 |
| 36.576 | 121.920 | 0.18466E-06 |
| 42.672 | 121.920 | 0.66350E-06 |
| 48.768 | 121.920 | 0.36435E-06 |
| 54.864 | 121.920 | 0.72695E-06 |
| 60.960 | 121.920 | 0.30156E-06 |
| 67.056 | 121.920 | 0.95396E-06 |
| 73.152 | 121.920 | 0.11760E-06 |
| 79.248 | 121.920 | 0.95410E-05 |
| 85.344 | 121.920 | 0.30156E-06 |
| 91.440 | 121.920 | 0.72723E-06 |
| 97.536 | 121.920 | 0.36435E-06 |

TABLE B-13. Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m³) |
|---|---|---|
| 103.632 | 121.920 | 0.66871E-06 |
| 109.728 | 121.920 | 0.18452E-06 |
| 115.824 | 121.920 | 0.70959E-06 |
| 121.920 | 121.920 | 0.19894E-06 |
| 128.016 | 121.920 | 0.26628E-06 |
| 134.112 | 121.920 | 0.54894E-06 |
| 140.208 | 121.920 | 0.25676E-06 |
| 146.304 | 121.920 | 0.55860E-07 |
| 152.400 | 121.920 | 0.23128E-06 |
| 158.496 | 121.920 | 0.37975E-06 |
| 164.592 | 121.920 | 0.30653E-06 |
| 170.688 | 121.920 | 0.14322E-06 |
| 176.784 | 121.920 | 0.43960E-07 |
| 182.880 | 121.920 | 0.59710E-07 |
| 188.976 | 121.920 | 0.12817E-06 |
| 195.072 | 121.920 | 0.19530E-06 |
| 195.072 | 115.824 | 0.24136E-06 |
| 195.072 | 109.728 | 0.99120E-07 |
| 195.072 | 103.632 | 0.46760E-07 |
| 195.072 | 97.536 | 0.21154E-06 |
| 195.072 | 91.440 | 0.26061E-06 |
| 195.072 | 85.344 | 0.79590E-07 |
| 195.072 | 79.248 | 0.90300E-07 |
| 195.072 | 73.152 | 0.28364E-06 |
| 195.072 | 67.056 | 0.19439E-06 |
| 195.072 | 60.960 | 0.28000E-07 |
| 188.976 | 60.960 | 0.31150E-07 |
| 182.880 | 60.960 | 0.34930E-07 |
| 176.784 | 60.960 | 0.39340E-07 |
| 170.688 | 60.960 | 0.44590E-07 |
| 164.592 | 60.960 | 0.51030E-07 |
| 158.496 | 60.960 | 0.58800E-07 |
| 152.400 | 60.960 | 0.68600E-07 |
| 146.304 | 60.960 | 0.80850E-07 |
| 146.304 | 54.864 | 0.72310E-06 |
| 146.304 | 48.768 | 0.12334E-06 |

TABLE B-13. Estimated 8-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.63896E-06 |
| 146.304 | 36.576 | 0.23464E-06 |
| 146.304 | 30.480 | 0.38458E-06 |
| 146.304 | 24.384 | 0.48377E-06 |
| 146.304 | 18.288 | 0.74900E-07 |
| 146.304 | 12.192 | 0.45451E-06 |
| 146.304 | 6.096 | 0.36085E-06 |
| 146.304 | 0.000 | 0.55860E-07 |
| 140.208 | 0.000 | 0.25676E-06 |
| 134.112 | 0.000 | 0.54894E-06 |
| 128.016 | 0.000 | 0.26628E-06 |
| 121.920 | 0.000 | 0.19894E-06 |
| 115.824 | 0.000 | 0.70959E-06 |
| 109.728 | 0.000 | 0.18452E-06 |
| 103.632 | 0.000 | 0.66864E-06 |
| 97.536 | 0.000 | 0.36421E-06 |
| 91.440 | 0.000 | 0.72709E-06 |
| 85.344 | 0.000 | 0.30142E-06 |
| 79.248 | 0.000 | 0.95403E-06 |
| 73.152 | 0.000 | 0.11767E-06 |
| 67.056 | 0.000 | 0.95403E-06 |
| 60.096 | 0.000 | 0.30163E-06 |
| 54.864 | 0.000 | 0.72709E-06 |
| 48.768 | 0.000 | 0.36442E-06 |
| 42.672 | 0.000 | 0.66864E-06 |
| 36.576 | 0.000 | 0.18452E-06 |
| 30.480 | 0.000 | 0.70959E-06 |
| 24.384 | 0.000 | 0.19887E-06 |
| 18.288 | 0.000 | 0.26628E-06 |
| 12.192 | 0.000 | 0.54894E-06 |
| 6.096 | 0.000 | 0.25676E-06 |

**TABLE B-14.** Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.34160E-05 |
| 0.000 | 6.096 | 0.22057E-04 |
| 0.000 | 12.192 | 0.27776E-04 |
| 0.000 | 18.288 | 0.45780E-05 |
| 0.000 | 24.384 | 0.29561E-04 |
| 0.000 | 30.480 | 0.23492E-04 |
| 0.000 | 36.576 | 0.14336E-04 |
| 0.000 | 42.672 | 0.39046E-04 |
| 0.000 | 48.768 | 0.75390E-05 |
| 0.000 | 54.864 | 0.44184E-04 |
| 0.000 | 60.960 | 0.49420E-05 |
| 0.000 | 67.056 | 0.44184E-04 |
| 0.000 | 73.152 | 0.75390E-05 |
| 0.000 | 79.248 | 0.39046E-04 |
| 0.000 | 85.344 | 0.14343E-04 |
| 0.000 | 91.440 | 0.23492E-04 |
| 0.000 | 97.536 | 0.29568E-04 |
| 0.000 | 103.632 | 0.45780E-05 |
| 0.000 | 109.728 | 0.27776E-04 |
| 0.000 | 115.824 | 0.22057E-04 |
| 0.000 | 121.920 | 0.34160E-05 |
| 6.096 | 121.920 | 0.15687E-04 |
| 12.192 | 121.920 | 0.33544E-04 |
| 18.288 | 121.920 | 0.16282E-04 |
| 24.384 | 121.920 | 0.12152E-04 |
| 30.480 | 121.920 | 0.43365E-04 |
| 36.576 | 121.920 | 0.11284E-04 |
| 42.672 | 121.920 | 0.40852E-04 |
| 48.768 | 121.920 | 0.22267E-04 |
| 54.864 | 121.920 | 0.44422E-04 |
| 60.960 | 121.920 | 0.18431E-04 |
| 67.056 | 121.920 | 0.58296E-04 |
| 73.152 | 121.920 | 0.71820E-05 |
| 79.248 | 121.920 | 0.58310E-04 |
| 85.344 | 121.920 | 0.18431E-04 |
| 91.440 | 121.920 | 0.44443E-04 |

TABLE B-14. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 97.536 | 121.920 | 0.22267E-04 |
| 103.632 | 121.920 | 0.40866E-04 |
| 109.728 | 121.920 | 0.11277E-04 |
| 115.824 | 121.920 | 0.43365E-04 |
| 121.920 | 121.920 | 0.12159E-04 |
| 128.016 | 121.920 | 0.16275E-04 |
| 134.112 | 121.920 | 0.33544E-04 |
| 140.208 | 121.920 | 0.15694E-04 |
| 146.304 | 121.920 | 0.34160E-05 |
| 152.400 | 121.920 | 0.14133E-04 |
| 158.496 | 121.920 | 0.23212E-04 |
| 164.592 | 121.920 | 0.18732E-04 |
| 170.688 | 121.920 | 0.87570E-05 |
| 176.784 | 121.920 | 0.26880E-05 |
| 182.880 | 121.920 | 0.36470E-05 |
| 188.976 | 121.920 | 0.78330E-05 |
| 195.072 | 121.920 | 0.11935E-04 |
| 195.072 | 115.824 | 0.14749E-04 |
| 195.072 | 109.728 | 0.60550E-05 |
| 195.072 | 103.632 | 0.28560E-05 |
| 195.072 | 97.536 | 0.12929E-04 |
| 195.072 | 91.440 | 0.15925E-04 |
| 195.072 | 85.344 | 0.48650E-05 |
| 195.072 | 79.248 | 0.55160E-05 |
| 195.072 | 73.152 | 0.17332E-04 |
| 195.072 | 67.056 | 0.11879E-04 |
| 195.072 | 60.960 | 0.17150E-05 |
| 188.976 | 60.960 | 0.19040E-05 |
| 182.880 | 60.960 | 0.21350E-05 |
| 176.784 | 60.960 | 0.24010E-05 |
| 170.688 | 60.960 | 0.27230E-05 |
| 164.592 | 60.960 | 0.31150E-05 |
| 158.496 | 60.960 | 0.35980E-05 |
| 152.400 | 60.960 | 0.41930E-05 |
| 146.304 | 60.960 | 0.49420E-05 |
| 146.304 | 54.864 | 0.44191E-04 |

**TABLE B-14.** Estimated 8-Hour Average Concentrations of Particle-Associated 2,4-D at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 48.768 | 0.75390E-05 |
| 146.304 | 42.672 | 0.39046E-04 |
| 146.304 | 36.576 | 0.14343E-04 |
| 146.304 | 30.480 | 0.23499E-04 |
| 146.304 | 24.384 | 0.29561E-04 |
| 146.304 | 18.288 | 0.45780E-05 |
| 146.304 | 12.192 | 0.2777[illegible]-04 |
| 146.304 | 6.096 | 0.22050E-04 |
| 146.304 | 0.000 | 0.34160E-05 |
| 140.208 | 0.000 | 0.15694E-04 |
| 134.112 | 0.000 | 0.33544E-04 |
| 128.016 | 0.000 | 0.16275E-04 |
| 121.920 | 0.000 | 0.12159E-04 |
| 115.824 | 0.000 | 0.43365E-04 |
| 109.728 | 0.000 | 0.11277E-04 |
| 103.632 | 0.000 | 0.40859E-04 |
| 97.536 | 0.000 | 0.22260E-04 |
| 91.440 | 0.000 | 0.44436E-04 |
| 85.344 | 0.000 | 0.18417E-04 |
| 79.248 | 0.000 | 0.58303E-04 |
| 73.152 | 0.000 | 0.71890E-05 |
| 67.056 | 0.000 | 0.58303E-04 |
| 60.096 | 0.000 | 0.18431E-04 |
| 54.864 | 0.000 | 0.44436E-04 |
| 48.768 | 0.000 | 0.22274E-04 |
| 42.672 | 0.000 | 0.40859E-04 |
| 36.576 | 0.000 | 0.11277E-04 |
| 30.480 | 0.000 | 0.43365E-04 |
| 24.384 | 0.000 | 0.12152E-04 |
| 18.288 | 0.000 | 0.16275E-04 |
| 12.192 | 0.000 | 0.33544E-04 |
| 6.096 | 0.000 | 0.15694E-04 |

TABLE B-15. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration (g/m$^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.12103E-04 |
| 0.000 | 6.096 | 0.78197E-04 |
| 0.000 | 12.192 | 0.98483E-04 |
| 0.000 | 18.288 | 0.16226E-04 |
| 0.000 | 24.384 | 0.10480E-03 |
| 0.000 | 30.480 | 0.83300E-04 |
| 0.000 | 36.576 | 0.50827E-04 |
| 0.000 | 42.672 | 0.13842E-03 |
| 0.000 | 48.768 | 0.26719E-04 |
| 0.000 | 54.864 | 0.15666E-03 |
| 0.000 | 60.960 | 0.17528E-04 |
| 0.000 | 67.056 | 0.15666E-03 |
| 0.000 | 73.152 | 0.26740E-04 |
| 0.000 | 79.248 | 0.13842E-03 |
| 0.000 | 85.344 | 0.50862E-04 |
| 0.000 | 91.440 | 0.83300E-04 |
| 0.000 | 97.536 | 0.10483E-03 |
| 0.000 | 103.632 | 0.16226E-04 |
| 0.000 | 109.728 | 0.98469E-04 |
| 0.000 | 115.824 | 0.78197E-04 |
| 0.000 | 121.920 | 0.12110E-04 |
| 6.096 | 121.920 | 0.55615E-04 |
| 12.192 | 121.920 | 0.11894E-03 |
| 18.288 | 121.920 | 0.57715E-04 |
| 24.384 | 121.920 | 0.43078E-04 |
| 30.480 | 121.920 | 0.15374E-03 |
| 36.576 | 121.920 | 0.40005E-04 |
| 42.672 | 121.920 | 0.14484E-03 |
| 48.768 | 121.920 | 0.78946E-04 |
| 54.864 | 121.920 | 0.15751E-03 |
| 60.960 | 121.920 | 0.65338E-04 |
| 67.056 | 121.920 | 0.20670E-03 |
| 73.152 | 121.920 | 0.25473E-04 |
| 79.248 | 121.920 | 0.20672E-03 |
| 85.344 | 121.920 | 0.65338E-04 |
| 91.440 | 121.920 | 0.15757E-03 |
| 97.536 | 121.920 | 0.78946E-04 |

**TABLE B-15.** Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 103.632 | 121.920 | 0.14489E-03 |
| 109.728 | 121.920 | 0.39977E-04 |
| 115.824 | 121.920 | 0.15374E-03 |
| 121.920 | 121.920 | 0.43099E-04 |
| 128.016 | 121.920 | 0.57694E-04 |
| 134.112 | 121.920 | 0.11894E-03 |
| 140.208 | 121.920 | 0.55636E-04 |
| 146.304 | 121.920 | 0.12103E-04 |
| 152.400 | 121.920 | 0.50113E-04 |
| 158.496 | 121.920 | 0.82285E-04 |
| 164.592 | 121.920 | 0.66416E-04 |
| 170.688 | 121.920 | 0.31038E-04 |
| 176.784 | 121.920 | 0.95270E-05 |
| 182.880 | 121.920 | 0.12936E-04 |
| 188.976 | 121.920 | 0.27762E-04 |
| 195.072 | 121.920 | 0.42308E-04 |
| 195.072 | 115.824 | 0.52297E-04 |
| 195.072 | 109.728 | 0.21476E-04 |
| 195.072 | 103.632 | 0.10129E-04 |
| 195.072 | 97.536 | 0.45836E-04 |
| 195.072 | 91.440 | 0.56469E-04 |
| 195.072 | 85.344 | 0.17248E-04 |
| 195.072 | 79.248 | 0.19558E-04 |
| 195.072 | 73.152 | 0.61453E-04 |
| 195.072 | 67.056 | 0.42119E-04 |
| 195.072 | 60.960 | 0.60690E-05 |
| 188.976 | 60.960 | 0.67550E-05 |
| 182.880 | 60.960 | 0.75670E-05 |
| 176.784 | 60.960 | 0.85190E-05 |
| 170.688 | 60.960 | 0.96670E-05 |
| 164.592 | 60.960 | 0.11053E-04 |
| 158.496 | 60.960 | 0.12747E-04 |
| 152.400 | 60.960 | 0.14861E-04 |
| 146.304 | 60.960 | 0.17521E-04 |
| 146.304 | 54.864 | 0.15667E-03 |
| 146.304 | 48.768 | 0.26726E-04 |

TABLE B-15. Estimated 8-Hour Average Concentrations of Particle-Associated 2,4,5-T at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Excavation (continued)

| X Coordinate (m) | Y Coordinate (m) | 8-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 146.304 | 42.672 | 0.13844E-03 |
| 146.304 | 36.576 | 0.50841E-04 |
| 146.304 | 30.480 | 0.83321E-04 |
| 146.304 | 24.384 | 0.10481E-03 |
| 146.304 | 18.288 | 0.16233E-04 |
| 146.304 | 12.192 | 0.98483E-04 |
| 146.304 | 6.096 | 0.78183E-04 |
| 146.304 | 0.000 | 0.12103E-04 |
| 140.208 | 0.000 | 0.55636E-04 |
| 134.112 | 0.000 | 0.11894E-03 |
| 128.016 | 0.000 | 0.57694E-04 |
| 121.920 | 0.000 | 0.43099E-04 |
| 115.824 | 0.000 | 0.15374E-03 |
| 109.728 | 0.000 | 0.39977E-04 |
| 103.632 | 0.000 | 0.14487E-03 |
| 97.536 | 0.000 | 0.78911E-04 |
| 91.440 | 0.000 | 0.15754E-03 |
| 85.344 | 0.000 | 0.65303E-04 |
| 79.248 | 0.000 | 0.20671E-03 |
| 73.152 | 0.000 | 0.25487E-04 |
| 67.056 | 0.000 | 0.20671E-03 |
| 60.096 | 0.000 | 0.65359E-04 |
| 54.864 | 0.000 | 0.15754E-03 |
| 48.768 | 0.000 | 0.78960E-04 |
| 42.672 | 0.000 | 0.14487E-03 |
| 36.576 | 0.000 | 0.39977E-04 |
| 30.480 | 0.000 | 0.15374E-03 |
| 24.384 | 0.000 | 0.43099E-04 |
| 18.288 | 0.000 | 0.57694E-04 |
| 12.192 | 0.000 | 0.11894E-03 |
| 6.096 | 0.000 | 0.55636E-04 |

**TABLE B-16.** Estimated 1-Hour Average Concentrations of Particle-Associated TCDD at Receptor Locations (x, y Coordinates) Around the Perimeter of the Herbicide Orange Site During Cement Cover Construction

| X Coordinate (m) | Y Coordinate (m) | 1-Hour Average Concentration ($g/m^3$) |
|---|---|---|
| 0.000 | 0.000 | 0.70900E-08 |
| 0.000 | 6.096 | 0.45830E-07 |
| 0.000 | 12.192 | 0.57720E-07 |
| 0.000 | 18.288 | 0.95100E-08 |
| 0.000 | 24.384 | 0.61420E-07 |
| 0.000 | 30.480 | 0.48820E-07 |
| 0.000 | 36.576 | 0.29790E-07 |
| 0.000 | 42.672 | 0.81130E-07 |
| 0.000 | 48.768 | 0.15660E-07 |
| 0.000 | 54.864 | 0.91820E-07 |
| 0.000 | 60.960 | 0.10270E-07 |
| 0.000 | 67.056 | 0.91820E-07 |
| 0.000 | 73.152 | 0.15670E-07 |
| 0.000 | 79.248 | 0.81130E-07 |
| 0.000 | 85.344 | 0.29810E-07 |
| 0.000 | 91.440 | 0.48820E-07 |
| 0.000 | 97.536 | 0.61440E-07 |
| 0.000 | 103.632 | 0.95100E-08 |
| 0.000 | 109.728 | 0.57710E-07 |
| 0.000 | 115.824 | 0.45830E-07 |
| 0.000 | 121.920 | 0.71000E-08 |
| 6.096 | 121.920 | 0.32600E-07 |
| 12.192 | 121.920 | 0.69700E-07 |
| 18.288 | 121.920 | 0.33830E-07 |
| 24.384 | 121.920 | 0.25250E-07 |
| 30.480 | 121.920 | 0.90100E-07 |
| 36.576 | 121.920 | 0.23440E-07 |
| 42.672 | 121.920 | 0.84890E-07 |
| 48.768 | 121.920 | 0.46270E-07 |
| 54.864 | 121.920 | 0.92310E-07 |
| 60.960 | 121.920 | 0.38290E-07 |
| 67.056 | 121.920 | 0.12114E-06 |
| 73.152 | 121.920 | 0.14930E-07 |
| 79.248 | 121.920 | 0.12116E-06 |
| 85.344 | 121.920 | 0.38290E-07 |
| 91.440 | 121.920 | 0.92350E-07 |
| 97.536 | 121.920 | 0.46270E-07 |