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John B. Wells,
Commander USN (Ret)
Executive Director

Admitted to practice:
Louisiana
Pennsylvania
District of Columbia

April 30, 2013

Hon. Eric Shinseki
Secretary of Veterans Affairs
810Vermont Ave. NW
Washington, DC 20420

Re: Blue Water Navy

Dear Mr. Secretary:

The Military-Veterans Advocacy Inc. (MVA), on behalf of itself and the Blue Water Navy Vietnam Veterans Association, Inc (BWNVVA) hereby demand that you immediately restore the presumption of Agent Orange exposure to the veterans who served afloat in the territorial seas of the Republic of Vietnam. Fulfilling this demand would constitute an implementation of HR 543 presently pending before the 113th Congress. (Exhibit A). The territorial seas are those claimed by Vietnam as documented in the December 1983 Department of State Bureau of Intelligence and Research Pamphlet No. 99, Straight Baseline: Vietnam. The enclosed nautical chart, Exhibit B, shows the territorial seas landward of the dark dashed line. These waters are plotted twelve miles outward of the baseline which is marked in red on the chart. Your failure to order the expansion of the presumption will result in action being taken pursuant to the Declaratory Judgment Act, the Administrative Procedures Act and the Mandamus Act.

Historical Background

In the 1960's and the first part of the 1970's the United States sprayed over 12,000,000 gallons of a chemical laced with 2,3,7,8-Tetrachlorodibenzodioxin (TCDD) and nicknamed Agent Orange over southern Vietnam. This program, code named Operation Ranch Hand, was designed to defoliate areas providing cover to enemy forces. Spraying included coastal areas and the areas around rivers and streams that emptied into the South China Sea. By 1967, studies initiated by the United States government proved that Agent Orange caused cancer and birth defects. Despite this finding the aerial defoliation continued without pause. Estimates of hundred of thousands of deaths and birth defects among the Vietnamese population were confirmed by the Vietnamese government. Similar incidence of cancer development and birth defects have been documented in members of the United States and Allied armed forces who served in and near Vietnam.

Throughout the war, the United States Navy provided support for combat operations ashore. This included air strikes and close air support, naval gunfire support, electronic intelligence, interdiction of enemy vessels and the insertion of supplies and troops ashore. Most operations were conducted within the territorial seas.

The South China Sea is a fairly shallow body of water and the thirty fathom curve (a fathom is six feet) extends through much of the territorial seas. The gun ships would operate as close to shore as possible. The maximum effective range of the guns required most operations to occur within the territorial seas as documented in Exhibit B. Often ships would operate in harbors or within the ten fathom curve to maximize their field of fire. The maximum range on all guns (except the Battleship) required the ship to operate within the territorial seas in order to support forces ashore.

It was common practice for the ships to anchor while providing gunfire support. Digital computers were not yet in use and the fire control systems used analog computers. By anchoring the ship's crew was able to achieve a more stable fire control solution, since there was no need to factor in their own ship's course and speed. It was also common for ships to steam up and down the coast at high speeds to respond to call for fire missions, interdict enemy sampans, etc.

Supplies and personnel were offloaded pierside or from an anchorage within the territorial seas. Small boat transfers were conducted within the territorial seas often quite close to land. Most but not all fueling operations took place outside the territorial seas. Some but not all replenishments via helicopter took place outside the territorial seas. Others occurred at anchor within the territorial seas. Small boat or assault craft launches of Marine forces always took place within the territorial seas.

Flight operations from aircraft carriers often occurred outside of the territorial seas. As an example, Yankee station was outside of the territorial seas of the Republic of Vietnam. Dixie Station was on the border of the territorial seas. Some carriers, especially in the South, entered the territorial seas while launching or recovering aircraft, conducting search and rescue operations and racing to meet disabled planes returning from combat. Aircraft carriers also entered the territorial seas for other operational reasons. A study by the Blue Water Navy Vietnam Veterans Association showed that less than half of the carriers sampled entered the territorial seas at some point during their deployment.

Hydrological Effect

It is well settled that rivers and streams run into larger bodies of water. Even the Nile River, which is reputed to run "backwards" empties into the Mediterranean. In adopting the Comprehensive Environmental Response Compensation and Liability Act, the United States Congress recognized that pollutants discharged from shore will contaminate the navigable waters, waters of the contiguous zone, and the oceans. 33 U.S.C. § 1251(a)(6). The topography of Vietnam is no different from any other location on the planet. Rivers run out to sea!

The Agent Orange that was sprayed over South Vietnam was mixed with petroleum. The mixture washed into the rivers and streams and discharged into the South China Sea. Additionally, the riverbanks were sprayed continuously resulting in direct contamination of the rivers. Exhibit C shows the discharge from the Mekong River into the South China Sea. The dirt and silt that washed into the river can be clearly seen entering the sea. This is called a discharge "plume" and in the Mekong, like the Mississippi, is considerable. Exhibit D. Declaration of Robinson Hordoir. Although the Mekong has a smaller drainage area than other large rivers, it has approximately 85% of the sediment load of the Mississippi. Exhibit E Wolanski and Nhan, *Oceanography of the Mekong River Estuary*. In two weeks, the fresh water of the Mekong will travel several hundred kilometers. Exhibit F. Chen, Liu et. al, *Signature of the Mekong River plume in the western South China, Sea revealed by radium isotopes,* JOURNAL OF GEOPHYSICAL RESEARCH, Vol. 115, (Dec. 2010). Notably, the Agent Orange dioxin dumped off the east coast of the United States was found in fish over one hundred nautical miles from shore. Exhibit G. Belton, et. al, *2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and 2,3,7,8-Tetrachlorodibenzo-p-Furan (TCDF), In Blue Crabs and American Lobsters from the New York Bight,* New Jersey Department of Environmental Protection (November 12, 1988).

By coincidence, the baseline and territorial seas are further out from the mainland off the Mekong River. This was due to the location of the barrier islands owned by Vietnam. Given the more pronounced effect of the Mekong plume, however, the broader area off the Mekong Delta is appropriate. The force of the water in this area is greater than the river discharge in other parts of the country.

Eventually, the Agent Orange/petroleum mixture would emulsify and fall to the seabed. Evidence of Agent Orange impingement was found in the sea bed and coral of Nha Trang Harbor. Exhibit H. *Pavlov, et, al*, *Present-Day State of Coral Reefs of Nha Trang Bay (Southern Vietnam) and Possible Reasons for the Disturbance of Habitats of Scleractinian Corals*, RUSSIAN JOURNAL OF MARINE BIOLOGY, Vol. 30, No. 1 (2004). During the Vietnam War, the coastline, especially in the harbors and within the thirty fathom curve was a busy place with military and civilian shipping constantly entering and leaving the area in support of the war effort. Whenever ships anchored, the anchoring evolution would disturb the shallow seabed and churn up the bottom. Weighing anchor actually pulled up a small portion of the bottom. The cavitation of military ships moving along the coast line, especially within the ten fathom curve, at high speeds, further impinged on the sea bottom. This caused the Agent Orange to constantly rise to the surface.

Accordingly, Navy ships within the South China Sea were constantly steaming through a sea of Agent Orange molecules.

The Australian Factor and the Distillation Process

In August of 1998 Dr. Keith Horsley of the Australian Department of Veterans Affairs met Dr. Jochen Mueller of the University of Queensland's National Research Centre for

Environmental Toxicology (hereinafter NRCET) in Stockholm at the "Dioxin 1998" conference. Horsley shared a disturbing trend with Mueller. Australian VA studies showed a significant increase in Agent Orange related cancer incidence for sailors serving offshore over those who fought ashore. Based on that meeting, the Australian Department of Veterans Affairs commissioned NRCET to determine the cause of the elevated cancer incidence in Navy veterans.

In 2002, as the American Department of Veterans Affairs (VA) was beginning to deny the presumption of exposure to the United States Navy veterans, NRCET published the result of their study. Their report, entitled the *Examination of The Potential Exposure of Royal Australian Navy (RAN) Personnel to Polychlorinated Dibenzodioxins And Polychlorinated Dibenzofurans Via Drinking Water*, (hereinafter NRCET study). The Executive Summary is attached hereto as Exhibit I.

The study noted that ships in the near shore marine waters collected water that was contaminated with the runoff from areas sprayed with Agent Orange. NRCET Report at 10. The distilling plants aboard the ship, which converted the salt water into water for the boilers and potable drinking water, according to the study, co-distilled the dioxin and actually enhanced the effect of the Agent Orange. NRCET Report at 7.

Although the VA tried to argue that there was no evidence that ships distilled waters off Vietnam or that the United States used different systems, those arguments have been dismissed as ludicrous. Many Australian ships were built to American design and the distillation system used in ships world wide prior to the 1990's was essentially the same. The world wide shipboard distilling process used water injected from the sea. It is passed through the distilling condenser and air ejector condenser where it acts as a coolant for the condensers. It is then sent through the vapor feed heater into the first effect chamber and into the second effect chamber where it is changed to water vapor. Vapor then is passed through a drain regulator into a flash chamber and passes through baffles and separators into the distilling condenser where it is condensed into water and pumped to the ship's water distribution system. Sea water not vaporized is pumped over the side by the brine pump. The dioxin co-distilled with the water vapor and was pumped into the shipboard water distribution system.

The VA has also weakly argued that ships did not distill potable water close to shore. While efforts were made to reduce potable water distillation in port or close to land, that was not always possible - especially if the ship was anchored in the near shore waters for long periods providing support. The Institute of Medicine also found that guidelines on distilling potable water near the mouth of rivers were widely ignored. Given the fact that the hydrological "plume" traveled for hundreds of kilometers, it would have also reached the ships far outside the mouths of rivers. Additionally, since the same distillation system was used for boiler water as for potable water, the internals of the system would be contaminated with Agent Orange even if the ship did not distill to potable water while anchored.

As confirmed by the University of Queensland, the co-distillation of the Agent Orange

caused it to contaminate the distillers and the water supply. Hydration is important in the tropics and potable water tanks were replenished daily. Sailors would have ingested a significant amount of water from the ship's tanks. Additionally the would have showered in it. Their clothes would have been washed in it. This water would also have been used to prepare food and wash dishes. Consequently, crew members were directly exposed to Agent Orange.

Commencing in late 2003 and accelerating in 2005 the Australians began granting benefits to those who had served (i) on land in Vietnam, (ii) at sea in Vietnamese waters, or (iii) on board a vessel and consuming potable water supplied on that vessel, when the water supply had been produced by evaporative distillation in Vietnamese waters, for a cumulative period of at least thirty days. They have defined Vietnamese waters as an area within 185.2 kilometers from land (roughly 100 nautical miles). In reliance upon the NRCET Study, they began promulgating Statements of Principles, similar to our Code of Federal Regulations, covering various cancers. For several years now, Australian Navy veterans have been receiving benefits denied to their American counterparts.

In 2005, the Australian Department of Veterans Affairs published a cancer incidence study. The *Cancer Incidence in Vietnam Veterans 2005* (hereinafter the 2005 Cancer Study), whose Executive Summary is attached as Exhibit I, found that Royal Australian Navy veterans had the highest rate of cancer, higher than expected by 22-26%, followed by Army veterans, higher than expected by 11-13% and Air Force veterans with a 6-8% higher than the expected rate of cancer. Navy and Army veterans showed a higher than the expected incidence of cancers of the colon, oral cavity, pharynx and larynx and cancers of the head and neck and the gastrointestinal system. Whereas Navy veterans demonstrated a higher than the expected incidence of gastrointestinal cancer, Army and Air Force veterans showed higher than the expected incidence of Hodgkin's disease and prostate cancer. The cancers unique to the Navy would appear to support the ingestion of the dioxin orally rather than nasally.

The fact remains that the distillation process co-distilled and enhanced the effects of Agent Orange. Sailors aboard those ships received a substantial toxic dosage of Agent Orange into their drinking water. The repeated refusal of the VA to recognize this proven fact borders on the malevolent.

Law of the Sea

The Agent Orange Act of 1991 provides that:

> ... [A] veteran who, *during active military, naval, or air service in the Republic of Vietnam* during the period beginning on January 9,1962, and ending on May 7,1975, and has ...[Diabetes Mellitus (Type 2)] shall be presumed to have been exposed during such service to an herbicide agent containing dioxin ... unless there is affirmative evidence to establish that the veteran was not exposed to any such agent during service.

38 U.S.C. § 1116(a)(3). (Emphasis added).

Vietnam claims a 12 mile territorial sea. That is consistent with the limitations of the United Nations Convention on the law of the Sea Article 3 and the Convention on the Territorial Sea and Contiguous Zone, [1958] 15 U.S.T. 1607, T.I.A.S. No. 5639. *United States v. Alaska* 521 U.S. 1, 62 (1997) (Thomas, J. et. al. Concurring in part and dissenting in part). Earlier, in *United States v. State of California*, 381 U.S. 139 (1965), the Supreme Court also relied upon the 1958 Convention to define the term "inland waters." *Id* at 161-68.

Article 5, Section 1,of the 1958 Convention defined inland[1] waters as follows:

> 1. Waters on the landward side of the baseline of the territorial sea form part of the internal waters of the State.

Vietnam claims as internal or inland waters the landward side of the baseline. United States Department of State *Bureau* of *Intelligence and Research, Limits in the Seas No. 99* Straight Baselines: Vietnam, (1983). Additionally, bays such as Da Nang Harbor are considered part of inland waters and are the sovereign territory of the nation.

The Secretary has recognized the presumption for those who served onboard ships who were in "inland" waters. They have failed to include those who served in ships in bays or waters landward of the baseline. The Secretary has irrationally interpreted inland waters to include only landward from the mouth of rivers. This interpretation does not comport with binding Supreme Court precedent.

Under the baseline method, nations draw a baseline from their farthest islands and the territorial sea is formed seaward of the baseline. *See,* 1958 Convention, *supra* at Article 11. This forms the beginning point of the territorial sea. See Red Line on Exhibit B,

In *Louisiana v. Mississippi,* 202 U.S. 1, 52 (1906), the Supreme Court held that the Mississippi Sound, and by analogy, the waters surrounding Da Nang as internal waters, were under the category of "bays wholly within [the Nation's] territory not exceeding two marine leagues in width at the mouth." Inland, or internal waters are subject to the complete sovereignty of the nation, as much as if they were a part of its land territory. *United States v. Louisiana*, 394 U.S. 11 (1969). When moored or anchored in a harbor, the ship and its crew were within the sovereign territory of Vietnam. The closer a ship was to shore, the higher the possibility that they steamed through waters contaminated with Agent Orange. As discussed *supra*., anchoring in those waters would have disturbed any Agent Orange contaminated sludge that had fallen to the seabed. The constant cavitation caused by ships entering and leaving the harbor and making fast along side of the piers would have also disturbed the sea bottom.

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[1] The Supreme Court in the decisions cited herein used the definition of internal waters to specify inland waters.

The definition of a bay in the 1958 Convention was again adopted by the Supreme Court:

> Article 7(2) of the Convention sets forth the following geographic criteria for deciding whether a body of water qualifies as a bay:
>
> "For the purposes of these articles, a bay is a well-marked indentation whose penetration is in such proportion to the width of its mouth as to contain landlocked waters and constitute more than a mere curvature of the coast. An indentation shall not, however, be regarded as a bay unless its area is as large as, or larger than, that of the semi-circle whose diameter is a line drawn across the mouth of that indentation." 15 U.S.T., at 1609.

Alaska v. United States. 545 U.S. 75, 93, 125 S.Ct. 2137, 2151 - 2152 (2005).

Exhibit K[2] is an aeriall view of Da Nang Harbor. It is surrounded on three sides by land with at least two rivers discharging into it. The harbor itself would partially contain and concentrate the Agent Orange dioxin. Depth of water in Da Nang was 27-42 feet, which would have resulted in the disturbance of the Agent Orange adhering to the sea bed by repeated anchoring and weighing anchor. Without question it meets the definition of "bay" under national and international law. Bays and harbors have been found to constitute sovereign territory.

In *Boumediene v. Bush* 553 U.S. 723, 832, 128 S.Ct. 2229, 2296 (2008), the Supreme Court of the United States noted that Guantanamo Bay was located within the sovereign territory of Cuba. This is based on Article 7 of the 1958 Convention which the Supreme Court relies upon in coastal disputes. *United States. v. Maine* 475 U.S. 89, 94, 106 S.Ct. 951, 954 (1986). The Supreme Court has noted that the 1958 Convention contains "the best and most workable definitions available." *United States v. California, supra.,* 381 U.S., at 165, 85 S.Ct., at 1415).

Dan Nang, Vung Tau, Nha Trang Harbors and Cam Ranh Bay certainly meet this legal requirement. Without question, these areas constitute bays under the 1958 Convention. There can be no argument that these bays are part of the sovereign territory of the nation and well within the scope of Article 1 of the 1958 Convention. Consequently, under both national and international law, ships entering these harbors and bays served in the Republic of Vietnam and should be afforded the presumption.

Additionally, the territorial seas are sovereign territory and any ship that entered that area should be covered by the presumption of exposure. Subject to the right of innocent passage, the coastal state, in this case Vietnam, has the same sovereignty over its territorial sea as it has with

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[2] After seeing this picture, VA Chief of Staff John Gingrich agreed that the policy of excluding harbors from the presumption of exposure did not make sense. In fact, until he was shown an excerpt from his own M 21-1R Manual, Gingrich thought that the exposure presumption encompassed Da Nang Harbor.

respect to its land territory. *See*, 1958 Convention, *supra*, Article 1-2; Law of the Seas Convention, Article 2. Any time a ship was within twelve miles of the baseline, they would have had to have been within the internal waters or territorial seas of Vietnam. As discussed *supra*., the range of the guns forced most ships on the gun line to operate within the territorial seas.

Procedural History

In 1991, the Congress passed and President George H. W. Bush signed, the Agent Orange Act of 1991, Pub.L. 102–4, Feb. 6, 1991, 105 Stat. 11. This federal law required VA to award benefits to a veteran who manifests a specified disease and who "during active military, naval, or air service, served in the Republic of Vietnam during the period beginning on January 9, 1962, and ending on May 7, 1975." Specified diseases included Non-Hodgkin's lymphoma soft-tissue sarcoma other than osteosarcoma, chondrosarcoma, Kaposi's sarcoma, or mesothelioma, chloracne or another acneform disease consistent with chloracne, Hodgkin's disease, porphyria cutanea tarda, respiratory cancers (cancer of the lung, bronchus, larynx, or trachea), multiple myeloma, Diabetes Mellitus (Type 2) and other diseases designated by the Secretary.

The Agent Orange Act of 1991 further required the Secretary to "take into account reports received by the Secretary from the National Academy of Sciences and all other sound medical and scientific information and analyses available to the Secretary." The Secretary is further required to consider whether the results are statistically significant, are capable of replication, and withstand peer review. The responsibility to prepare a biennial report concerning the health effects of herbicide exposure in Vietnam veterans was delegated to the Institute of Medicine (IOM), a non-profit organization which is chartered by the National Academy of Sciences.

The Department of Veterans Affairs (hereinafter VA) drafted regulations to implement the Agent Orange Act of 1991 and defined "service in the Republic of Vietnam" as "service in the waters offshore and service in other locations if the conditions of service involved duty or visitation in the Republic of Vietnam." 38 C.F.R. § 3.307(a)(6)(iii) (1994). This was in contrast to a previous definition which defined "service in Vietnam" as "service in the waters offshore, or service in other locations if the conditions of service involved duty or visitation in Vietnam." 38 C.F.R. § 3.313 (1991). These regulations allowed the presumption of exposure throughout the Vietnam Service Medal area, the dark solid line marked on Exhibit B. Under this definition, a ballistic missile submarine was covered as were the aircraft carriers on Yankee Station and submarines conducting operations in the Gulf of Tonkin in an area of the coast where no Agent Orange was sprayed. These ships would not be covered under HR 543.

In 1997 the VA General Counsel issued a precedential opinion excluding service members who served offshore but not within the land borders of Vietnam. The opinion construed the phrase "served in the Republic of Vietnam" as defined in 38 U.S.C. § 101(29)(A) not to apply to service members whose service was on ships and who did not serve within the borders of the Republic of Vietnam during a portion of the "Vietnam era." The opinion stated that the definition of the phrase "service in the Republic of Vietnam" in the Agent Orange

regulation, 38 C.F.R. § 3.307(a)(6)(iii), "requires that an individual actually have been present within the boundaries of the Republic to be considered to have served there," and that for purposes of both the Agent Orange regulation and section 101(29)(A), service "in the Republic of Vietnam" does not include service on ships that traversed the waters offshore of Vietnam absent the service member's presence at some point on the landmass of Vietnam." VA Op. Gen. Counsel Prec. 27-97 (1997). This opinion was authored by Mary Lou Keener. She later became the wife of Hershel Gober who served as Acting Secretary of the Department from 2000-2001.

After lying dormant for a few years, VA Op. Gen. Counsel Prec. 27-97 (1997) was incorporated into a policy change that was published in the Federal Register during the last days of the Gober tenure. 66 Fed.Reg. 2376 (January 11, 2001). The final rule was adopted in Federal Register in May of that year. 66 Fed. Reg. 23166. Comments by the VA concerning the exposure presumption recognized it for the "inland" waterways but not for offshore waters or other locations only if the conditions of service involved duty or visitation within the Republic of Vietnam.

Historically the VA's Adjudication Manual, the M21-1 Manual, allowed the presumption to be extended to all veterans who had received the Vietnam service medal, in the absence of "contradictory evidence." In a February 2002 revision to the M21-1 Manual, the VA incorporated the VA General Counsel Opinion and the May 2001 final rule and required a showing that the veteran has set foot on the land or entered an internal river or stream. This "boots on the ground" requirement is in effect today.

On August 16, 2006, the Court of Appeals for Veterans Claims ruled that Navy sailors who served in the near shore waters off Vietnam were entitled to benefits whether or not they set foot on land. *Haas v. Nicholson*, 20 Vet.App. 257 Vet.App.,2006.

In April of 2008, the Department of Veterans Affairs published a notice rescinding the previous section of the M 21-1 Manual allowing the presumption of exposure to be extended to recipients of the Vietnam Service Medal. This recision was based on a rejection of the NRCET report. The VA conclusions were widely criticized. See Exhibit L Comment of John B. Wells, and Exhibit M Comment of Dr. Caroline Gaus. No final rule rescinding the M 21-1 report was ever promulgated.

On May 8, 2008, the Federal Circuit overturned the Court of Appeals for Veterans Claims based on administrative law grounds. *Haas v. Peake*, 525 F.3d 1168, 48 A.L.R. Fed. 2d 787 (Fed.Cir. 2008). The decision noted that the M 21-1 Manual was an interpretive rather than substantive regulation and that prior notice and comment was not required. *Id* at 1195. This decision, in *dicta*, criticized the NRCET report based on the Department's Federal Register preliminary notice. *Id.* at 1194. Reconsideration was denied on October 9, 2008. *Haas v. Peake*, 544 F.3d 1306 (Fed.Cir. 2008). This reconsideration, in *dicta*, criticized the application of the law of the sea while noting that the issue was not decided since it was not raised in the court below. *Id.* at 1309-10.

In June of 2008, I traveled to San Antonio to present to the Institute of Medicine's (IOM) Committee to Review the Health Effects in Vietnam Veterans of Exposure to Herbicides (Seventh Biennial Update) in San Antonio Texas. I provided the IOM with copies of the NRCET report and testified as to its applicability and authenticity. The IOM Committee conducted an exhaustive review of the NRCET study and requested an independent review by Dr. Steve Hawthorne who is the Senior Research Manager of the Energy & Environmental Research Center (EERC), University of North Dakota. Dr. Hawthorne validated the findings of the NRCET study.

In July of 2009, the IOM Seventh Biennial Committee produced their report which included the blue water navy issues I raised. Relevant pages of this report are 54-55 and 655-56. See, http://www.nap.edu/openbook.php?record_id=12662&page=R1. The IOM report accepted the proposition that Navy veterans off the coast were exposed and recommended that they be given the presumption of exposure. In their recommendation, the IOM committee stated: "Given the available evidence, the committee recommends that members of the Blue Water Navy should not be excluded from the set of Vietnam-era veterans with presumed herbicide exposure." *Id* at 656.

Although you accepted many recommendations of that committee, you did not accept the recommendation concerning the Blue Water Navy veterans. Instead you ordered another study.

On May 3, 2010, I testified before the Institute of Medicine's Board on the Health of Special Populations in relation to the project "Blue Water Navy Vietnam Veterans and Agent Orange Exposure." This was the new study you ordered. The Committee reported out on May 20, 2011. Their report had four major conclusions. They found that there was a plausible pathway for some amount of Agent Orange to have reached the South China Sea through drainage from the rivers and streams of South Vietnam as well as wind drift. Secondly they replicated the NRCET report and found the conclusions by the University of Queensland were sound. Their only criticism was that the Australians may have underestimated the toxic effect of the co-distillation process. Third, they indicated that based on the lack of firm scientific data and the four decade passage of time, they could not specifically state that Agent Orange was present in the South China sea. The indicated that there was no more or less evidence to support its presence off the coast than there was to support its presence on land or in the internal waterways. Fourth, they stated that the decision to extend the presumption of exposure should be based on policy and not science.. Notably the most recent IOM report (2011) did not contradict the findings of the previous Committee report (2009). They did not disagree with that Committee's finding that the blue water Navy personnel should not be excluded from the presumption of exposure.

On January 24, 2012, while still serving as Director of Legal and Legislative Affairs for the BWNVVA, I briefed your Chief of Staff, John Gingrich, on many of the matters contained herein. He agreed that it did not make sense to exclude the harbors from the presumption,

especially Da Nang Harbor. He ordered an inquiry into the reason for the original General Counsel's opinion and promised that the VA would work with the BWNVVA in ascertaining whether or not the current policy should be modified or rescinded. No such co-operation ever occurred.

Instead, on December 26, 2012, without any kind of notice to BWNVVA, the Department published a Federal Register Notice., 77 Fed. Reg. 76170 (December 26, 2012). This Notice misinterpreted the conclusions of the IOM and omitted findings favorable to the Blue Water Navy Veterans. The Notice contained the following statement: "After careful review of the IOM report, 'Blue Water Navy Vietnam Veterans and Agent Orange Exposure,' the Secretary has determined that the evidence available at this time does not support establishing a presumption of exposure to herbicides for Blue Water Navy Vietnam Veterans." There was no opportunity for comment on the determination.

Conclusion.

It is the position of MVA and BWNVVA, that the "boots on the ground" policy, as reiterated in the December 26, 2012 notice, is arbitrary and capricious, unsupported by substantial evidence and in violation of current federal and international law.

The past forty to fifty years has seen changes in the seascape surrounding Vietnam. Some of the dioxin has been carried out to sea where it has been spread across the Pacific. Emulsified dioxin has been covered by the shifting sea bottom. While the presence of dioxin has been confirmed in Nha Trang, no other studies have been conducted to confirm its presence. Logic and common sense, however, indicates that not only the harbors but the territorial seas and beyond were inundated with the dioxin.

BWNVVA does not have the resources to conduct core samples and coral inspections along the entire coast of what was once the Republic of Vietnam. Certainly the VA could, with proper diplomatic clearance, order such a study, but the cost would probably exceed the cost of paying benefits. The individual veteran, however, should not be required to shoulder such an arduous task.

Congress has designed the VA's adjudicatory process "to function throughout with a high degree of informality and solicitude for the claimant." *Walters v. National Assn. of Radiation Survivors*, 473 U.S. 305, 311, 105 S.Ct. 3180 (1985). A unanimous[3] Supreme Court of the United States has upheld "the canon that provisions for benefits to members of the Armed Services are to be construed in the beneficiaries' favor." *Henderson ex rel. Henderson v. Shinseki* 131 S.Ct. 1197, 1206 (2011), *citing*, *8St. Vincent's Hospital,* 502 U.S. 215, 220–221, n. 9, 112 S.Ct. 570, (1991); *Coffy v. Republic Steel Corp.,* 447 U.S. 191, 196, 100 S.Ct. 2100 (1980);

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[3] Justice Alito wrote the opinion in which seven Justices joined. Justice Kagan took no part in this case.

Fishgold v. Sullivan Drydock & Repair Corp., 328 U.S. 275, 285, 66 S.Ct. 1105 (1946).

The Federal Circuit has also recognized the paternalistic non-adversarial intent of the system designed by Congress. *Gambill v. Shinseki, supra,* 576 F.3d at 1317. The *Gambill* court described the process as follows:

> "[T]the character of the veterans' benefits statutes is strongly and uniquely pro-claimant." *Hodge v. West,* 155 F.3d 1356, 1362 (Fed.Cir.1998) . The relationship between the veteran and the government is nonadversarial, *Jaquay v. Principi,* 304 F.3d 1276, 1282 (Fed.Cir.2002) (en banc), and because of the paternalistic nature of DVA proceedings, the DVA is required "to fully and sympathetically develop the veteran's claim to its optimum before deciding it on the merits," *Comer v. Peake,* 552 F.3d 1362, 1368 (Fed.Cir. 2009); *McGee v. Peake,* 511 F.3d 1352, 1357 (Fed.Cir. 2008). The process is "designed to function throughout with a high degree of informality and solicitude for the claimant." *Walters,* 473 U.S. at 311, 105 S.Ct. 3180. Then-Chief Judge Mayer put the point succinctly when he stated, "Viewed in its entirety, the veterans' system is constructed as the antithesis of an adversarial, formalistic dispute resolving apparatus." *Farce v. Principi*, 284 F.3d 1335, 1360 (Fed.Cir. 2002) (*en banc*) (Mayer, C.J., dissenting).

Id at 1316.

It is well settled that the VA has a duty to assist a claimant in the development of their claim. 38 U.S.C. § 5103A(a)(1), 38 C.F.R. § 3.159. *Godwin v. Derwinski,* 1 Vet.App. 419, 425 (1991). The duty to assist the veteran does not end with the rating decision but continues while the claim is pending before the BVA. The statute imposes a continuing obligation upon the VA to assist the claimant in developing the facts of his claim throughout the entire administrative adjudication. *Murincsak v. Derwinski,* 2 Vet.App. 363, 373 (1992). Yet here the VA has never worked to assist the Blue Water Navy veterans. If anything, the actions of the VA have been confrontational and obstructionist.

Congress has expressed an interest in resolving this matter. HR 3612, introduced midway through the last Congress had 128 co-sponsors. HR 543, introduced in this Congress already has 98 co-sponsors. Many Members are awaiting a final Congressional Budget Office Score. A preliminary ten year estimate of $2.8 billion is expected to be revised downward.

You do not have to wait for Congress, however. You can grant the presumption of exposure with a stroke of a pen.

Despite the lack of assistance and the active opposition of the VA, we have built a strong circumstantial evidence case. We know the Agent Orange went into the rivers and streams. We know the rivers and streams flow out to sea. We know that at least one harbor was contaminated and if one harbor was contaminated all harbors were probably contaminated. We know the silt

and sediment traveled hundreds of kilometers. We know that Navy ships were in the harbors and the territorial seas. We know the distilling plants co-distilled and enhanced the dioxin. We know that the dioxin went into the ship's potable water tanks. We know that the crew was exposed through the drinking water.

Frankly, there is no excuse for the VA position. At best it is arbitrary and capricious. Evidence does not support your position and it is contrary to law. I urge you to grant the presumption of exposure to ships that operated in the harbors, inland waters and the territorial seas of Vietnam. This will prevent litigation and future embarrassment for your Department. More importantly, I urge you to take positive action because it is the right thing to do.

Pursuant to 5 U.S.C. § 555(e), if you refuse to accede to this demand, provide a brief statement of reasons for each point delineated herein that you have rejected. I will take no further action until May 30, 2013 to allow you sufficient time to consider this demand.

Sincerely,

John B. Wells
Executive Director

113TH CONGRESS
1ST SESSION

H. R. 543

To amend title 38, United States Code, to clarify presumptions relating to the exposure of certain veterans who served in the vicinity of the Republic of Vietnam, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

FEBRUARY 6, 2013

Mr. GIBSON (for himself, Mr. WALZ, Mr. MASSIE, Mr. HOLT, Ms. PINGREE of Maine, Mr. TIERNEY, Mr. GRIJALVA, Ms. EDWARDS, Mr. CICILLINE, Mr. RAHALL, Ms. CLARKE, Mr. CONYERS, Ms. SCHWARTZ, Mr. YOUNG of Florida, Mr. HANNA, Mr. TONKO, Mr. LEWIS, Mr. COURTNEY, Ms. NORTON, Mr. SCOTT of Virginia, Mr. MCGOVERN, Mr. THORNBERRY, Mr. BRIDENSTINE, Mr. BARLETTA, Mr. GRIFFIN of Arkansas, Mr. RUSH, Mr. BRALEY of Iowa, Mr. POE of Texas, Mr. HIMES, Mr. MEEKS, Mr. GRIMM, Mr. RANGEL, Mr. YOUNG of Alaska, Mr. MICHAUD, Mr. MCINTYRE, Mr. POLIS, Mr. FITZPATRICK, Mr. KING of New York, Ms. ROS-LEHTINEN, Mr. STIVERS, Mr. WELCH, Mr. ISRAEL, and Mr. LARSON of Connecticut) introduced the following bill; which was referred to the Committee on Veterans' Affairs

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A BILL

To amend title 38, United States Code, to clarify presumptions relating to the exposure of certain veterans who served in the vicinity of the Republic of Vietnam, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Blue Water Navy Vietnam Veterans Act of 2013".

SEC. 2. CLARIFICATION OF PRESUMPTIONS OF EXPOSURE FOR VETERANS WHO SERVED IN VICINITY OF REPUBLIC OF VIETNAM.

(a) COMPENSATION.—Subsections (a)(1) and (f) of section 1116 of title 38, United States Code, are amended by inserting "(including the territorial seas of such Republic)" after "served in the Republic of Vietnam" each place it appears.

(b) HEALTH CARE.—Section 1710(e)(4) of such title is amended by inserting "(including the territorial seas of such Republic)" after "served on active duty in the Republic of Vietnam".

(c) EFFECTIVE DATE.—The amendments made by subsections (a) and (b) shall take effect as of September 25, 1985.

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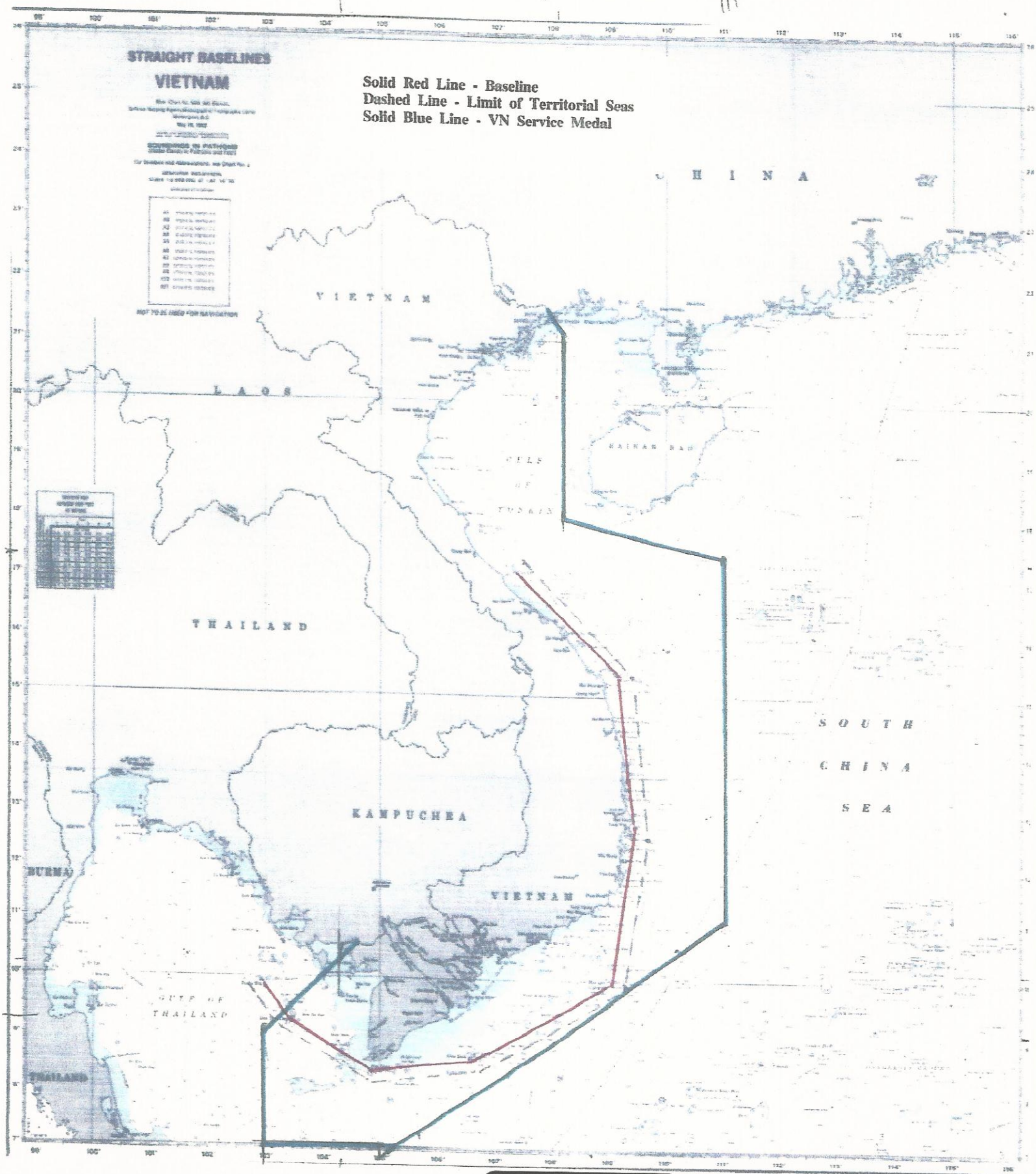


EXHIBIT

tabbies

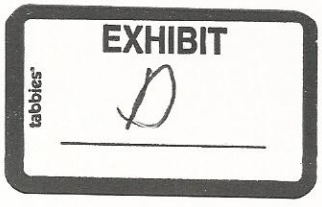
B

DECLARATION OF ROBINSON HORDOIR, Ph.D.

I, Robinson Hordoir, Ph.D., state and declare as follows:

1. I am 36 years old and a resident of Norrköping, Sweden. I was contacted by Terrence J. O'Toole, the attorney for Claimant Marvin K. Davis. Mr. O'Toole advised me that Mr. Davis was making a claim for veterans benefits based on Mr. Davis' actual or presumed exposure to Agent Orange while serving aboard a United Stated Navy destroyer, USS Newman K. Perry, while cruising the coastal water of South Vietnam. Mr. O'Toole provided me with Deck Logs for the Newman K. Perry dated 21 Nov. 1966 to 30 Nov. 1966. I am not being compensated for my services in rendering the opinions expressed in this Declaration.

2. I am employed as a researcher by the Swedish Meteorological and Hydrological Institute ("SMHI"). SMHI is an agency of the Swedish government. Information about SMHI can be found at http://www.smhi.se/en/about-smhi. I am a French national and I am fluent in English, among other languages.



3. I received by doctorate degree from the University of Caen which is located in Caen, Normandy, France. I received my Ph.D. in 2007 in Physical Oceanography. My curriculum vitae is attached to this Declaration. A significant research topic that I undertook in earning my Ph.D. degree was an investigation into the extent to which freshwater discharged from the Mekong River influences ocean water in the coastal area adjacent to the Mekong Delta. The results of this study were published in *Journal of Geophysical Research*, a peer-reviewed journal of the American Geophysical Union (AGU). The article is referenced as: Hordoir, R., K. D. Nguyen, and J. Polcher (2006), *Simulating Tropical River Plumes, A Set Of Parametrizations Based On Macroscale Data: A Test Case In The Mekong Delta Region*, J. Geophys. Res., 111, C09036, doi:10.1029/2005JC003392 (hereafter referred to as the "Mekong Delta Plume Study")

4. The object of the Mekong Delta Plume Study was to model the Mekong River plume and its impact the coastal waters of southern Vietnam. Most rivers create plumes. A plume is formed when the outflow of fresh water from a river system empties into a larger body of water. The plume, generally

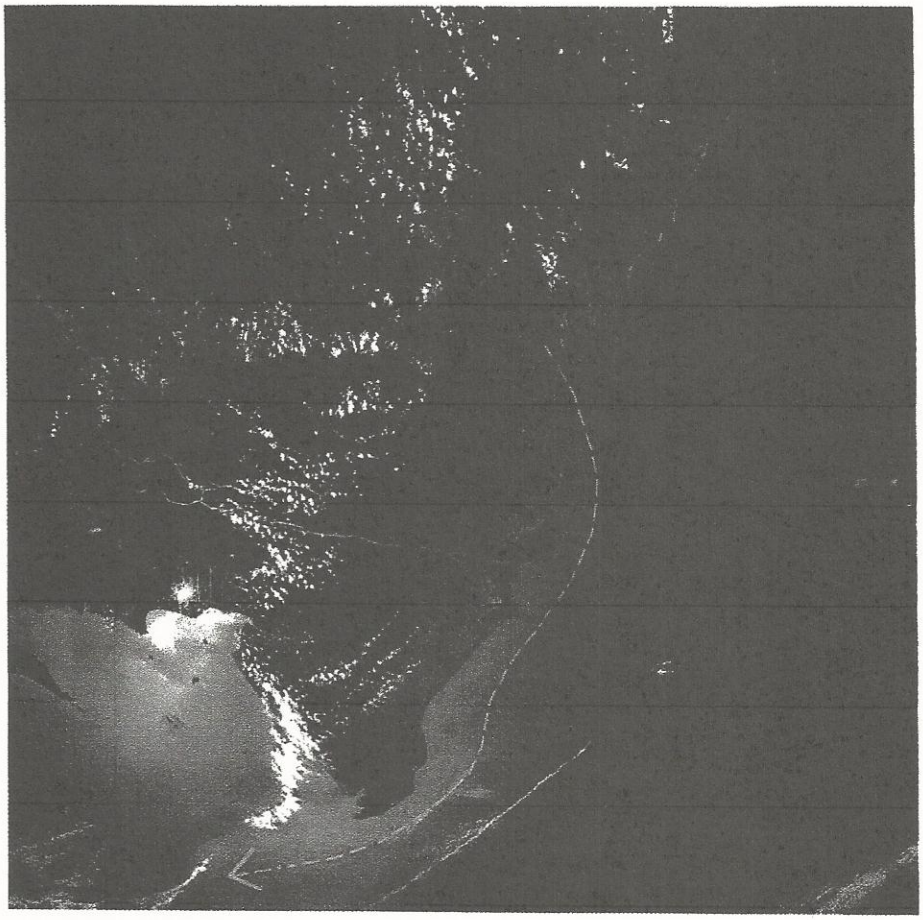
speaking, is the area of the larger body that is influenced by the fresh water discharge. The existence of the plume is mostly related to the salinity difference between river water (i.e. : freshwater) and that of the larger body that is the sea in most cases. Because of their density difference, river water and sea water do not mix immediately but create a density front. The presence of the front usually creates a coastal current that is influence by the Earth rotation (also known as the "Coriolis Force"). This phenomenon is extremely close, from a physical point of view, to that of "Thermal Wind" that most people also refer to as "Sea Breeze". The input of freshwater creates what is called a "baroclinic" current in the coastal area. "Baroclinic" is a term that is used both in Ocean and Atmospheric dynamics, and that refers to this density difference. This baroclinic current is made of two layers, the upper layer that is a mix of freshwater and sea water, and the lower layer that is mostly sea water. This dual system can be described as a "coastal overturning" : the input of freshwater attracts sea water below the river plume and that sea water eventually becomes mixed with freshwater when it

reaches the vicinity of the river mouth. This mix of freshwater and sea water is the main body of the upper part of the plume. If wind blows in the same direction as the coastal current, or if wind can be neglected, this coastal current becomes "coastally trapped". This means it flows with the coast on its right (in the Northern Hemisphere), and flows parallel to the coast. For major river systems, like the Mekong River, or the Amazon or Mississippi, the river's plume can be considerable. Depending on latitude, on meteorological, oceanographic and other conditions, a river's plume may extend hundreds of kilometers from the river's delta area. Some coastal currents like the Norwegian Coastal Current that flows all along the Norwegian coast, extend from the South of Norway up to the Arctic Ocean. In the case of the Norwegian Coastal Current, it is mostly explained by the freshwater outflow from the Baltic Sea. Because of their nature, the width of these currents are highly influenced by latitude. In tropical regions, such currents have a higher width because of the lower Coriolis force, whereas this width is smaller closer to the poles. Obviously, the closer the plume to the

mouth of the river, the higher the percentage of river water that is mixed in the water of the receiving body. These dynamics are now quite well understood to Physical Oceanographers around the world thanks to measurements and numerical models.

5. The Mekong River is one of the world's major rivers. It is the world's 12th-longest river and the 7th-longest in Asia. Its estimated length is 4,350 km (2,703 mi), and it drains an area of 795,000 km2 (307,000 sq mi), discharging 475 cu. km. (114 cu mi) of water annually. The Mekong flowing southwesterly through Vietnam and empties into the South China Sea through several channels that form the very extensive Mekong Delta. The following image is a satellite

photo of the Mekong and its delta:



6. Based on my review of the *Perry* deck logs, it appears that The *Perry* was anchored in various positions off the coast of the Mekong delta area between November 24th and November 30, 1966. Taking into account recorded longitude/latitude coordinates, water depth and on the narrative description of the *Perry's* location, the *Perry* sailed closed to the southernmost channels through

the Mekong delta which named "Tranh De" and "Din An". The black circle on the photo shows the approximate location of the *Perry* during this time.

7. Using this data, it is clear that the *Perry* never sailed or was never anchored less than 15 nautical miles off the coast of the Mekong delta, and that the *Perry* always sailed and was always anchored close to the southernmost tip of the Mekong delta. In fact, it is clear that, on some of these days, the *Perry* maneuvered very close to the coastline of Vietnam. For example, on 24 November 1966, the Deck Log reflects that the *Perry* anchored at the mouth of the Mekong River, 3 miles from the beach.

8. In southeast Asia and, specifically in the Mekong River basin, the month of November can be considered as the end of the wet season from a climatological point of view. During that period, I calculate the total freshwater discharge of the Mekong delta at 10,000 - 15,000 cubic meter per second (approximately 353,000 – 529,000 cu. ft per second). At that time of the years, the prevailing wind in the area of the Mekong Delta would be out of the Northeast

blowing Southwest.

9. Based on these meteorological and hydrological elements, in November 1966, a coastally trapped baroclinic circulation of Mekong River water would be headed in a southwesterly direction. Baroclinic flow would cause Mekong River water to be transported into the area where the *USS Newman K Perry* sailed or was anchored. Prevailing winds from the northeast contribute to the trapping of the freshwater close to the coast. This baroclinic current reaches its highest width off the southern-most point of the Mekong delta where all the freshwater from all the mouths of the delta meet to form a surface current flowing parallel to the coast. I would estimate the width of this current to be in a range from 20 nautical miles to 50 nautical miles. The dashed yellow arrow on the photo in ¶ 5, above, illustrates the baroclinic flow of Mekong River water and its direction.

10. Based on the kind of computer modeling used in the Mekong River Plume Study and using the specific data relevant to the *Perry*'s position between

24 November and 30 November, 1966, one can say that the surface salinity where the *Perry* sailed or was anchored between November 24th and November 30th 1966 ranged between 10 grams per liter and 24 grams per liter. These salinity values should be contrasted to he average salinity of that same region of 36 grams per liter. This means that the *Perry* sailed or was anchored between November 24th and November 30th 1966 in an area in which the surface water is heavily influenced by the freshwater outflow from the Mekong river.

11. Based on these salinity data, one can estimate that the percentage of Mekong river water at the sea surface of the area where the *Perry* sailed or was anchored between 24th and November 30th 1966, at between 51% and 72%. To put it more simply, using our modeling techniques, the about half to three quarters of the water surrounding the *Perry* would have been water from the Mekong River.

12. I am able to make a rough guess that the baroclinic current of circulating Mekong River water would have had a depth of anywhere from 5 to 10

meters.

13. It should be noted that during the monsoon season, the prevailing winds in the Mekong Delta are out of the southwest blowing to the northeast. This change in wind direction results in Mekong River water being driven away from the coast. A boat sailing miles away from the Mekong Delta coast, would therefore sail in an area which surface water is heavily influenced by the Mekong River. On the contrary, during that precise season, a boat anchored close to the Vietnamese coast but a few miles south west of the southernmost delta branch, would notice the presence of only a small percentage of Mekong river water at the surface of the sea. I say this to make the point that it is unscientific to believe that there is a precise boundary between river water (brown water) and ocean water (blue water) within what is referred as the "Region of Freshwater Influence" of the Mekong river. In a system like the Mekong Delta, the flow of river water and its mixture with sea water is complex and subject to a number of variable. I also wish to add that in the case of the Perry, the extreme proximity of the

Mekong river branches makes it very unlikely that the percentage of Mekong river water could have been less than 20% at the sea surface, and this regardless of the season. However, the end of the wet season (from October to December) coincides with the highest probability of having a high percentage of Mekong river water close to the coast, as the end of the wet season is this only time of the year that makes it possible to have both a high river discharge and wind blowing from the North East which ensure freshwater is trapped close to the Mekong delta coast and flows towards the South West.

Pursuant to 28 U.S.C. § 1748, I declare under penalty of perjury under the laws of the United States of America, that the foregoing is true and correct.

Executed this 28th day of May, 2010

Robinson Hordoir, Ph.D.

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Robinson HORDOIR

Summary

RESEARCH SCIENTIST IN PHYSICAL OCEANOGRAPHY

Experience

2008 to date — **Permanent Researcher** — OCEANOGRAPHY RESEARCH DEPT., SWEDISH METEOROLOGICAL AND HYDROLOGICAL INSTITUTE, NORRKÖPING, SWEDEN

- Process analysis for the Baltic Sea
- Numerical modelling of the Baltic Sea thermo-haline circulation
- Biogeochemical analysis with a focus on eutrophication, carbon sources and sinks, benthic phosphorus resuspension

2004 to 2007 — **PhD thesis** — LABORATOIRE DE MORPHODYNAMIQUE CONTINENTALE ET CÔTIÈRE, UNIVERSITÉ DE CAEN, FRANCE

Parameterisation of river inflows in Ocean General Circulation Models. Supervisor : Dr. Jan Polcher from Laboratoire de Météorologie Dynamique, Paris

- Numerical modelling of river plumes and interaction with large scale circulation
- Created local numerical configurations using POM (Princeton Ocean Model) and ROMS, also used NEMO/OPA global ocean model
- Set parametrisations to take into account meso-scale processes using macro-scale accessible data
- Goal is to provide a parametrisation of freshwater fluxes between global ocean models and global land surface models from volumic, haline and energetic points of view.

2000 to 2004 — **Research engineer** — LABORATOIRE D'OCÉANOGRAPHIE ET DU CLIMAT, EXPÉRIMENTATION ET APPROCHES NUMÉRIQUES *(formerly LODYC)*, PARIS, FRANCE

NEMO/OPA global ocean model system team. I have interfaced with users on physical, numerical and computational aspects. Supervisor : Dr. Gurvan Madec

- Work on sea ice module
- Management of global runoff flow datasets required by the NEMO/OPA model
- Management of forcing datasets

1999 — **Development engineer** — WL DELFT HYDRAULICS, DELFT, THE NETHERLANDS

Water quality team

- Coupling between 1-D hydrodynamics and water quality module (chemical and biochemical tracers modelling)
- Develloped a coupling interface

1998, June to Sept. — **Research trainee** — CSIR, COUNCIL FOR SCIENTIFIC & INDUSTRIAL RESEARCH, STELLENBOSCH, SOUTH AFRICA

Coastal engineering team

- Simulation of coastal sediment transports in a non-stationary turbulent bottom boundary layer
- Wrote a non-stationary model to take turbulence related processes into account

1997, July to Sept.	**Research trainee**	INSTITUTE OF MECHANICS, HANOI, VIETNAM
		Numerical simulation team
		- Created, wrote and tested a code solving shallow water equations using a TVD scheme. Application to dam break problems and to river flood forecasting

Education

1997 to 1999	ENSEEIHT, TOULOUSE, FRANCE *French "Grande Ecole" System, "Ingénieur" in fluid mechanics and hydraulics* - Major in environmental dynamics - PhD prerequisite courses in environmental physics & chemistry
1995 to 1997	UNIVERSITÉ D'AIX-MARSEILLE II, MARSEILLE, FRANCE - Master's degree in fluid mechanics, with Honours, ranked second among all graduates - Bachelor's degree in mechanics, with High Honours, ranked first among all graduates - Selected as the first student to participate in an exchange programme with the Hanoi Institute of Mechanics, Vietnam
1992 to 1995	LYCÉE RASPAIL, PARIS, FRANCE - Intensive training courses for competitive admission exams to French national engineering schools - Ranked first in final year, passed competitive exams in physics and chemistry at Engineering Grand National Schools

Languages

English	Fluent; trips to and long term stays in Great Britain, Ireland, South Africa, the United States and Canada
Swedish	Good basic knowledge
German	Good basic knowledge
French	Mother tongue

Computer skills

Programming	Wide experience of data analysis and visualisation with IDL, extensive knowledge of Fortran programming and code porting on supercomputers including parralelisation
Systems	Linux, Unix, MS Windows
Software	Netcdf & NCO, LaTeX, OpenOffice

Some interests

Sailing	Experience as skipper and crew on a variety of sloops, dinghies and catamarans
Scuba diving	Experienced diver
Music	Transverse flute, focus on Celtic (Irish and Breton) folklore, participated to many courses in Ireland and Britanny
Software law	Active member of an Open Source community coaching consumers willing to get their "Windows Tax" back, if necessary in court. Adviser in more than twenty legal actions, won most of them.

Personal data

European Union citizen
Married, One Child

Publications in peer reviewed journals :

- **R. Hordoir** ; Meier M. - Freshwater Fluxes in the Baltic Sea - a model study, *J. Geophys. Res.*, doi :10.1029/2009JC005604

- **R. Hordoir**; Polcher, J.; Brun-Cottan, J-C.; Madec, G. - Towards a parametrization of river discharges into Ocean General Circulation Models. A closure through energy conservation. *Climate Dynamics*, Volume 31, Numbers 7-8, DOI 0.1007/s00382-008-0416-4, Pages 891-908.

- **R. Hordoir**; Nguyen, K. D.; Polcher, J. - Simulating tropical river plumes, a set of parametrizations based on macroscale data : A test case in the Mekong Delta region - *J. Geophys. Res.*, Vol. 111, No. C9, C09036 doi : 10.1029/2005JC003392

Talks & posters :

- **R. Hordoir** , Nguyen K.D., Polcher J. - Simulating tropical river plumes, a set of parametrizations based on macro-scale data. Comparison with observations in the region of freshwater influence of the Mekong Delta, *Oral Presentation given at the EGU - General Assembly, Vienna, April 2006*

- **R. Hordoir**, Polcher J., Brun-Cottan J-C., Madec G. - Spotting what lacks to resolve properly river inflows in ocean general circulation models, *Oral Presentation given at the EGU - General Assembly, Vienna, April 2007*

- **R. Hordoir**, Polcher J., Brun-Cottan J-C., Madec G. - River inflows in ocean general circulation models : a closure through energy conservation, *Poster Presentation given at the EGU - General Assembly, Vienna, April 2007*

Oceanography of the Mekong River Estuary

Eric Wolanski[1] and Nguyen Huu Nhan[2]

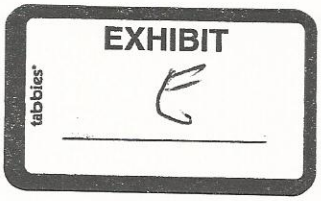
[1] *Australian Institute of Marine Science, PMB No. 3, Townsville MC, Queensland 4810, Australia. E-mail: e.wolanski@aims.gov.au*

[2] *Southern Center for Hydro-Meteorological Service, 8 Mac Dinh Chi Street, Dist 1, Ho Chi Minh City, Vietnam. E-mail: huu-nhan@hcm.vnn.vn*

The 4,800 km long Mekong River drains an area of 0.795 10^6 km^2. The river forms a delta downstream of Kompong Cham, Cambodia, where the river discharge varies seasonally between typically 2,100 m^3 s^{-1} in April (the low-flow season) and 40,000 m^3 s^{-1} in September (the high-flow season). The delta is drained by main channels that have a thalweg about 10m deep in the freshwater region located 30 km upstream from the mouth. Closer to the mouth, saline oceanic water intrude in the low-flow season, and the depth decreases to typically 5 m in the thalweg, with extensive shoals on either side. Even shallower waters are found in coastal waters near the mouth.

The sediment discharge is about 160 10^6 tonnes $year^{-1}$. To place the Mekong in perspective with other major rivers, the Mekong River has a smaller drainage area than the Yangtze (41%), the Amazon (12%), the Mississippi (24%) and the Ganges-Brahmaputra (53%) rivers. However the Mekong River sediment load is about the same as that of the Mississippi, it is 85% that of the Yangtze River and it is 12% larger than that of the Amazon.

Mixed, mesotidal tides prevail with a strong diurnal inequality. At the mouth the mean maximum and average tidal ranges are respectively about 3.2 m and 2.2 m. The average tide range decreases with distance upstream. At Can Tho (123 km from the mouth) it is



only 1.9 m in the low-flow season and 0.7 m in the high-flow season. At Cau Doc (228 km from the mouth) it is 0.49 m in the low-flow season and 0 m in the high-flow season.

About 8 million Cambodians, 4 million Laotians, 25 million Vietnamese and several million Chinese live in the Mekong basin, most of them depending on the Mekong for the livelihood. The desire for hydropower led China to construct the Manwan hydroelectric dam on the main river in 1994 and Thailand to build the Pak Mun on the Mun River, a tributary of the Mekong. China is presently building a cascade of eight dams on the main river. There have been no published studies that we could find of the resulting environmental and socio-economic impact in the Mekong Estuary and its delta. Such studies are urgently needed and should be integrated within the studies of estuarine processes occurring naturally. This potential problem is further aggravated by plans for constructing 100 hydroelectric dams and water diversion schemes upstream on the Mekong River, principally in China, Thailand, Cambodia and Laos, these plans appear not to include the environmental and socio-economic impact in Vietnam in their cost-benefit analysis evaluation.

These studies of natural processes in the estuary have been carried out through field studies and numerical modelling by Vietnam's Southern Center for Hydro-Meteorological Service. These studies have focused on the immediate, urgent, socio-economic problems generated by salinity intrusion in the low-flow season, and flooding by storm surges and by river floods. For instance, the tidal dynamics can be modelled successfully as a friction-damped, progressive wave in branched, one-dimensional channels, with the tidal amplitude decreasing and the time lag increasing with distance from the river mouth. River floods were also be modelled successfully using 2-D models

in branched estuaries and coastal waters. These models are used predictively and have great, beneficial socio-economic relevance including saving human lives.

In view of the likely, longer-term environmental impacts from the construction of dams on the Mekong and the flow regulation that results, preliminary, field studies of fine-sediment transport were also carried out in the Mekong Estuary in both the high-and low-flow seasons.

In the freshwater region, erosion and deposition of suspended sediment occur at tidal frequency. The mean suspended-solid concentration is typically about 250-500 mg l^{-1}. The suspended sediment is mostly fine silt, and the clay fraction accounted for only 15%. The suspended sediment is transported either as individual particles or agglomerated with organic detritus.

In the wet season, there is a strong down-river transport at a mean velocity of 1 m s^{-1}. A salt wedge is present near the mouth and is flushed out of the estuary at low tide. Flow reversal occurs across the pycnocline. A turbidity maximum zone is present at the toe of the salt wedge at flood tide. Most of the suspended sediment is coagulated with little organic matter. The bulk of the suspended sediment is exported to coastal waters, but some sediment returns to the estuary in the salt wedge. At such times, the Mekong River plume has been tracked all the way into the middle region of the Gulf of Thailand.

By contrast in the dry season, the semidiurnal, macro-tides and shallow water effects result in a tidal asymmetry with peak flood tidal currents 10% stronger than peak ebb tidal currents. The salinity intrusion extends 50 km up-river with vertical stratification in salinity occurring around slack tidal currents. The suspended sediment is still mainly fine silt and flocculation occurs in the saline region. The asymmetry of tidal currents, along

with the baroclinic circulation, pump sediment upstream. It is advected from the South China Sea where it may have been deposited at the previous wet season. This sediment is sequestrated in the estuary. The saline region of the estuary is more turbid than the freshwater region and the location of the turbidity maximum varies spatially with the tides.

Modelling predicts that, as a result of these schemes, the Mekong Estuary will suffer major siltation, possibly in as little as 30 years. These changes, together with changes in salinity and their impact on farming, may cause significant, negative, socio-economic problems.

The problems of managing water resources, controlling floods and salinity intrusion in the Mekong are not just for the future, there are already severe. Additional present problems deal with new complicated hydrodynamics features introduced by engineering developments in the delta (dykes, channels, sluices, roads and other infrastructures). This requires the development of a methodology, database and integrated tools for management and prediction of water resources, water quality, floods, and salinity intrusion. This is carried out by an integrated model " HydroGis". It was applied successfully in a number of applications of flooding, storm surges, and salinity intrusion in the period 2000-2004.

Detailed scientific studies of the Mekong Estuary are warranted to integrate land and water management at the entire river catchment, including the river and the estuary, as one ecosystem; this solution goes against present political and administrative practices. The successful management of the Mekong Estuary and its delta requires an ecohydrology-based, basin-wide approach. This necessitates changing present practices

by official institutions based on countries as an administrative unit, or the narrowly-focused approaches of managers of specific activities (e.g. farming and fisheries, water resources, hydroelectricity, and nature conservancy). Without this change in thinking and management concept, the Mekong delta may degrade, with huge environmental and socio-economic implications, whatever integrated coastal management plans are implemented.

Signature of the Mekong River plume in the western South China Sea revealed by radium isotopes

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[1] We investigated the distribution of ^{223}Ra, ^{228}Ra, and ^{226}Ra in the surface water of the western South China Sea (SCS) during summer based on a 30 day cruise conducted in August–September 2007. The activities of ^{223}Ra varied from almost undetectable to 0.74 disintegrations per minute (dpm)/100 L, and those of ^{228}Ra varied from 12.2 to 61.5 dpm/100 L. Their spatial distribution was characterized by a jet of high ^{228}Ra (>48 dpm/100 L) and ^{223}Ra (>0.4 dpm/100 L) extending eastward from the Vietnam coast along ~11°N, curling up in the vicinity of 112°E and swirling counterclockwise to form a cyclonic eddy with lower ^{228}Ra (21–25 dpm/100 L) and ^{223}Ra (0.04–0.14 dpm/100 L) at its center. High ^{226}Ra (10–14 dpm/100 L) appeared in the eastward jet and decreased to 6.0–8.5 dpm/100 L along the track of the jet described above. The observed distribution of Ra isotopes was consistent with the pattern of the Southeast Vietnam Offshore Current in the western SCS in summer. The higher radium activities were in all likelihood derived from the Mekong River. Using a simple two-end-member mixing model based on the ^{228}Ra/^{226}Ra activity ratio and salinity, we calculated that approximately 53% of the surface water in the western SCS was originated from the Mekong River diluted water. Note that this estimation should be regarded as an upper limit due to the lack of sampling at its immediate source, the Mekong estuary. The data revealed that more than 2 weeks were required for the transportation of freshened water from the Mekong River's mouth several hundred kilometers to the western SCS.

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1. Introduction

[2] River plumes play an important role in the transport and transformation of terrestrial materials in coastal margins [*Dagg et al.*, 2004]. Along plume boundaries, mixing of dissolved riverine and oceanic components and coagulation and settling of particles create fronts, which are often zones of enhanced biological productivity and biogeochemical reactions [*Lohrenz et al.*, 1990]. However, such processes are highly complex and not easy to grasp due to the dynamic and inhomogeneous nature of river plumes. Plumes from some major rivers may extend hundreds of kilometers into the open ocean [*Muller-Karger et al.*, 1988], and are commonly traced by offshore negative salinity and/or positive silica anomalies. However, the salinity signal can be altered by precipitation and evaporation, and the silica signal is sensitive to biological uptake. To circumvent these drawbacks, radium isotopes can be employed [*Moore and Krest*, 2004; *Moore et al.*, 1986; *Moore and Todd*, 1993; *Rutgers van der Loeff et al.*, 2003]. Unlike salinity and silica, the ^{228}Ra/^{226}Ra activity ratio (AR) only changes by decay of ^{228}Ra and mixing. Moreover, using short-lived radium isotopes (^{223}Ra and/or ^{224}Ra), the time scale of transport of a river plume and its mixing with the adjacent coastal water can be further constrained [*Moore and Krest*, 2004; *Moore and Todd*, 1993]. Thus, from a combined use of two or more Ra isotopes, it is possible to characterize better the dispersal of river water.

[3] There are four naturally occurring radium isotopes, that is, ^{223}Ra ($t_{1/2}$ = 11.4 days), ^{224}Ra ($t_{1/2}$ = 3.6 days), ^{228}Ra ($t_{1/2}$ = 5.75 years) and ^{226}Ra ($t_{1/2}$ = 1600 years), which are introduced to a water body through its contact with thorium-bearing sediments. In fresh river water, Ra isotopes are strongly adsorbed on particles and they tend to be desorbed as the ionic strength of the ambient water increases upon estuarine mixing [*Elsinger and Moore*, 1980; *Key et al.*, 1985; *Li et al.*, 1977]. Following the deposition of sediments, Ra isotopes regenerated by Th decay can be released at the sediment-water interface or into the sediment interstitial water. Due to their vast difference in half-lives, ^{223}Ra and ^{224}Ra are continually regenerated and supplied from the estuarine sediments, while ^{226}Ra and ^{228}Ra are regenerated much more slowly [*Moore and Todd*, 1993]. After complete desorption, ^{223}Ra and ^{224}Ra are expected to change with

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mixing and significantly decay during the lifetime of a plume while ^{226}Ra and ^{228}Ra change primarily by mixing with offshore water. Thus Ra isotopes can be used as tracers to study the advection and mixing of river plumes with ocean water after they leave the river/ocean mixing zone [*Moore*, 2000a, 2000b; *Moore and Krest*, 2004; *Moore and Todd*, 1993].

[4] The Mekong River is one of the largest rivers in the world. It empties into the South China Sea (SCS) at ~10°N and 107°E with a mean annual discharge of 470 km^3 [*Dagg et al.*, 2004]. This freshwater discharge changes seasonally, being lowest in May and highest in October [*Mekong River Commission* (*MRC*), 2008], and the plume flows southward in winter and northward in summer in response to the switch in direction of the monsoon winds [*Hu et al.*, 2000]. In contrast with other extensively studied world major river plume systems, such as the Amazon, Changjiang and Mississippi River plumes [*Chen et al.*, 2008; *Dagg et al.*, 2004; *Lohrenz et al.*, 1999; *Smith and DeMaster*, 1996], little is known about the Mekong River plume. This is true both in terms of the plume variability and the associated biogeochemical processes. Previous study has shown that the Mekong River's influence on nitrogen fixation is confined to the upwelling region off Vietnam along a belt stretching ~500 km from the river's mouth [*Voss et al.*, 2006]. In this study, we used the distribution of three radium isotopes (^{223}Ra, ^{228}Ra, ^{226}Ra) to identify the signature of the Mekong River plume in the western SCS. To our knowledge, this is the first time that ^{223}Ra, ^{228}Ra, and ^{226}Ra were determined concurrently at a high spatial resolution in the western SCS. It enabled us to assess the time scale of the transport of the river plume and its mixing with the adjacent coastal and ocean waters.

2. Materials and Methods

2.1. Study Area

[5] The SCS is the largest marginal sea at low latitude in the world. The western SCS can be roughly divided into two parts: the continental shelf and the deep basin. The shelf is narrow and lies roughly west of 109°E. To the south of the western SCS is a region known as the Nansha Archipelago, where many islands and reefs are irregularly distributed. The climate of the western SCS is tropical and is influenced by the seasonal monsoonal cycle. The monsoonal winds are southwesterly in summer (June–September) and northeasterly in winter (November–March), with transitions in spring (April–May) and fall (October to early November). During the summer, surface circulation in the western SCS is characterized by a unique and strong eastward jet, namely the Southeast Vietnam Offshore Current (SVOC) [*Fang et al.*, 2002; *Hu et al.*, 2000]. This eastward jet leaves the coast between 10°N and 12°N and bifurcates in the vicinity of 113°E. The northern branch flows toward the center of the western SCS and forms a cyclonic eddy off the Vietnam coast, while the southern branch turns to the south and forms an anticyclonic eddy centered in the southern SCS. Thus, there exists a dipole mode circulation off the southeast Vietnam coast [*Fang et al.*, 2002; *Shaw et al.*, 1999]. Upwelling off Vietnam occurs during the summer when the southwest monsoon wind prevails, and it can be enhanced by the eastward jet [*Dippner et al.*, 2007; *Fang et al.*, 2002].

2.2. Sampling

[6] The cruise in the western SCS was conducted from 15 August to 14 September 2007 onboard R/V *Dongfanghong-II*. It was divided into two legs (Table 1 and Figure 1b), with the first leg (15–28 August) visiting stations to the north of 13.5°N and the second leg (1–14 September) occupying the area to the south of 13.5°N and SEATS (115.96°E, 18.03°N, a time series station in the SCS). Station TS1 in leg 1 was revisited in leg 2, when it was renamed Station 3YS4.

[7] During the cruise, large-volume (100 L) samples were pumped from ~5 m below the surface into plastic cubitainers onboard. After the sample volume was recorded, the water was passed immediately through a column of MnO_2-coated acrylic fiber (Mn fiber) to quantitatively remove Ra at a flow rate less than 1 L per minute. The surface temperature and salinity were measured using a YSI 6600 sonde (YSI Co.). This set of data was well calibrated with a SBE-21 CTD unit (Sea-Bird Co.).

2.3. Determination of ^{223}Ra With a RaDeCC System

[8] In the shipboard laboratory, each Mn fiber sample was rinsed with Ra-free deionized water, partially dried with a stream of air and then placed in the radium delayed coincidence counter (RaDeCC) following *Moore and Arnold* [1996]. The RaDeCC utilizes the difference in the decay constants of the short-lived Po daughters of ^{219}Rn and ^{220}Rn to identify alpha particles derived from ^{219}Rn and ^{220}Rn decay and hence to determine activities of ^{223}Ra and ^{224}Ra on the Mn fiber [*Giffin et al.*, 1963; *Moore and Arnold*, 1996]. To reduce the effect of ^{224}Ra on the measurement of ^{223}Ra, the samples were recounted for a longer time after 7–10 days. The expected error of ^{223}Ra measurements was 10% [*Moore*, 2008].

[9] Although the RaDeCC system can provide the ^{223}Ra and ^{224}Ra data simultaneously after a sequence of runs, we failed to obtain the ^{224}Ra data due to a shortage of helium (the carrier gas) onboard during the survey for the last transect (transect Y3). When the samples were returned to the shore-based laboratory about 10 days later, ^{224}Ra had decayed too much to allow further analysis.

2.4. Determination of ^{228}Ra and ^{226}Ra by γ-Spectrometry

[10] In a shore-based laboratory, following the procedure of *Moore et al.* [1985], the Mn fiber sample was leached with a mixture of 1 M hydroxylamine hydrochloride and hydrogen peroxide solution at 50°C. Radium isotopes in the solution were coprecipitated with $BaSO_4$ and the precipitate was stored in a small vial for 3 weeks to allow ^{222}Rn to equilibrate with ^{226}Ra. The absolute ^{226}Ra and ^{228}Ra activities of the sample were measured using a well-type germanium detector (ORTEC, GWL-120-15-S). The detector was calibrated by counting reference sources processed from a solution containing known activities of ^{228}Ra and ^{226}Ra. The solution was prepared by dissolution of Congo pitchblende (with ^{238}U and ^{226}Ra in secular equilibrium) and an old Th-nitrate salt (with ^{232}Th and ^{228}Ra in equilibrium). The ^{226}Ra activity in samples was determined from the photon peaks of its daughters: ^{214}Pb (295.22 and 351.99 keV) and ^{214}Bi (609.32 keV) [*Moore*, 1984], whereas the ^{228}Ra activity was measured via the peaks of

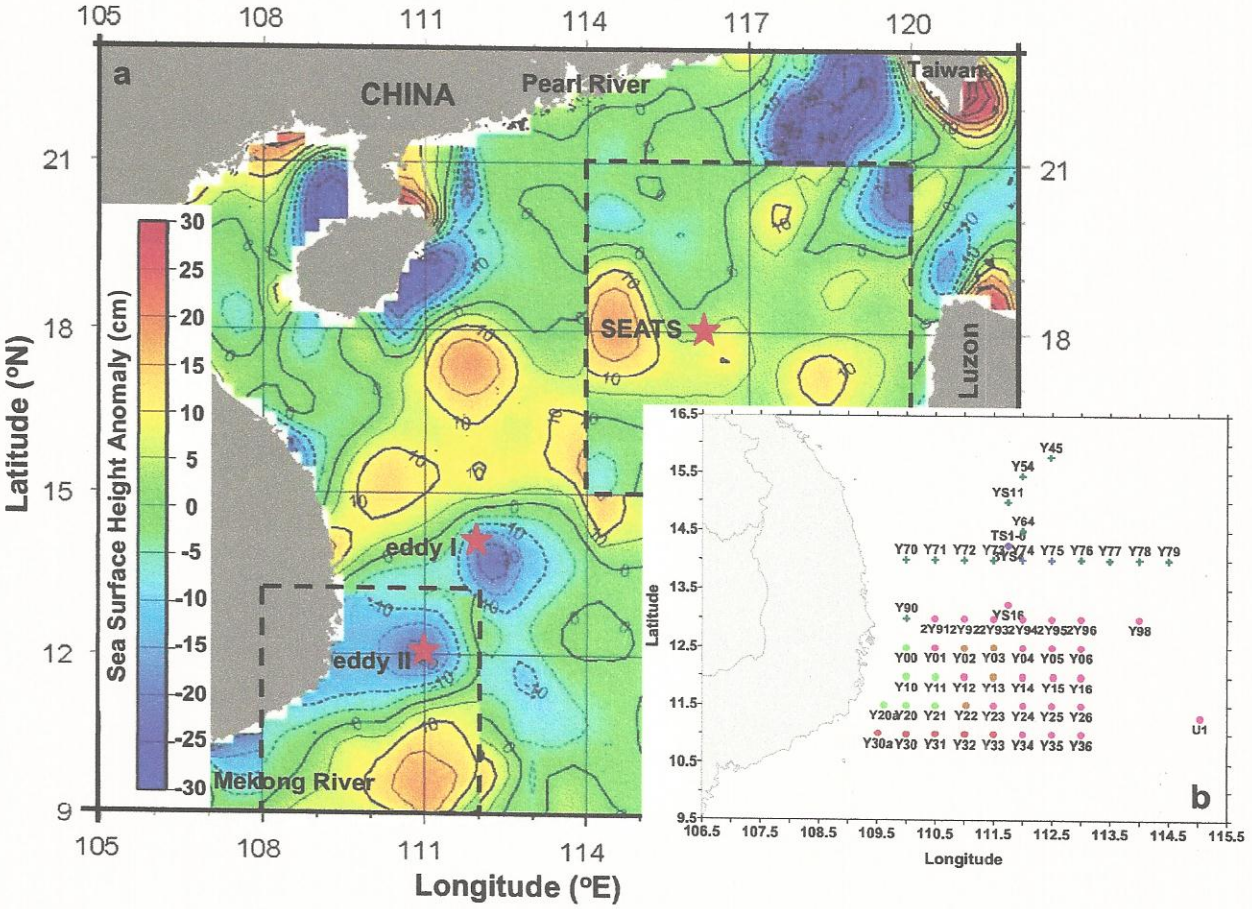

Figure 1. (a) Map showing a mosaic of real-time satellite images (taken on 23 August 2007) with contours of sea surface height anomaly (SSHA) in the South China Sea (http://argo.colorado.edu/~realtime/gsfc_global-real-time_ssh/). The whole image is for 23 August 2007 (date when samples from eddy I were taken), and the dashed lines on the map indicate boundaries of 5 September 2007 (date when samples from eddy II were taken) (108°E to 112°E, 9°N to 13°N) and 13 September 2007 (date when samples from SEATS were taken) (114°E to 120°E, 15°N to 21°N). Against the backdrop of the SSHA are three key stations (indicated by red stars) occupied for this study: eddy I (111.7°E, 14.2°N), eddy II (111.0°E, 12.0°N), and SEATS (115.96°E, 18.03°N). (b) All sampling sites during the cruise. Crosses represent stations during leg 1 (15–28 August 2007), and dots indicate stations in leg 2 (1–9 September 2007). The symbols are shown in various colors (as those used in Figure 4) to distinguish different water masses.

^{228}Ac at 338.63, 911.07 and 968.90 keV [*Elsinger et al.*, 1982; *Moore*, 1984]. The errors for the ^{228}Ra and ^{226}Ra measurements were 5–10%, including counting statistics and standard propagation of errors associated with the data reduction.

3. Results

3.1. Hydrography

[11] During the cruise, two well-developed cold eddies were identified from the sea surface height anomaly (SSHA). These two eddies (referred to as eddy I and eddy II hereafter) were centered at ~112.5°E, 13.5°N and 111°E, 12°N (Figure 1a). Altimetric history of these two cold-core cyclonic eddies suggested the intensification of eddy I from 14 August to 30 August and eddy II from 26 August to 12 September. Two stations were occupied inside the eddies (TS1 in eddy I and Y12 in eddy II; Figure 1b) and sampled during the intensification phases (eddy I: 23 August; eddy II: 5 September; Figure 1a).

[12] Figure 2 shows that sea surface temperature in the area covered varied from 27°C to >30°C and sea surface salinity varied from 31.3 to 34.3. Eddy I, with high salinity (>34) and low temperature (<28°C) at its center, clearly existed around 112°E, 14°N during leg 1 (Figures 2a and 2b), consistent with satellite altimetry observations during the same time showing negative SSHA (Figure 1a).

[13] A strong eastward jet characterized by low salinity (<32) and high temperature (>29°C) leaving the coast of Vietnam around 11°N was observed during leg 2 (Figures 2a and 2b). The low-salinity signal in this area can only be attributed to the input of fresh water from the northward Mekong River plume (J. Y. Hu et al., "The kinematics of a cold eddy in the southwestern South China Sea: An observational study," manuscript in preparation, 2010). *Voss et al.* [2006] have utilized the criterion of S < 33.2 to denote the

Table 1. Radium Isotopes (^{223}Ra, ^{228}Ra, and ^{226}Ra) in the Surface Water of the Western South China Sea

Sample Code	Longitude (°E)	Latitude (°N)	Sampling Date[a]	Salinity	^{223}Ra (dpm 100 L^{-1})	^{228}Ra (dpm 100 L^{-1})	^{226}Ra (dpm 100 L^{-1})	^{228}Ra/^{226}Ra[b]
Y70	110.0	14.0	2007-8-15	33.75	0.02	25.0 ± 8.8	9.0 ± 5.5	2.8 ± 2.0
Y71	110.5	14.0	2007-8-15	33.77	0.05	14.6 ± 2.9	6.4 ± 1.4	2.3 ± 0.7
Y72	111.0	14.0	2007-8-15	33.73	0.06	18.7 ± 3.0	8.8 ± 1.2	2.1 ± 0.4
Y73	111.5	14.0	2007-8-15	33.77	0.01	20.9 ± 2.9	8.4 ± 1.0	2.5 ± 0.5
Y74	112.0	14.0	2007-8-15	34.14	0.07	15.2 ± 1.4	6.6 ± 0.5	2.3 ± 0.3
Y75	112.5	14.0	2007-8-16	34.13	0.01	12.2 ± 2.5	8.6 ± 0.8	1.4 ± 0.3
Y76	113.0	14.0	2007-8-16	33.79	0.01	24.9 ± 1.8	8.1 ± 0.7	3.1 ± 0.3
Y77	113.5	14.0	2007-8-16	33.68	0.03	25.1 ± 3.6	9.5 ± 0.9	2.6 ± 0.5
Y78	114.0	14.0	2007-8-16	33.77	0.04	19.9 ± 2.1	7.5 ± 0.7	2.6 ± 0.4
Y79	114.5	14.0	2007-8-16	33.73	0.02	17.5 ± 2.4	7.8 ± 0.7	2.2 ± 0.4
Y90	110.0	13.0	2007-8-18	33.77	0.07	16.0 ± 1.3	6.2 ± 0.4	2.6 ± 0.3
Y64	112.0	14.5	2007-8-20	33.68	0.02	17.6 ± 1.7	8.0 ± 0.6	2.2 ± 0.3
Y54	112.0	15.5	2007-8-22	33.57	0.01	18.5 ± 2.6	7.2 ± 0.7	2.6 ± 0.4
TS1	111.7	14.2	2007-8-23	34.06	0.00	14.0 ± 1.3	9.4 ± 0.9	1.5 ± 0.2
YS11	111.7	15.0	2007-8-27	33.79	0.13	18.7 ± 1.6	6.7 ± 0.5	2.8 ± 0.3
Y45	112.5	15.8	2007-8-28	33.51	0.18	22.1 ± 2.9	7.5 ± 1.0	3.0 ± 0.5
3YS4	111.8	14.3	2007-9-1	32.63	0.20	48.2 ± 3.1	10.8 ± 0.6	4.5 ± 0.4
YS16	111.7	13.2	2007-9-1	32.46	0.15	45.3 ± 1.8	8.6 ± 0.5	5.3 ± 0.4
2Y91	110.5	13.0	2007-9-2	32.73	0.26	52.5 ± 3.9	11.3 ± 1.0	4.6 ± 0.5
2Y92	111.0	13.0	2007-9-2	33.27	0.13	30.6 ± 2.9	8.0 ± 0.7	3.8 ± 0.5
2Y93	111.5	13.0	2007-9-2	32.79	0.32	46.3 ± 2.9	9.2 ± 0.8	5.1 ± 0.5
2Y94	112.0	13.0	2007-9-3	32.88	0.20	41.4 ± 3.6	11.0 ± 0.8	3.8 ± 0.4
2Y95	112.5	13.0	2007-9-3	33.10	0.05	31.9 ± 3.5	9.1 ± 1.0	3.5 ± 0.5
2Y96	113.0	13.0	2007-9-3	33.27	0.06	24.1 ± 1.9	7.2 ± 0.6	3.4 ± 0.4
Y06	113.0	12.5	2007-9-3	32.66	0.06	28.9 ± 3.8	7.1 ± 1.2	4.1 ± 0.9
Y05	112.5	12.5	2007-9-3	32.83	0.06	32.8 ± 2.5	8.0 ± 1.0	4.1 ± 0.6
Y04	112.0	12.5	2007-9-3	33.04	0.20	28.6 ± 3.2	5.6 ± 1.2	5.1 ± 1.2
Y03	111.5	12.5	2007-9-4	33.23	0.14	24.2 ± 2.2	7.8 ± 0.8	3.1 ± 0.4
Y02	111.0	12.5	2007-9-4	33.49	0.10	24.9 ± 2.5	9.6 ± 1.1	2.6 ± 0.4
Y01	110.5	12.5	2007-9-4	32.93	0.15	37.9 ± 3.2	10.2 ± 2.1	3.7 ± 0.8
Y00	110.0	12.5	2007-9-4	33.70	0.02	15.7 ± 2.0	7.0 ± 1.0	2.2 ± 0.4
Y10	110.0	12.0	2007-9-4	33.70	0.09	16.4 ± 1.6	8.2 ± 1.1	2.2 ± 0.4
Y11	110.5	12.0	2007-9-5	33.42	0.09	18.7 ± 2.0	8.0 ± 0.9	2.3 ± 0.4
Y12	111.0	12.0	2007-9-5	32.59	0.07	35.6 ± 4.2	8.1 ± 1.7	4.4 ± 1.1
Y13	111.5	12.0	2007-9-5	33.53	0.05	21.3 ± 2.3	7.6 ± 0.8	2.8 ± 0.4
Y14	112.0	12.0	2007-9-5	32.41	0.28	46.1 ± 3.6	9.9 ± 1.3	4.7 ± 0.7
Y15	112.5	12.0	2007-9-5	32.26	0.26	38.1 ± 2.9	10.4 ± 0.9	3.7 ± 0.4
Y16	113.0	12.0	2007-9-5	32.38	0.14	42.4 ± 3.6	9.2 ± 1.3	4.6 ± 0.7
Y26	113.0	11.5	2007-9-6	32.41	0.14	39.3 ± 3.3	10.9 ± 1.2	3.6 ± 0.5
Y25	112.5	11.5	2007-9-6	32.38	0.35	31.4 ± 2.2	8.1 ± 0.8	3.9 ± 0.5
Y24	112.0	11.5	2007-9-6	32.51	0.19	36.8 ± 3.2	9.0 ± 1.5	4.1 ± 0.8
Y23	111.5	11.5	2007-9-6	32.53	0.36	36.6 ± 1.9	8.6 ± 0.9	4.2 ± 0.5
Y22	111.0	11.5	2007-9-6	33.43	0.04	22.5 ± 2.8	6.8 ± 0.9	3.3 ± 0.6
Y21	110.5	11.5	2007-9-7	33.60	0.11	16.7 ± 1.8	6.7 ± 0.7	2.5 ± 0.4
Y20	110.0	11.5	2007-9-7	33.72	0.15	14.7 ± 1.9	7.3 ± 0.7	2.0 ± 0.3
Y20a	109.6	11.5	2007-9-7	33.27	0.17	26.0 ± 3.1	7.4 ± 1.1	3.5 ± 0.7
Y30a	109.5	11.0	2007-9-7	31.29	0.54	53.2 ± 2.4	11.5 ± 1.4	4.6 ± 0.6
Y30	110.0	11.0	2007-9-7	31.50	0.46	53.9 ± 4.0	14.0 ± 2.1	3.9 ± 0.6
Y31	110.5	11.0	2007-9-7	31.26	0.74	61.5 ± 2.5	12.8 ± 1.1	4.8 ± 0.5
Y32	111.0	11.0	2007-9-8	31.48	0.57	52.5 ± 2.7	10.3 ± 0.9	5.1 ± 0.5
Y33	111.5	11.0	2007-9-8	31.75	0.41	47.9 ± 2.6	11.6 ± 1.1	4.1 ± 0.5
Y34	112.0	11.0	2007-9-8	32.47	0.17	39.5 ± 4.4	9.5 ± 2.0	4.2 ± 1.0
Y35	112.5	11.0	2007-9-8	32.56	0.04	38.4 ± 2.4	9.9 ± 0.8	3.9 ± 0.4
Y36	113.0	11.0	2007-9-8	32.31	0.34	43.1 ± 3.9	11.7 ± 1.3	3.7 ± 0.5
U1	115.0	11.3	2007-9-8	33.24	0.07	21.9 ± 1.4	6.9 ± 0.5	3.1 ± 0.3
Y98	114.0	13.0	2007-9-9	32.82	0.29	42.4 ± 2.0	9.2 ± 0.9	4.6 ± 0.5

[a]Date format is year-month-day.
[b]Activity ratio.

Mekong River influenced area in the western SCS. Based on the same criterion, our data suggested that the Mekong River may have influenced about half of the western SCS during leg 2 (Figure 2a).

[14] The eastward jet curled up around 112°E and formed a cyclonic eddy centered around 111°E, 12.5°N (eddy II) to the north of the jet, with high-salinity (>33.2) and low-temperature (~28.2°C) water at the center of the eddy (Figures 2a and 2b). Compared to eddy I, the surface signatures of salinity and temperature in eddy II were less evident, which might be due to the Mekong River plume. Hu et al. (manuscript in preparation) suggest that due to surface heating and the Mekong River plume, the surface signatures of eddy II was not as evident as those below 25 m. Such a circulation pattern is again consistent with satellite altimetry observations (Figure 1a) and is also observed in

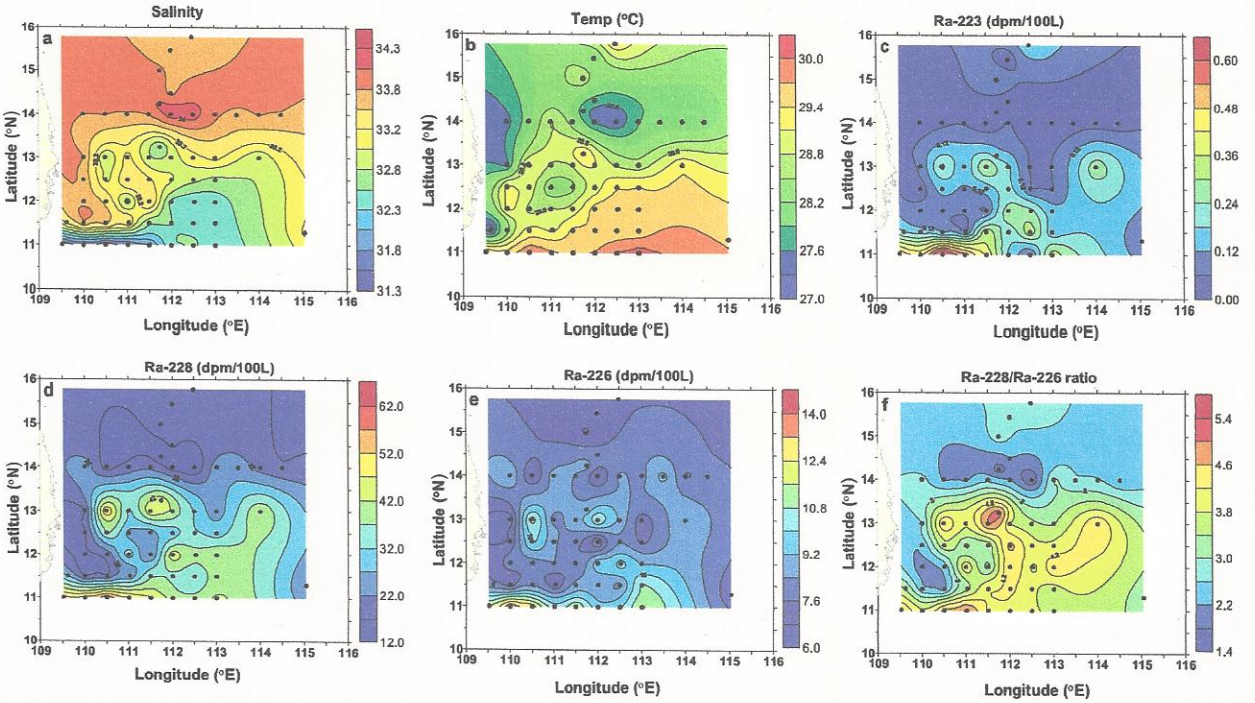

Figure 2. Contour maps showing distribution of (a) salinity, (b) temperature (°C), (c) ^{223}Ra (dpm/100 L), (d) ^{228}Ra (dpm/100 L), (e) ^{226}Ra (dpm/100 L), and (f) ^{228}Ra/^{226}Ra activity ratio in the western South China Sea. Contour lines on the maps are plotted with a software package (SURFERTM by Golden Software) using a linear kriging technique to grid the data points. Note that the contour maps were plotted without considering temporal variations from leg 1 to leg 2 and between stations for the known reasons associated with any ship-based observations.

previous studies [*Fang et al.*, 2002; *Shaw et al.*, 1999], and thus may represent a perennial phenomenon.

[15] Along the southeast Vietnam coast, the elevated salinity (>33.5) suggested upwelling of the subsurface water. As mentioned earlier, coastal upwelling off southeast Vietnam is a typical feature during summer, which is very often enhanced by the eastward jet [*Dippner et al.*, 2007; *Fang et al.*, 2002].

3.2. Water Column Profiles of ^{228}Ra and ^{226}Ra in the SCS

[16] To assess the impact of vertical processes on the distribution of Ra isotopes in surface waters, the water columns at stations TS1 and SEATS were sampled on 23 August and 13 September, respectively, for ^{228}Ra and ^{226}Ra analyses. The profiles (Figure 3) show a sharp decrease with depth of ^{228}Ra across the thermocline and an increase with depth of ^{226}Ra throughout the water column. These trends are typical of these two Ra isotopes and indicate that ^{228}Ra-enriched surface water is advected laterally from adjacent shelf areas, whereas ^{226}Ra is primarily derived from the bottom [*Ku and Luo*, 1994; *Moore*, 1969]. Downward transport of ^{228}Ra is limited by its short half-life and hindered by the strong density gradient below the surface mixed layer. Therefore, ^{228}Ra is usually depleted in the interior of ocean basins and away from boundaries. In contrast, ^{226}Ra is more concentrated near its bottom source, i.e., the ^{230}Th-enriched sediments at the deep ocean floor, and this long-lived Ra isotope can be transported on a basin-wide scale.

[17] These profiles suggested that upwelling of subsurface water lowered ^{228}Ra but raised ^{226}Ra activities at the surface.

3.3. Sea Surface Distribution of ^{223}Ra, ^{228}Ra, ^{226}Ra, and ^{228}Ra/^{226}Ra

[18] Surface activities of ^{228}Ra, ^{226}Ra and ^{223}Ra showed considerable spatial variations in the study area (Table 1 and Figure 2). During leg 1, the ^{223}Ra activity was almost undetectable (<0.1 dpm/100 L) except at Station YS11 and Station Y45, while the ^{228}Ra activity ranged from 12 ~ 25 dpm/100 L with the lowest value around Station TS1 (Figures 2c, 2d, and 2e). We explain this feature by the addition of ^{228}Ra-depleted subsurface water at the center of eddy I.

[19] Ra-223 and Ra-228 measured during leg 2 were higher (>30 dpm/100 L) than those measured during leg 1 except at the center of eddy II and along the Vietnam Coast. The most salient feature during leg 2 was a tongue with high ^{223}Ra (>0.4 dpm/100 L), ^{228}Ra (>48 dpm/100 L) and ^{226}Ra (>10 dpm/100 L) extending eastward from the Vietnam coast along ~11°N (Figures 2c, 2d, and 2e). The presence of the highest ^{223}Ra and ^{228}Ra to the south of the western SCS reaffirmed that the Mekong River was the source of these freshened waters. Along the track of the jet described above,

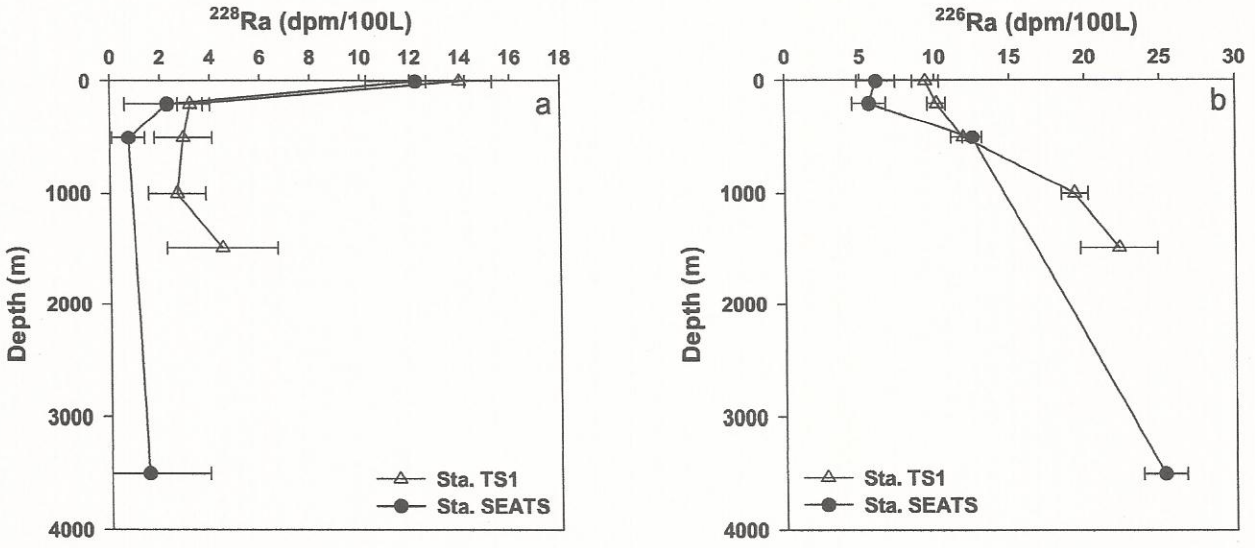

Figure 3. Vertical profiles of (a) ^{228}Ra (dpm/100 L) and (b) ^{226}Ra (dpm/100 L) at Station TS1 (triangles) and Station SEATS (solid circles) in the South China Sea.

the activity of ^{223}Ra decreased from >0.6 to <0.3 dpm/100 L (Figure 2c) due to mixing and radioactive decay. Similar to the pattern of ^{223}Ra, the ^{228}Ra activity decreased from >50 to <30 dpm/100 L along the jet track, mimicking the distribution of salinity (Figure 2d). In contrast, the long-lived ^{226}Ra was more evenly distributed in the western SCS, except in the aforementioned regions with high activities (Figure 2e). Previous studies show that the activity of ^{228}Ra is much higher than that of ^{226}Ra in estuarine waters due to more pronounced release of ^{228}Ra from estuarine sediments [*Key et al.*, 1985; *Moore*, 1981; *Moore et al.*, 1986]. Due to its much longer half-life, the decay of ^{226}Ra can be ignored. Thus the concentration gradient of ^{226}Ra between inshore and offshore waters was much smaller compared with those of ^{223}Ra and ^{228}Ra.

[20] Along the Vietnam coast (stations Y00, Y10, Y20a and Y20), the ^{223}Ra activities were low or almost undetectable (<0.15 dpm/100 L) and the ^{228}Ra activities were also low (averaging 16.8 ± 1.2 dpm/100 L) compared to other sites occupied during leg 2. In view of the location of these sites, coastal upwelling off the southeast Vietnam, which is a typical phenomenon in summer, may be responsible for the observed low activities. Compared to those around the center of eddy I (Station Y74, Station Y75 and Station TS1, 14–16 dpm/100 L) and the aforementioned upwelling regime, ^{228}Ra activities at the center of eddy II were substantially higher (20–25 dpm/100 L). We relate this to the encirclement of the Mekong River plume around the edge of eddy II (Hu et al., manuscript in preparation).

[21] Our ^{228}Ra and ^{226}Ra activities measured during leg 1 compared favorably with those reported previously for adjacent locations in winter (^{228}Ra: 14.9–18.4 dpm/100 L; ^{226}Ra: 7.0–8.7 dpm/100 L) [*Nozaki and Yamamoto*, 2001]. Also, the ^{228}Ra activities measured during leg 2 were comparable with the values in the Nansha Archipelago (i.e., to the south of the eastward jet) in the same season (>30 dpm/100 L) [*Huang et al.*, 1996]. However, in November, the activities of ^{228}Ra in the Nansha Archipelago dropped to 19.6 dpm/100 L [*Cai et al.*, 2002], similar to our results during leg 1. In summer, the eastward jet bifurcates in the vicinity of 113°E with the southern branch turning to the south [*Fang et al.*, 2002; *Shaw et al.*, 1999], which might result in higher ^{228}Ra activities in the Nansha Archipelago during this period.

[22] During leg 1, the ^{228}Ra/^{226}Ra ARs were lowest (1.4–2.3) at the center of eddy I and averaged 2.6 ± 0.3 for the rest of the sites (Figure 2f). In contrast, the ^{228}Ra/^{226}Ra ARs obtained in leg 2 were substantially higher (>3), with the lowest ratios (<2.6) confined to the coastal upwelling area. Along the pathways of the jet, the ^{228}Ra/^{226}Ra ARs were 3.4–5.3, which stood out from the study area and certainly represented water from the Mekong estuary (Figure 2f).

3.4. Radium Isotope Versus Salinity Diagrams

[23] In lieu of T-S diagrams, the ^{228}Ra activities and ^{228}Ra/^{226}Ra ARs were plotted versus salinity to identify water masses in the western SCS (Figures 4a and 4c). The ^{223}Ra and ^{226}Ra activities were also plotted versus salinity for further reference (Figures 4b and 4d). Based on these plots, the surface seawater in the study area may be roughly divided into six water masses, two for leg 1 and four for leg 2 (Which are also indicated in Figure 1b by the same colored symbols as in Figure 4). The former two were set out at the high-salinity end (>33.5) with low ^{228}Ra/^{226}Ra ARs (<3) in Figure 4c while the latter four lay at the opposite end except the coastal upwelling water (CUW). During leg 1, the surface water, apart from eddy I, was not affected by the freshened water and had ^{228}Ra/^{226}Ra ARs similar to the values for winter surface water (~2.2 [*Nozaki and Yamamoto*, 2001]). Thus it represented the surface water under normal "background" conditions. At the center of eddy I, the surface water showed a different characteristic. If the water at 200 m of Station TS1 was used to represent the subsurface water, the plots of ^{228}Ra and ^{228}Ra/^{226}Ra AR versus salinity suggested

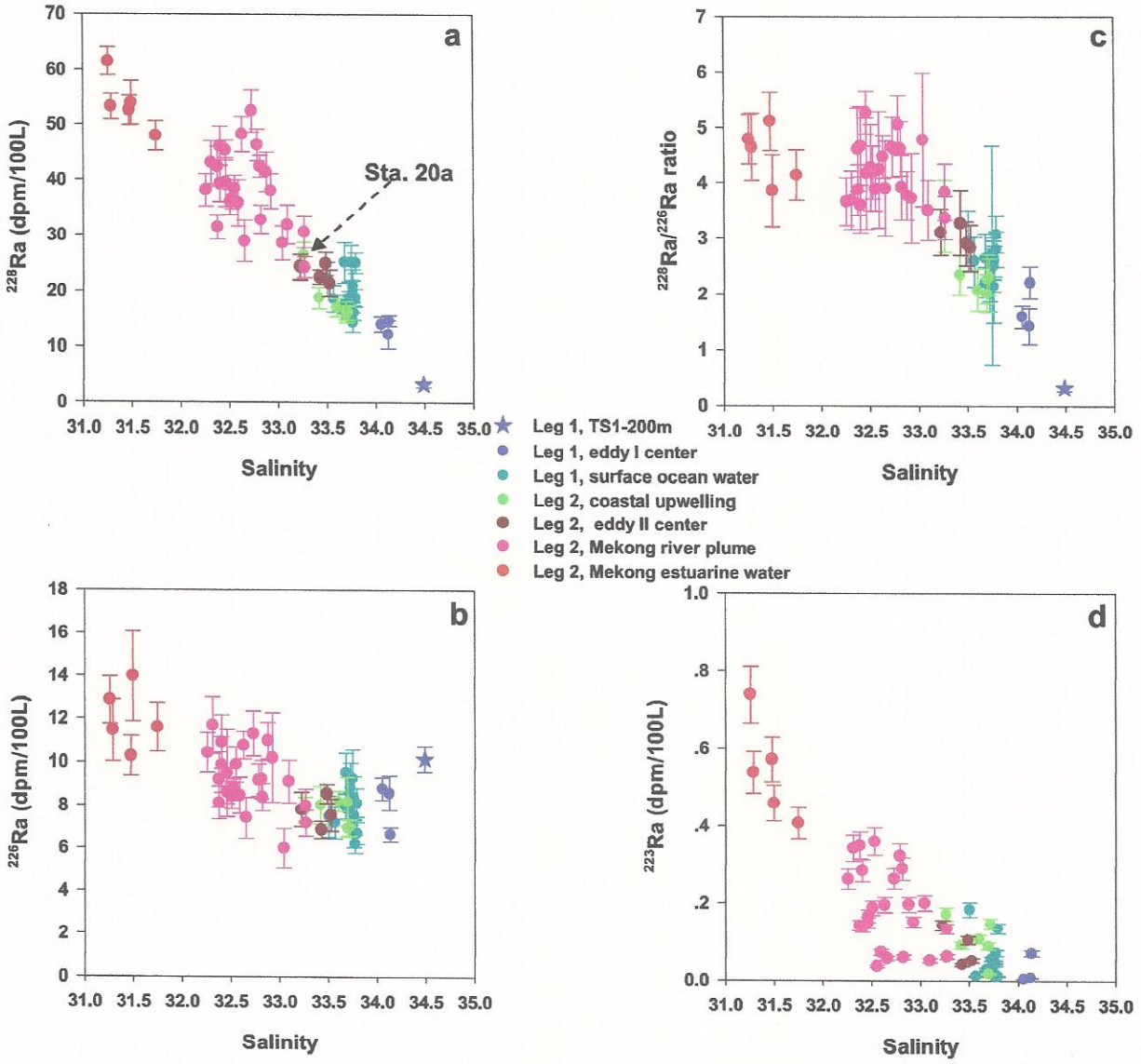

Figure 4. Diagrams of (a) ^{228}Ra (dpm/100 L), (b) ^{226}Ra (dpm/100 L), (c) ^{228}Ra/^{226}Ra, and (d) ^{223}Ra (dpm/100 L) versus salinity in the surface water of the western South China Sea. The water was categorized into six groups: eddy I center water (blue dots), surface ocean water (dark cyan dots), coastal upwelling water (green dots), eddy II center water (dark red dots), Mekong River plume water (pink dots), and Mekong estuarine water (red dots). The blue star represents subsurface water at the center of eddy I.

that the surface water at the center of eddy I was a mixture of the ambient surface water and the subsurface water.

[24] Characterizing the surface water during leg 2 was more complicated. Although it was relatively easy to identify the Mekong estuarine water (S < 32), the water can only be taken as a pseudo-end-member for river water. The other water masses were Mekong River plume water (MRPW), eddy II center water (ECW) and coastal upwelling water (CUW) (Figure 4). The criterion of S < 33.2 and higher ^{228}Ra/^{226}Ra ARs (>3) was used to denote the MRPW. It would be difficult to distinguish between ECW and CUW based on temperature-salinity or silica-salinity relationships (M. Dai, unpublished data, 2007). However, this can be done more easily using the ^{228}Ra and ^{228}Ra/^{226}Ra AR versus salinity diagrams. Unlike the water at the center of eddy I, the ECW was located between the ambient surface water (leg 1) and the MRPW in the diagram (Figure 4c), implying that the latter was swirled into the former and entrained in the eddy. In comparison with the ECW, the CUW was closer to the subsurface water (Figure 4c), suggesting more subsurface water input from coastal upwelling. Thus, higher ^{228}Ra activities and ^{228}Ra/^{226}Ra ARs appeared in the ECW,

making a fine distinction between ECW and CUW. It should be noted that, although the water at Station Y20a was categorized as the CUW, it was somewhat distant from the CUW at other sites but closer to the MRPW in Figure 4a, which suggested that it might be affected by the Mekong River plume or by diffusion of the coastal water for it was inshore of other stations.

4. Discussion

4.1. Revealing the Mekong River Plume Component

[25] The rather high ^{228}Ra activities and ^{228}Ra/^{226}Ra ARs in the western SCS and hence steep gradients of these values clearly showed the influence of the Mekong River plume on the study area. Assuming conservation of salt and the longer-lived radium isotopes (^{228}Ra and ^{226}Ra) and using the two-end-member mixing model of *Moore et al.* [1986] and *Moore and Todd* [1993], the contribution of the Mekong estuary water to the surface water in the western SCS can be estimated by solving the following equations:

$$f_{oc} + f_{es} + f_{P-E} = 1 \quad (1)$$

$$S_{obs} = S_{oc} \times f_{oc} + S_{es} \times f_{es} \quad (2)$$

$$AR_{obs} = \left(^{228}Ra_{oc} \times f_{oc} + ^{228}Ra_{es} \times f_{es}\right) / \left(^{226}Ra_{oc} \times f_{oc} + ^{226}Ra_{es} \times f_{es}\right) \quad (3)$$

where f means the fraction (out of 1), S is salinity, ^{228}Ra and ^{226}Ra are activities of the indicated Ra isotopes, AR is the ^{228}Ra/^{226}Ra activity ratio, and the subscripts oc, es, obs, E and P represent the oceanic end-member, the estuarine end-member, the observed values, evaporation and precipitation, respectively. Here, salinity was used to correct for evaporation/precipitation. Although we can solve the two-end-member mixing model with the ^{226}Ra or the ^{228}Ra distribution alone, it is better to choose the ^{228}Ra/^{226}Ra activity ratio not only for better quality of the activity ratio (determined from one gamma spectrum), but also to reduce the effect of biological utilization of a single isotope on the calculation.

[26] From the above equations, f_{es} and f_{oc} can be solved as follows:

$$f_{es} = \frac{S_{obs} \times (AR_{obs} \times ^{226}Ra_{oc} - ^{228}Ra_{oc})}{AR_{obs} \times (^{226}Ra_{oc} \times S_{es} - ^{226}Ra_{es} \times S_{oc}) - ^{228}Ra_{oc} \times S_{es} + ^{228}Ra_{es} \times S_{oc}} \quad (4)$$

$$f_{oc} = \frac{S_{obs} - S_{es} \times f_{es}}{S_{oc}} \quad (5)$$

[27] In applying the model, there are two underlying assumptions. One is that salinity and the activities of Ra isotopes in the two end-members do not change over the time period of interest; the other is that there is no addition or loss of Ra isotopes except by horizontal mixing [*Moore et al.*, 1986; *Moore and Todd*, 1993]. In our study, the second assumption was obviously not applicable to the coastal upwelling regime due to the input from the subsurface water. Thus, the estuarine fraction was estimated only for the stations covered by the MRPW as defined by the radium isotope versus salinity diagrams. The following end-member values were used in the calculation:

$$S_{es} = 31.26$$

$$^{228}Ra_{es} = 61.5 \pm 2.5 \text{ dpm}/100\text{ L}$$

$$^{226}Ra_{es} = 12.8 \pm 1.1 \text{ dpm}/100\text{ L}$$

$$S_{oc} = 33.74$$

$$^{228}Ra_{oc} = 21.7 \pm 3.3 \text{ dpm}/100\text{ L}$$

$$^{226}Ra_{oc} = 8.5 \pm 0.7 \text{ dpm}/100\text{ L}$$

[28] Here, the values at Station Y31 were taken to represent the estuarine end-member because of the lowest-salinity and the highest ^{228}Ra and ^{223}Ra activities, while the average values for section Y7 during leg 1 were used as the oceanic end-member. However, the values at Station Y74 and Station Y75 were excluded because they were probably influenced by the subsurface water.

[29] The calculated values for f_{es} in the western SCS are listed in Table 2 and Figure 5. To the east of 112°N, the f_{es} values decreased with distance offshore and were less than 50% except at Station Y16 and Station Y98. In contrast, the f_{es} values varied from 40% to 140% to the west of 112°N without any obvious trend, probably suggesting more complicated oceanic conditions in that region. Small-scale irregularity in convergence/divergence associated with an eddy or upwelling might add or subtract Ra isotopes from the system and affect the model calculation. To cancel out these possible effects we took all stations, except the upwelling regime and those affected by eddy II during leg 2, as a whole and calculated an overall f_{es} value of 0.53 based on the same end-member values. It should be noted that any results derived from a model are no better than the assumptions made. In this case, we were not able to test the assumption that the estuarine component remained constant over the time period of interest. Nor could we fully justify our use of the pseudo estuarine end-member. Previous studies show that the calculation of the f_{es} value is very sensitive to the assignment of end-member values [*Moore et al.*, 1986]. We performed a sensitivity analysis of the f_{es} by varying salinity and Ra activities for the estuarine end-member (Figure 6). For initial ^{228}Ra and ^{226}Ra activities (^{228}Ra = 61.5 dpm/100 L; ^{226}Ra = 12.8 dpm/100 L), setting the estuarine end-member at S = 21 rather than S = 31.26 would increase the computed estuarine component by 20%. On the other hand, with salinity fixed, changing either ^{228}Ra or ^{226}Ra activities by ±5% from the values given above would result in changes of the f_{es} value by 10–40%. The

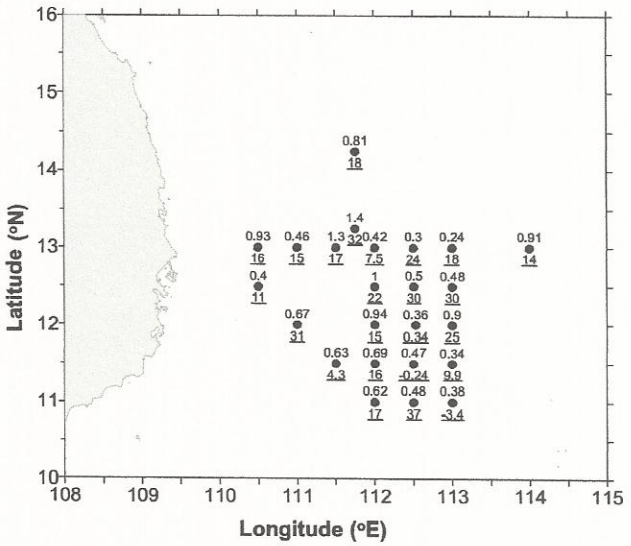

Figure 5. Map showing spatial variation of the estuarine component f_{es} (values indicated above the dots) and apparent age (underlined values below the dots) of the Mekong River plume in the western South China Sea. These values were calculated using a model and with the end-member discussed in the text.

uncertainty of the model and the use of the pseudo estuarine end-member might explain the unusually high f_{es} and negative f_{oc} at some stations. Despite all these uncertainties, the rough estimates made above still revealed a strong signature of the Mekong River plume in the western SCS, although quantitative assessment remains difficult.

4.2. Age of the Mekong Plume Water Derived From ^{223}Ra

[30] The ^{223}Ra-salinity relationship shown in Figure 4d, with the highest ^{223}Ra activity corresponding to the lowest salinity near the Mekong River estuary, unequivocally points to the dispersal of the river water offshore. After this plume water enters the western SCS, it floats at the surface and is carried farther away from the estuarine water and sediment-water interface, i.e., the sources of ^{223}Ra. Thus, the decrease of ^{223}Ra in these waters may be used to estimate the apparent age of the Mekong River plume with reference to its end-member water along its transport pathway. This method was proven to be applicable to the study of the Mississippi plume [*Moore and Krest*, 2004]. The equation for apparent age (t) is

$$t = -\frac{\ln\left[\frac{^{223}Ra_{obs}}{^{223}Ra_{es} \times f_{es}}\right]}{\lambda_{223}} \quad (6)$$

where λ_{223} is the decay constant of ^{223}Ra, 0.061 d^{-1}.

[31] The calculated apparent ages of the MRPW varied from a few days to more than one month, with most of them longer than 10 days (Table 2 and Figure 5). A significant uncertainty in the ^{223}Ra-derived ages is the determination of f_{es}, and therefore the negative water ages might be related to the unusually high f_{es}. Additionally, the initial ^{223}Ra activities might vary temporally in the estuary due to the difference in sediment interaction and groundwater input [*Moore*, 2000a], which could also affect the estimate of ^{223}Ra-derived ages. Using f_{es} = 0.53, $^{223}Ra_{es}$ = 0.74 dpm/100 L (Station Y31) and $^{223}Ra_{obs}$ = 0.167 dpm/100 L (i.e., the average of all stations except the upwelling regime during leg 2), the calculated age was ~14 days. This represented an

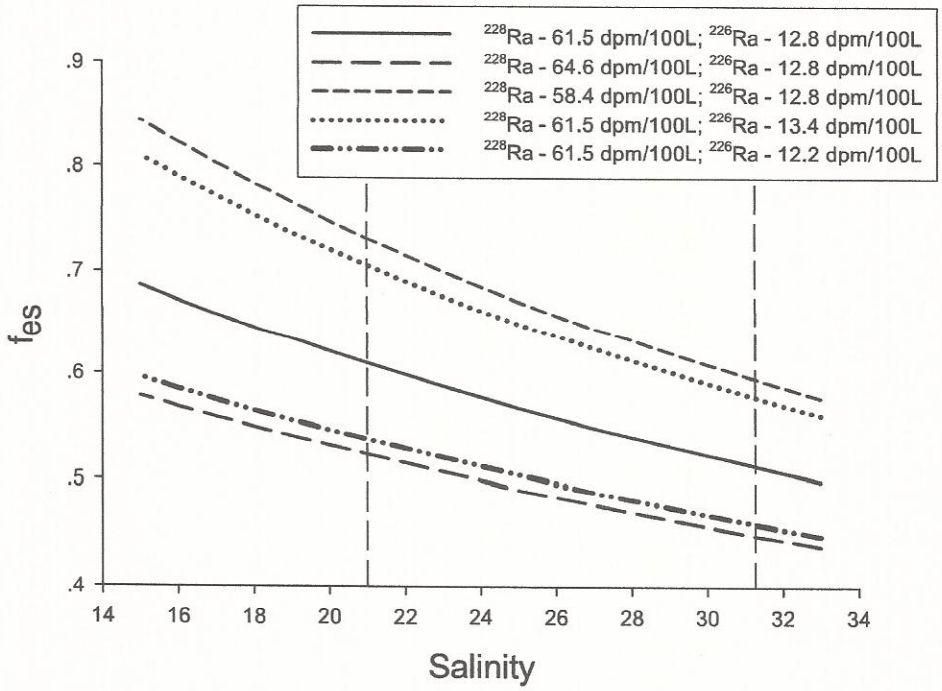

Figure 6. A schematic plot showing the sensitivity of the calculated f_{es} value to the assigned salinity, the initial Ra activities (^{228}Ra = 61.5 dpm/100 L; ^{226}Ra = 12.8 dpm/100 L), and their variations (i.e., ±5%).

Table 2. Values Used on a Two-End-Member Mixing Model and the Calculated Ages of Freshened Waters in the Western South China Sea

	Salinity	$^{228}Ra/^{226}Ra$[a]	^{223}Ra (dpm 100 L^{-1})	Fraction Mekong, End-Member	Age (Days)
Sample 3YS4	32.6	4.5	0.20	0.82	18.3
Sample YS16	32.5	5.3	0.15	1.44	-
Sample 2Y91	32.7	4.6	0.26	0.93	15.6
Sample 2Y92	33.3	3.8	0.13	0.48	16.0
Sample 2Y93	32.8	5.1	0.32	1.25	-
Sample 2Y94	32.9	3.8	0.20	0.44	8.3
Sample 2Y95	33.1	3.5	0.05	0.33	25.4
Sample 2Y96	33.3	3.4	0.06	0.27	19.5
Sample Y06	32.7	3.9	0.06	0.50	30.6
Sample Y05	32.8	3.9	0.06	0.51	30.2
Sample Y04	33.0	4.8	0.20	1.04	21.8
Sample Y01	32.9	3.7	0.15	0.42	11.8
Sample Y12	32.6	4.2	0.07	0.67	31.5
Sample Y14	32.4	4.7	0.28	0.94	14.5
Sample Y15	32.3	3.7	0.26	0.38	1.3
Sample Y16	32.4	4.6	0.14	0.90	25.2
Sample Y26	32.4	3.6	0.14	0.36	11.0
Sample Y25	32.4	3.9	0.35	0.48	0.3
Sample Y24	32.5	4.3	0.19	0.70	16.4
Sample Y23	32.5	4.2	0.36	0.64	4.5
Sample Y34	32.5	4.2	0.17	0.63	16.9
Sample Y35	32.6	3.9	0.04	0.49	37.7
Sample Y36	32.3	3.7	0.34	0.40	−2.5
Sample Y98	32.8	4.6	0.29	0.91	13.8
Average[b]	32.8 ± 0.4	4.0 ± 0.6	0.17 ± 0.10	0.53	13.9

[a]Activity ratio.
[b]The average for the stations except for the coastal upwelling regime during leg 2.

apparent time period for the Mekong plume to travel from the perceived location of the pseudo estuarine end-member (to be further discussed in 4.3).

[32] In addition to ^{223}Ra, ^{224}Ra is also a potential tracer for calculating the apparent age of freshened water. However, ^{224}Ra should be applied to a time scale less than 2 weeks due to its short half-life. For instance, using ^{224}Ra, *Moore and Todd* [1993] calculate an age of less than 10 days for freshened water in the Caribbean Sea and, using $ex^{224}Ra/^{223}Ra$, *Moore and Krest* [2004] obtain an age of <14 days for most of the Mississippi plume water. Considering the long distance from Station Y31 to the Mekong estuary (~10°N, 107°E), the age of the Mekong plume in the western SCS is probably too old for ^{224}Ra to be a suitable tracer in this case.

4.3. Transit Time of the Mekong Plume Water

[33] During the cruise, Station TS1 was occupied twice, first on 23 August (leg 1) and then on 1 September (leg 2). Indeed, during this 9 day time span, large changes were observed at this site, with the ^{228}Ra activity increasing from 15 to 48.2 dpm/100 L, the ^{223}Ra activity from nil to 0.20 dpm/100 L, and the $^{228}Ra/^{226}Ra$ AR from 1.5 to 4.5. Meanwhile, salinity decreased from 34.06 to 32.63 (Table 1). Therefore, these changes strongly suggest an increased input of fresh water from leg 1 to leg 2. Since Station TS1 is located in the center of the western SCS, the Mekong River water carried by the SVOC was the only possible explanation for these low-salinity and high radium isotope signals. This scenario is analogous to what was observed in the western Atlantic where the signal of the Amazon River's water could be traced even to a distance 1500 km from the river's mouth [*Moore et al.*, 1986]. The SVOC current system may transport at a velocity of 50–120 cm/s according to *Fang et al.* [2002]. Using the lower end of the current velocity, it would take ~2 weeks to travel ~700 km, approximately the distance from the Mekong River's mouth to Station TS1. This estimate was consistent with the Mekong plume age derived from ^{223}Ra.

[34] Although we do not have time series data of Ra isotopes in the eddy, surface salinity at TS1 remained high

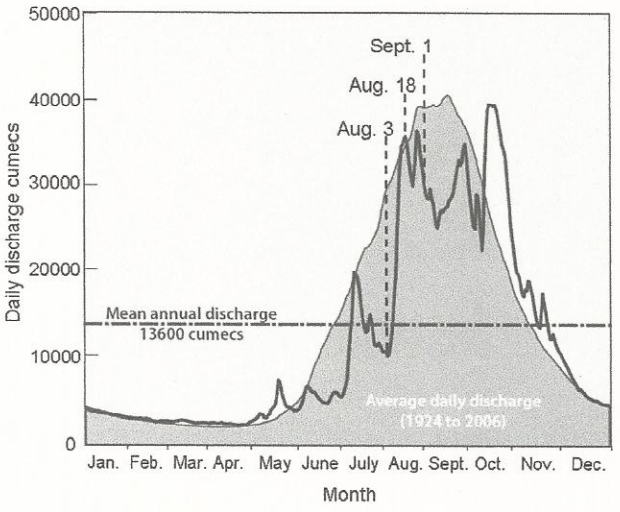

Figure 7. The daily discharge (m^3/s (cumecs)) in 2007 (thick line) compared with an 83 year historical mean daily discharge (thin curve) and mean annual discharge (the dash-dotted line) at Kratie (the lower reach of the Mekong River) (redrawn from Figure 30 of *MRC* [2008] with permission).

from 22 August to 27 August without any indication of freshwater input during this period (M. Dai, unpublished data, 2007). Based on the daily discharge record at Kratie (the lower reaches of the Mekong River), 3 August marked the beginning of the 2007 flood season of this river [*MRC*, 2008] and the first peak discharge happened on 18 August (Figure 7). It is interesting to note that the interval between these dates and the time when Station TS1 was revisited (27 August to 1 September) again supports the view that it may take 2–4 weeks for Mekong River water to reach Station TS1.

5. Conclusion

[35] Isotopes of Ra constitute a unique set of tracers for studying river plumes and the associated water circulation and biogeochemical processes. Their utility as built-in time elements for water in the plume cannot be readily replaced by other means.

[36] During August–September 2007, a jet of water with high radium activities and high $^{228}Ra/^{226}Ra$ ARs extended eastward from the Vietnam coast along ~11°N, curling up in the vicinity of 112°E and swirling counterclockwise to form a cyclonic eddy to the north of the western SCS. In contrast, lower levels of ^{228}Ra and $^{228}Ra/^{226}Ra$ were observed in the coastal upwelling and at the center of cold eddies. The observed distribution of Ra isotopes was consistent with the general circulation pattern of surface water in the western SCS in summer.

[37] The source of the observed high radium activities was no doubt the Mekong River plume. Using a simple two-end-member mixing model based on the $^{228}Ra/^{226}Ra$ AR and salinity, we estimated that approximately 53% of the surface water in the western SCS originated from the Mekong River plume in summer. The apparent age derived from ^{223}Ra revealed that more than 2 weeks were required to transport the freshened water several hundred kilometers from the Mekong River mouth into the western SCS. These estimates entailed the use of a pseudo estuarine end-member (Station Y31) due to difficulties in taking samples in the estuarine mixing zone. Despite the fact that the Mekong estuary was not studied in this work, our data strongly demonstrated the applicability of Ra isotopes in studying water mixing processes after the Mekong River plume left the river mouth. Although they may lead to uncertainties of 10–40% or even more in the calculation of f_{es}, these estimates still reveal a strong signature of the Mekong River plume in the western SCS.

[38] Besides supplying radium isotopes, the river plume may provide nutrients and other materials, thus affecting the biogeochemistry (such as nitrogen fixation) in its estuary and beyond. Further effort is certainly warranted to explore the utility of multiple Ra isotopes in studying the oceanic circulation and mixing of riverine water and the associated chemical dynamics.

[39] **Acknowledgments.** This work was supported by the Natural Science Foundation of China through grant 40821063 and by the NSC through grant NSC97-2611-M-001-002-MY3. We are grateful to the captain and crew of R/V *Dongfanghong-II* for their assistance at sea. We also thank Tzu-Chi Yeh, Qian Li, and Yang Liu for their help in the field and/or in the laboratory and Professor John Hodgkiss for polishing the English in this manuscript. Comments from Michiel Rutgers van der Loeff and an anonymous reviewer have improved the quality of the paper.

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2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and 2,3,7,8-Tetrachlorodibenzo-p-Furan (TCDF) In Blue Crabs and American Lobsters from the New York Bight

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ABSTRACT

An investigation of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and 2,3,7,8-tetrachloro dibenzo-p-furan (TCDF) bioaccumulation in blue crabs and American lobsters collected from Newark Bay and the New York Bight revealed widespread contamination across the continental shelf. Separate analyses of muscle and hepatopancreas tissue identified the presence of TCDD and TCDF in the latter tissue only. Analyses of the edible tissue (combined muscle and hepatopancreas) displayed varying concentrations across the ranges of both organisms. Blue crabs from the winter dredge fishery area, at their seaward migratory limit, displayed the highest levels (TCDD = 73 pg./g; TCDF = 67 pg./g). American lobsters sampled beyond the ocean dumpsites for harbor dredge spoils have slightly higher levels of TCDD (Mean: 40 pg./g) than inshore, Ambrose fishery lobsters (31 pg./g) and offshore lobsters caught near the edge of the continental shelf. Some locational differences are caused by offshore dumping of dredge spoils and are shown to fluctuate seasonally due to the migratory movements of the lobsters. The additive toxicity of TCDF was calculated as TCDD equivalents, summed with the measured TCDD and compared to FDA "Levels of Concern" and revealed unacceptable levels of risk associated with the consumption of these organisms.

INTRODUCTION

In 1984, dioxin contamination of soils was discovered at a pesticide-manufacturing site on the Passaic River in New Jersey prompting a study of sediments and biota both upstream to the head of tide and downstream into Newark Bay and the New York Bight (1). Sixty percent of the sediments sampled from the river, adjacent to the facility, showed detectable levels of 2,3,7,8-tetrachloro dibenzo-p-dioxin (TCDD) with higher levels being found upstream and at depth possibly due to the flood dominated, salt--wedge dynamics in the estuary. It is estimated that substantial quantities of this contaminant are in storage within the sediments of the river and its downstream embayment as well as at the dredge spoil dumpsite, 12 miles offshore, in the New York Bight (Figure 1).

A wide range of finfish and crustacea from the river showed tissue levels of TCDD (Figure 1a). Blue crabs from the lower estuary contained the highest concentrations (Mean: 468 pg./g in hepatopancreas and 22 pg./g in muscle). Several migratory species, blue crabs and striped bass from the downstream embayments and American lobsters from nearshore ocean waters also showed elevated levels of TCDD. American lobsters from the New York Bight showed consistently high levels of TCDD in the edible hepatopancreas (Mean: 77 pg./g) and combined muscle and hepatopancreas (Mean: 44 pg./g). These lobsters were collected at the mouth of New York harbor and approximately twenty miles offshore beyond the ocean waste disposal sites for dredge spoils, fly ash and sewage sludge.

The identification of TCDD in blue crabs and lobsters distant from the only apparent source suggested a more widespread zone of contamination and a potentially higher human health risk due to the intensive amount of commercial fishing in these offshore waters. The objectives of the present study were to: 1.) Investigate other potential areas of TCDD impact by sampling the seaward migratory limit of the blue crab (i.e., Raritan Bay) and the entire migratory range of the American lobster within the New York Bight (i.e., up to 150 miles offshore); 2.) Estimate the relative effects of location and season on lobster contamination due to their migratory behavior; 3.) Identify the presence of TCDF in the animals (which shows an equivalent level of toxicity compared to TCDD); 4.) Convert any levels of TCDF found into TCDD equivalents for summation of the total risk as compared to the Food and Drug Administration's (FDA) "Levels of Concern" for TCDD; and to 5.) Investigate the relative role of the Historical Area

Remediation Site (HARS) or ocean dredge material dumpsite as a possible intermediary in the transport of TCDD and TCDF to ocean waters and biota.

EXPERIMENTAL SECTION

Sampling

Blue crabs were collected by the use of crab pots, otter trawls and purchases from commercial Crabbers. Sites sampled included locations from Raritan Bay, Sandy Hook Bay and upper New York harbor. American lobsters were collected in lobster pots and otter trawls for Raritan and Sandy Hook Bays or purchased from commercial lobstermen for deepwater areas. Lobster catch locations were sub-divided into three fisheries as defined by NMFS, the National Marine Fishery Service (2), which generally reflect different ports of departure for the fishing fleets operating in these waters (Figure 2). The Ambrose fishery includes Raritan and Sandy Hook Bays extending to a hypothetical 7 nautical mile radius on the Ambrose Light leading into New York Harbor. This area also includes the blue crab sampling locations previously mentioned. The Alongshore fishery is a box-like area extending from Long Branch to Point Pleasant and extends offshore approximately 25 nautical miles following the Hudson Canyon. This area includes the ocean waste disposal sites for dredge spoils, fly ash and sewage sludge (Note: this sewage sludge dump is now closed and material is now deposited 106 miles offshore). The Offshore fishery extends eastward from the 50-fathom line to the 100-fathom line approximately 100 miles seaward to the edge of the continental shelf.

Analysis

Samples for analysis consisted of standardized edible portions (Figure 2a) including the thoracic, claw, leg and tail meat as well as the hepatopancreas combined (i.e., worst case exposure). Tissue from five organisms of similar size and weight were composited and homogenized in a food processor to generate comparable amounts of material which was then held frozen until extraction. In order to determine if differential bioaccumulation was occurring, a small number of analyses were performed on single lobsters in which the muscle and hepatopancreas tissue were processed separately (Figure 2b).

Tissue analyses were performed using a modified EPA method (3) with high-resolution gas chromatography, low-resolution mass spectroscopy. The modification included a saponification of the tissue prior to the initial extraction. Clean up involved passing the extract through a series of five columns with the final step involving an activated carbopak/elite mix in a 2-cm column with final TCDD and TCDF elution by toluene. Before clean up the samples were fortified with C_{13} labeled TCDD and TCDF as an internal standard. The extracts were analyzed using an electron impact GC/MS instrument with a direct capillary interface, and a 60-meter isomer specific fused silica capillary column. If TCDD or TCDF were not detected, a detection limit was calculated based on a 2.5 times signal-to-noise ratio at the retention time of the respective contaminant and the C_{13} labeled internal standard.

The QA/QC procedures followed EPA guidelines (4) and included spiking tissue of each species with appropriate standards, analyzing replicate and blind control samples and demonstrating the proper isomer specificity and ion ratios. The mean percent recovery for spiked samples with internal standards was 96.8 % with +/- 1 % error for the full range of analyses. The actual values reported in the tables are not corrected for recovery.

Statistics

All data are reported as arithmetic means with the method detection limit of 10 pg./g used for all non-detectable values in summation and statistical analyses. Since it is not possible to catch lobsters at all locations and seasons due to life history characteristics and sampling limitations, it proved difficult to test the significance of any space/time interactions on a strictly monthly or seasonal basis. Knowing that the animals do perform a regular onshore/offshore migration, however, it was possible to separate the data into Spring-Summer (Onshore) and Fall-Winter (Offshore) migration periods. These spatio/temporal differences were tested for significance via a 2-Way ANOVA (5) for unbalanced design on raw and ranked (i.e., non-parametric) data. The model used Season and Location as classes and TCDD and TCDF as the dependent variables. A significance level of 0.05 was used for all hypothesis testing concerning the F statistic.

The data for TCDF was converted to "TCDD Equivalents" via the EPA Toxic Equivalency Factor Method (6) recommended to quantify the additive risk from this contaminant. The results were then compared to the FDA recommended "Levels of Concern" for TCDD in order to estimate the level of unacceptable risk (7). These recommendations are: 1.) No consumption for levels greater than 50 pg./g; and 2.) Reduced consumption for levels between 25 and 50 pg./g.

RESULTS

Blue Crabs

Blue Crabs tissue (i.e., muscle and hepatopancreas combined) from Raritan Bay and the lower Hudson River (Table 1) show mean TCDD concentrations of 73 pg./g (Range 10-260 pg./g) and TCDF at 67 pg./g (Range: 10-110 pg./g). When TCDF is converted to TCDD equivalents the actual concentration increases to 80 pg./g. A large percentage of the captured animals tested positive for both TCDD (53%) and 2,3,7,8-TCDF (73%) with the latter being more ubiquitous. An analysis of the distribution of TCDD and TCDF in Blue Crabs across the harbor (Figure 3) shows that the contaminants are usually found together and an apparent increase in concentration occurs from inner Raritan Bay out to the mouth of the Hudson River. All of the control samples from Delaware Bay showed no detectable levels for either contaminant. The TCDD levels for these Blue Crabs collected in 1986 (at the seaward limit of their migratory range) were similar to levels found (1) within Newark Bay in 1983 (Figure 3a).

American Lobsters

Separate analyses of lobster muscle and hepatopancreas showed that both of the contaminants were present only in the hepatopancreas (Range: TCDD= <10-290 pg./g; TCDF= <10-320 pg./g). However, they may be present at levels below the relatively high detection limits in this study. Analyses of combined muscle and hepatopancreas for the entire New York Bight lobster fishery (Table 1) show mean TCDD concentrations of 28 pg./g (Range: <10-110 pg./g) and TCDF at 26 pg./g (Range: <10-120 pg./g). When TCDF is converted to TCDD equivalents the actual dosage increases to 30 pg./g. In contrast to the crab data, a smaller percentage of the lobsters tested positive for both TCDD (36%) and TCDF (20%) with the former being more ubiquitous. This may reflect the more remote exposure to the source of contamination (Passaic River) or may be due to the large number of lobster analyses showing high detection limits (i.e., >25 pg./g).

If the New York Bight lobster results are broken into sub-fisheries extending progressively offshore as categorized by NMFS (2) the data reveal some significant locational differences (Figure 4). TCDD and TCDF are high in both the Ambrose and Alongshore fisheries but low to non-detectable in the far offshore areas (Figure 4a). The 15 pg./g TCDD for Offshore lobsters is based on only 2 positive results out of 17

composites. The results illustrate that levels of TCDF appear to drop off linearly as one progresses offshore. However, this differs dramatically from the TCDD levels, which are higher in the Alongshore area, near the dredge spoil dumpsite, than in either, the Ambrose or Offshore fishery areas. These spatial differences may be related to seasonal feeding patterns and migratory movements.

In Figure 5a the monthly lobster landings for New Jersey waters (N.J. Div. Fish, Game and Wildlife) are superimposed on the mean monthly TCDD results from the 1985-1986 sampling season. The annual commercial landings appear unimodal. They begin to increase in early spring (March) as water temperatures increase and the lobsters become more active and begin their shoreward migration. The commercial fishing activities also increase at this time, as the lobsters are actively feeding and the milder weather conditions are more suitable to commercial lobstering. The landings reach a peak in late summer (August) and steadily decline thereafter as the water temperature drop and the animals seek deeper water to avoid severe winter conditions.

In contrast the TCDD data for the New York Bight fishery appears bimodal with high values in the winter/early spring followed by a steady rise in contamination from May through September. The latter trend probably reflects the lobster's active feeding and growing phase but does not explain the high levels found in the winter and early spring. These anomalies results become less contradictory if the data are separated into Ambrose and Alongshore areas and examined with an understanding of the seasonal, migrational movements of the lobsters within these sub-fisheries.

The Ambrose lobsters (Figure 5b) consistently had non-detectable levels of TCDD through the spring and summer but then rose remarkably high in the fall and winter. The Alongshore lobsters on the other hand (Figure 5c) had elevated levels of dioxin in all four seasons with an apparent increase in late fall. These trends were similar for both the 1985 and 1986 samplings seasons.

Spatial partitioning for TCDD (Figure 4) originally indicated that levels were higher in the Alongshore than in the Ambrose fishery. Migrational analysis (Figure 6a) reveals that this relationship only holds for the Spring-Summer (onshore migration) period and that by the Fall-Winter (offshore migration) this trend is reversed with higher levels inshore and progressively lower values as sampling moved offshore. Spatial partitioning for TCDF (Figure 4) originally indicated that the highest concentrations were found inshore and that progressively lower levels occurred offshore. Migrational results (Figure 6b) reveal that this relationship only holds for the Fall-Winter (offshore) period and that by the Spring-Summer (onshore migration) the data resemble the TCDD results with higher levels of contamination Alongshore than in the Ambrose fishery. Therefore, on a seasonal/migratory basis the levels and distribution of these two contaminants seem to fluctuate in a similar pattern.

This relationship is borne out statistically by the ANOVA which shows significant differences between location and seasonal effects on the concentrations of both TCDD ($P > F = 0.001^*$) and TCDF ($P > F = 0.03^*$) in American lobsters. Significance results were identical for both raw and ranked data so only the raw results are reported here. However, when the variances are partitioned into a partial sum of squares, season becomes non-significant for TCDD while location ($P > F = 0.02^*$) and the interaction term ($P > F = 0.003^*$) remain significant. The levels of TCDF on the other hand show non-significant effects in the partial sum of squares for location, season and the interaction term.

DISCUSSION

The Blue Crab has only a three year life span which begins as a microscopic larva that is spawned into the nearshore ocean waters. They then undergo a series of sequential metamorphoses, molts and movements back into the estuary where they exist as adults until the females once again migrate seaward to spawn (8). Therefore the animals that were found contaminated in Raritan Bay in 1986 had just entered the estuary from their offshore planktonic stage when the original 1983 investigation was initiated. This indicates that the contamination is not only transported out of the estuary into the nearshore food chain but that it is persistent over time. In addition the amount of TCDD found in these crabs exceeds the FDA's "Level of Concern" recommending no consumption (i.e., >50 pg./g). The presence of TCDF also adds to the risk as indicated by its conversion to TCDD equivalents.

American lobsters in the New York Bight exhibit high yet varying levels of both TCDD and TCDF across their entire geographic range. Although low levels of TCDF congeners have been reported for American lobster hepatopancreas in the past (9) this was the first evidence of TCDD and high TCDF contamination. In addition, the broad distribution of contamination across the New York Bight appears unique compared to other reported contamination events for this species which tend to be localized in the nearshore (10) or estuarine areas (11).

The statistical analysis supports the presence of spatio/temporal differences in TCDD and TCDF contamination in American Lobsters across the New York Bight section of the continental shelf. The lack of significance for TCDF in the partial sum of squares analysis may be due to the unbalanced design and large variances inherent in the data. For TCDD the partitioning analysis indicates that location is more important than season although the significant interaction term suggests that the spatial effects are strongly dependent on the time of year in some unspecified way. Biologically the interaction term may be synonymous with the definition of migratory behavior, which manifests itself as changes in spatial relationships based on temporal cues during the annual life cycle of an organism.

The significance of the location effect and the interaction term may be better understood if we ignore the three artificial fishery boundaries and consider the lobsters as biological populations. Field studies indicate that regardless of latitude the seaward American lobster populations for the eastern continental shelf consist of two sub-populations (12); one that remains in the nearshore area and moves at most 15 km across a home territory and a second deepwater population that resides much further offshore and performs true long-range migration. The seasonal migration is possibly associated with maximizing degree-days for molting, growth, gonadal development, and egg extrusion (13). In addition, the mature lobsters on average move significantly greater distances than immature lobsters with the latter tending to travel along the coastline whereas the larger more mature animals move seaward and to greater depths, as they grow older.

Therefore, the Ambrose and Alongshore locations may circumscribe two ends of the same inshore lobster territory with a size-stratified population moving to variable directions and depths and being exposed alternately to two sources of contamination - the Hudson River plume and the HARS (i.e., ocean dredge spoil disposal site). Moving slowly inshore during the spring/summer period the deepwater, more mature lobsters will mix with the smaller inshore population. Animals in the entire Ambrose fishery then bio-accumulate higher levels of TCDD and TCDF during this more active phase until the mature animals move offshore in the Fall. Then they either depurate some levels during over-wintering at the Alongshore area and/or mix with the landward edge of the less contaminated offshore population resulting in lower

average levels over the winter. In contrast smaller lobsters within the Ambrose fishery aestivate during the winter by burying themselves in the soft muddy channels which criss-cross the Lower Bay. During this time they metabolize much of their stored fat and may release any associated contaminants.

Although it is difficult to separate out the proximate causes of the observed spatio/temporal variations in TCDD and TCDF contamination, we can assume that it includes differences in source exposure, activity cycles, lipid metabolism and possibly depuration. The seasonally persistent high levels of contamination at the seaward end of the inshore population's range (i.e., the Alongshore area) strongly suggests that dredge spoils were supplying a continuous source of TCDD and TCDF to American lobsters. In support of this observation is data from a subsequent study of Newark Bay blue crabs, Alongshore lobsters and soils from the manufacturing site on the Passaic River (14) which reveals similar GC/MS fingerprints of other dioxin and furan congeners between animals and sites.

The amount of TCDD in the New York Bight fishery and more specifically the inshore Ambrose and Alongshore fisheries exceeds the FDA's "Level of Concern" recommending reduced consumption (i.e., >25 pg./g). If TCDF is converted to TCDD equivalents the actual dosage increases in the Alongshore fishery towards a recommendation of no consumption. The large number of lobster analyses showing high detection limits (i.e., 28 % >25 pg./g) may also mask more contamination. This is especially critical when an advisory level exists in the low parts per trillion range. Unfortunately this is a common analytical problem for tissue samples requiring picogram per gram sensitivity since the presence of other organochloride contaminants such as PCBs may mask the presence of both TCDD and TCDF (15). PCBs are a common contaminant in lobsters along the entire eastern seaboard including the New York Bight (1) Long Island Sound (16) and New Bedford Harbor (11). In addition, the conversion to TCDD Equivalents of the other PCDD and PCDF congeners recently found to bioaccumulate in these animals (14) reveals a much higher level of risk than expected from the TCDD and TCDF analysis presented here, although most of the risk comes from the highly toxics TCDD and TCDF.

Concerning the safety of New York Bight lobsters as a food source it is apparent that a threat does exist but the presence of the contaminants in a secondary part of the edible tissue (hepatopancreas) gives health officials some latitude in advising the public concerning the risks. The risk to consumers could be much reduced by not eating the hepatopancreas. I addition, separating the hepatopancreas before cooking (i.e., cooking lyses the organ and disseminates the contamination (10)) can significantly reduce the potential exposure to this contaminant. In addition a recent study has shown that TCDD residues in fish may be reduced through selective cooking and processing techniques (17). A similar study is needed to address the way that lobsters and crabs are usually cooked (i.e., boiled whole). It is to our benefit, considering the Earth's dwindling natural resources, and its ever-increasing human population, to preserve and protect these important food species.

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Table 1. TCDD, TCDF and TCDD Equivalent[1] Levels in Blue Crabs and American Lobster From Raritan Bay and the New York Bight

Blue Crab	X	TCDD[2] S.D.	n	%Pos	% > 25pg/g4	X	TCDF S.D.	n	% Pos	TCDD Equivalents X
	73.1	(82.9)	15	53	60	70	(36.4)	15	73	80
American Lobster[3]										
New York Bight	27.5	(25.7)	47	36	36	26	(28.9)	39	20	30
Ambrose	31.2	(30.2)	19	37	37	35.0	(35.0)	19	37	34.7
Alongshore	40.5	(22.8)	11	73	73	24.5	(19.5)	11	36	42.9
Offshore	15.0	(13.9)	17	12	12	<10	-	9	0	15.0

1. After Barnes et al 1986
2. Arithmetic means include all non-detectable values at 10 pg/g method detection limit for summation SD = standard deviation N = no of 5 organism composites analyzed % Pos = Percent Positive
3. Lobsters data presented for NY Bight as a whole and its sub-fisheries 4. FDA "Level of Concern" recommending reduced consumption is 25 pg/g

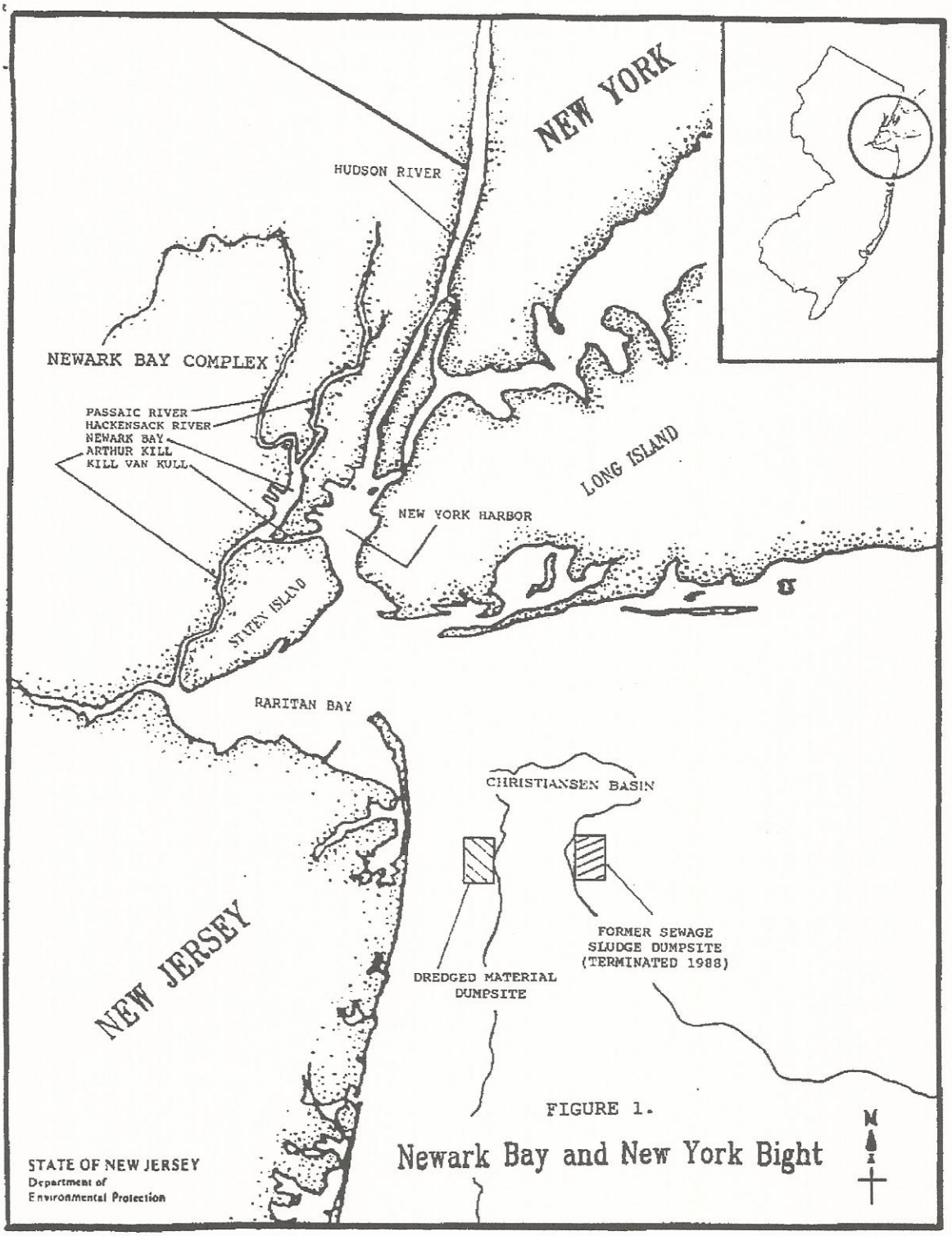


FIGURE 1.

Newark Bay and New York Bight

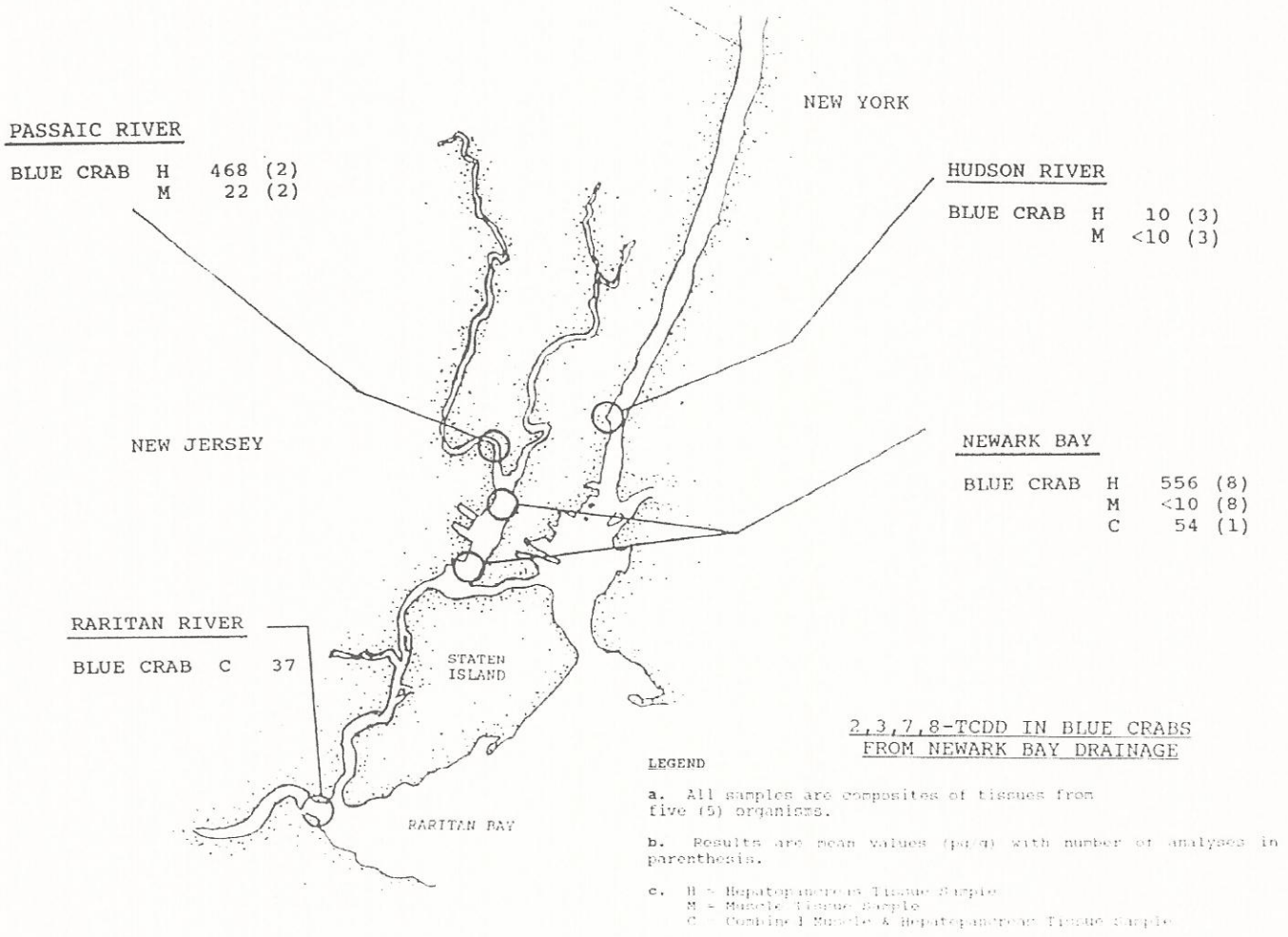


Figure 1a. Dioxin (2,3,7,8,-TCDD) in Blue Crabs From Newark Bay 1984*

From Belton et al. 1985

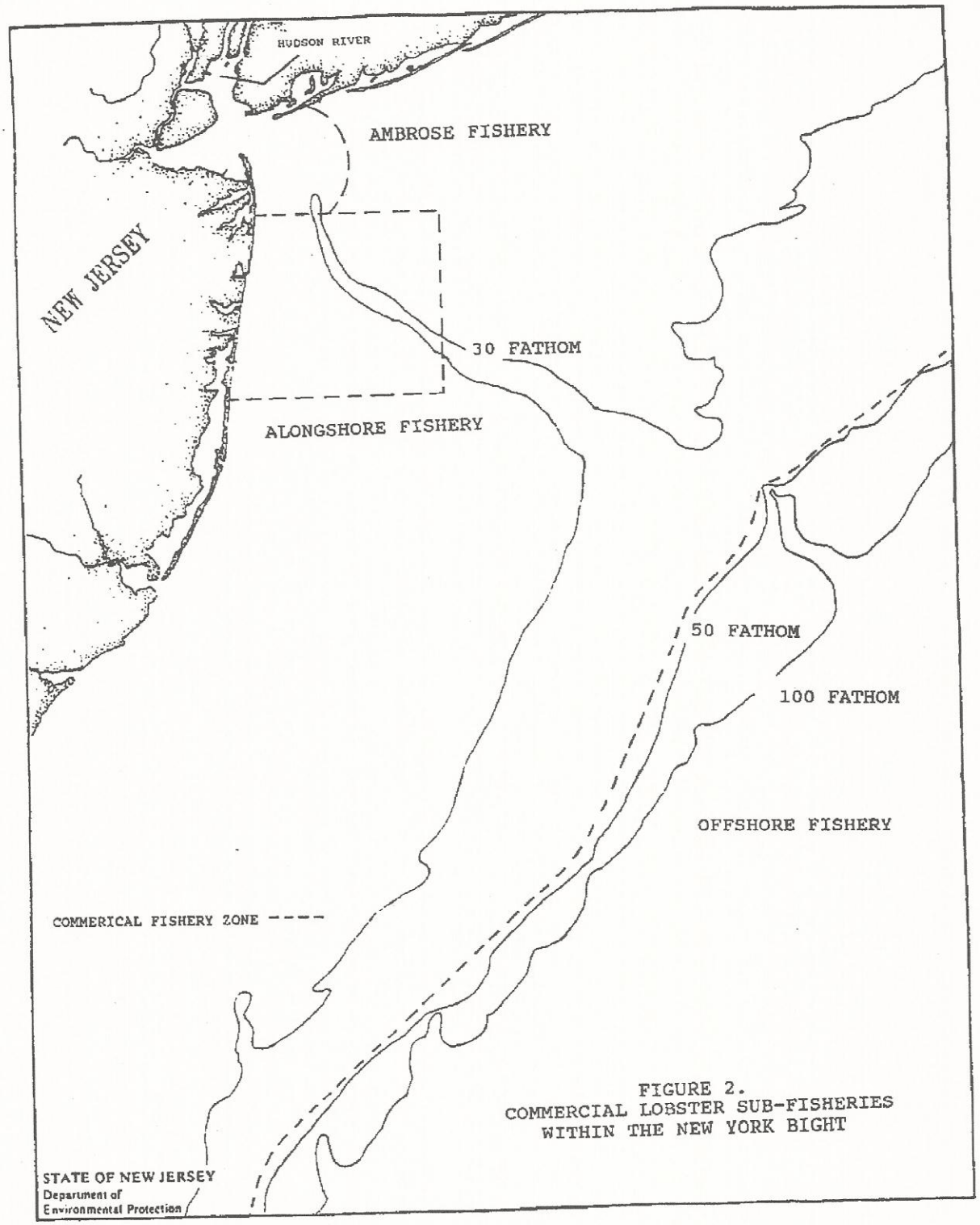


FIGURE 2.
COMMERCIAL LOBSTER SUB-FISHERIES
WITHIN THE NEW YORK BIGHT

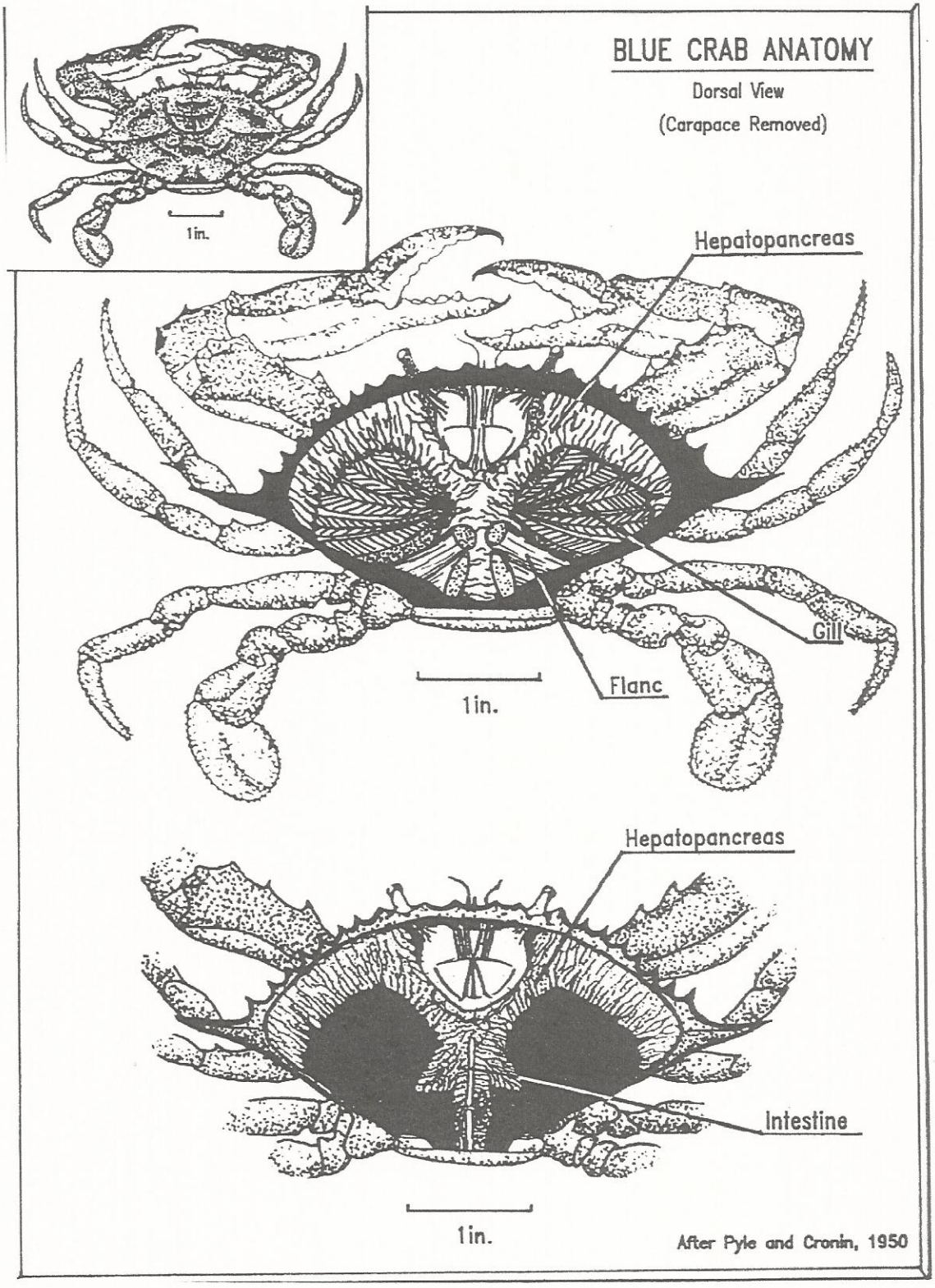


Figure 2a. Blue Crab Anatomy

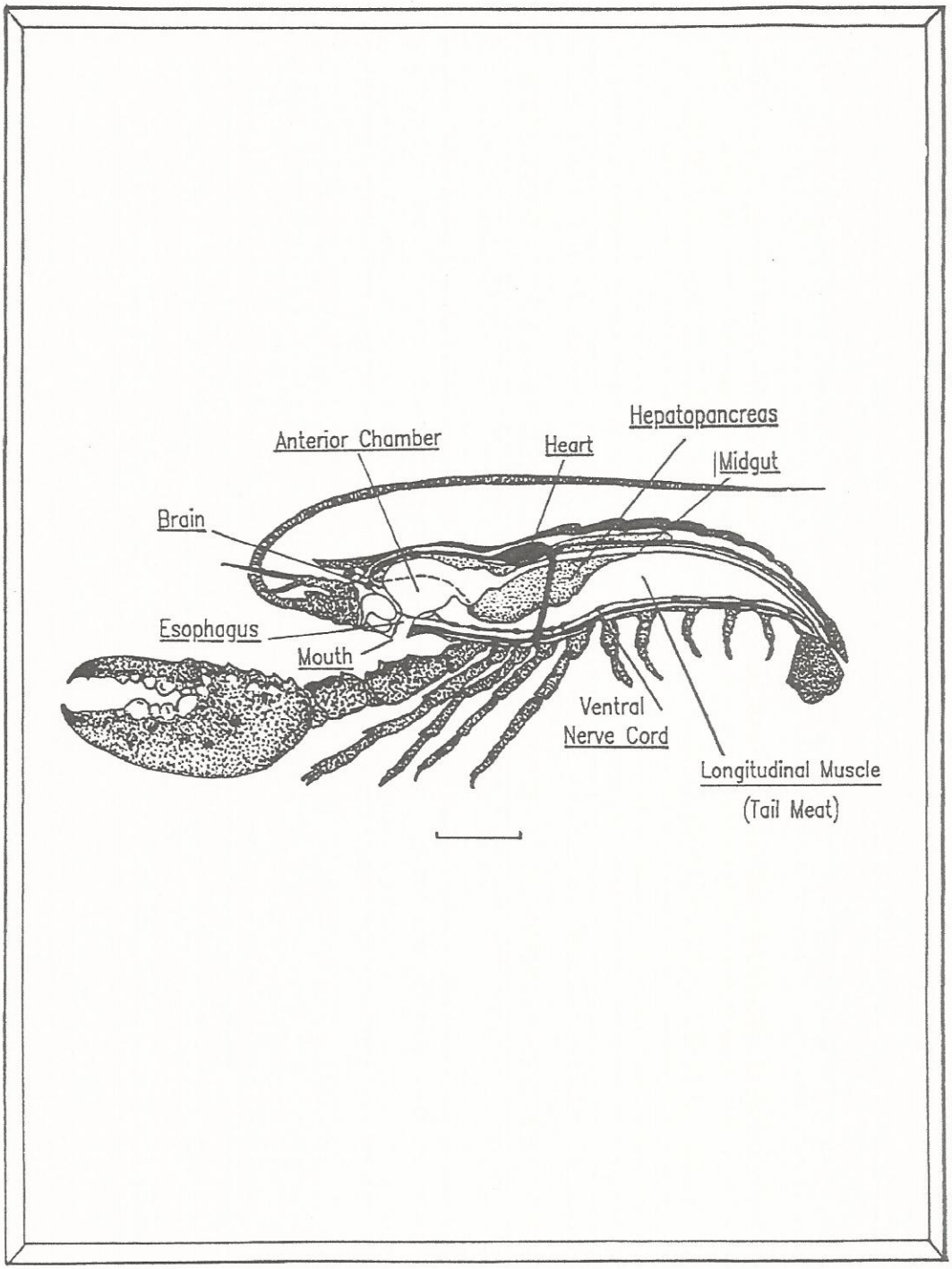
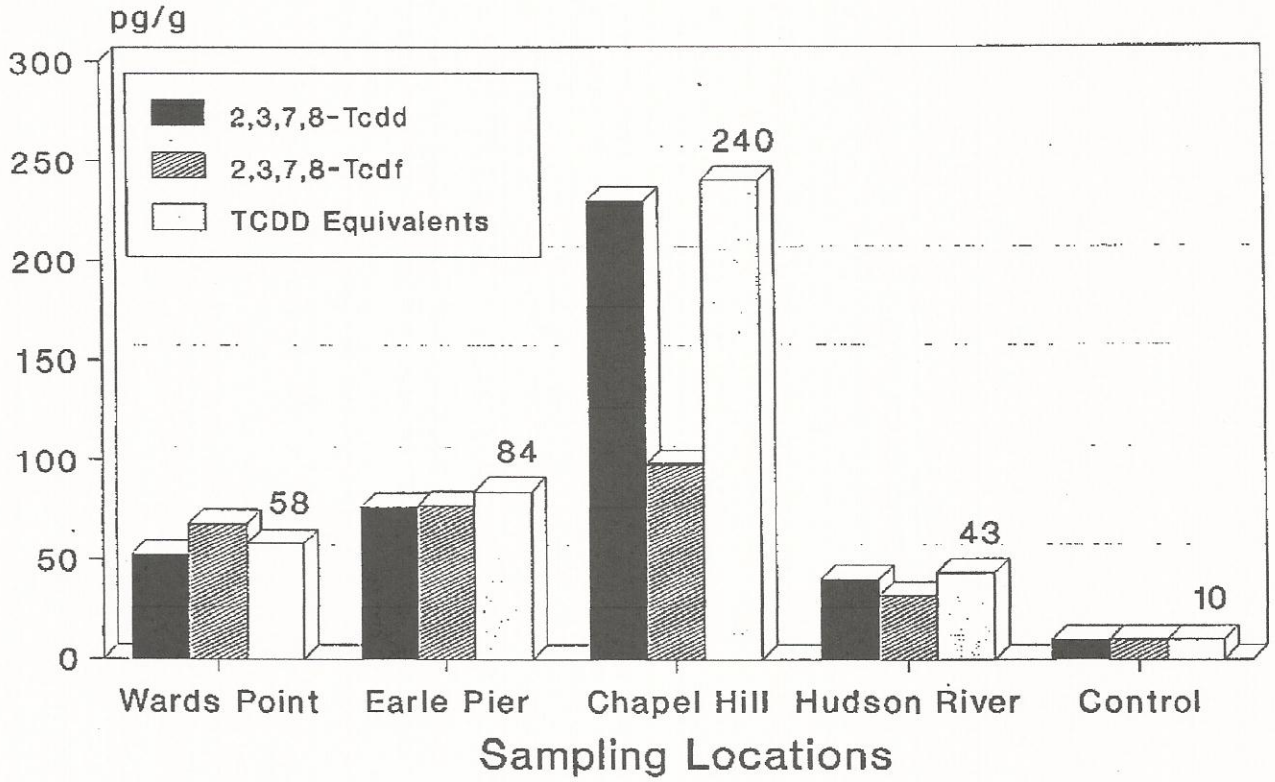
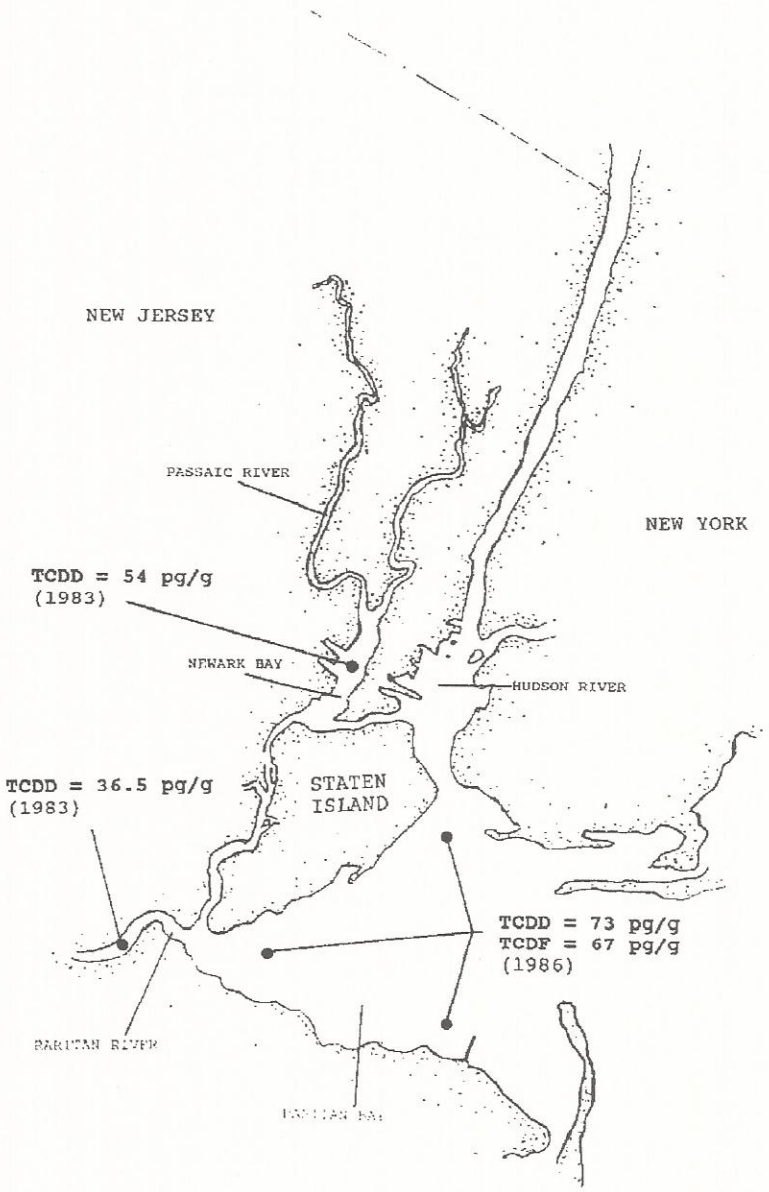


Figure 2b. American Lobster Anatomy

Figure 3. 2,3,7,8-TCDD, 2,3,7,8-TCDF and TCDD Equivalents in Blue Crabs from Raritan Bay and the Lower Hudson River



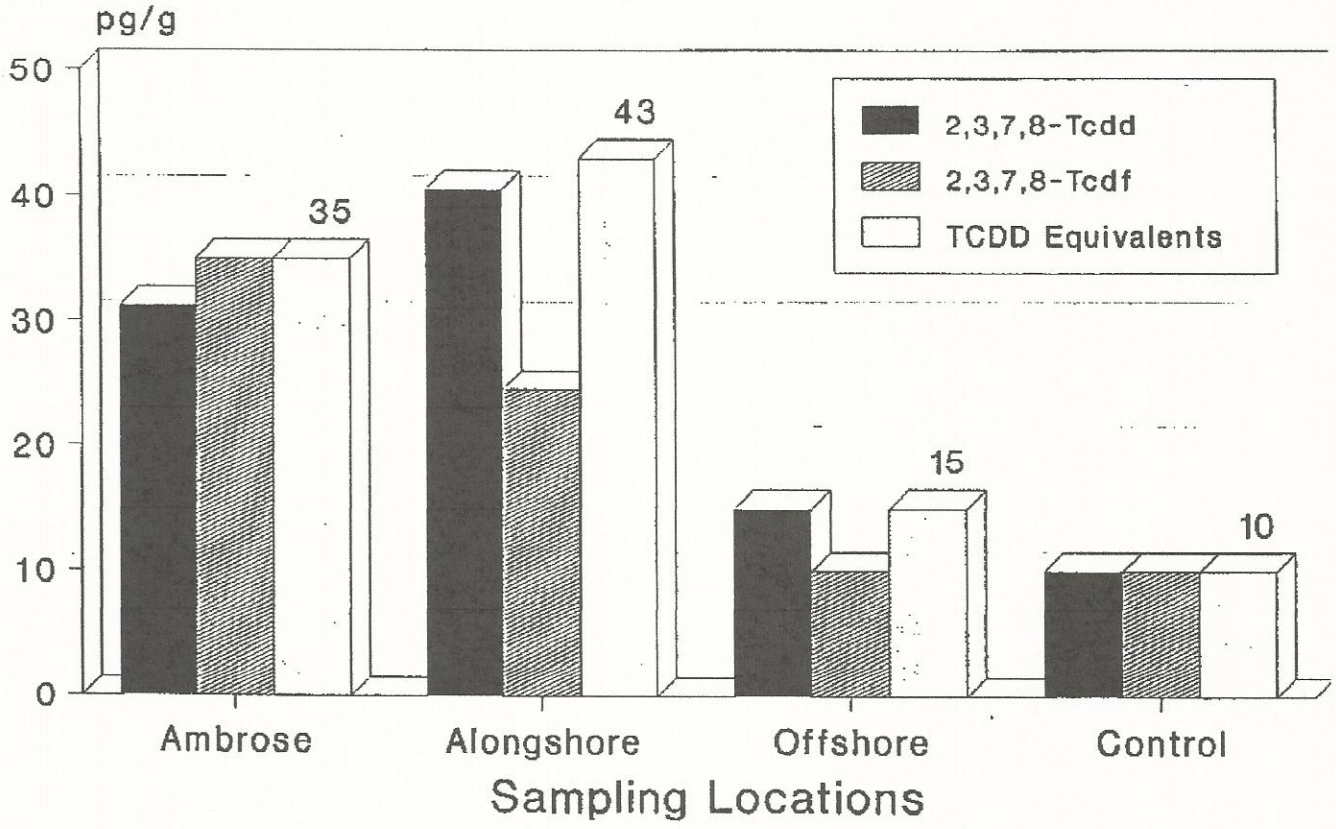
TCDD Equivalents via Barnes et al 1986
Controls are from Delaware Bay,
10 pg/g is the method detection limit.



MEAN 2,3,7,8-TCDD/TCDF IN BLUE CRABS
FROM HUDSON-RARITAN ESTUARY
(1983-1986)

Figure 3a.

Figure 4. 2,3,7,8-TCDD, 2,3,7,8-TCDF and TCDD Equivalents in Lobsters from Sub-Fisheries in the New York Bight



TCDD Equivalents via Barnes et al 1986.
Controls are from Maine.
10 pg/g is the method detection limit.

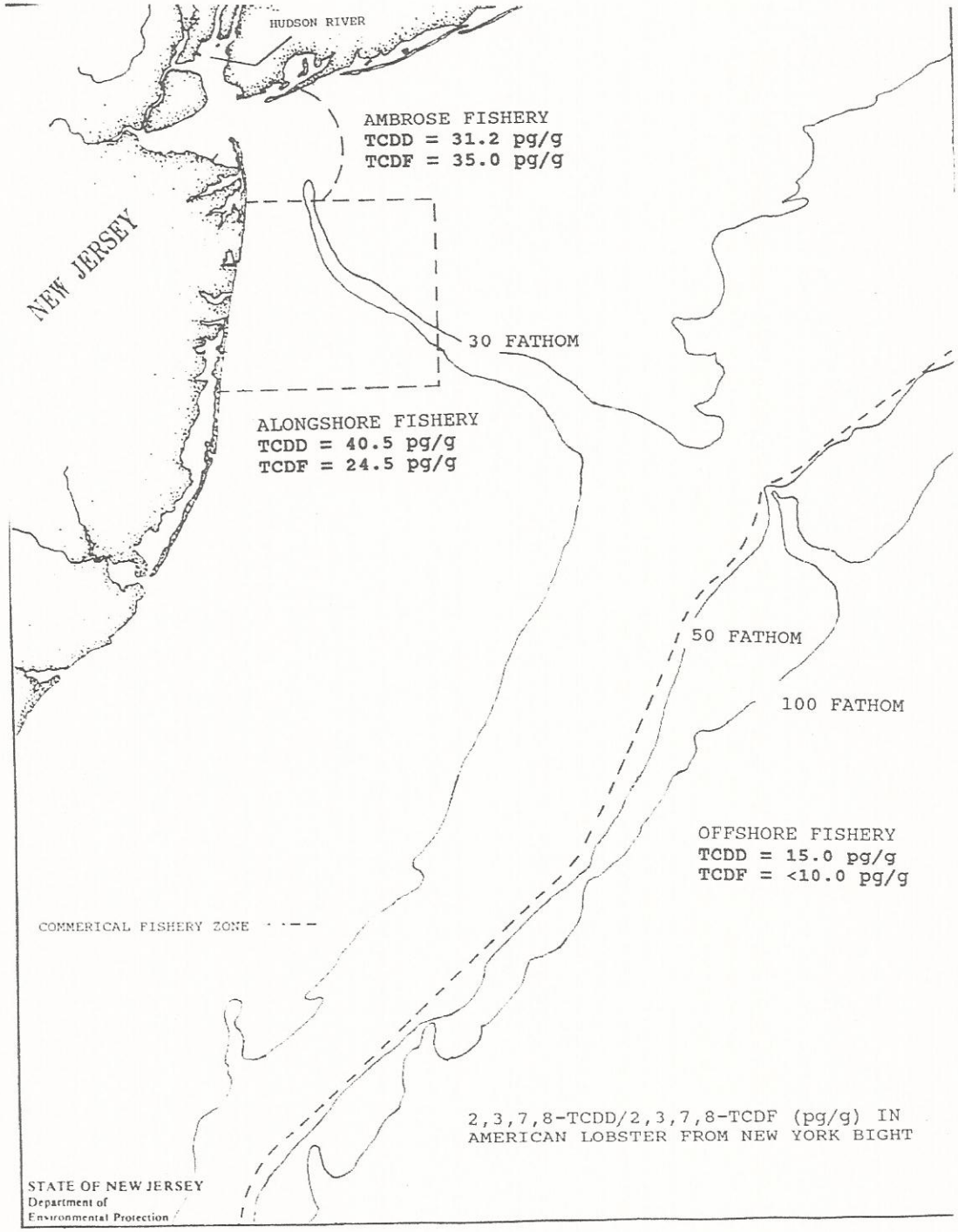

HUDSON RIVER
AMBROSE FISHERY
TCDD = 31.2 pg/g
TCDF = 35.0 pg/g
NEW JERSEY
30 FATHOM
ALONGSHORE FISHERY
TCDD = 40.5 pg/g
TCDF = 24.5 pg/g
50 FATHOM
100 FATHOM
OFFSHORE FISHERY
TCDD = 15.0 pg/g
TCDF = <10.0 pg/g
COMMERICAL FISHERY ZONE
2,3,7,8-TCDD/2,3,7,8-TCDF (pg/g) IN
AMERICAN LOBSTER FROM NEW YORK BIGHT
STATE OF NEW JERSEY
Department of
Environmental Protection

Figure 4a.

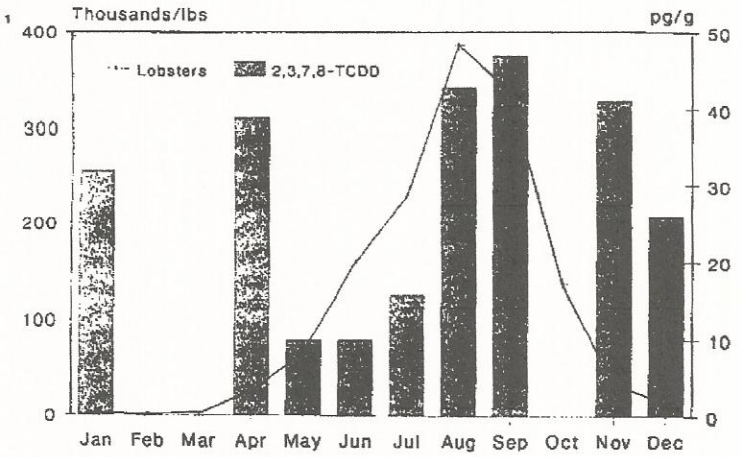
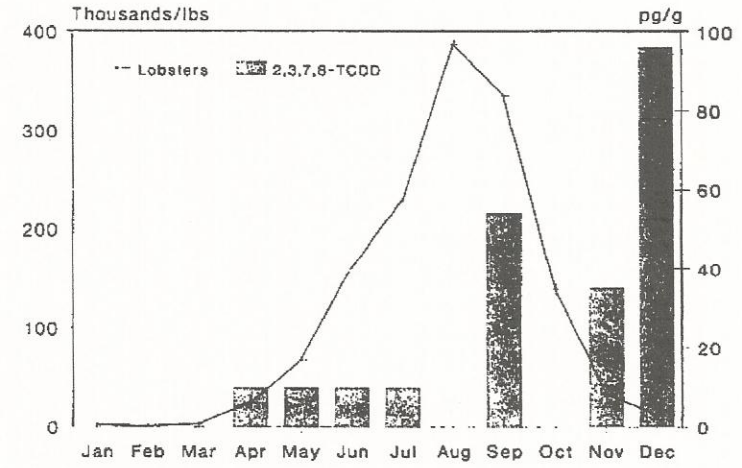


Figure 5a. Landings and 2,3,7,8-TCDD Levels in New York Bight Lobsters



1985-86 Toxics Data; 1987 Landings
10 pg/g is the method detection limit.

Figure 5b. Ambrose Fishery

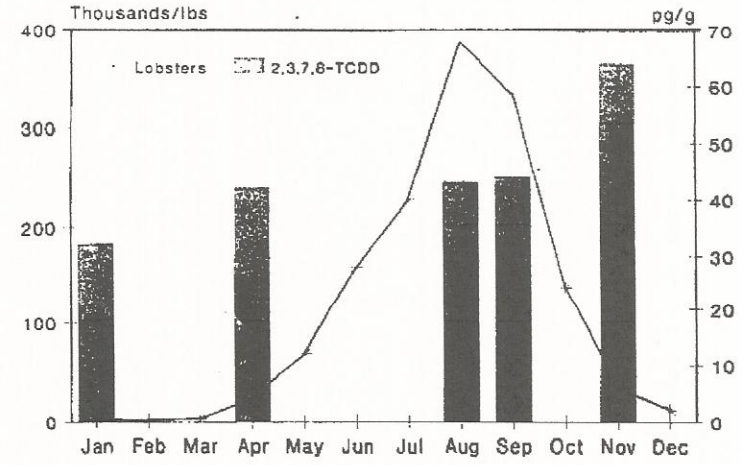
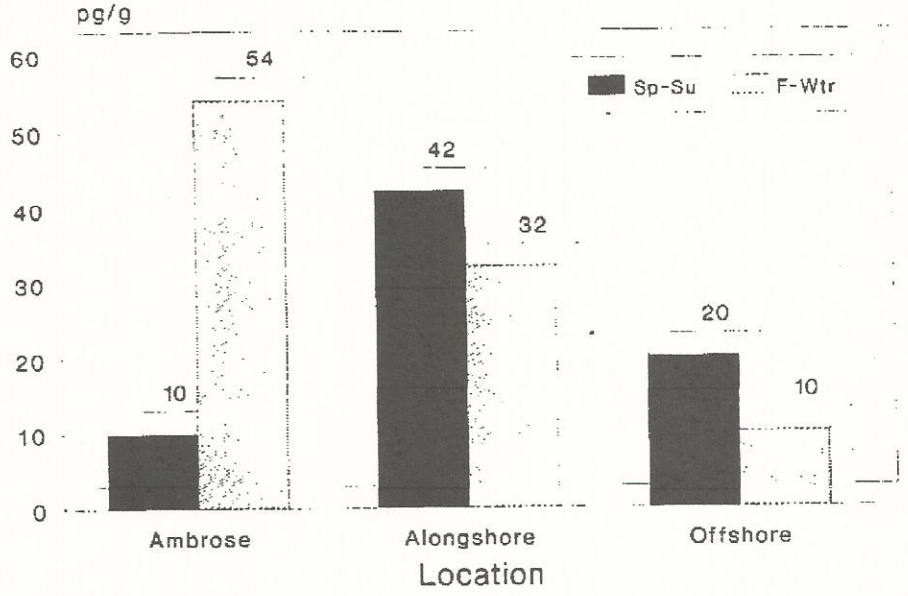


Figure 5c. Alongshore Fishery

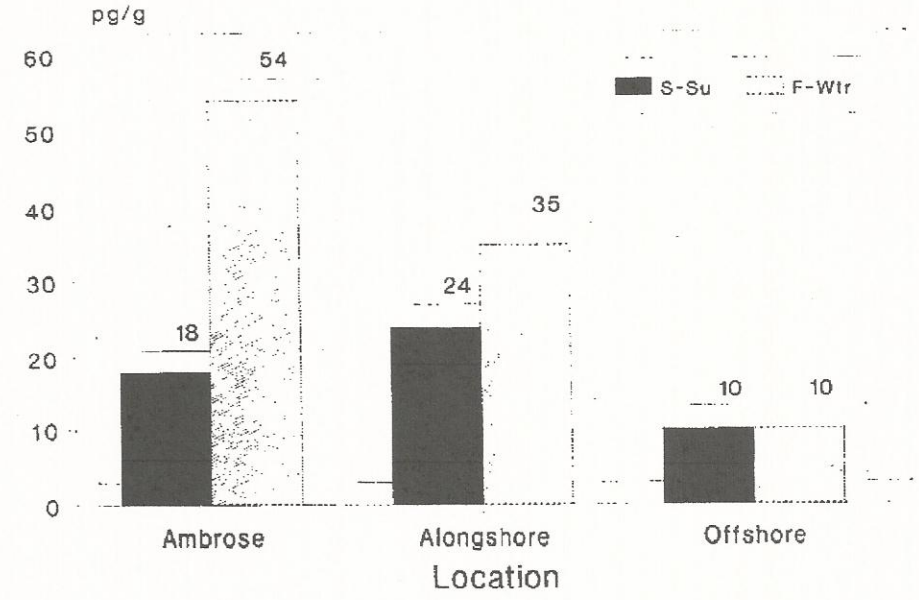
FIGURE 5a,b,c.

Figure 6a. Mean 2,3,7,8-TCDD in Lobsters
by Location and Migration Period



S-Su is Onshore Migration
F-Wtr is Offshore Migration

Figure 6b. Mean 2,3,7,8-TCDF in Lobsters
by Location and Migration Period



S-Su is Onshore Migration
F-Wtr is Offshore Migration

FIGURE 6a,b

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ECOLOGY

Present-Day State of Coral Reefs of Nha Trang Bay (Southern Vietnam) and Possible Reasons for the Disturbance of Habitats of Scleractinian Corals

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Abstract—Our investigations were conducted from 1990 to 2002. Sampling of bottom sediments and biological objects, as well as photo and video shooting, were performed during scuba diving. The state of the environment and coral reef communities was assessed using the chemical–analytical, fluorometric, and luminometric methods, as well as the Ames test and the transect technique. The research results suggest that the spectrum and distribution pattern of persistent congeners of PCDD/Fs (dioxins) in bottom sediments are similar to those of the defoliant "Agent Orange" and that the bottom sediments are toxic and display photo inhibition and a mutagenic effect. The bottom of the bay is heavily silted throughout its depth. Many large dead colonies of corals without mechanical damage were observed everywhere. The total coverage by live corals in all sites investigated does not exceed 30%. Although, without a doubt, many factors contributed much to the disturbance of the bay ecosystems, the actual trigger for the degradation of the coral reefs seems to be the input of dioxin-containing chemicals used as defoliants during the American–Vietnamese war (Vietnam War).

Key words: Coral reefs, scleractinians, ecodiagnosis, ecotoxicology, dioxins, defoliants, "Agent Orange."

In recent decades, there has been a tendency toward the deterioration of the state of near-shore coral reefs in various regions of the world [15, 22, 24–26], and for Vietnam in particular, it has become a challenge. Vietnam has extensive sea borders, and the biological resources of the sea are of great importance in the economy of the country. The productivity of the coastal waters is largely determined by the state of the corals reefs.

It has been reported that Nha Trang Bay (South China Sea) has favorable biotopes and one of the richest scleractinian faunas in Vietnam [4, 5, 19, 23]. A series of monographs "Scleractinian Corals of Vietnam" provided a detailed account of the species composition and distribution of scleractinians in Nha Trang Bay up to the year 1986 [6–9]. The purpose of the present research is to examine the present-day state of near-shore coral reefs in Nha Trang Bay and to make a comprehensive integral evaluation (ecological diagnostic) of the quality of the benthic environments and to clarify the possible reasons for the degradation of the coral reefs of the bay.

MATERIALS AND METHODS

In planning this research and in our analysis of the results, we used, along with other publications and our own data, the available reports of expeditions of the Institute of Marine Biology (IMB, then of the Far Eastern Branch of the USSR Academy of Sciences) for the years 1981, 1982, and 1986, as well as the reports of the Russian–Vietnamese Tropical Center (Russian Academy of Sciences) and the Institute of Oceanography (National Center for Scientific Research of Vietnam) in Nha Trang.

The investigations were carried out from 1990 to 2002 at 60 stations, which were located practically throughout the bay (Fig. 1).

In planning the research, we singled out four transects within the bay:

1. Transect A—the northern bay. In this part of the bay, there is a large coral bank (stations 41, 42, 43, 44), the islands of Dum (station 45) and Tyala (station 49), and Binhkanh Bay (stations 46 and 47) with numerous shrimp farms and the Ngada River emptying into the bay.

2. Transect B—the entrance channel of the Kay River. Here, between the coral bank and Che Island

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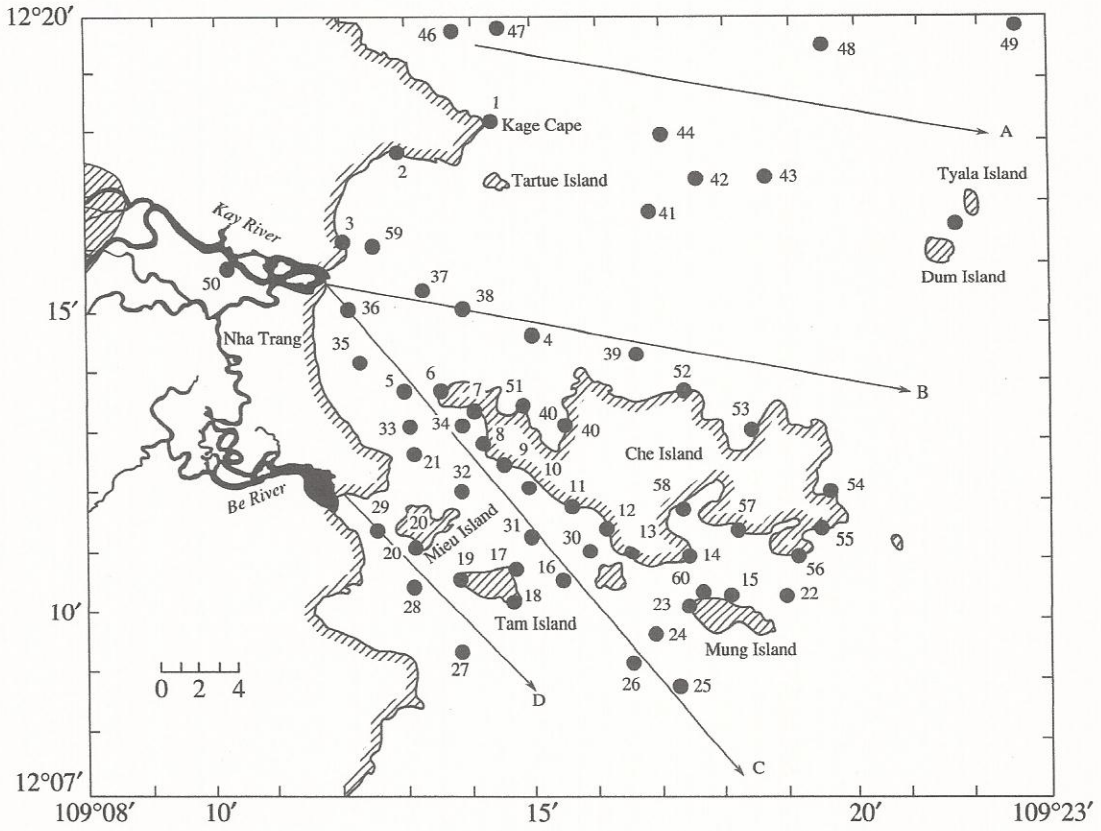

Fig. 1. The location of stations in Nha Trang Bay, 1990–2002. The shaded patch in the upper reaches of the Kay River (left upper part of the map) is the lower limit of the area where dioxin-containing defoliants were used during the American–Vietnamese war (Vietnam War). Transects A, B, C, and D are shown by arrows (explanation in the text).

(stations 4, 37, 38, 39) at a depth of 15–20 m, a non-silted sand plateau was observed in the late 1980s and the early 1990s.

3. Transect C—the area between Che Island and the islands of Mieu and Tam. By virtue of the hydrological features of the bay, a large part of the suspended material from the Kay River is deposited here.

4. Transect D—the southern bay. It receives suspended material from the Be River.

Analyses were performed in the Laboratory of Ecotoxicology, the Institute of Ecology and Evolution Problems, Russian Academy of Sciences. In the bottom sediment samples collected at stations 5, 16, 20, 21, 24, 27, 29, 30, 33, 36, 37, 39, 41, 44, 49, and 50, the total content of dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) (in all, 17 congeners) was determined by high resolution chromato-mass spectrometry and expressed using the international equivalents of toxicity (1-TEQ or dioxin equivalent) relative to the most toxic congener 2,3,7,8-TCDD [3]. Specific isomer analysis of PCDD and PCDF was carried out on a GC-MS "Finnigan" MAT-95XL, Hewlett Packard HP 6890 Plus, at a resolution of 10000 [20]. Dioxins are long-lived superecotoxicants [3, 18] and mask well less persistent compounds (among them toxic), the components of which they were formerly.

As is customary in chemico-analytical research, for averaging of small-scale nonuniformity in the distribution of the constituents of bottom sediments, samples at each station were taken at 4–5 points lying about 1 m from each other. Bottom sediments were removed to a depth of 10–15 cm (on hard sands) or 50–70 cm (on soft silts). Samples collected at the same station were pooled, while under water, into an integrated sample and placed in a 1.5-liter tightly sealed plastic vessel. Subsamples of the integrated samples were used in the toxicological research.

The following biological methods of environmental diagnostic [14] were used: fluorimetric, bioluminometric, and genetic methods and the transect technique.

Coral coverage and the state of bottom communities were assessed using the transect technique. Scleractinian corals were selected as the major object of study because, as was noted above, they are edificatory species indicative of the state of coral communities. Transects were made at stations 1, 3, 6, 11, 12, 15, 18, 19, 23, 25, 40, 42, 46, 47, and 49. The transect (graduated rope 100 m long) was perpendicular to the shore-

line starting with a zero depth. Along the transect, at 10 m intervals, photo and video shooting of objects was made within a 1 × 2 m aluminium frame with internal 25 × 25 cm quadrates.

Sediment sampling and photo and video shooting were made during scuba diving. The exact position of station was fixed from the ship using a Garmin GPSIII plus; where possible, the location of stations was tied to on-land reference points. The depth and transparency of the water were registered at each point of sampling.

The toxicity of the bottom sediments in the bay was studied using samples collected on four transects at stations 5, 16, 20, 24, 27–29, 30, 32, 33, 36, 37, 39, 41, 44, 47, 49, and 59, which more or less fully represent the diversity of the biotopic and hydrological characteristics of the bay. In addition, a sample of sediments from the former riverbed of the Kay River, which is completely inundated during the floods (station 50), was analyzed.

The effect of bottom sediments on photosynthetic activity was examined using cultures of the marine algae *Thalassiosira weissflogii* (Grunow) Fryxell et Hasle (Bacillariophyta), *Tetraselmis viridis* (Rouch) Morris (Prasinophyta), *Nannochloris* sp. (Chlorophyta), and *Isochrysis galbana* Parke (Prymnesiophyta). These algae—routine objects of marine toxicology—belong to the main large taxonomic groups of native inhabitants of marine plankton and periphyton. Scleractinian corals harbor photosynthgetic organisms (zooxanthellae), and fluorimetric studies were made to reveal the adverse effects of the environment on the zooxanthellae, which inevitably tell on the coral host [16]. The working concentration of the bottom sediment suspension in toxicological experiments was 20 mg/ml. Cultures (10 ml) without bottom sediment suspension were the control. Photosynthetic activity (PA) was estimated by the relative proportion of pulse-amplitude-modulation fluorescence $q = F_v/F_m = (F_m - F_o)/F_m$ when measuring the chlorophyll fluorescence rate in open (F_o) and closed (F_m) reaction centers [10]. F_o and F_m in algal suspension were recorded with a portable two-beam impulse fluorimeter designed by the Chair of Biophysics of the Biological Faculty of Moscow State University [1]. The impulse duration of the testing excitation light of fluorescence was 4 μs; the average power density of the exciting light in the measurement of F_o and F_m was 0.4 and 3000 Wt/m^2, respectively. The fluorescence rate was measured before adding the bottom sediment suspension and 24, 48, and 72 h after the addition; the same was done to the control cultures at the same time intervals. Prior to measurements, the algal cultures with the bottom sediment suspensions added were thoroughly stirred. A series of methodical experiments showed that at a sediment concentration of 20 mg/ml, the suspension of particles does not interfere with the estimation of the fluorescence parameters of the algae. From the q values, the inhibition coefficient of PA was estimated:

$$K_{PA} = (1 - (q_{exp}/q_{contr})) \times 100\%,$$

where q_{exp} is the relative contribution of pulse-amplitude-modulation fluorescence in algae in the experimental cultures exposed to the bottom sediment suspension; and q_{contr}, in control cultures. The methodical tests showed that the standard deviation value of K_{PA} changes in some cultures in the range from 0 to 9%; hence, K_{PA} values exceeding 2δ (18%) were considered significant.

The effects of bottom sediments on the vital activity of aerobic nonphotosynthesizing heterotrophic bacteria, as well as the degree of integral toxicity of the bottom sediments were evaluated using the "Biotox-6" and "Biotox-10" devices. This investigation was undertaken because heterotrophic bacteria are important in maintaining the near-shore ecosystem stability in the South China Sea [15] and because an integral evaluation of the toxicity of the bottom sediments for humans is needed. The rate and degree of suppression of the bioluminescence of biosensors was measured. The biosensors were test cultures of heterotrophic chemoluminescent bacteria. The response of the bacteria to supplemented substances is analogous to that in other living organisms, and the value of 50% fluorescence quenching in bacteria completely correlates with a 50% lethal dose for humans. The intensity of bioluminescence of special biosensors ("Ecolum" biosensor in our investigations) containing chemoluminescent bacteria changes in relation to the toxic effect and is represented by the index of toxicity [2, 11]

$$T = 100(I_o - I)/I_o,$$

where I_o and I are respectively the intensity of fluorescence of the control and the experiment at a fixed time of exposure of the test solution with the test object. According to the "Biotox" user's manual [12], a value of the toxicity index from 0 to 20 indicates that the test substances are virtually nontoxic; with index values of 20 to 50, the test substance is toxic; and with values exceeding 50, toxicity is high. Negative values of the toxicity index are indicative of the presence in samples of substances stimulating metabolic processes in bacteria. In tests with chemoluminescent bacteria, the procedure for the preparation of bottom sediment suspensions was analogous to that used in the fluorimetric study. Samples of bottom sediments were dried and ground in porcelain dishes, then 5 g of the sediment was diluted in 25 ml of filtered pasteurized seawater (distilled water for river samples) to attain a working concentration of 20 mg/ml. For each sample, the toxicity of the suspensions was measured in 12 replicas.

Increased mutagenicity of the environment is one of the factors that not only induces negative responses in some organisms (including humans), but also disturbs the stability of the population structure and ecosystems as a whole. Mutagenic effects of bottom sediments were evaluated using generally accepted methods. Acetone–hexane extracts were made from dried (to con-

Table 1. Mutagenic index of extracts from the bottom sediments in the presence of (+MA) and without (–MA) the metabolic activation system of the strain TA-98 sensitive to mutagens inducing the shift of the reading frame of the genetic code and the strain TA-100 sensitive to mutagens causing mutations of the base substitution type

Reagent			Dose per petri dish	*Salmonella typhimurim* strains			
				TA-98		TA-100	
				+MA	–MA	+MA	–MA
Control	DMSO		0.1 ml	1.0	1.0	1.0	1.0
	2- aminoanthracene		0.5 g	**44.8**	0.9	**8.5**	1.0
Extracts of bottom sediments from stations	River	50	0.1 ml	1.1	**2.3**	0.9	1.5
	Transect C	36	0.1 ml	0.9	0.9	**2.6**	**2.0**
		5	0.1 ml	**1.8**	1.6	0.7	0.9
		30	0.1 ml	**5.4**	1.6	1.0	1.3
	Transect D	29	0.1 ml	**3.0**	1.1	0.9	1.2
	Transect A	44	0.1 ml	**1.8**	**1.9**	0.8	1.2

Note: Bold-faced numerals indicate a significant mutagenic effect.

stant mass at 50°C) bottom sediment samples. The extracts were evaporated, dissolved in dimethylsulfoxide (DMSO), and tested according the Ames method in three replicas. A positive control test with promutagen 2-aminoanthracene was run simultaneously. *Salmonella typhimurim* TA-98 and TA-100 strains were used. The strain TA- 98 is sensitive to mutagens inducing the shift of the reading frame of the genetic code, while TA-100 is susceptible to mutagens causing mutations of the base substitution type. Promutagens (mutagens present in the environment in the inactive state) were revealed according to the standard method [21] using the metabolic activation of bottom sediment extracts. The results of tests (Table 1) are represented as the mutagenic index (MI) reflecting the ratio of the number of colonies his^+ *Salmonella* revertants in the experiment to the control (DMSO). With MI from 1.7 to 10, the mutagenic effect was considered positive; from 10 to 100, moderate; and more than 100, high [17].

RESULTS

Long-term studies of the bottom biotopes using the transect method revealed a more or less pronounced tendency toward the degradation of coral reefs, siltation, and the suppression of scleractinians at all depths and at all stations in the bay. We compared the results of charting coral reefs made by T.A. Britaev and M.V. Pereladov (unpublished report of the Tropical Center for 1990) and the results from our survey in the early 1990s at stations 8, 9, 11, 12, 13, 14, 51, 40, and others adjacent to Che Island with the data obtained by the expeditions of the IMB in 1983 and 1986. Over the following 6–7 years, once rich scleractinian settlements had degraded markedly but still remained. By 2001, in many areas neighboring Che Island scleractinian settlements had disappeared almost completely; dead corals overgrown with periphyton, coral debris covered with silt, or even continuous silt fields were observed on the bottom. Particularly marked siltation occurred in the western and southern bay in the area between Che Island and the mainland (transects C and D, stations 5, 16, 21, 25–33, 35–37, and 59; see Fig. 1). In extensive areas of the bay, the silt thickness was up to several tens of centimeters. In bottom areas where the silt layer exceeded 1–3 cm, live scleractitians were completely lacking. Young scleractinian colonies (seldom more than 10 cm in diameter) or small end growths on old dead colonies of branched corals occurred in weakly silted areas of the bottom (Fig. 2b). Relatively large colonies (up to several tens of centimeters in diameter) were usually encountered on boulders, raised fragments of dead coral reefs, or elevations of the bottom (Fig. 2a).

Earlier ([4, 6], unpublished reports of expeditions of the IMB and the Tropical Center of the RAS until the year 1990), Nha Trang Bay was characterized by a high coverage (up to 100%) of the substratum with live corals in coral habitats. Toward the end of the study period, large dead coral colonies without mechanical damage were found everywhere (Fig. 2c). Mainly small (young) specimens of other hermatypic coral species were found. The total live coral coverage was not above 30% at all points surveyed. The maximum coverage was found for the near-shore reefs of Cape Kage (Station 1), Mung Island (stations 15 and 60), and Tam Island (station 19), where at depths down to 10 m a considerable quantity of live corals was observed on the bottom elevations (ridges) against the background of the silty bottom between the ridges (Fig. 2a).

The fluorimetric studies showed that in most cases the photosynthetic activity was inhibited after a 1-day exposure of algae with bottom sediment suspension and sensitivity varied among the algal species (Table 2). Pooling the data on the suppression of photosynthetic

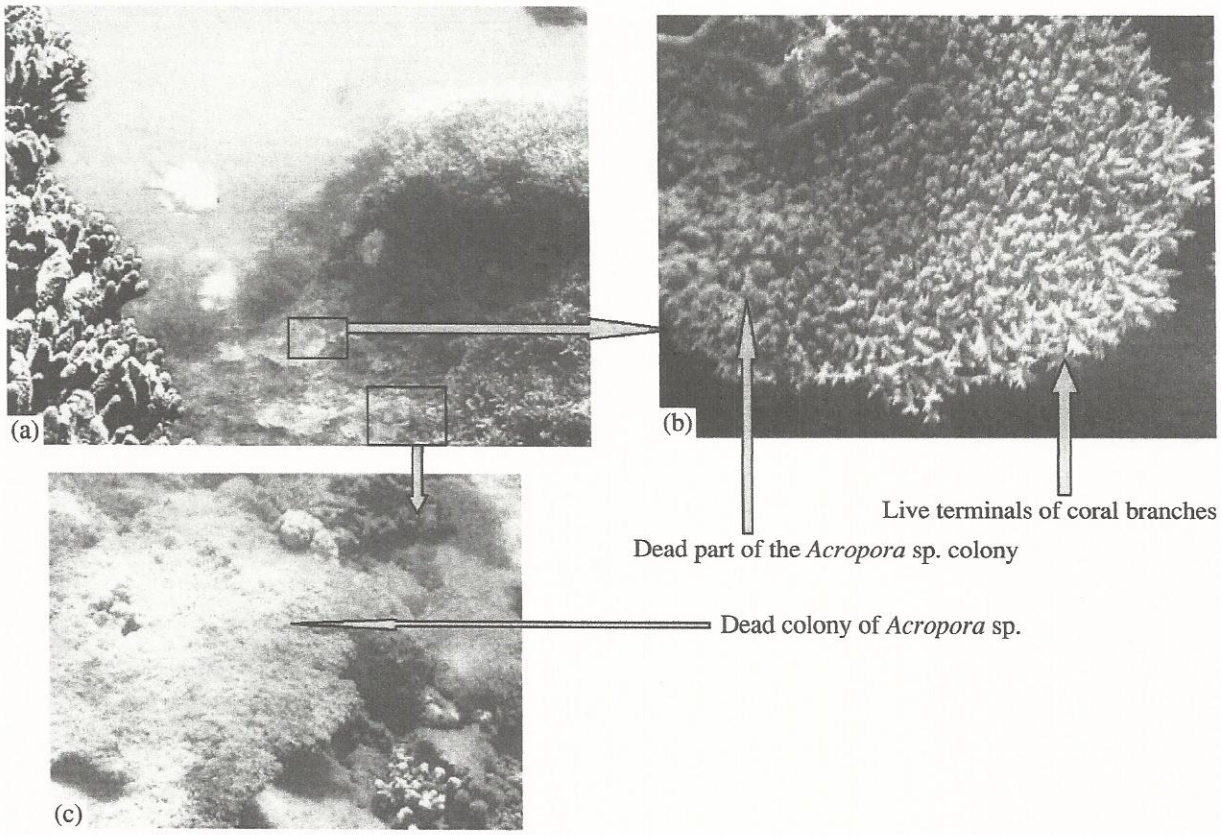

Fig. 2. Station 15 (Mung Island). Depth is about 4 m and transparency about 12 m (see text for explanation).

activity 24 h after supplementing the bottom sediment suspension for four test cultures, we calculated the average values of $^{24}K_{PA(avg)}$ (Table 2), which, to some degree, represent the total response of the multispecies natural community of photoproducers. Most of the tested samples exerted a significant inhibitory effect on photosynthetic activity (Table 2). Inhibition of photosynthetic function was highest ($^{24}K_{PA(avg)}$ = 60%) with the bottom sediments sampled at station 5. In most cases (10 stations), the values of $^{24}K_{PA(avg)}$ varied in the range of 23–37%. In *Nannochloris* sp. exposed to the bottom sediment suspension with the highest content of dioxins (4–20 ng/kg) (stations 16, 33, and 59), K_{PA} increased on the 2nd–3rd day, while at a dioxin concentration of less than 4 ng/kg, K_{PA} decreased with time (Table 2). The exception was a decrease in K_{PA} after the first day of exposure with sediments from the former bed of the Kay River at a dioxin concentration of 7.9 ng/kg (station 50). It is possible that the decrease was due to the different composition of toxic substances in the sediments of the river and the sea bay.

The data on the effect of bottom sediment suspension on bioluminescence agreed well with the data on photosynthetic activity (Table 2). A pronounced toxic effect on bacteria was found for sediments from almost all of Nha Trang Bay, excluding stations 20, 27, 28, 29 (channel of the Be River), station 49 at Tyala Island (which is the farthest from the mouth of the Kay River), and station 47 in Binhkanh Bay. Despite the strong anthropogenic impact (except station 49), bottom sediments from these points produced a pronounced positive effect, increasing bioluminescence. Bottom sediments from the cutoff meander of the Kay River (station 50), despite the high dioxin content (I-TEQ = 7.9), induced no pronounced inhibition of bioluminescence. Bioluminometric data, along with the results of other tests, suggest the toxicity of bottom sediments from transects C, B, and partly A, as well as the mosaic distribution pattern and different present-day composition of toxicants in bottom sediments of the bay.

All the extracts of bottom sediments tested displayed a weak mutagenic effect (Table 1). The extracts of sea bottom sediments showed a mutagenic effect only following metabolic activation and induced a shift of the reading frame of the genetic code. On the other hand, extracts of the bottom sediments from station 36 located in the immediate proximity of the Kay River mouth and sediments from station 44 (coral bank) showed a direct mutagenic effect, which was retained after metabolic activation. Bottom sediment extracts from station 36, in contrast to all others, caused mutations of the base substitution type. River sediment

Table 2. Inhibition of the photosynthetic activity of algae (% of the control) on 24, 48, and 72 h exposure and of chemoluminescence of heterotrophic bacteria (toxicity index) in the presence of the bottom sediment suspension

Transect	Station	Depth, m	1-TEQ, ng/kg	Coefficient of inhibition of algae photosynthesis (K_{PA}) on 24, 48, and 72 h exposure												$^{24}K_{PA}$ (avg)	Toxicity index (I_t) for 30 min exposure
				Tetraselmis viridis			*Nannochloris* sp.			*Isochrysis galbana*			*Thalassiosira weissflogii*				
				24	48	72	24	48	72	24	48	72	24	48	72		
River	50	1.5	**7.9**	37	21	15	22	16	14	41	42	29	38	30	20	**35**	15
C	36	15.4	**2.4**	28	30	20	14	17	14	71	87	80	24	27	16	**34**	**44**
	5	25.7	**3.1**	39	38	30	32	32	22	94	69	91	76	41	55	**60**	**49**
	33	22.7	**4.2**	20	24	18	14	12	19	32	15	2	33	25	0	**25**	**73**
	32	19.4	–	8	25	18	11	17	13	24	0	0	18	0	0	15	**44**
	30	21.5	**1.8**	27	20	8	14	19	23	29	8	0	22	0	9	**23**	**62**
	16	20.6	**20.8**	11	17	17	9	17	16	23	0	0	18	0	0	15	**37**
	24	32.7	**0.4**	29	19	23	13	7	5	26	18	10	30	28	14	**25**	**94**
B	59	7.5	**16.8**	27	25	8	20	18	31	30	17	0	31	6	3	**27**	**80**
	37	21.8	**1.9**	14	10	0	9	9	13	22	7	14	8	0	0	13	**70**
	39	20.5	**0.8**	9	4	8	0	3	0	0	18	0	2	0	0	3	**30**
D	29	14.0	**1.0**	21	16	3	8	12	1	16	16	2	26	20	2	**18**	–97
	28	10.6	–	39	29	2	28	19	1	22	21	20	26	26	22	**29**	–47
	27	9.5	**2.1**	58	45	23	24	19	3	22	14	0	42	24	13	**37**	–108
	20	4.5	**0.7**	2	0	0	4	9	0	0	0	0	2	0	0	2	–157
A	41	21.0	**0.8**	29	25	13	15	9	4	31	18	17	15	13	10	**23**	**50**
	44	18.0	**0.5**	2	0	2	0	0	0	0	2	6	0	0	0	1	**49**
	49	18.0	**1.3**	0	0	0	0	0	0	0	8	6	0	0	0	0	–201
	47	5.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–65

Note: The depth and total amount of dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) represented by the international equivalents of toxicity (I-TEQ) are given for stations of bottom sediment sampling. Bold-faced values indicate a significant toxic effect; "–"—measurements were not made.

extract also induced a direct mutagenic effect, which, however, was lost following metabolic activation. We note that a reduction in the mutagenic index in some experiments, compared to the control (MI < 1), might indicate the presence of compounds toxic to *Salmonella*. Thus, the Ames test, suggesting the presence in bottom sediment samples of mutagens and toxicants, indirectly supports the above assumption on the different present-day composition of toxicants in the bottom sediments of the river and the sea bay.

The results of chromatographic and mass spectrometric analyses revealed the presence of persistent congeners PCDD and PCDF in bottom sediment samples from the bay. The spectrum and distribution pattern of congeners in all samples were close to those of the defoliant "Agent Orange" (predominantly 2,3,7,8-TCDD, 1,2,3,4,6,7,8-HpCCD, OCCD, and 1,2,3,7,8,9-HxCDF, OCDF). The total amounts of dioxins in the bottom sediments at sampling stations varied from 0.409 to 20.806 ng/kg in I-TEQ (Table 2), which is several orders of magnitude higher than the accepted sanitary standards.

DISCUSSION

The impairment of the state of near-shore coral reefs in Nha Trang Bay has been explained by various reasons. Among them global warming of the climate, much increased recreation pressure and coral harvest for souvenirs, injurious use of corals for lime production, fishing with the use of explosives, and pollution of the Kay and Be rivers by agricultural and municipal waste water.

Our integral assessment of the state of the bottom habitats in the bay suggests that bottom sediments contain long-lived components of herbicide chemicals of the "Agent Orange" type and that the environment is unfavorable (toxic) to many groups of organisms in the greater part of the bay. The diagnostic data allow us to come back to the earlier hypothesis [13] that despite the undeniable and apparently considerable adverse affects of the above factors on the bay's ecosystems, one of the most probable reasons and a trigger for the degradation of the reef-forming communities were toxic dioxin-containing components of herbicides, which were used as defoliants during the American–Vietnamese war (Vietnam War) and have entered the bay via the Kay River run-off.

In the basin of the Kay River and its tributaries, hundreds of thousands of highly toxic defoliants were sprayed in the course of military operations. Both soluble and little-soluble highly toxic components of dioxin-containing chemicals were transferred into the bay via floodwaters and heavy fractions of river silts and detritus. The range of long-lived ecotoxicants (PCDD and PCDF) in the modern sediments of the river and the bay bears a sharply pronounced resemblance to that of soils in areas treated with "Agent Orange" during the war [20]. This suggests that the transfer into the bay of at least part of the dioxins occurred via river run-off from the defoliant-treated areas.

It is very likely that over a relatively short period of time (2–3 years) after the massive treatments of the jungles were stopped considerable amounts of dioxin-containing defoliants, which were sprayed over the extensive watershed of the Kay River, were transferred via river run-off into the sea. Little-soluble and adsorbed components of toxicants together with bottom silts were subsequently redistributed over the bay. The toxic action of dioxin-containing defoliants on marine organisms entailed the inhibition of primarily hermatypic photosynthetic organisms and aerobic heterotrophic bacteria, which are the main components of reef ecosystems maintaining their stability. The primary massive chemical action was aggravated due to the periodic (during the rainy seasons) input of defoliant components from the river valley and to increasing anthropogenic pressure. Thus, the state of the bottom environments and the near-shore bottom communities in Nha Trang Bay has deteriorated markedly. The results of our investigations suggest that the presence of residues of dioxin-containing ecotoxicants in the marine bottom sediments is evidently the major stress factor (along with significant anthropogenic pressure) for the modern near-shore communities of Southern Vietnam. The adverse effect of dioxin-containing ecotoxicants is aggravated by the periodic stirring-up of silts during the storms and generally increased turbidity of the water as the results of the reduced coverage by live corals, which are the natural biological filters in the near-shore tropical ecosystems.

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Australian Government
Department of Veterans' Affairs
Australian Institue of
Health and Welfare

Cancer Incidence

in Australian Vietnam Veterans

Study 2005

Executive Summary

Study initiation

A key recommendation of the 1997 *Mortality of Vietnam Veterans: The Veteran Cohort Study* was to monitor the mortality of Vietnam veterans and repeat the study after 2000. In 2002, the then Minister for Veterans' Affairs agreed that the Repatriation Commission should undertake the *Third Vietnam Veterans Mortality Study* and *Cancer Incidence in Vietnam Veterans Study*. The Commission asked the Australian Government Department of Veterans' Affairs (DVA) to conduct these studies which were undertaken with assistance from the Australian Institute of Health and Welfare (AIHW).

This report is the first of four volumes to be published and is the first investigation of cancer incidence for male Australian Vietnam veterans from all three branches of the armed forces – Navy, Army and Air Force. The number of females who served in Vietnam were too few for meaningful results in a study of this kind.

Study objectives

The objectives of the cancer incidence study were to:

- identify cases of cancer (excluding non-melanocytic skin cancers) among Vietnam veterans during the period 1982 to 2000 inclusive;
- compare the number of cases of cancer among Vietnam veterans with the number of expected cancers based on cancer incidence of the Australian community;
- report any differences in the cancer incidence for specific types of cancer, as highlighted by past studies and the literature review, from the Australian community;
- investigate any differences in cancer incidence between Navy, Army and Air Force Vietnam veterans;
- investigate any relationship between cancer incidence and exposure of Navy veterans to Vietnamese waters; and
- establish lists of personnel who served onboard HMA ships and Army small ships deployed to Vietnam and determine cancer incidence on a ship-by-ship basis.

Study design

The cancer incidence study is a retrospective cohort study of male Australian personnel who served in Vietnam between 23 May 1962 and 1 July 1973. The study examines cancers diagnosed during the period from 1982 to 31 December 2000. The study compares the cancer incidence rates of male Australian Vietnam veterans with those of Australian males in the general community. All comparisons have been standardised by age and year of diagnosis. In addition, the study analyses whether cancer incidence rates vary between different groups of Vietnam veterans or by duration of service in Vietnamese waters.

Report structure

Chapter One provides a background to previous studies and an overview of the study. **Chapter Two** of this Report provides a brief summary of the Vietnam War and Australia's involvement, which was formally announced in May 1962. There was a gradual build up of numbers, peaking in 1968, followed by a gradual decline until most of the troops had departed by the end of 1972.

The roll compiled for this study was drawn from the Nominal Roll of Vietnam Veterans currently maintained by DVA, as described in **Chapter Three**. The Nominal Roll has been extensively updated since it was last published in 1997. The Study Roll is a list of all those male defence personnel currently identified as serving in Vietnam between May 1962 and July 1973. The Study Roll contains a total of 59,179 Vietnam veterans.

The methodology for this study is outlined in **Chapter Four**. In brief, the Study Roll was matched against a number of databases, allowing determination of vital status (that is, whether a person is alive or dead), and determining the number of cancers. Vital status was determined for 97.5% of the cohort and 2.5% were lost to follow up. The number of cancers observed amongst the Vietnam veterans was compared to the number expected in Australian men of the same age.

As outlined in **Chapter Five**, the nature of service varied considerably between the Service branches. Army and Air Force veterans averaged approximately one year of service in Vietnam whereas Navy veterans averaged approximately three months. The Navy personnel were substantially younger than the Army or Air Force personnel when they first served in Vietnam.

The results of the cancer incidence analysis are presented in **Chapter Six** and these findings are discussed in **Chapter Seven**.

Findings

The results presented in **Chapter Six** show that Australian Vietnam veterans have a significantly elevated overall cancer incidence rate that is 13-15% higher than expected.

Incidence rates for specific cancers of *a priori* interest showed a mixed pattern. Rates of five cancers (head and neck, lung, prostate, Hodgkin's disease and melanoma) were significantly higher than expected. Four cancers (liver, thyroid, multiple myeloma and non-Hodgkin's lymphoma) showed a significantly lower cancer rate than expected.

The pattern of cancer incidence varied between the Service branches. Navy veterans had the highest rate of cancer, higher than expected by 22-26%, followed by Army veterans, higher than expected by 11-13%. In comparison Air Force veterans had a 6-8% higher than the expected rate of cancer, although this was not statistically significant.

Veterans from all Service branches showed a higher than expected incidence of genitourinary cancers and melanoma. Navy and Army veterans showed a higher than the expected incidence of cancers of the lung, oral cavity, pharynx and larynx and cancers of the head and neck. Whereas Navy veterans demonstrated a higher than the expected incidence of gastrointestinal cancer, Army and Air Force veterans showed higher than the expected incidence of Hodgkin's disease and prostate cancer. It should be noted that veterans from all three Service branches showed lower than the expected incidence of non-Hodgkin's lymphoma.

An exposure of particular interest to Vietnam veterans is the herbicides that were used in Vietnam. The rate for several of the cancers that have been associated with herbicide exposure are high in this study; several others do not differ from expectation; others are significantly below the community norm.

Within the limitations of the service details available for Navy personnel, the higher than expected cancer incidence among this group could not be attributed to either the ship on which they served or the time spent in Vietnamese waters.

Strengths and Weaknesses of the Study

As discussed in **Chapter Seven**, the strengths of the study include its size, data quality, high percentage of known vital status, homogeneity of the study population, extensive consultation with the veteran community and close external scientific advice.

The study had limited ability to quantify exposures, making it difficult to assign any observed outcome to a particular exposure. A discussion of the possible exposures that could be an explanation of the observed pattern of cancer is contained within this Report, but, given the uncertainties associated with exposure, this discussion is, by necessity, speculative in nature.

Conclusion

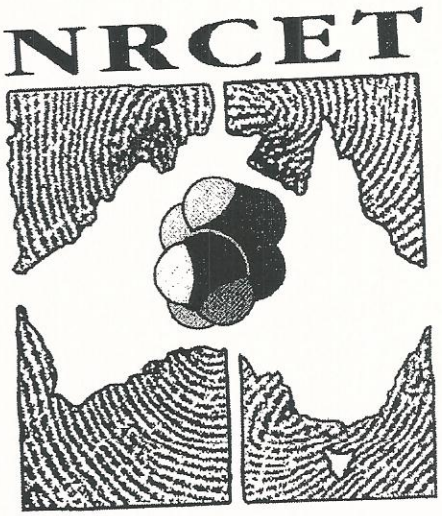
In conclusion, this study provides good evidence that Australian male veterans of the Vietnam War have an increased rate of cancer overall. There was an excess of 613 cancers; 88% of this excess consisted of lung cancers, oral cavity, pharynx and larynx cancers, prostate cancers and melanomas. The pattern is not generally consistent across the Navy, Army and Air Force veterans, although melanoma, and to a lesser degree prostate cancer, were consistently elevated in all three groups.

Additional Work

Three more reports will be completed in this series during 2005. The second volume will be a mortality study of all male Vietnam veterans. The third volume will investigate the mortality and cancer incidence of national service veterans and non-veterans. Finally the fourth volume will repeat the 1992 Dapsone study to investigate the effect of exposure to this anti-malarial drug on mortality and cancer incidence among the male Army cohort.

This further research may enable more useful observations to be made about the health of Vietnam veterans.

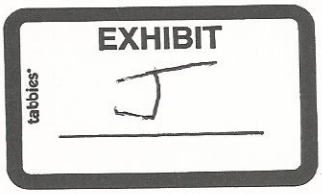
EXAMINATION OF THE POTENTIAL EXPOSURE OF ROYAL AUSTRALIAN NAVY (RAN) PERSONNEL TO POLYCHLORINATED DIBENZODIOXINS AND POLYCHLORINATED DIBENZOFURANS VIA DRINKING WATER



A REPORT TO THE DEPARTMENT OF VETERAN AFFAIRS, AUSTRALIA

THE NATIONAL RESEARCH CENTRE FOR ENVIRONMENTAL TOXICOLOGY (ENTOX)

QUEENSLAND HEALTH SCIENTIFIC SERVICES (QHSS)



EXAMINATION OF THE POTENTIAL EXPOSURE OF RAN PERSONNEL TO POLYCHLORINATED DIBENZODIOXINS AND POLYCHLORINATED DIBENZOFURANS VIA DRINKING WATER

A REPORT TO:

THE DEPARTMENT OF VETERAN AFFAIRS, AUSTRALIA

This report is dedicated to

Ralph Hayden Spooner

EX Ran Warrant Officer

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COMPOUND ABBREVIATIONS

I-TEq	2,3,7,8-Tetrachlorodibenzodioxin toxicity equivalents
PCDDs	Polychlorinated dibenzodioxins
TCDD	Tetrachlorodibenzodioxin
PeCDD	Pentachlorodibenzodioxin
HxCDD	Hexachlorodibenzodioxin
HpCDD	Heptachlorodibenzodioxin
OCDD	Octachlorodibenzodioxin
PCDFs	Polychlorinated dibenzofurans
TCDF	Tetrachlorodibenzodioxin
PeCDF	Pentachlorodibenzodioxin
HxCDF	Hexchlorodibenzodioxin
HpCDF	Heptachlorodibenzodioxin
OCDF	Octachlorodibenzodioxin
HCB	Hexachlorobenzene
DDE	Dichlorodiphenyl ethane
DDT	Dichlorodiphenyl trichloroethane
DDD	Dichlorodiphenyl dichloroethane
DMA	Dimethyl arsenic acid

EXECUTIVE SUMMARY

Studies of Australian Vietnam veterans have revealed greater than expected mortality, with the highest overall levels of mortality occurring among the Royal Australian Navy (RAN).

During the Vietnam War, large quantities of phenoxy herbicides (Agent Orange) contaminated with 2,3,7,8-tetrachlorodibenzodioxin (TCDD), arsenical herbicides (Agent Blue) and organochlorine pesticides were used. There has been concern that exposure to these chemicals may have long-term adverse health effects. TCDD for example is now known to have many toxic effects in humans, including carcinogenesis.

In RAN veterans, exposure to chemicals such as the TCDD is unlikely to be related to overhead spraying or other forms of direct contact.

The aim of this study was to investigate the potential for exposure of sailors to contaminants via drinking water. On Navy ships and Army small ships, potable water was produced from evaporative distillation of surrounding estuarine water. This water would have had variable salinity and amounts of suspended solids. It may have also contained contaminants in solution.

The study was carried out in two phases. First, the co-distillation of organic pollutants such as dioxins along with water in ship's distillation units was examined. Phase One results of this study demonstrated that:

- **Co-distillation of organochlorine pesticides and dioxins was observable in all experiments conducted;**

- **In pure or saline water, between 75% and 95% of 2,3,7,8-TCDD was co-distilled with the first 10% of water distilled. Thus, distillation results in an increase in the contaminant concentration in the distillate;**

- The tendency of several other organochlorines to co-distill was greater than for TCDD. For dioxins a tendency of decrease in co-distillation with increasing molecular mass was apparent. Hepta- and octachlorinated dioxins showed little tendency to enrich in the distilled water;

- A compounds' co-distillation decreased with increasing levels of suspended solids in the water. This can be attributed to the increase in sorption (fugacity) capacity in the source water. At a highest level of 1.44 g total suspended solids in the water about 38% of 2,3,7,8-TCDD co-distilled in the first 10% of water distilled. Nevertheless, even at these relatively high levels of suspended solids, TCDD was enriched by almost a factor of 4 in the distillate (assuming only 10% of the water is distilled);

- Co-distillation of dioxins and organochlorines from water collected from the Brisbane River (water was added to known amount of chemicals of interest) demonstrated that the process is reproducible using estuarine water. In these samples 48 – 60% of the TCDD co-distilled within the first 10% of distilled water.

Overall, Phase One of the study clearly demonstrated that if source water is contaminated, co-distillation is a process which can result in the contamination of ships water supplies with chemicals such as dioxins.

In Phase Two of the study the investigations included the potential co-distillation of the Agent Blue component dimethylarsenic acid, which is now known to be a potent carcinogen.

In addition, experiments were carried out in which the capacity for de-novo synthesis of dioxins from the main components of Agent Orange was evaluated. Evaporative distillation entails heating of the source water using copper elements. Combustion of the components of Agent Orange has great potential to produce dioxins. Moreover, copper (which formed part of the distillation unit) is a known catalyst for dioxin formation.

Finally exposure calculations were carried out for personnel on board ships. These calculations were based on some of the first analytical results from fish samples that were caught during the early 1970's in contaminated waters from Vietnam and analysed in the 1970's for TCDD.

Phase Two results of this study were:

- **Dimethylarsenic acid does not co-distill at significant levels during evaporation and thus the drinking water on board of RAN ships was unlikely to be contaminated with dimethylarsenic acid;**

- **No de-novo synthesis of TCDD or any other dioxins from the other components of Agent Orange was detected under the experimental conditions. However, the copper element on board ships was probably significantly hotter than in the simulation experiments selected in the laboratory, and thus these results should not be used as absolute evidence that such a formation did not occur in the distillation units of the RAN ships;**

- **TCDD exposure via drinking water may have been substantial, and it is likely that solely the consumption of drinking water resulted in exposure levels that exceeded the recommended Total Monthly Intake (TMI) values for TCDD of 70 pg / kg bw / month significantly. A TMI of 70 pg/kg bw / month is a level set by many European authorities; it is also the level proposed by the draft recommendation of the National Health and Medical Research Council in Australia.**

Overall the findings of this study demonstrate that evaporative distillation of water does not remove but rather enriches certain contaminants such as dioxins in drinking water. The study provides some evidence that use in the distillation process of water contaminated with TCDD would result in contamination of potable water. Subsequent ingestion by sailors on board ships (as well as

soldiers and airmen, who were passengers) is thus a vector for exposure to these chemicals.

While it is unlikely that accurate exposure of the personnel on board ships can be estimated, the study findings suggest that the personnel on board ships were exposed to biologically significant quantities of dioxins. This may explain some of the epidemiological findings in this study group.

INTRODUCTION

Studies undertaken by the Australian Government have indicated that Australian Vietnam veterans experience greater than expected mortality (Crane et al., 1997a) and that when mortality of two cohorts of conscripted veterans are compared, greater relative mortality (Crane et al., 1997b). Subsequent studies have revealed validated elevation in certain types of cancer in the veterans, and in their children, small increases in some birth defects and the rate of deaths, particularly suicide (AIHW, 1999).

The highest elevation in mortality was among veterans of the Royal Australian Navy, rather than the land and air forces (Crane et al., 1997a). Uncertainty remains as to whether this increase in mortality is related to the use of "Agent Orange" contaminated with polychlorinated dibenzodioxins and dibenzofurans (PCDD/Fs). In addition to "Agent Orange" and various other Agents that contained dioxin impurities, "Agent Blue" was the third most commonly used herbicide. It consisted of an aqueous solution of dimethylarsenic acid (DMA), or more commonly cacodylic acid. DMA was sprayed primarily in crop destruction missions (50%) or was used in the control of grasses around base perimeters. Recent research has demonstrated that DMA is a carcinogen itself (for details see Ng 2002, attached in Appendix II) and hence in Phase 2 this project was expanded to include preliminary evaluation of exposure to DMA.

A starting point of the study was that elevated levels of mortality were found in sailors. These sailors were never present in the areas where "Agent Orange" or any other Agents were directly employed for defoliation. Hence, prior to this study it was assumed that the significantly higher incidences of mortality observed in this cohort could not be related to the use of defoliants.

However, marine vessels such as the troop carrier and supply vessel HMAS Sydney served for substantial periods in estuarine waters in Vietnam and relied on collection of potentially contaminated estuarine water, which was then distilled for drinking. According to personnel on these ships a common procedure was to produce and store

drinking water from the relatively turbid estuaries, while the distilled water that was produced in open sea was primarily used for the boilers of the vessel's steam engines.

In the general population, exposure of humans to PCDD/Fs is attributed primarily to the consumption of contaminated food (e.g. Beck et al., 1989, Liem et al., 2000). This is due to the physico-chemical properties of these chemicals including their hydrophobicity and persistence and the resulting accumulation of these chemicals in lipophilic compartments of plants (Müller et al., 1997) and animals (McLachlan, 1996 1997).

These physico-chemical properties and in particular the exceptionally high sorption coefficients and very low solubility of PCDD/Fs in water are factors which reduce the risk of contamination of surface and ground water. Environmental fate models, as well as experimental evidence, suggest that consumption of contaminated water is a pathway which can safely be neglected in the calculation of exposure of humans to these compounds (Hattemer-Frey & Travis, 1989; Fürst, 1998, Liem et al., 2000).

However, in supply ships and other vessels which regularly visited the conflict areas in Vietnam, the water consumed by the crew has an unusual history. It was often collected from near-shore marine waters that received runoff from areas which had been sprayed with Agent Orange and Agent Blue. To make this water suitable for drinking and other purposes aboard ship the water was distilled aboard.

Evaporative distillation is a process that is suitable for obtaining water which is relatively free from salts and other high boiling components with a high water solubility. However, in contrast to their high sorption coefficient, both experimental data and models have indicated that the Henry's Law constant of chemicals such as dioxins is sufficient to allow desorption from natural water surfaces (i.e. Lyman et al., 1990). It seems feasible that co-distillation could occur during the distillation process on the marine vessels.

The aim of the study was to undertake laboratory experiments which provide information to assess whether PCDD/Fs and also DMA can co-distill in significant quantities in the distillation units of ships. Further, the study aimed to evaluate

potential exposure of PCDD/Fs to personnel aboard ships. The results are useful for an assessment of exposure pathways of PCDD/Fs to crew and troops aboard ships which regularly loaded sea water for distillation and subsequent consumption.

MATERIALS AND METHODS

Distillation Experiments with Dioxins and other Organochlorines

The project's goal was to identify whether significant quantities of potentially harmful chemicals may have co-distilled into drinking water in the ships which transported Australian Troops during the Vietnam conflict. The distillation plants used on the various ships at the time of the conflict all operated using the same principles. In general, sea water was fed into an evaporator where the water was boiled by a combination of heating and reduced pressure (vacuum) and the vapour was condensed in the condenser from where it was pumped into feed tanks (Figure 1). A detailed description of the operation and function of the distilling plants of ships is given in Naval Marine Engineering Practice Vol 1 (1959). The aim of this project was to reproduce the distillation plants principal processes in the laboratory and to assess the potential for co-distillation of chemicals in the distillation unit. Ultimately, this has provided information that allows us to evaluate the potential for contamination of drinking water from distillation of contaminated sea water.

Chemicals Tested

Agent Orange, the key defoliant used during the Vietnam conflict was contaminated with up to ~ 45 ppm of 2,3,7,8-TCDD and traces of 1,2,3,7,8-PeCDD (Young et al. 1978 quoted in IoM, 1999). It has been estimated that a total of 368 pounds of dioxin were sprayed in Vietnam over a six-year period (Gough, 1986 quoted in IoM, 1999). Although the defoliants did not usually contain relevant levels of any of the other 2,3,7,8-chlorine substituted PCDD/Fs, the study was extended to include a range of other 2,3,7,8-chlorine substituted PCDD/F congeners as well as the relatively nontoxic 1,2,3,4-TCDD and a range of organochlorine pesticides including DDT, HCB, lindane and dieldrin. This extension of the compound group allowed us to assess physico-chemical properties which govern the water volatility of lipophilic

organic chemicals and thus to predict water volatility for compounds which have not been studied here. In addition to the chemicals that were tested in Phase 1 of the project, we undertook further studies in Phase 2 of the project using DMA. A list of the chemicals used, including physico-chemical properties, is provided in Table 1.

Laboratory Distillation Plant

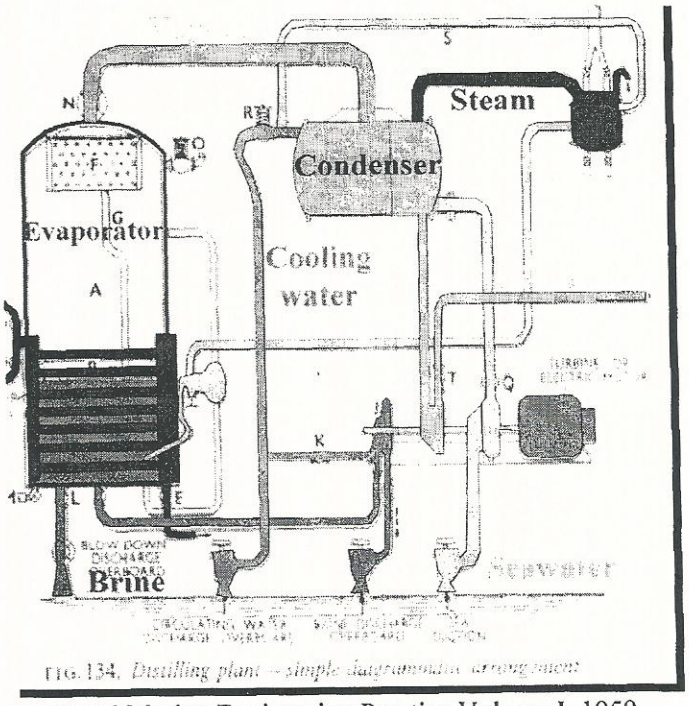
For the purpose of this study a commercially available rotary evaporator (Büchi, Switzerland) was used. Discussions with seamen and mechanics who served on RAN vessels during the conflict made certain that the principles by which solvents are evaporated in rotary evaporators were essentially the same as those used in the Naval Vessel Distillation Plants. Rotary evaporators such as the one used in this study essentially function as a batch evaporator. The water to be distilled is contained in a round bottomed flask with a seal which fits to the steam duct which leads the water vapour into the condensing chamber (Figure 2). The flask is lowered into a water bath which is maintained at the temperature of interest (in this study we used 58° C which is similar to that used in the distillation plants of the ships). In the condensing chamber, chilled water runs through a condenser coil and the water which condenses on the coils is collected in a solvent collection flask. The rotary evaporators are equipped with a pump, which is controlled through a vacuum control unit that allows accurate control of the vacuum during evaporation of the solvent. For the purpose of this study, the vacuum in the unit was set initially to 14 kPa (about 14 % of atmospheric pressure) and then slowly decreased until boiling of the water was observable. Water was then carefully evaporated since it was important to avoid non-vapour water containing the chemicals transferring through the condenser to the collection chambers ('bumping').

Distillation Experiments - Variations of Parameters

We studied the process through a series of experiments in which experimental parameters or compounds were altered. The key parameters which were altered were salinity of the water and quantity of suspended solids in the water.

For the experiments one litre round bottom flasks were cleaned with toluene and acetone and once they were dry, were spiked with a solution of the chemicals of interest. The round bottom flask was slowly swirled to coat the interior surface and to allow the solvent to evaporate. Once the solvent had evaporated, 1 L of reversed osmosis water (RO-water) was added and, depending on the variant of the experiment, known quantities of NaCl and/or sediment were added to the sample.

The round bottom flasks were then sealed, wrapped in aluminum foil and put on a shaker for at least one week so that the chemicals could equilibrate between the surface of the round bottom flask and the water.



Naval Marine Engineering Practice Volume I, 1959

Figure 1: Schematic diagram of the distillation unit on board RAN vessels

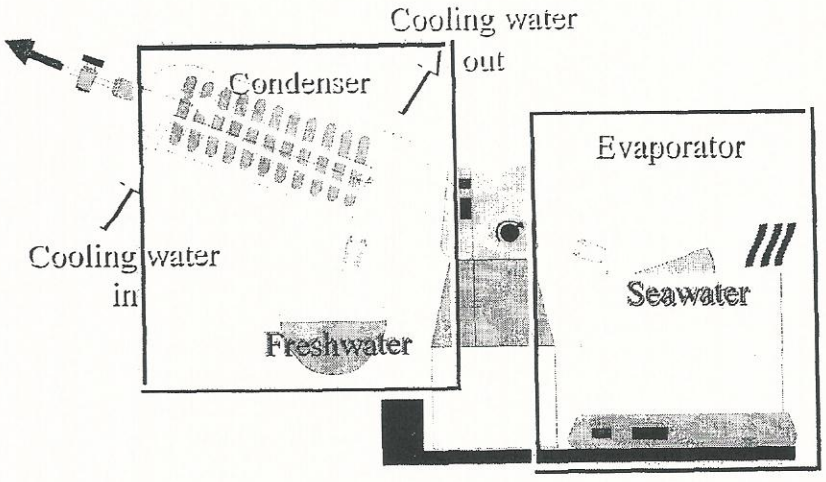


Figure 2: Schematic representation of the laboratory distillation unit

Table 1: List of chemicals used in the experiment, Molar mass, Henry's Law constant and water solubility data compiled from Mackay et al. 1992, Windholz, 1983, Paasivirta et al., 1999 and reviews by Huelster, 1994, Mueller, 1997, Cavanagh 2000 and IARC, 1987.

Compound	Molar mass (g)	Vapour Pressure* (Pa)	Aqueous solubility	H (Pa m^3 mol^{-1})	Spiked amount ng/L	RRT
HCB	284.8	0.0023	5 ug/L	131	100	0.36
Lindane	290.8	7-213 E-4	2.2 – 10 mg/L	0.005-1.5	100	0.50
Heptachlor	373.3	0.2 – 0.5	6 – 200 ug/L	18-233	100	0.54
Heptachlorepoxide	-	3.5-450 E-4	20-200 ug/L	2-4.3	100	0.59
Aldrin	364.9	0.0008-0.75	10-200 ug/L	1.4-91	100	0.73
Dieldrin	380.9	0.2-9 E-4	20-2000 ug/L	0.02-5.8	100	0.82
DDT	354.5	0.2 – 20 E-4	1-460 ug/L	0.86-7.3	200	0.86
DDE	318.1	1.7 – 10 E-4	1-55 ug/L	0.8-124	200	0.98
DDD	320.1	1-9 E-4	2-160 ug/L	0.27-9	200	1.02
2,3,7,8-TCDD (D4)	322.0	1.2 – 6.2E-4	8-200 ng/L	3.347	40	0.99
1,2,3,4-TCDD	322.0	6.38E-6	640 ng/L	3.8	8.6	1.14
1,2,3,7,8-PeCDD	356.4	4.23E-6	120 ng/L [a]	0.266	40	1.18
1,2,3,4,7,8-HxCDD	391.0	1.45E-6	4.4 ng/L	1.084	40	1.36
1,2,3,4,6,7,8-HpCDD	425.2	1.77E-7	2.4 ng/L	1.273	40	1.61
OCDD	460.0	1E-10 -9E-7	0.074-0.4 ng/L	0.684	60	1.96
2,3,7,8-TCDF	306.0	1.2 – 2E-4	419 ng/L	1.461	40	1.00
1,2,3,7,8-PeCDF	340.4	1.72E-5	236 ng/L [b]	0.505	40	1.14
1,2,3,6,7,8-HxCDF	374.9	3.08E-6	17.7 ng/L	1.454	37	1.31
OCDF	443.8	5.0 E-10	1.4 ng/L	0.191	61	1.95
DMA	138.0	n.a. but low	2 kg/kg	n.a. but very low	1000	n.a.

RRT was calculated from retention times on a DB1 column; *vapour pressure data represent subcooled liquid vapour pressure's; [a] for 1,2,3,4,7-PeCDD; [b] for 2,3,4,7,8-PeCDF

For the volatilization study, the rotary evaporator was disassembled and all sections which could come into contact with the chemicals were thoroughly cleaned to avoid contamination of the samples. In order to determine the quantity of water which had been distilled, the mass of the collection flask was determined before the start of the experiment. The temperature was controlled through a water bath which was set to 58^0 C as described in the manual for the ships distillation unit. In all experiments the goal was to slowly distill a fraction of the water and evaluate the amount of dioxins and organochlorines which co-distilled. Although in the initial proposal it was only proposed to analyze one distillate it was decided to distill two fractions, a first fraction of about 10 % of the water and a second fraction with about a further 30 % of the water. For the distillation process the round bottom flask was attached to the rotary evaporator and the vacuum in the system was increased until about 13 - 14 % of atmospheric pressure (14 kPa) was reached. The flask was rotated to increase the surface area of the water to be distilled and to avoid 'bumping'. Chilled water (10^0C) was circulated through the condenser unit. The experiment was carefully observed over the first few minutes until the water temperature in the flask had increased to the assigned temperature to avoid 'bumping'. Once the system temperature had equilibrated the vacuum was carefully decreased to a pressure which resulted in a slow and steady distillation of the water. Markings on the collection flask allowed a rough assessment of the quantity which had been distilled and in the distilled fraction 1 (F1) about 10 % of the water and in the distilled fraction 2 (F2) a further 30 % of the water was collected (For details of the collected fraction see Appendix I Table 3.). Following the distillation of the first fraction F1, the inside of the condenser unit of the rotary evaporator was rinsed with RO water which was added to the F1 fraction. Once the second fraction, F2, was distilled the inside of the rotary flask was rinsed with about 10 mL of acetone followed by dichloromethane, both of which were added to F2.

Following the distillation the various fractions F1, F2 as well as the remaining non-distilled water (R) were transferred into separating funnels and subjected to liquid-liquid partitioning using dichloromethane and hexane. The nonpolar fractions were combined and concentrated to a small volume (< 500 µl). In the preliminary

experiment and Expt.1 the samples were quantitatively transferred into 50 µl microvial inserts, concentrated under a gentle stream of nitrogen to almost dryness and filled with 15 µl of toluene.

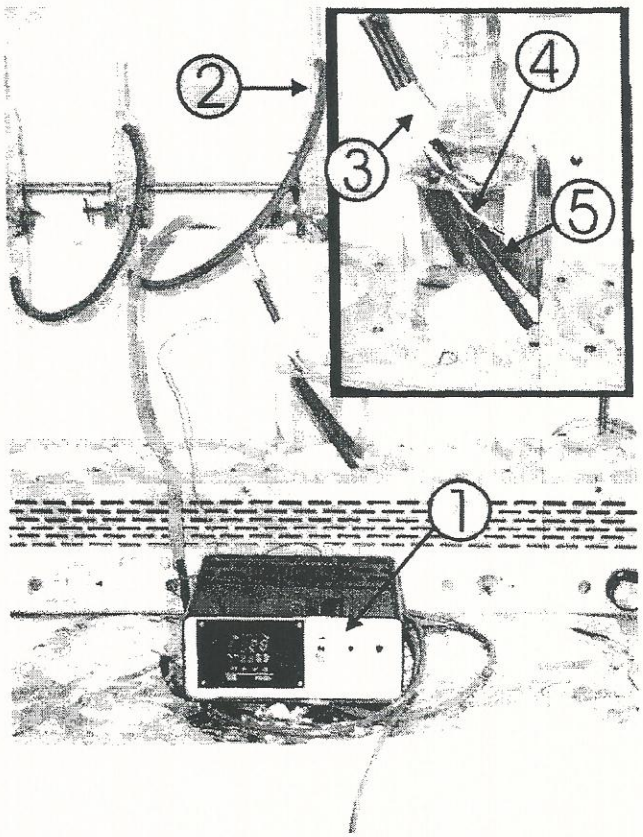
For Experiment 2 it was decided to include a clean-up step using H_2SO_4 and KOH impregnated silica gel in series in a Pasteur pipette. Samples were eluted using hexane, the hexane was evaporated and the samples were transferred into vials, concentrated and filled with toluene as described above.

Since it was of great relevance to this study to detect congeners in all three fractions (F1, F2 and R) to undertake the mass balance type approach we decided to use the most sensitive tool available for this study. The fact that known quantities of standards were added allowed the use of gas chromatography coupled to electron capture detection where the sample was injected onto columns of varying polarity. The results from the experiment indicated that mass spectrometric quantification was sufficiently sensitive for this study. Hence further analysis of PCDD/Fs and organochlorines were performed on a Gas Chromatograph (DB-5 fused silica column, 30 m, 0.25 mm i.d., 0.24 µm film thickness) interfaced to a quadropole mass spectrometer operating in selective ion monitoring mode. Organochlorines and PCDD/Fs were identified using retention times in the standard solution and evaluation of correct isotope ratios M^+ and M^{2+}. Quantification was undertaken by external calibration against some standard used to spike the samples. (Note that the study did not require absolute quantification of the concentrations since the aim was to evaluate the relative proportions of the chemicals of interest in various fractions of the distillate.)

Formation Experiments

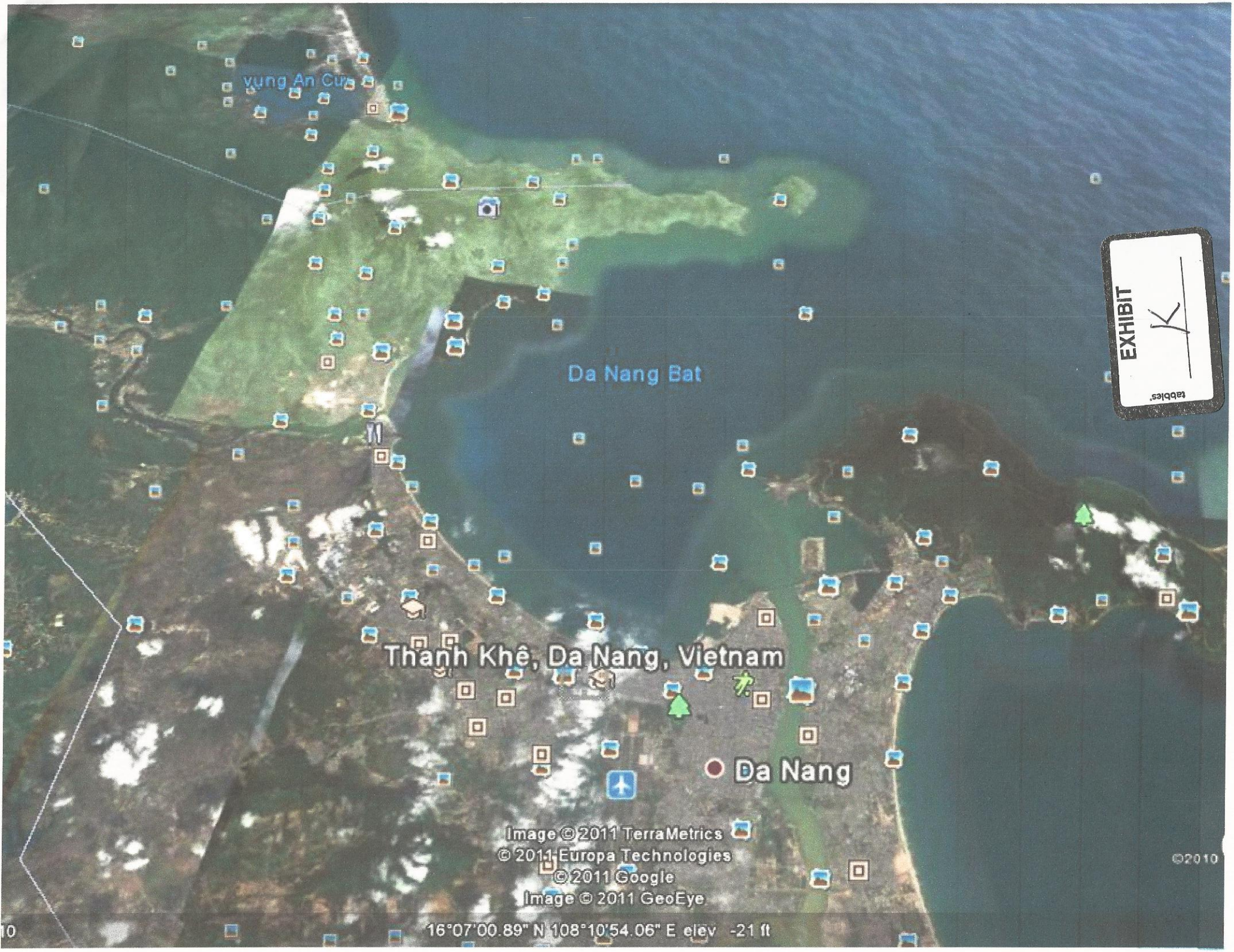
In order to evaluate "de-novo" formation of dioxins in the distillation unit itself from precursors, a system was developed in which an electrical heating element was inserted into copper tubing to represent the heating element in the distillation units aboard ships which also consisted of copper tubing (Figure 3). The element was operated in connection to a thermocouple so it could operate at a water temperature of 55°C, which was similar to that in the ship's distillation unit.

The copper coated element was then mounted at an angle into glass jars that were specifically designed to allow the element to be sealed inside while a condenser was mounted onto the top to make certain that the distilled water was reused in the flask. The formation experiments were conducted using the Agent Orange components 2,4,5-T and/or 2,4-D, which could act as a precursor for formation of TCDD and PeCDD. In the formation experiment, empty flasks were spiked with precursors, then RO water and additionally 30 g NaCl was added to obtain a salinity level similar to that of an outer estuary. The water was then equilibrated for 5 days or more. The copper coated heating element and thermocouple were then inserted into the solution and the opening sealed with Teflon tape. Finally, the condenser was inserted into the top of the flasks and the thermocouple was set at 55°C in the outer periphery of the flask. The formation experiments were carried out for 12 hours. In addition to the test samples, blank samples containing 2,4,5-T and/or 2,4-D were added to water but not heated, and a blank consisting only of water were also included.



1. Temperature Controller
2. Condenser
3. Teflon Seal
4. Thermometer
5. Copper header

Figure 3: Experimental set-up of the formation experiments. Agent Orange components were spiked into the glass vessel and heated up using the copper coated heating element.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COMMENT BY JOHN B. WELLS

My name is John B, Wells and I am a retired Navy Commander as well as an attorney-at law. I write to comment upon the most recent Department of Veterans Affairs proposed regulations to implement 38 U.S.C. § 1116. I refer to the VA RIN 2900-AM74-Definition of Service in the Republic of Vietnam as announced in VA-2008-VBA-0014-0001.

I entered the Navy in February of 1972 and was commissioned an Ensign in June of 1973. In June of 1974 I completed the Main Propulsion Assistant course and was assigned to the *USS Holder* (DD-819) as Main Propulsion Assistant. Ships of that class served frequently on the gun line off the coast of Vietnam but in its territorial waters. The ship's distilling plant/evaporators (hereinafter distillers) were part of the equipment under my purview. In October of 1976 I transferred to the *USS Coronado*, (LPD 11) also as Main Propulsion Assistant. In the fall of 1977 I was reassigned as Chief Engineer after that Engineer was detached for cause. I guided the ship through a successful Operational Propulsion Plant Examination. Again, the ship's distillers were part of the equipment under my purview. Later I was asked to oversee the preparation of the ship's repair plan for the upcoming shipyard overhaul. While I was onboard, the ship deployed twice to the Mediterranean and once to the Carribean.

After a two year shore assignment, I was assigned to the Surface Warfare Officers School Department Head Course. That course included several months of engineering training as well as combat systems and fundamentals. I was assigned to the *USS Badger* (FF-1071) as Operations Officer. I was also in charge of the ship's shipyard overhaul. When the *Badger's* Chief Engineer was fired, I was assigned to that position. Again, the ship's distillers were part of the equipment under my purview. I guided the ship through a successful Light Off Examination

and Operational Propulsion Plant Examination. In 1982, I was assigned to the *USS Worden*, (CG-18) as Chief Engineer. Again, the ship's distillers were part of the equipment under my purview. The ship made deployments to the Western Pacific, Indian Ocean and the North Arabian Sea.

In late 1984, I was reassigned to the staff of the Commander Naval Surface Reserve Force. My responsibilities included the operation and scheduling for nineteen ships of the Naval Reserve Force. In 1987, I was assigned to the pre-commissioning unit of Battleship *Wisconsin* (BB-64) as main Propulsion Assistant. I served as Acting Chief Engineer for a number of months until the Engineer reported. Again, the ship's distillers were part of the equipment under my purview. I was later reassigned as Executive Officer (second in command) of the *USS Puget Sound* (AD-38). *Puget Sound*'s mission was the repair of other ships. The ship deployed to the North Atlantic and Indian Ocean-Persian Gulf while I was on board.

In 1989 I was reassigned as Commanding Officer, Naval Reserve Readiness Center Pittsburgh, PA. At this time I began attending law school during the evening. Part of my responsibilities was the training of over 1000 reservists. We developed many training courses including engineering course to include ship's distillers. I retired from the Navy, as a Commander on 1 August, 1994. I graduated from Duquense Law School with a J.D. approximately 6 weeks prior to my retirement.

I was qualified as a Surface Warfare Officer, Officer of the Deck (underway), Combat Information Center Watch Officer, Command Duty Officer, Tactical Action Officer, Navigator, and Engineering Officer of the Watch. I was also qualified for command at sea. I received a mechanical engineering subspecialty based on significant experience.

While in the Navy, my ships operated with units of the Royal Navy and the Royal Australian Navy. This included NATO exercises, RIMPAC exercises and other multi-national exercised operations and operations throughout the world.

I am familiar with the National Research Centre for Environmental Toxicology and the Queensland Health Services, EXAMINATION OF THE POTENTIAL EXPOSURE OF ROYAL AUSTRALIAN NAVY (RAN) PERSONNEL TO POLYCHLORINATED DIBENZODIOXINS AND POLYCHLORINATED DIBENZOFURANS VIA DRINKING WATER, Brisbane Queensland, Australia (2002). I have talked with the authors of that report via e-mail. My wife, who is a Louisiana notary and paralegal, and also an Australian native, went to Brisbane to interview the authors of the report. A copy of that report is attached as Appendix A to this comment. Additionally, I filed the amicus brief in *Haas v. Nicholson*. I believe that I am qualified to address in some detail, the DVA's position.

As a threshold matter, the vessels of both Australian and American origin should be referred to as "ships" and not "boats." Boats are nicknames for submarines or refer to craft carried on ships. I make this comment because it underscores the lack of nautical knowledge and experience of the authors of the DVA's position.

To answer one of the DVA's first objections to the Australian report, the study was peer-reviewed and published. The report was presented to the 21st International Symposium on Halogenated Environmental Organic Pollutants and POPs in Gueongu Korea on 9-14 September 2001. It was them published in Volume 52 of Organohalogen Compounds (ISBN 0-9703315-7-6) which is published by Dr. Jae Ho Yang, Catholic University of Daegu, Korea. Please see http://espace.library.uq.edu.au/view/UQ:95837 (last visited June 13, 2008). More importantly,

the study was prepared at the request of and for the Australian Department of Veterans Affairs. They accepted the results as indicated by their subsequent promulgation of the following Statement of Principles, which is a rough equivalent to the Code of Federal regulations:

> (1) *Statement of Principles concerning Malignant Neoplasm of the Lung*, NO. 17 OF 2006 FOR THE PURPOSES OF THE VETERANS' ENTITLEMENT ACT OF 1986 AND THE MILITARY REHABILITATION AND COMPENSATION ACT OF 2004 http://www.dva.gov.au/pensions/SOPs/b004rh_malignant_neoplasm_lung.htm
>
> (2) *Statement of Principles concerning Malignant Neoplasm of the Larynx*, NO. 1 OF 2006 FOR THE PURPOSES OF THE VETERANS' ENTITLEMENT ACT OF 1986 AND THE MILITARY REHABILITATION AND COMPENSATION ACT OF 2004 http://www.dva.gov.au/pensions/SOPs/b013rh_malignant_neoplasm_larynx.htm

The authors have informed me that based on the acceptance and incorporation of the report by the Australian government into their Statements of Principles they saw no reason for further peer review.

I noted no uncertainty regarding the amount of concentration of dioxins in the estuary waters noted in the Australian report (hereinafter RAN report). The study noted that ships in the near shore marine waters collected waters that were contaminated with the runoff from areas sprayed with Agent Orange. RAN Report at 10. The authors later reported to this office that estuary containing the dioxins extended more than three nautical miles form shore. (See Appendix A). This means that the contamination would have extended well past the gun line. The distilling plants aboard the ship, which converted the salt water into potable drinking water, according to the study, actually enhanced the effect of the Agent Orange. RAN Report at 42. The study found that there was an elevation in cancer in veterans of the Royal Australian Navy which was higher than that of the Australian Army and Royal Australian Air Force. RAN Report at 13. The report further found that oral ingestion can cause multi-site cancer in the human body.

RAN Report at 58. The RAN report at page 35 noted significant concentrations at Vung Tau. Anecdotal evidence reports Agent Orange in the waters of the rivers which then empty out into harbors and eventfully the estuaranine waters. Notably, in the Clean Water Act Congress recognized that pollutants discharged from shore will contaminate the navigable waters, waters of the contiguous zone, and the oceans. 33 U.S.C. § 1251(a)(6). The DVA's comment that the exposure levels were not comparable to the amount of exposure land soldiers received is incorrect. As discussed in the RAN report the distilling process enhanced the effect of the dioxin. Additionally the dioxin was ingested orally through drinking waters, food showers etc. The DVA presents no evidence to show that the concentration of dioxins in the water tanks and piping of the ship was less than found on land. On land, the dioxin, once sprayed, would become embedded in the soil. Since the water systems of the ships would have been thoroughly contaminated, the dioxin would have adhered to piping and continued to contaminated in an ever increasing amount. The authors confirmed this in their discussions with my office. (See Appendix A). The cumulative effect of the contamination would have resulted in a very high concentration. It would have taken months and perhaps years to completely flush the system once the ship moved away from contaminated waters. The Australian study confirmed the enhancing effects of the shipboard distilling plants. RAN Report at 42. In other words, the effect was even more pronounced than if the veteran had merely ingested Agent Orange by breathing it or by drinking water from a contaminated stream. The authors of the report confirm this position. (See Appendix A).

The DVA report contain the curious comment that one had to assume that the sailors drank only the contaminated water and only for an extended period of time. That is a safe

assumption. All Navy ships, manufacture potable drinking water from sea water. This water is replenished almost daily http://www.bluewaternavy.org/distillation/Water%20treatment.pdf at 2-3. (last visited June 7, 2007). These ships did not have the capacity to carry potable water throughout the voyage without replenishment via their distillers. The distillers all work on similar principles to produce water (feed water) for the boilers and potable water for the ship's crew. *See, e.g.* Main Propulsion Plant DD-445 and 692 Classes and Converted Types, Operation Manual http://www.hnsa.org/doc/destroyer/steamsec10.htm (last visited April 4, 2006). Water is injected from the sea and is passed through the distilling condenser and air ejector condenser where it acts as a coolant for the condensers. It is then sent through the vapor feed heater into the first effect chamber and into the second effect chamber where it is changed to water vapor. Vapor then is passed through a drain regulator into a flash chamber and passes through baffles and separators into the distilling condenser where it is condensed into water and pumped to the ship's water distribution system. Sea water not vaporized is pumped over the side by the brine pump. *Id.* This is the same process discussed in the RAN report. It was used by American, British and Australian ships. In fact many Royal Australian Navy ships were retired United States Navy ships or ships of the same class as the American Navy. Those that were not of American design were constructed by the British. They all used the same system. This system was used well into the 1990's. More recently a new system, reverse osmosis, is being adopted, but that did not see service in any ship off the coast of Vietnam during the Vietnam War.

It is obvious that the author of the DVA comment and the "scientists and experts" who supported the positions taken know little about the concepts of nautical engineering or even basic thermodynamics. They obviously know little about shipboard life. Potable water was

manufactured continuously along with "feed" water for the ship's boilers. It was a constant headache and as a Chief Engineer there were many times that I was given round the clock hourly briefings on the status of water. This was especially true in southern latitudes such as Vietnam since the higher ambient sea water temperatures reduced the efficiency of the distilling process. Water was not only a morale factor, it was a requirement for survival. Nor was there any means to transport large quantities of water outside of the reserve potable water tanks.

The DVA's interpretation of Congressional intent is also irrational. The interpretation does not comport with national or international law. U.S. Navy ships, like their Australian counterparts, steamed within the territorial waters of Vietnam. Territorial waters were historically defined as

> 1, the water area comprising both inland waters (rivers, lakes and true bays, etc.) and 2, the waters extending seaward three nautical miles from the coast line, i.e., the line of ordinary low water, (ofttime called the 'territorial sea'). Seaward of that three-mile territorial sea lie the high seas.

C. A. B. v. Island Airlines, Inc. 235 F.Supp. 990, 1007 (D.C.Hawaii 1964). A wider area, the contiguous zone, reaches out to twelve miles from the coast. *United States v. Louisiana* 394 U.S. 11, 23 n. 26. (1969). Vietnam claimed a 12 mile territorial sea limit, which defines its sovereignty. http://www.cia.gov/cia/publications/factbook/fields/2106.html (Last visited 3 April 2006). That is consistent with the limitations of the United Nations Convention on the law of the Sea Article 3. Three nautical miles is within the outermost range of the 5" 38 gun mounts of Destroyer type ships used in the Vietnam war. Twelve nautical miles (24,000 yards) is beyond the maximum range of the most commonly used shipboard batteries, the 5"38 or the 5"54 naval gun. http://www.fas.org/man/dod-101/sys/ship/weaps/guns.htm last visited June 13, 2008.

Accordingly, ships had to have been within the 12 mile limit, or the territorial waters, whenever conducting gunfire support.

The enabling statute, 38 U.S.C. § 1116(a)(1)(A) recognizes a presumption of service connection when the veteran manifests a disease, including lung cancer, when the person was "a veteran who, during active military, naval, or air service, served in the Republic of Vietnam during the period beginning on January 9, 1962, and ending on May 7, 1975." The threshold factors are the existence of a prescribed disease and service in Vietnam.

In *Louisiana v. Mississippi,* 202 U.S. 1, 52 (1906), the Supreme Court held that the Mississippi Sound, and by extension the waters surrounding all harbors as inland waters, were under the category of "bays wholly within [the Nation's] territory not exceeding two marine leagues in width at the mouth." Inland, or internal waters are subject to the complete sovereignty of the nation, as much as if they were a part of its land territory. *United States v. Louisiana, supra.* Thus the presumption should apply to <u>any harbor</u> as well as inland waters. The territorial waters to include the contiguous zone are also under the control of the sovereign nation, although innocent passage may not be denied. *Id.* Subject to the right of innocent passage, the coastal state, in this case Vietnam, has the same sovereignty over its territorial sea as it has with respect to its land territory. *See*, 1958 Territorial Sea Convention Article 1-2; Law of the Seas Convention, Article 2.

Thus any time a Navy ship was firing its guns ashore, it would have had to have been within the territorial waters of Vietnam. When at anchor in a harbor, it was within the inland waters of Vietnam. At all relevant times, the ship was within the sovereignty of Vietnam and therefore its crew "served in the Republic of Vietnam." The distance to shore directly

corresponds to the maximum range of the support of forces ashore. Consequently, most naval units often operated close to shore. Gunfire missions were often shot from four or five thousand yards or less, well within the three nautical mile limit. The closer a ship was to shore, the higher the possibility that they steamed through waters contaminated with Agent Orange. In the case of the harbor anchorages, the ships were not only within the sovereign territory of Vietnam, they were within the inland waters. Consequently, under both national and international law, most ships served in the Republic of Vietnam.

The DVA position is irrational, arbitrary and capricious, unsupported by substantial evidence and in contravention of the enabling legislation. Accordingly, the proposed regulations should be rescinded and replaced with a regulation extending the 38 U.S.C. § 116 presumption to servicemembers on ships that served within the 12 mile territorial limit of Vietnam, or certainly, that anchored or operated within any harbor within the territorial limits of Vietnam.

I am available to answer any questions concerning this matter.

Respectfully Submitted,

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APPENDIX A

REPORT ON MEETING BY JANICE WELLS WITH PROFESSOR MICHAEL MOORE AND RESEARCH FELLOW MS. CAROLINE GAUS IN BRISBANE AUSTRALIA ON JULY 3, 2006.

I met with Professor Michael Moore at Queensland Health Scientific Services (QHSS) in July, 2006 to go through the report of the study of the Examination of the Potential Exposure of Royal Australian Navy (RAN) Personnel to Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans via Drinking Water that was issued by QHSS in 2002.

Professor Moore explained that Dr. Keith Horsley, Senior Medical Advisor for The Australian Government, Department of Veteran Affairs (DVA), approached The National Research Centre for Environmental Toxicology (ENTOX) and the Queensland Health Scientific Services (QHSS) and requested that they undertake an Examination of the Potential Exposure of Royal Australian Navy (RAN) Personnel to Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans via Drinking Water. The study was requested by the DAV, following the discovery that statistical evidence showed that the morbidity and cancer levels were far higher in service members of the Royal Australian Navy than those in the Royal Australian Army who had served in Vietnam. Professor Moore explained that this was unexpected by both the Department of Veteran Affairs and the Royal Australian Navy because it was thought that Army service members would be at greater risk because of the type and length of exposure to dioxins. Naval service members deployment was for 6 weeks in the Mekong delta and service members rarely set foot on land while Army service members were exposed during their deployment for an extended period of time in the country of Vietnam. The study was requested to discover the reason. The research took about three years and the report was issued in 2002.

I asked Professor Moore if he had any knowledge of any similar studies in the United States or research in a similar vein and he said he did not. He said he was surprised at that because United States Naval personnel consumed distilled drinking water too and were therefore exposed to the same dioxins. The same mobility and cancer statistical increases would have been apparent in records of the United States Naval service members as compared to those in the United States Army service members. I asked him if he thought that the statistical increase would be higher given that USN personnel were deployed for longer period's of time than the 6 weeks RAN service members were consuming the distilled drinking water. He advised that it would, but the dioxin exposure was so high in the estimated distilled water consumption in a short period of time, that an increase in time of exposure would make an already extremely high exposure that much worse. Professor Moore commented that the exposure by RAN service members for 14 days was far above World Health Organization acceptable levels, and that 6 months exposure would be off the scale. He advised that Caroline Gaus, who was personally involved in the research, would be available to meet with me, and would be able to take the time to explain dioxin levels and the process of distilling the water on board ship and in the laboratory.

Professor Moore went on to explain while undertaking the research it was found that the only difference between Naval and Army service members was the water they consumed and how it was processed. He said that it was originally thought that because the water was distilled it was pure. Additionally it was thought that because the dioxins were not soluble that they would not be present in the water. However it was found that during distillation of the sediment contaminated water from the estuary, because the dioxins were not soluble, the dioxins would attach to the sediment. Therefore the more particles in the intake water the higher the level of dioxins in the resulting distilled water. It was acceptable practice for the uptake of water to be taken up as close to the shore as possible in the estuary thus reducing the amount of salt, the resulting distilled water would therefore contain more dioxin. Professor Moore noted that the purest water following distillation was used for the boilers and that which contained more sediment (and thus more dioxins), after distillation, would be used for drinking.

Professor Moore also noted that the further out from shore from the mouth of the estuary the less sediment in the water. But as the estuary and the sediment it contained extended more than three nautical miles from shore, it would mean that distillation of water from anywhere in the Mekong delta would result in heavy dioxin levels in the final drinking water. He also advised that Caroline Gaus may have more information on the spread of the sediment pattern from the river, the Mekong delta and the estuary.

I questioned Professor Moore as to what other particles the dioxins would become attached to. Professor Moore communicated that the dioxins would attach to the distilling plant tubing, but would attach also to any food or drinks that used distilled water in its preparation. He particularly mentioned coffee and tea and any food preparation that required the washing of food and cooking of food in water. He said that dioxins would attach to any sediment whether it be soil sediment or food. He suggested that Caroline Gaus would be able to explain the laboratory process of distillation and how the dioxins were deposited on distillation plant tubing and storage tanks which would occur during the distillation process. He went on further to state that the study only took into account the RAN process of distillation on board ship. I informed Professor Moore that the class of ship we were investigating was the same class of ship that was used by the RAN and USN.

When asked about the link of the ingestion of dioxin to cancer Professor Moore commented that as the dioxins attached to fatty tissue in the body they would remain in the body for a long time. He said that cancer caused by the presence of dioxins would not present itself in just a few years but he did think that the presence of dioxins would result in cancer in 15 - 20 years. When asked if he had the mobility statistics for the diagnosis of cancer or death in service member personnel he advised that he did not have them but that the DVA did.

I also met with Ms. Caroline Gaus. Ms. Gaus is a Research Fellow for the National Research Centre for Environmental Toxicology and had been involved in the research and the laboratory distillation tests on this study. Ms. Gaus confirmed the information that Professor Moore had previously given me.

As background Ms. Gaus informed me that inclusion of the dioxins was a malfunction or rather an end result of the manufacturing process for the defoliant but it was not recognized as a problem because the dioxins were not soluble it was thought they would not be in the water. But because by its nature the dioxin attaches to the sediment or other properties - it is a problem. Also Ms. Gaus said that when the defoliant was manufactured it was never anticipated that so much would be used over such large areas for such a long time. Ms. Gaus said that it was not recognized that there was a problem until it was realized that the RAN mobility and cancer statistics were too high and the DVA had to look for a reason.

I asked Ms. Gaus about the sediment in the estuary and how far it spread out to sea. Ms. Gaus confirmed that the sediment extended at least three nautical miles out from shore. She advise that this pattern would be easy to confirm by looking at the satellite pictures for the Mekong delta for the same period of the year as the test period. Ms. Gaus commented that the sediment pattern was easy to see from these pictures and it would be easy to measure the distance the sediment spreads out to sea. Ms. Gaus indicated that Professor Arnold Schecter from the University of Texas, School of Public Health had done a study on humans and had also been to the Mekong delta and estuary and had taken water and sediment samples. Ms Gaus thought that Professor Schecter may have statistics on the estuary in addition to human mobility statistics.

I questioned Ms. Gaus about which other particles, besides sediment the dioxins would attach to. She explained that the dioxins would attach to the tubing in the distilling plant as well as the storage tanks. But that it was impossible to say how much or for how long it would be there before scale residue would get into future distilled water. She commented that the level of the dioxins would be so high in the processed water that the dioxins that would be deposited on the tubing would only add to an already high level when released from the tubing as scale residue. Ms. Gaus noted that in the laboratory, dioxins did attach to the glass tubing during the distillation process and therefore they did shake the glass components for 7 - 14 days to remove as much of the toxins into the water as possible - but as she said previously - the level of contamination was so high that the extra (even if very little) would just make the level higher. Ms. Gaus noted that tubing used in distillation on a shipboard plant is copper and dioxins would adhere more readily to copper than it would to glass creating a scale like residue that would eventually passed into future distilled water. Again, how long and in what quantity was not possible to determine in the laboratory tests. Ms. Gaus commented that the dioxins would accumulate in tanks as scale like everything else but almost impossible to say how much. But Ms. Gaus reasoned that again the levels were so high during the initial exposure by using the distilled water for drinking and cooking that any future ingestion would have just increased the total level of exposure. Ms. Gaus went further to suggest that the material used for the distillation process would make a difference to the level of dioxins in the final output. However whether it was copper as on board ship or glass as in the laboratory or if the purest form of silver were used for the tubing and the tanks it would still produce distilled water that contained high levels of dioxins. Even the lowest level would still be far too high for consumption.

Ms. Gaus noted that "a key goal of the study was to attempt an evaluation of exposure of RAN

personnel aboard ship on duty in Vietnam by consumption of contaminated water as well as from other potential pathways"[1] Ms. Gaus advised that in the distillation process their recent information suggested that about 5 - 10% of the uptake water was distilled and the rest was discharged into the estuary. That previously it was thought that 50% of the water was distilled that produced the enrichment factor of 2 (i.e. 0.08 - 1.4ng/L) that when 5 - 10% of the water was distilled that the factor increased to approximately 10 - 20. When 50% - 95% of previous distilled water, full of contaminated, was discharged back into the estuary, it is predictable that the uptake water at a later time could have a higher level of contaminates because it had previous been distilled and discharged to mix with the estuary water. So it is possible that distillation again would produce a higher level of dioxins than the original source uptake water from the estuary.

Ms. Gaus noted that it was determined that sailors consumed an average of 5 liters of distilled water per day. That this direct consumption would lead to a daily body burden of about 0.4 - 7 ng/day. The water was also used to prepare food and as a result of the hydophobic character of the dioxins the TCDD would also accumulate in the food. Hence they estimated that the total exposure due to water contamination food was similar to that of the direct consumption of drinking water - another 0 .04 - 7 ng/day. This meant a total of 0.08 - 14 ng/day.

Ms. Gaus noted that it was important to estimate the overall exposure period. She also noted that "According to the reports from RAN personnel the rule on board ship was to produce drinking water primarily during the periods when the ship was in the turbid estuarine water since the water was less pure and could have caused potential damage to the engines if used in boilers. While in the pristine water offshore the distillation units produced water primarily for the ships engine. Hence the drinking water that was produced during the periods in contaminated water lasted for a significant portion of the return trip."[2] Therefore the ingestion of dioxin contaminated water would continue after the RAN service members left the waters of Vietnam. Ms. Gaus commented that the report estimated that in a 14 day period the total body burden of dioxin through direct consumption of water that originated from distilling in Vietnamese waters are estimated to be between about 10ng to 190 ng. Ms. Gaus advised that as it noted in the report that the "US-EPA have concluded that the dioxin background contamination which is in the range of .05 - 2 pg per kg bw per day at the present may pose a significant cancer risk between 10^{-2} to 10^{-3}."[3] and that the US-EPA recommended guidelines were "2 orders of magnitude lower than the values set by the WHO/ICPS and various European committees."[4] Ms. Gaus commented that RAN members may have received exposure which is one to two orders of

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[1] National Research Centre for Environmental Toxicology report page 33

[2] National Research Centre for Environmental Toxicology report page 35

[3] National Research Centre for Environmental Toxicology report page 36

[4] National Research Centre for Environmental Toxicology report page 36

magnitude above the acceptable intake values. Ms. Gaus noted that dioxins attach to fatty tissue in the body after ingestion and would remain present in the body for a long time.

I questioned Ms. Gaus about TCDD and OCDD and she informed me that TCDD and OCDD is produced during the distillation process and TCDD attaches to the sediment and because of low molucular weight and low lipoph stays in the drinking water. Ms. Gaus noted that ODCC was produced also but because of high molucular weight and high lipoph it stays in source water. Therefore when only 10 - 30% of the source water is distilled the OCDD remains in the source water and it is discharged as bilge water into the estuary again.

Both Professor Michael Moore and Research Fellow Ms. Caroline Gaus said that they would be available for telephonic interview at a later date should it be necessary to discuss the study of the Examination of the Potential Exposure of Royal Australian Navy (RAN) Personnel to Polychlorinated Dibenzodioxins and Polychlorinated Dibenzofurans via Drinking Water that was issued by QHSS in 2002.

Both Ms. Gaus and Dr. Moore were surprised, that the United States Department of Veterans Affairs had not adopted their findings or at least contacted them concerning those findings.

Respectfully Submitted,

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1. "The study was not peer reviewed or published..."

The study was accepted for presentation at the 21st International Symposium on Halogenated Environmental Organic Pollutants and POPs and is published in the associated peer reviewed conference proceedings: Müller, J.F., Gaus, C., Bundred, K., Alberts, V., Moore, M.R., Horsley, K., 2001. Co-distillation of TCDD and other POPs during distillation of water - a potential source for exposure. Organohalogen Compounds 52, 243-246.

The results of the study were also accepted for presentation at the IXth International Congress of Toxicology; the abstract is published in: Mueller, J.F., Gaus, C., Bundred, K., Moore, M.R., Horsley, K., 2001. Water volatility of dioxins - exposure through consumption of distilled water. Toxicology 164, 157-158.

The study was cited in "*The Third Australian Vietnam Veterans Mortality Study*" published in 2005 by the Department of Veterans' Affairs and Australian Institute of Health and Welfare and resulted in the Department's consideration of Royal Australian Navy Vietnam Veterans as potentially exposed Vietnam Veterans.

2. "...VA's scientific experts have noted many problems with this study that caution against placing significant reliance on the study. In particular, the authors of the Australian study themselves noted that there was substantial uncertainty in their assumptions regarding the concentration of dioxin that may have been present in estuarine waters during the Vietnam War."

The problem referred to in this comment is associated with estimating the exposure level of Vietnam Veterans, not with the study's primary finding that exposure to dioxins was likely if i) drinking water was sourced via distillation and ii) the source water was contaminated.

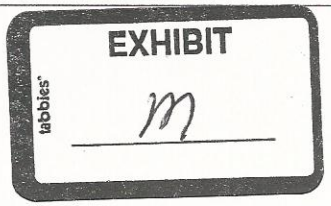
As highlighted by the authors, the exact level of exposure via this pathway is uncertain due to the lack of data on contaminant levels in the source water during the Vietnam War. The attempt made by the study to estimate the level of exposure serves only as an indication that exposure may have been considerable (and depends on the concentrations in the source water).

Hence, the problem lies in the lack of exposure information, not with the study. The study clearly demonstrates that if source water is contaminated, dioxins are expected to co-distil with drinking water.

3. "...VA's scientific experts have noted many problems with this study that caution against placing significant reliance on the study. [...]. Further, although distillation concentrated the dioxin level in the water, the concentrating effect was shown to depend upon the amount of sediment in the water, such that a large sediment levels, consistent with estuarine waters, could significantly reduce the concentrating effect."

This issue is also not related to the study's quality, but rather highlights one of its findings out of context. The study noted that, while increasing suspended sediment loads in the source water decrease the co-distillation of dioxins, dioxins still co-distil with water at the highest level of suspended sediment in the water tested (i.e. at 1.44 g/L 38% of 2,3,7,8-TCDD co-distilled in the first 10% of source water). If 10% of the source water is distilled, TCDD would enrich in the drinking water by a factor of almost 4 compared to the source water. This was confirmed by using water from a tropical estuary with naturally high suspended sediment loading, where 48-60% of TCDD co-distilled with the first 10% of source water.

4. "...VA's scientific experts have noted many problems with this study that caution against placing significant reliance on the study. [...]. Moreover, even with the concentrating effect found in the Australian study, the levels of exposure estimated in this study are not at all comparable to the exposures experienced by veterans who served on land where herbicides were applied. This is true even if we were to assume that a person drank only such distilled water and did so for an extended tour."



As noted above and in the study itself, estimating the level of exposure via this pathway is difficult due to the lack of data on the concentrations of dioxins in the source water. The level of exposure would depend strongly on the dioxin concentrations in the source water (which would have varied from location to location) as well as on the amount and duration of water consumed for drinking and/or cooking.

The study attempted to provide an estimate on the concentrations of dioxins in source water (0.043-0.69 ng/L). While the uncertainty around this value is large (approximately in the order of a factor of 10 or more), it cannot be determined whether it represents an over- or underestimate (which would also depend on location). Hence, it would be difficult to determine whether the level of exposure was similar, higher or lower compared to veterans who served on land. However, the study demonstrates that exposure is likely to have occurred if source water was contaminated and suggests that exposure may have been considerable.

Sincerely,

Dr Caroline Gaus
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