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Contaminant Levels in Sirenians and Recommendations For Future Research and Conservation Strategies

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Abstract
World wide marine contamination is of greater concern especially as developing countries become more industrialized, yet have few if any regulations controlling their production of contaminants, especially those which may affect the various species that live in marine habitats. This may also affect humans who live on or near these bodies of water and who still hunt species such as sirenians. However, controversy exists as to whether the levels of contaminants in sirenians (dugongs and manatees) is of concern to the survival of these species or whether these levels might be detrimental to the humans consuming them. To better understand the present levels of contaminants in the Order Sirenia, we reviewed the literature to quantify these levels and to see if contaminant levels had increased over time. The possible role these contaminants may play in future research and conservation initiatives is also discussed. Although it is thought by some that marine species such as sirenians may be able to detoxify or neutralize many contaminants, levels must be identified, measured and monitored to prove if detoxification does occur. This important physiological process must be verified if any conservation plan to save these species is to be successful and maintain viable populations. As well, certain human populations might be at risk from consuming these animals and therefore measuring these contaminants is necessary to protect these vulnerable communities from contaminant related health issues. [JMATE. 2008;1(1):32-39]
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Picture 1. Free ranging Florida manatee Tricechus manatus latirostis. **Reproduced with permission from OERS.**

Introduction

Research into world wide marine pollution has experienced a surge of interest in recent years as developing countries have become more industrialized and are producing more contaminants which are released into the lakes, rivers, streams and oceans (33, 30, 29). These contaminants may become a concern to not only the various animal species that live in these ocean habitats but to humans that live on or near these bodies of water as well (29). Many of these marine species filter out or bioaccumulate these contaminants that can be potentially dangerous for those other animal species who consume them and to humans as well. A large section of the population of developing countries still hunt many of these animal species (marine mammals, fish, etc) which forms a key source of their protein (25). There is ongoing controversy as to whether the hunting of sirenians, especially dugongs, still exists. Some scientists and government officials believe that dugongs are not being hunted for food or hides and therefore hunting does not pose a threat to their existence. However, there are many recent publications proving that this activity is still being practiced in many developing countries today and that hunting still poses a serious threat to the survival of dugongs (12, 23, 24).

Dugongs are the only surviving members of the family Dugongidae and can be found from eastern Africa to the Philippines and Palau, and between Australia and Okinawa (26). Within the manatees, there are three species- West African (*Trichechus senegalensis*), Amazonian (*Trichechus inunguis*), and West Indian (*Trichechus manatus*). These species can be found in or along the Atlantic tropical and subtropical rivers, estuaries and coastlines usually located in less developed countries (22). Sirenians are usually long living and either stay in specific seasonal areas or move along coastlines which make them ideal study species for long term, geographical studies (6). As herbivores, sirenians must eat large volumes of vegetation daily and this vegetation absorbs or filters contaminants through the soil or water in which they thrive. It is therefore important to look at how sirenians accumulate and store the increasing amounts of contaminants that are being released into their environment. In addition, pollution in these various aquatic habitats, especially those found in developing countries, is actually subject to worsening contamination which is expected to continue for many decades.

Materials and Methods

The scientific literature was reviewed for levels of various contaminants such as elements (arsenic, copper, lead and mercury) and organochlorines (polychlorinated biphenyls- PCBs, dichlorodiphenyltrichloroethane-DDT, Dieldrin) from 1976 to 2000, a timeline where data was available for sirenians. All

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values were converted to reflect the same units (mg/kg wet weight) and blubber and liver samples were used for consistency of reporting.

Information gathered through reports, books, and various publications from various government departments (Australia), non government organizations (Oceanographic Environmental Research Society) and official agencies (United Nations, Marine Mammal Commission) was used to evaluate the present status of research strategies and conservation actions. The contaminant levels that were garnered from the review, was used to discuss the implications and success of future research strategies or conservation actions to preserve the manatee and dugong.

Discussion

Present Levels

There is limited information concerning contaminants in marine mammals such as sirenians for numerous reasons. It is logistically and financially very difficult to study them in their natural habitat. This is due in part to the political apathy as no government is willing to assume a leadership role or funding responsibilities for such studies. Funding for long term projects to study the effects of pollutants on these species is proving to be difficult to secure (27). Ideally, research should validate the exact amounts or types of contaminants being released, what possible effect each type of contaminant can have individually or in combination with each other, the temporal and spatial changes over long periods of time, the possible effects of other environmental stressors combined with contaminants, and what possible pathological effects these contaminants can have in sirenians (19, 27). Contaminants are not only toxic themselves but their metabolites also can be of concern and it would require the analysis of over 300,000 compounds to monitor these synthetic organic chemicals and their possible detrimental effects which are currently in use (28).

Element and Heavy Metal Contaminants

In marine mammals it is very difficult to directly correlate specific levels of contaminants to a specific effect (33, 5). The research that has been done in harbor seals and dolphins has established contaminant levels that seem to cause a detrimental effect on these species (29, 5). However, these results were produced under artificial conditions in captive animals which makes it hard to correlate the corresponding detrimental effects that wild animals would experience who are exposed to various other stress factors including the huge number of contaminants in their habitat.

It is generally accepted that manatees have low levels of contaminants compared to other marine mammal species and that these low levels are not a threat for the future of these species (6). However the research literature seems to indicate that organochlorines have a greater effect on sirenians when compared to heavy metals. It has been reported that dugongs seem to be susceptible to organochlorines such as polychlorinated dibenzo-*p*-dioxins (PCDDs) and that PCDDs may have an adverse effect on their health and therefore may be a risk to present and for future generations of dugongs (10). In the literature, it has been reported that heavy metals such as mercury can affect the neurological development of the young of certain mammalian species (rats, monkeys and humans) but as yet no direct link has been established in any marine mammal (5, 33). In the past 30 years, much of the sirenian research has focused on measuring the levels of contaminants in small geographical regions, with little research on establishing what effects these contaminants may have on the various organs of this species, or on the possible effects on the development of their young or what the lethal levels might be for them (12).

Dugongs

The data available on elements and heavy metal contaminants in the tissue of dugongs shows an increase over time (Table 1). Arsenic maximum levels in dugong livers between 1982 to 2000 have shown increases from 1.25 to 7.7 mg/kg wet weight and copper maximum levels have ranged from 425 to 303 mg/kg wet weight between 1978 to 2000. Concurrently, lead and mercury maximum levels have also risen from 0.10 to 3.08 and 0.05 to 1.11 mg/kg wet weight between 1978 to 2000. Other heavy metals such as iron, magnesium and nickel have shown similar increases. Although it has not yet been established that these levels of elements and heavy metals may have reached levels that can have detrimental effects on dugongs, it is clear that levels are rising.

Manatee

Manatee research has focused on levels of persistent organic pollutants with less emphasis on elements and heavy metals. Studies looking at these contaminants (elements and heavy metals) date from 1984 and 1991, precluding any comments on today's levels. New research needs to be done to reflect the current levels of these contaminants (Table 2). The few heavy metal studies published that focused on sirenians are mostly found in Florida manatees and were over a relatively short 5 year time interval (1977 to 1982). These studies showed that copper maximum levels had decreased (840 < 39.76 mg/kg wet weight), lead remained the same (3.08 > 3.57 mg/kg wet weight) and mercury had increased (0.14 > 0.38 mg/kg wet weight).

Organochlorine Compounds

In general, there is limited knowledge on the accumulation of persistent organic pollutants or POPs in sirenians and their possible effects. Since 1994 there have been a total of 5 major papers dealing specifically with organochlorines or organohalogen contaminants (14, 1, 32, 15, 12). Three of these publications dealt with dugongs in Australia, one looked at dugongs in Thailand and one in manatees within Florida. These studies only studied organochlorine pesticides such as dioxins and polychlorinated biphenyls (PCBs) and the Haynes publication studied these contaminants from samples that were taken between 1996 to 2000 (12). In 1998, the Marine Mammal Commission sponsored a workshop "to review what is known, and what needs to be learned, about the possible effects of persistent ocean contaminants on marine mammals" (18). The scope of this workshop was ambitious and its objectives ranged from reviewing the literature, looking at any potential effects, identifying the importance of, outlining research and monitoring programs, and expanding present research/monitoring programs of harmful persistent contaminants or organochlorines in marine mammals. This workshop concluded that "there is good reason to be concerned that survival and reproduction in certain marine mammal populations may have been affected, and are being affected, by persistent contaminants, particularly organochlorines" (18). It must be taken into consideration that most of the information used to publish the proceedings of this workshop was published prior to 1998.

Dugongs

Heavy Metal Year (Reference)	Amount (mg/kg wet weight)		Location
	Minimum	Maximum	
ARSENIC			
1996 to 2000 (13)	0.45	7.7	Queensland, Australia
1996 (13)	1.54	2.17	Great Barrier Reef, Australia
1992 (12)	0.18	0.40	Torres Strait, Australia
1982 (17)	no value	1.25	Okinawa, Japan
COPPER			
1996 to 2000 (13)	9.5	303	Queensland, Australia
1996 (13)	53.9	117.8	Great Barrier Reef, Australia
1992 (12)	22	370	Torres Strait, Australia
1992 (13)	6.0	19.6	Northern Territory, Australia
1991-1993 (13)	58.1	984.2	Torres Straight, Australia
1984 (13)	15.3	74.9	Northern Territory, Australia
1974-1978 (7)	6.4	425.6	Queensland, Australia
LEAD			
1996 to 2000 (13)	<0.08	3.08	Queensland, Australia
1992 (12)	0.05	0.10	Torres Strait, Australia
1974-1978 (7)	Not Detectable		N Queensland, Australia
MERCURY			
1996 to 2000 (13)	0.05	1.11	Queensland, Australia
1992 (12)	0.02	0.04	Torres Strait, Australia
1977- 1980 (12)	0.01	0.05	Cleveland Bay, NE Australia

Table 1. Toxic Element Levels in Dugong Livers (12, 13, 17, 7)

Heavy Metal Year (Reference)	Amount (mg/kg wet weight)		Location
	Minimum	Maximum	
COPPER			
1982 (21)	15.26	39.76	South Western Florida
1977-81 (20)	3.08	840	Throughout Florida
LEAD			
1982 (21)	0.31	3.57	South Western Florida
1977-81 (20)	1.26	3.08	Throughout Florida
MERCURY			
1982 (21)	Not Detectable	0.38	South Western Florida
1977-81 (20)	Not Detectable	0.14	Throughout Florida

Table 2: Toxic Element Levels in Manatee Livers (20,21)

Haynes et al. in 1999 reported that levels of POPs in dugongs were equivalent to those found in carnivorous marine mammals (12). The accumulation of POPS and PCBs within marine mammal populations found in the Northern Hemisphere have been related to reproductive, nervous and immunological abnormalities (12). What is known of POPs in sirenians has been reported using small numbers of animals and were done in very specific geographical locations.(Table 3) Kemper et al. in 1994 published a review of organochlorine levels in the blubber of marine mammals found in Australian waters (14). In 2 dugongs, the authors found that there were non- detectable levels of PCBs and DDTs. In 1996, Ames et al. published levels of DDT (0.087 and 0.356 µg/g wet weight), HCB (0.085 µg/g wet weight) and DDD (0.672 µg/g wet weight) in the livers of Florida manatees(n=19) (1). In 2001, Vetter et al. published **blubber** levels in 3 Australian dugongs showing PCB levels between 89 to 209 (µg/kg lipid weight) and DTT levels between 15 to 173 (µg/kg lipid weight) (32). Haynes et al. in 2005 published that concentrations of organocompounds such as dieldrin (1-43 µg/kg lipid weight) and DDT (2.8 - 66 µg/kg lipid weight) were present in low concentrations in dugong **blubber** samples(n=52) taken between 1996 to 2000 and that their dieldrin levels (0.4 - 9.2 µg/kg wet weight) were similar to those that were measured in the livers of dugongs taken from the same region (0.32 - 1.02 µg/kg wet weight) (12). However, Gaus et al. in 2004 reported that dugongs (n=17) from Queensland, Australia had higher PCDD/F (polychlorinated dibenzodioxin) levels (80 - 2000 pg/g lipid) than dugongs from Thailand or other trophic marine mammals found in remote, low industrial areas such as the Arctic or New Zealand, but similar to that of orcas found in waters off the British Columbia coast (1250 - 2400 pg/g lipid) (10). The potential immediate risks of organochlorine compounds to dugongs is unknown and what effects they may have on the long term conservation efforts to save them is undetermined.

Manatee

As in the dugong, information concerning organochlorine contaminants and their effects in manatees is limited. The few papers published looking into organic contaminants in the manatee mostly looked at tissue from the Florida manatee (*Trichechus manatus*) (Table 4) (9, 20, 21, 1). The Ames paper published in 1996 actually was reporting organochlorine levels in tissue from the Florida manatee taken between 1990-1993 (1). There has been no published data on organochlorine levels in tissue from the Florida manatee since 1993, so the current status is unknown. Total PCB levels in both blubber and liver of manatees reveals that from 1977 to 1993 there has been non detectable to low maximum levels (4.6 mg/kg wet weight). Total DDT levels in manatee **blubber** reveals a similar trend between 1974 to 1993, from <1.0 to non-detectable levels (mg/kg wet weight) respectively. Dieldrin levels reveal the same trend of non-detectable levels from 1974 to 1993.

When studying contaminants in the tissues of any species or within their environment one must realize that present and future levels will constantly be in flux for many decades or even centuries as contaminants are still being released into the air, ground and water. These enter into the marine environment either directly or indirectly. For instance, despite the fact that PCB use and production was halted in the 1970s, 35% is still being used, 30% is located in dump sites and an astounding 34% is unaccounted for (28). The levels of many contaminants still seem to be increasing in the various tissues of numerous species despite measures to control or reduce them (33). The immediate or long term effects of these contaminants on the various species found along the food chain is presently unknown or can only be speculated. Extensive research proposals and long term conservation strategies, especially in developing countries where these contaminants are being released, need to be implemented.

Organochlorine & Year (Reference)	Tissue	Amount (mg/kg wet weight)		Location
		Minimum	Maximum	
∑PCBs				
1996-1999 (32)	Blubber (10 congeners)	Not Quantified	209 (lipid)	Queensland, Australia
1996 (13)	Liver (17 congeners)	Not Detectable		Great Barrier Reef, Australia
∑DDT				
1996-2000(13)	Blubber	0.5	59	Queensland, Australia
1996-1999 (32)	Blubber	Not Quantified	6.5	Queensland, Australia
1996 (13)	Liver	Not Detectable		Great Barrier Reef, Australia
Dieldrin				
1996-2000(13)	Blubber	Not Detectable		Queensland, Australia
1996-1999 (32)	Blubber	Not Quantified	14	Queensland, Australia
1996 (13)	Liver	Not Detectable	0.5	Great Barrier Reef, Australia

Table 3: Organochlorine Levels in Various Tissues of Dugongs (13,32)

Organochlorine & Year (Reference)	Tissue	Amount (mg/kg wet weight)		Location
		Minimum	Maximum	
∑PCBs				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1982 (21)	Blubber	Not Detectable		South western Florida
1977-81(20)	Blubber	Not Detectable	4.6	Throughout Florida
1974 (9)	Blubber	<1.0	<1.0	North eastern Florida
1990-1993 (9)	Liver	Not Detectable		Throughout Florida
1974 (9)	Liver	<1.0	<1.0	North eastern Florida
∑DDT				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1982 (21)	Blubber	Not Detectable	0.25	South western Florida
1977-81(20)	Blubber	Not Detectable	0.28	Throughout Florida
1974 (9)	Blubber	<1.0	<1.0	North eastern Florida
Dieldrin				
1990-1993 (1)	Blubber	Not Detectable		Throughout Florida
1977-81(20)	Blubber	Not Detectable	0.36	Throughout Florida
1974 (9)	Blubber	Not Detectable		North eastern Florida

Table 4: Organochlorine Levels in Various Tissues of Florida Manatees (1,9,20,21)

Research Strategies and Conservation Actions

The immediate and long term goal for research strategies or conservation actions obviously include ensuring the preservation of current species thereby creating biodiversity. Establishing biodiversity will allow for the prospering of individual species thereby increasing the number of species and ensuring healthy and flourishing ecosystems. In return, these ecosystems would allow for the future sustainable harvest of multiple species of animals that will be necessary to feed the continually expanding human population. However, these ecosystems are facing various stressors that are preventing these species of animals to reproduce and maintain healthy populations. The world's rivers and oceans have been and continue to be used as sites for the disposal of contaminants. Many species of key fish stocks have been over-fished beyond possible recovery. Important habitats, necessary to insure the survivability of many species, have been changed and key species have become extinct. The effects of climate change have created disturbances that have happened so quickly that many species have not been able to adapt quickly enough thereby causing massive die offs of local populations. Recently, the introduction of new stresses such as noise is causing behavioral changes and even the possible death of marine mammals. Drastic and innovative research strategies and conservation actions are required to be able to save as many species as possible, several of which are presently endangered or threatened, in order to maintain natural ecosystems and preserve biodiversity. Being a key species and a possible sentinel of how healthy the marine environment can be, sirenians require research strategies that are focused and conservation actions that are strong and vigorous to ensure its protection.

A review of the research literature reveals that since 1954 there have been 163 published research articles concerning the dugong and 319 for manatees. Most of these articles looked at sirenians and their preferred habitat, types of seagrasses eaten, population numbers and impact of indigenous fishing and anthropomorphic influences such as boats and tourism. Only recently has interest focused on contaminants within their environment or tissues. In 2002, Marsh et al. published an assessment report and action plan for developing countries in which dugongs were found (17). Under chemical pollutants, Marsh wrote that high levels of heavy metals were found in older dugongs and that there was no evidence that these heavy metal pollutants were harmful. However, certain tissue levels were at levels reported potentially harmful to humans. Information on pesticides was very limited and low compared to other marine mammals found elsewhere in the world. It was suggested that chemical pollution should be looked at in the dugong's range that had higher population numbers as opposed to looking at small isolated numbers. The report went on to describe threatening processes and research initiatives for the survival of dugongs (Table 5). The majority of threats and research work examined in dugongs has been reserved to mostly looking at determining abundance, habitat mapping, mortality rates and causes and anthropogenic impacts. No comprehensive environmental study exist that measures the amounts of contaminants found within dugongs or assessing levels that may be potential harmful to this species and be a potential threat to humans who hunt these animals for sustenance. The only country that has studied contaminant levels

Country	Threatening Processes	Existing Research Initiatives
East Africa/Red Sea/Arabian Coast	Habitat loss/Degradation, Fishing pressure/Hunting	Determining abundance/Habitat mapping/ Habitat use/Impact of oil spills
India/Sri Lanka	Habitat loss/Fishing pressure/ Hunting	Determining abundance/Habitat mapping/ Habitat use/Mortality Source
East and Southeast Asia	Habitat loss/Fishing pressure/ Hunting	Determining abundance/Habitat use
Taiwan	Habitat loss	Determining abundance/Habitat mapping
China	Habitat loss/Fishing /Hunting/ Ecotourism	None
Philippines	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Impact of fisheries/Anthropogenic impacts
Thailand/Cambodia/ Vietnam	Habitat loss/Degradation, Fishing pressure/Hunting	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/prepare conservation strategy
Malaysia/Singapore/ Brunei	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/Prepare conservation strategy/Anthropogenic impacts
Indonesia	Habitat loss/Fishing pressure/ Hunting/Boat impacts	Determining abundance/Habitat mapping/ Habitat use
Pacific Islands	Habitat loss/ Hunting/Ecotourism	Determining abundance/Poaching & hunting activities
Papua New Guinea// Solomon Islands/New Caledonia/Vanuatu	Habitat loss/Fishing pressure/ Hunting/Ecotourism/Boat impacts	Little or no recent research
Australia	Habitat loss/Fishing pressure/ Hunting/Ecotourism/Boat impacts	Determining abundance/Habitat mapping/ Habitat use/Mortality rates & causes/ Conservation strategy/ Anthropogenic impacts/Chemical pollution

Table 5: Dugong Threats And Existing Research (17)

intensively in dugongs has been Australia and most of these have been with small numbers or within a small geographical area.

Conceivably, to be successful any research strategy concerning sirenians should:

- be well funded
- be logistically organized between a large number of countries and over large geographical regions
- be centrally coordinated and managed by scientific committees composed of scientists, biologists, technicians and experienced field personnel (rangers, local fishermen, etc)
- have a central research facility that would store and maintain a tissue bank so that tissue and information could be shared between regions and countries to reduce the repetition of studies and maximize the information produced
- be composed of a well conceived research strategy that effectively looks at contaminants and their effects on sirenians by studying the following 3 major components:

i) the accumulation of contaminants over time
ii) the accumulation of contaminants in various small and large geographical locations
iii) the effect of these contaminants on the various physiological systems.

Although it would seem that although sirenians and numerous other marine mammals may have physiological methods to detoxify many contaminants, this does not negate the importance of identifying toxic levels of these contaminants if any conservation plan is to be successful. In summary to be successful, research strategies must include adequate financial investments, technical assets and human resources in a systemic plan that looks at every member of a species as being critical to maintain a viable population.

Conservation Actions

As in human medicine, to be truly successful, conservation action ideally should be geared to prevention and not reaction. For example, in Japan hundreds of people died and several

thousands more suffered as a result of mercury poisoning in the 1950's and '60's. Despite this, meat from several marine mammals are still being offered for consumption in today's Japanese markets even though that they contain high mercury levels (8). In the Arctic, many wild species in that region, have very high contaminant levels and thus pose a similar and serious hazard to the many communities who are still dependent upon hunting these species as their source of protein (33). These indigenous people continue to eat meat which may be hazardous to their lives, most likely because no direct correlation has been confirmed between these contaminants in marine species and their causing sickness or disease.

When looking at sirenians, conservation actions must be instigated with the idea to predict problems ahead of time thereby preventing the introduction of these contaminants into the environment which might affect their reproduction or survival. For instance, it is known that an increase in rainfall leads to greater amounts of runoff which kills the seagrasses that dugongs eat (4) and increases contaminants reaching the waterways. As a result, dugongs die either from starvation or other non-specific causes including possible contaminants or move to another region which can cause competition between animals. If proper clear cutting or farming practices would be introduced to prevent the increase of runoff during the rainy seasons, this would minimize the effect on the dugongs by preventing deaths and lowering the amount of contaminants into the environment. In the manatee, numbers of death have been lowered from collisions with speeding water craft by changing legislation and promoting public awareness, but new threats such as hypothermia or the higher number of deaths within perinatal young have prevented an increase the manatee population (2). The immediate cost of reacting to cleaning up contaminants in terms of money, equipment and human resources are extremely high and result in damage to our environment that requires decades to restore or repair (3). To successfully conserve sirenians in the many countries in which they geographically range, all conservation plans must be proactive and co-operative in preventing the introduction of contaminants into their environment.

As our human population continues to grow, the demand for more sources of protein will increase. As proof, McNiven et al. concluded that "pre-colonial hunting rates of 300 dugongs a likely minimum for the Strait (Torres) and 500 dugongs per year (the current mean catch rate) plausible" (18). So more dugongs are now being hunted than in pre-colonial times thereby increasing the likelihood of a human health issue. This review provides the realization that little progress has been made since the publication of the Marine Mammal Commission's workshop in 1999 that concluded "there remains great uncertainty about specific effects of contaminants in marine mammals" and that "closing of these knowledge gaps will make science better able to guide policy, management, and regulatory decisions related to contaminant impacts on marine mammals (23). When specifically looking at sirenians, the workshop also stated that "Because sirenians feed near the bottom in coastal and inland waterways and are herbivores, their exposure to contaminants may include less widely recognized chemicals…". So it would seem that since 1999, little has been done to explore the levels of contaminants or their effects within sirenians.

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