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Disappearance of Soft Tissue and the Disarticulation of Human Remains from Aqueous Environments

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ABSTRACT: Human remains recovered from aquatic environments were scored for regional presence of soft tissue, exposure of bone, and loss of body parts to determine the general pattern of soft tissue loss and loss of body parts. Regions scored were: the cranium, mandible, neck, hands, forearms, upper arms, feet, legs, pelvic girdle, and trunk. Initial disappearance of soft tissue, resulting in exposure of underlying bones, occurred in areas thinly overlain by soft tissue beginning with the head, hands, and anterior lower legs. Disappearance of body parts followed the general sequence: bones of the hands and wrists, bones of the feet and ankles, and the mandible and cranium. The lower legs, forearms, and upper arms are the next units to separate from the body.

Known postmortem intervals for remains analyzed ranged from weeks to years and could not reliably be estimated based on the condition of the body at the time of recovery. As parts drop away from a floating carcass in large or current-driven bodies of water, they are often separated from the major body unit. This complicates recovery. Knowledge of disarticulation sequences allows more informed assessment of skeletal element recoveries to be expected and assists in the interpretation of artifacts and events produced by different disarticulating environments.

KEYWORDS: forensic science, disarticulation, taphonomy, decomposition, aqueous environments, adipocere

Water has been suggested as an environment that might produce patterns of disarticulation distinct from those observed for carcasses recovered on land that are scavenged, unscavenged, or carcasses exposed to sedimentation or partial burial [*1*,*2*]. Previous observations of vertebrate carcass putrefaction and disarticulation in aqueous environments have focused on nonhumans. The studies of Dodson [*3*] and Payne [*4*] furnish longitudinal observations on the rate and stages of decomposition and putrefaction in small animal carcasses. Dodson examined decomposition of mice (*Mus*) and frogs (*Bufo*) in an aquarium of pond water. Deterioration of muscle was followed by skin, and then tendon. Dodson [*3*] noted the disarticulation sequence for mice as separation of caudal vertebrae from each other, the femur from the acetabulum, the jaw from the skull, and the hand from the arm.

Payne [*4*] reported on decomposition and insect succession of fetal pigs (*Sus scrofa*) [*4*]. He included observations for soft tissue disappearance and loss of body parts. Previously frozen fetal pigs were thawed and then placed in wire baskets suspended in tanks

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of water. Specimens were weighed at 4 h intervals for up to 20 h. Insect succession was monitored. The process of decomposition was divided into six stages: submerged fresh, early floating, floating decay, bloated deterioration, floating remains, and sunken remains. In the submerged fresh stage, the majority of carcasses sank. They bloated in two days in summer or two to three weeks in winter. In the early floating stage the distended abdomen was usually the first part of the body to project above water. Blowfly eggs were laid on surfaces of the body above the water line. Decomposition and insect scavenging took place in tandem. By the stage of bloated deterioration, most exposed flesh was gone and most maggots had migrated from the body, although many remained to feed on the carcass below the water line. Head, shoulders, abdomen, and hindquarters were separated by this time. Subsequently, the anterior portion of the carcass floated until it lost buoyancy and sank.

In 1927, Wieglet [5] commented on the disarticulation sequences of cows in salt water marshes and coastal quicksand. He observed that the mandible separates from the carcass first and then disarticulation proceeds with separation of the extremities. Schäfer [6] contributed anecdotal observations of North Sea mammals. He noted that the bones of whale carcasses drifting in water become separated before the skin ruptures. Once rupture occurs, bones fall one by one as if from a sack. For seals, whales, and dolphins, the integument tears where the tensile stresses are particularly high: above the roof of the skull, at the outer rims of jaws, and above the shoulder, scapula, and tail sections. Schäfer suggested that carcasses of seals drifting in water experience drying of gum tissue that results in teeth being "pulled" from the gums. Phalanges and forelimbs are next to disarticulate.

The following report is a cross-sectional survey that focuses on the pattern of disappearance of soft tissue and disarticulation of eleven partially skeletonized human remains recovered from aqueous environments.

Methods

The eleven human remains reported here were recovered in the context of forensic investigations and represent bodies exposed to a variety aqueous environments including, salt water sound, fresh and salt water rivers, and fresh water lakes (Table 1). Only remains in advanced stages of decomposition, characterized by exposure of bone and/or loss of body parts were considered. Eight cases from the Pacific Northwest, in the general area of Seattle, are represented and three examples are from New York City.

Results

Table 1 summarizes observed cases in terms of sex, type of water environment, elapsed postmortem exposure interval, month of year exposed, whether the body was submerged or floating at the time of recovery, and presence or absence of clothing. All individuals were adults. A total of 73% of the individuals were male and 27% female. Known postmortem intervals ranged from 5 weeks to 36 months and were determined for identified remains from the date the person was last known to be alive to the date of recovery. Five individuals were recovered from fresh water rivers, two from a fresh water lake, three from the salt waters of Puget Sound, and one body drifted from a fresh water river to the Sound. At the time of discovery three individuals were submerged, six were floating, and two were beached. Five individuals were fully clothed when recovered, two possessed remnants of disintegrated clothing, and four were nude.

Table 2 summarizes scores for the loss of skin and muscle overlying bone, exposure of bone, and absence of body parts. Each remains was scored for regional presence or absence of soft tissue (skin, muscle, and fat overlying bone), exposure of bone, and loss

TABLE 1—*Summary of cases.*

Case number	Sex/ age	Water environment	Postmortem interval (months)	Month		Floating or submerged	Clothing at time of recovery			
				In	Out		Shirt	Pants	Footwear	Gloves
1	F/29	Fresh H_2O River	1.25	May	Jun	Submerged	Y	Y	Y	N
2	F/18	Fresh H_2O Lake	26	Jul	Sep	Submerged[a]	D	D	Y	N
3	M/46	Fresh H_2O River	9	Dec	Aug	Floating	Y	Y	Y	N
4	M/26	Fresh H_2O Lake	31	Nov	May	Submerged[a]	Y	Y	Y	N
5	M/—	Salt H_2O River	—	—	—	Floating	Y	Y	Y	N
6	M/—	Fresh H_2O River	—	—	—	Floating	Y	Y	Y	N
7	M/52	Puget Sound	2.6	Apr	Jun	Floating	—	—	—	—
8	M/—	Puget Sound	—	—	—	Floating	—	—	—	—
9	F/—	Salt H_2O River	—	—	—	Floating	—	—	—	N
10	M/35	River + Sound	36	Nov	Nov	Beached	D	D	Y	—
11	M/—	River + Sound	—	—	—	Floating	—	—	—	—

[a] = sequestered in vehicle.
— = unknown.
D = disintegrated remnant.

TABLE 2—*Disappearance of soft tissue and bone for bodies subjected to aqueous environments. (In order of increasing tissue and body part loss scores.)*

Case	Mandible	Cranium	Hand	Lower leg	Neck	Forearm	Feet	Upper arm	Trunk	Upper leg	Pelvic girdle	Total	Postmortem interval
1	1	1	0	0	0	0	0	0	0	0	0	2	1.25
2	1	1	1	0	0	0	0	0	0	0	0	3	26
3	1	1	1	1	0	0	0	0	0	0	0	4	9
4	1	1	1	1	0	0	1	0	0	0	0	5	31
5	2	2	1	1	1	0	0	0	0	0	0	6	—
6	2	2	2	1	2	0	0	0	0	0	1	9	—
7	4	2	4	3	1	1	0	1	0	0	0	16	2.5
8	4	4	4	3	3	3	4	2	1	1	0	29	—
9	4	4	4	1	2	4	3	3	1	2	1	29	—
10	4	4	4	3	4	4	3	4	3	1	1	35	36
11	4	4	4	4	4	4	4	4	3	1	1	37	—
Total	28	28	26	18	17	16	15	14	8	5	4		

0 = soft tissue complete;
1 = partial exposure of bone;
2 = total exposure of bone;
3 = exposure of bone and partial absence of area;
4 = total absence of the region.

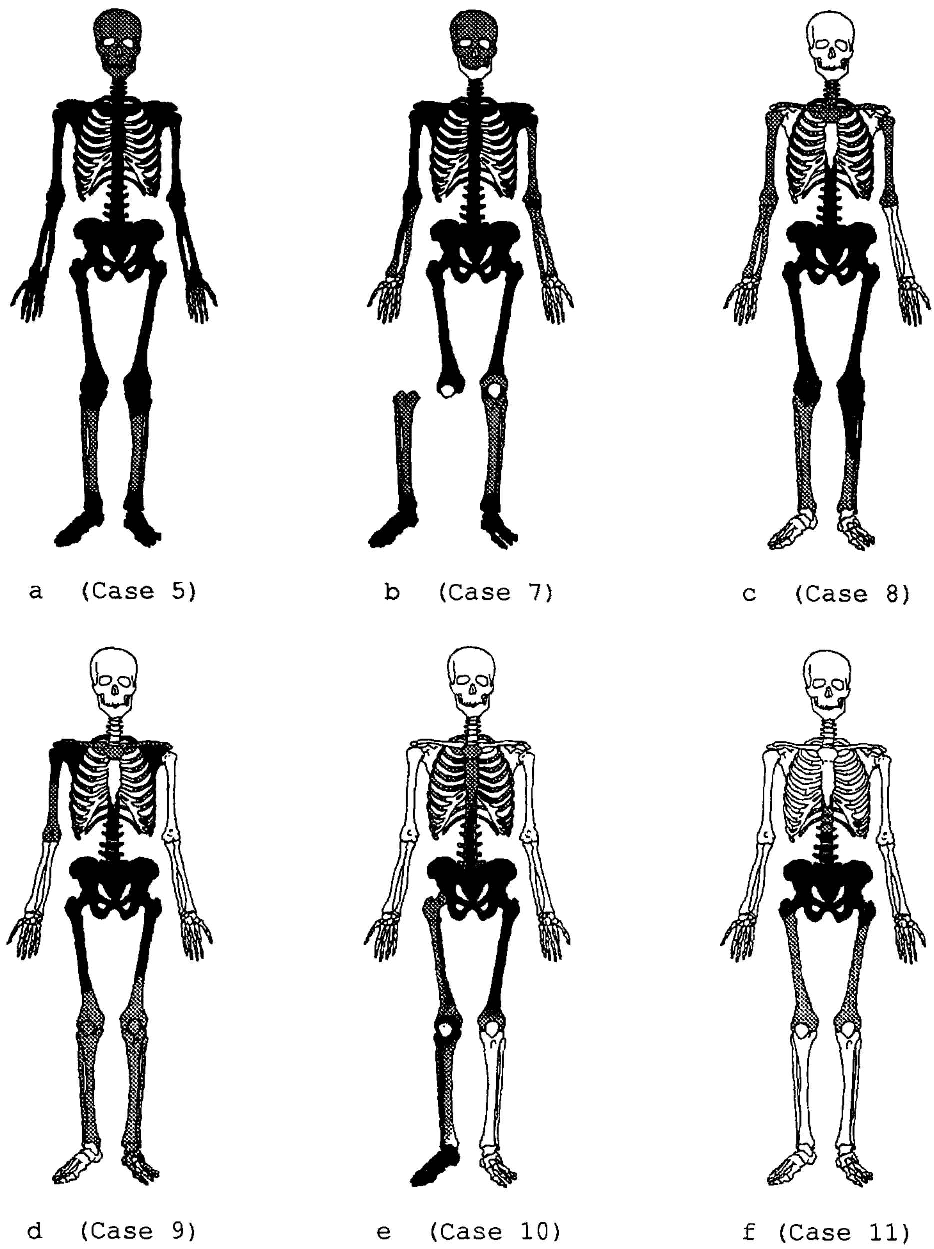

FIG. 1—*Patterns of bone exposure and loss of body parts in selected remains found in water. Dark shading = presence of skin, muscle and fat overlying bone; light shading = bone exposed due to absence of skin, muscle, and fat, and no shading = complete absence of part. The disarticulated leg of b.* (Case 7) *was beached 17 miles (27.37 km) distant from where the rest of the body was recovered.*

of body parts. Figure 1 diagrammatically represents patterns of bone exposure and body part loss for selected cases. The convention for scoring was: 0 = all soft tissue complete; 1 = partial exposure of bone due to loss of overlying soft tissue in some areas; 2 = total exposure of bone due to loss of all overlying soft tissue with articulations maintained by ligaments only; 3 = total exposure of retained bones with partial loss of bones from a defined region; 4 = complete absence of the region. Eleven body regions scored were: the cranium, mandible, neck, hands and wrists, forearm, upper arm, feet and ankles, lower leg, upper leg, trunk, and pelvic girdle. Sums of scores are provided for individual cases as well as for each body region scored. Cases and body regions, except for feet, appear in order of increasing total scores.

Initial disappearance of soft tissue, resulting in exposure of underlying bones, occurs at the mandible, head, hands, and the anterior tibial crest. Observed separation of regions from the body follows the general sequence: hands and wrists, mandible, and cranium. The next regions to separate are the lower legs, forearms, and upper arms (excluding the pectoral girdle). Portions of the trunk plus the pelvic girdle with the femora articulated are the last body portions to totally disarticulate.

Discussion

It is understandable that the mechanism that affects the pattern and sequence of disarticulation for human remains that have disarticulated in aqueous environments is different from disarticulation of bodies that occurs on land surfaces. Land surfaces provide a firm and usually static support to remains, whereas a body suspended in water can move in three dimensions. The flexible joints of dangling appendages such as the wrists, ankles, neck, elbows, and knees, are most affected by wave and current action. This contributes to rapid weakening of their soft tissue connections.

Over time, a body in an aqueous environment may be subjected to a wide spectrum of temperatures, depths, and currents. Except for those persons submerged within sequestered environments, such as closed compartments of vehicles (case numbers 2 and 4), it is often that only the point of recovery, and possibly, the point of entry into the water that are known. This makes total assessment of the postmortem history speculative for a majority of cases. To further complicate matters, aqueous environments may be obstructed by floating or stationary debris and occupied by various aquatic organisms. Table 3 lists major variables of the body and the environment that affect the fate of a human remains exposed to aqueous environments.

Decomposition of soft tissue in aqueous environments can take place in the form of putrefaction saponification, or mummification. An admixture of these processes can occur as observed in the floating remains of case number 6 where soft tissue of the anterior thorax was exposed to sun and wind above the water line, and dehydrated and mummified. The majority of cases reported here are from waters of the Pacific Northwest. These

TABLE 3—*Factors of environment and the body affecting the postmortem fate of remains exposed to aqueous environments.*

Environment	Body
Temperature	Presence of clothing
Depth	Body habitus
Currents	Submerged or floating
Water life	Type of joint
Obstructions and debris	Position of joint
	Amount of surrounding tissue
	Trauma

water environments maintain low temperatures year-round and they are especially conducive to saponification of submerged soft tissue.

It must be noted that the character of adipocere changes over the postmortem interval [7]. Fresh adipocere has a soft, greasy consistency; older adipocere may be hard and brittle. Unfortunately, the terms to characterize adipocere and saponified tissue are loosely applied and not uniformly defined by investigators. Once soft tissue has been modified by saponification, affected areas may persist for long periods of up to several years (case numbers 2 and 4) [8]. Case 2 represented the remains of a young woman recovered from a 200 foot depth of Lake Washington after 26 months. The body had been submerged within the vehicle with the windows up. This provided an environment protected from water life and currents. Water temperature at this depth range between a fairly constant 33 to 35°F (0.56 to 1.67°C). Hard, friable adipocere formed a crust which encased the remains. There was exposure of the superior cranium, partial face, and mandible. The body was intact except for disarticulation of bones of the right hand and loss of several wormian bones of the lambdoid suture. Internal organs were in place and showed nearly normal coloration, but demonstrated extensive softening and autolysis.

Early sites of disappearance of soft tissue and exposure of bone in human bodies recovered from water parallel somewhat the sequence of soft tissue disappearance for bodies decomposing on land [9]. That is, exposure of bone first occurs in areas such as the head, hands, and anterior tibia, areas with thin tissue overlay (cases 1 to 4, Table 2). The mechanism of soft tissue destruction in the face, neck, and upper torso of bodies floating face-up may be facilitated by insect activity focused at natural ports of entry such as the eyes, nose and mouth. Where larger muscles overlay bone (such as the gastrocnemius and soleus), the muscles may sag from the midshafts of the bone, while remaining attached at their origins and insertions. Other soft tissue destruction results from the feeding activity of crustaceans such as crabs and shrimp as in case 1 where soft tissue destruction of the lips, nose, and abdomen had occurred. Smith has previously commented on feeding by aquatic arthropods [10]. Fish, and other marine organisms such as sharks can consume soft tissue as well as fracture bone [11]. The chaffing movement of clothing over soft tissue surfaces may aid in removal of soft tissue from areas such as the anterior tibia.

The sequence of disarticulation is influenced by the nature and relative anatomical position of the joint involved [2]. Less flexible joints such as those of the vertebral column, with their complex interlocking nature and ligamentous bindings, persist longer than the more flexible radio-carpal, tibial-tarsal, elbow, and knee joints. Loss of the upper limb distal to the glenohumeral joint is no doubt facilitated by the shoulder's loose joint capsule and shallow glenoid fossa, which renders it capable of multiaxial movement. The sequence of disarticulation of human bodies in water tends to generally progress at major joints from the distal to the proximal. For the upper extremity, first to disarticulate is the radial-carpal joint, then the elbow joint, and finally the glenohumeral joint. For the lower extremity, first to disarticulate is the tibial-tarsal joint and then the knee. Crania are often the sole body part recovered from bodies that have disarticulated in large bodies of water. The mandible may disarticulate at about the same time as the hands and wrists from the lower arm (Fig. 2*b*). In case 5 the mandible was nearly completely detached, with only a remnant of lateral ligament spanning the left temporal mandibular joint. Early loss of the mandible matches observations of disarticulation of animal carcasses in marshy environments [5]. The cranium is usually lost about the same time as separation of the elbow occurs (Fig. 1*b* and 1*c*). Bodies floating in open water that is devoid of obstructions adhere to these general trends of disarticulation. Previous trauma to the body, and strenuous wave, current, or surf action can affect the pattern of disarticulation, hence body units recovered or lost.

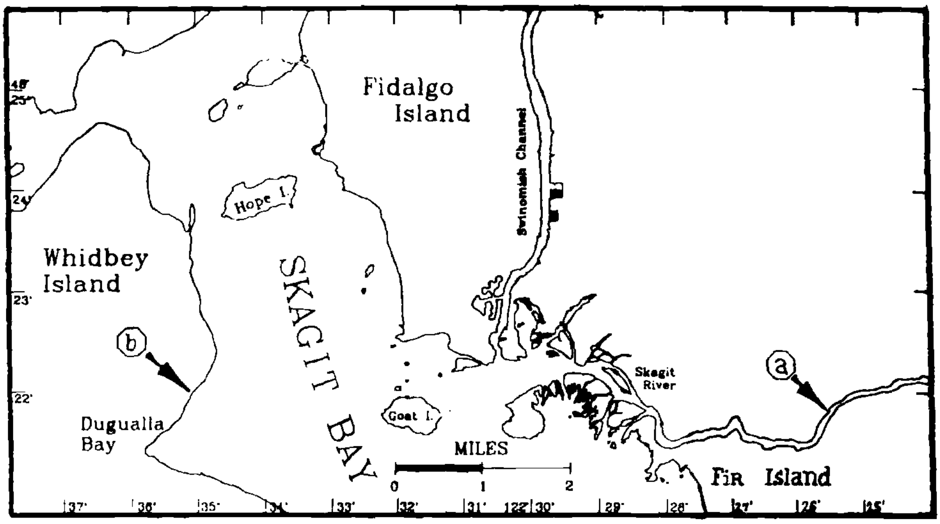

FIG. 2—*The remains of a male* (Case 11) *drowned in the North Fork of the Skagit River in 1987, point a. His remains rafted with tree debris, across Puget Sound's Skagit Bay, to be found on a Whidbey Island public beach three years later, point b.*

Clothing, not unlike the skin of marine mammals [*6*], packages and tends to inhibit the release of disarticulated bones. Presence of foot apparel acts to preserve and retain soft tissue of the feet and ankles and high-top boots may tend to anchor the tibia and fibula with the foot and ankle (cases 1, 5, and 9). Long shirt sleeves entrap disarticulated arm elements, as do pants the disarticulated elements of legs. This occurred in case 7 where the disarticulated lower leg bones were retained within the pant leg (Fig. 1*b*). Once clothing disintegrates, such elements are lost. The disintegration of various fabrics in water needs more attention by forensic investigators.

Eventually, disarticulated bony elements and carcass units separate from a carcass and the carcass loses buoyancy. It is unclear at what stage of disarticulation this actually occurs. Once buoyancy is lost, remains settle to a new environment where they are subjected to different taphonomic circumstances. Disarticulated body units and skeletal elements may be moved by deeper currents and come to rest on bottom substrates. At that point they may be moved along the substrate or be silted over.

In addition to entrapment of disarticulated elements in clothing, other circumstances may prevail that cause separate portions of the body to remain associated. For example, case 11 involved a 35-year-old man who drowned while fishing, three years prior to discovery of his body (Fig. 1*e*). His nude remains were discovered beached on an island in the Puget Sound in December of 1990. The victim had drowned in a mainland river approximately three miles (4.82 km) from where it empties into Puget Sound (Fig. 2). The remains were recovered in two portions that were associated with tree debris. One section was represented by cervical vertebrae number seven through thoracic vertebrae number nine. Sternum and ribs, absent soft tissue, were articulated with this section. The second section of remains included thoracic vertebrae number ten through the coccyx, the pelvic girdle, the left leg missing distal to the femur, and a complete right lower extremity. The right foot was clad in a sock and boot and remnants of jockey-type shorts remained around the waist. Although the body was in two separate sections, the hard, gritty saponified tissue of the posterior trunk retained an indentation consistent with having rafted with the tree debris associated with it on the beach.

There are differences between the patterns of disarticulation on land and that observed in aqueous environments. For example, disarticulation of the upper extremity in aqueous environments occurs at the glenohumeral articulation with the pectoral girdle retained with the trunk, whereas, removal of the upper limb by canid scavengers usually includes removal of the pectoral girdle with the limb [*12,13*]. Disarticulation in water leaves surfaces of recently disarticulated elements clean with bony features well preserved. As the interval of water exposure increases, sharp features of bone become smooth and rounded. This process is accelerated by heavy current-driven sediment loads [*14*]. Obstructive boulders or rocky bottoms may further contribute to fractures. Large animals such as sharks may severely damage bone [*8*].

In conclusion, the postmorten environment the body is exposed influences taphonomic history as it pertains to the disappearance of soft tissue, disarticulation, dispersion, and modification of skeletal elements. Different environments result in different disarticulation patterns, skeletal element recovery, and modification of soft tissue. Knowledge of these differences can aid forensic death investigators in distinguishing environmentally induced phenomenon from evidence of forensic import and help to eliminate their confounding of forensic issues. This paper has demonstrated a consistent pattern of disarticulation of human bodies recovered from aqueous environments. There is much to be learned about human remains in aqueous environments. Significant gaps exist in our understanding of the sinking or floating behavior of bodies in water: when they sink or float; changes of soft tissue; deterioration of clothing; modification of bone; and postmortem interval information such as can be gleaned from growth of sedentary aquatic organisms.

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