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THE CONCEPT OF ASSIMILATIVE CAPACITY

The phrase "assimilative capacity" was coined by Professor Edward Goldberg of the Scripps Institution of Oceanography and used as the theme of a NOAA Workshop at Crystal Mountain, Washington, in 1979. At that meeting it was taken to mean "the amount of material that could be contained within a body of water without producing an unacceptable biological impact" (Goldberg 1979). The workshop report further stipulated that the "carrying capacity of the waters should not be exceeded" and that unacceptability could be decided by "titration of the pollutant against the water body until an end point is reached." The difficulty with the concept of titration is that, although changes are taking place, nothing is observed until the end point is reached at which moment there may be an abrupt change in color. In the environment the analog of this could be a sudden substantial change in the wellbeing of some animal after a period of previously unobserved effects.

Therefore we changed the original concept to reduce the possibility of surprise; instead of determining the moment at which there might be sudden serious damage we sought to determine the threshold of earliest toxic effect--that is, to discover the contaminant concentration at which the first most delicate effect can be seen at the microscopic or molecular level. This lowest level of toxicity is difficult to detect, especially considering natural biological variability between individuals and the uncertainties about what is normal for each season in each species. In any case, we proposed the work described in this collection of papers as a way of assigning numerical values to the effects of an assortment of contaminants in specific small regions of coastal waters. Table 1 illustrates the concept of assimilative capacity.

It is generally accepted that all animals, including those living in open coastal waters, have some capacity for withstanding contamination. This is to be expected because many of the contaminants released by

Table 1. **The concept of assimilative capacity. Although many substances normally present in the sea can be toxic at high concentrations, the same ones can be tolerated without damage by sea animals over a wide range of lower concentrations.**

Level of Contaminant Substance	Effect	Description
High	Excessive contamination causes toxic or reproductive damage to sea animals	Pollution
		Threshold of damage 100%
Moderate Addition by man or external sources Low	Rise in contaminant substances within tolerance (detoxification capacity) of sea animals	↑ Assimilative capacity ↓
		0% Threshold of manmade contamination
Natural levels	There is a wide range of natural contaminant substances in sea animals that are not believed to cause damage	Control or reference condition

Note: NO LOCATIONS ARE KNOWN WHERE OPEN COASTAL WATERS HAVE NO CONTAMINANTS.

man are naturally present in coastal waters or, as in the case of synthetic organic compounds, are similar to natural compounds (Fenical 1982). Thus, sea animals have long been accustomed to living with a collection of elements and substances which, when contributed by man, are called contaminants. Because the natural range of concentrations is large, as shown in Table 2, one would expect animals to have a similar range of natural defenses. Therefore, assimilative capacity depends upon the utilization of an animal's natural defenses to resist contaminant levels between background and the first indication of damage.

Table 2. Amounts of metals naturally present in the sea.

Metals	Average in Southern California Coastal Waters[a] (mg/L)	Bottom[b] (mg/dry kg)	Range in Fish Muscle of 8 Species of Coastal Pelagic Fish[c] (mg/wet kg)
Hg (total)	0.0005	0.02-0.05	0.046-2.18
Ag	0.01	0.06-1.7	0.002-0.006
Cd	0.05	0.1-1.7	0.01-0.078
Cr	0.54	6.5-43	0.018-0.075
Cu	0.60	2.8-31	0.2-0.48
Zn	0.73	9.8-62	2.59-6.4

[a] After Young et al. (1977).
[b] SCCWRP control survey of 1977.
[c] Schafer et al. (1982).

When we set out to assign percentage values to the amount of assimilative capacity that has been used, we proposed making four kinds of measurements throughout the year along a gradient of sampling sites whose contaminant levels ranged from very contaminated to virtually uncontaminated. Each kind of measurement was based on a hypothesis of cause and effect, and it was believed the four kinds of data would be mutually supporting. Each required the measurement of sublethal effects in animals that lived at the sites. The four effects we looked for were 1) reduction of reproductive capacity in fish; 2) spillover of unneeded metals into the enzyme fraction of fish liver cytosol; 3) spillover of chlorinated hydrocarbons, or their metabolites, into the metallothionein fraction of fish liver cytosol; 4) histological changes in various fish tissues. We expected to be able to assign a different assimilative capacity value to the area around each station. The emphasis was on fish because they are higher in the food web, likely to feed both in the water and on the bottom, and they are the animals of greatest interest to the public.

The work was successful in that we were able to make the measurements proposed in vital organs and relate these to contaminant levels. Not surprisingly, we discovered some complexitites not previously considered. For example, we selected a sampling station in Santa Monica Bay (SMB 2-3) as a control station because it seemed to have a normal fish community and a higher-than-control Infaunal Index number and because it was a convenient running distance for the survey ship. Well into the study we found that, although the animals seemed undisturbed, the fish living at this location contained DDT residues higher than that known to cause pathology. This meant that the station was unacceptable as a control and that we would have to go much farther away to obtain suitably uncontaminated specimens.

So began a search for truly acceptable control animals--but even after sampling at such distant locations as San Clemente Island and Cortes Bank in the southern California Bight; Punta Banda, Mexico; and Morro Bay on the open coast north of Point Conception, we still do not have uncontaminated samples of the same species of fish on which most of the measurements were made. The problem is that, without animals from pristine locations, the natural variability of normal animals cannot be determined. For example, one of our criteria is vacuolation (excessive amounts of lipids) in liver tissue. We suspect that some vacuolation is normal and that the amount of it changes from season to season with the lipid demands of the reproductive cycle. It may also be related to diet and food availability, or to other circumstances, as well as to the presence of chlorinated hydrocarbon residues from man's wastes. We cannot say how much change, if any, has occurred until we know that normal figure. Another puzzling aspect is that we found vacuolation in livers of fish living among fish of the same species that showed no vacuolation, far from known sources of contamination. Thus the effects of contaminants, if that is what we are finding, vary considerably, even within a single species at a single location. In the meantime, based on a combination of possibly related data and instinct, we have set the working criterion for a normal fish liver as follows: after slide preparation, less than one-third of the cytoplasm remains unstained--indicating lipids.

A similar problem exists with the examination of gonad slides. Sometimes resorption of eggs can be seen, and a small amount of this may be normal. We hope to make additional measurements in areas of less contamination (during the appropriate season) to learn what is normal. In the worst case measured, 50% of the individuals of one species had impaired reproduction (the number of viable eggs was reduced as much as 70%). The remainder seemed normal; whether or not these could have been successfully fertilized (or what percent are normally fertilized) is not known. Moreover, if this species lays its eggs in clusters on a contaminated bottom, it may be that even fertilized eggs do not develop. In any case, the successful propagation of a <u>species</u> only requires that one male-female pair of hundreds of eggs spawned reach maturity and spawn again. We do not know if this happens, but the fact that the species measured were taken in most trawls at all stations suggests that they are abundant in spite of substantial contamination. However, since few juveniles of some of the species studied are captured near the large outfalls, the fish taken may be recruited to the region as adults.

To the those problems one can add the ever-present problem of natural variability between fish of the same species and size. Considerable replication is necessary, but for some species in some seasons at some areas this is not possible. Our best efforts produced some inadequate data. Several of the original species selected for the year-long study went elsewhere to spawn, just when we most needed them.

The above matters are technical in nature and presumably solvable. The philosophical problems of using the data to set a number on the assimilative capacity of an area are even greater. We had expected that, in a small region where the kinds and concentrations of sediment contamination are uniform, the uptake and reactions of the animals would be more similar than was found. Now we know these responses are highly variable, even among the few species we selected. Undoubtedly there are even greater variations among the numerous other species living in each area.

The four criteria we selected originally have been better defined and slightly expanded. We have reasonably good measurements of each, but these raise questions such as: How does one select a threshold or end point? Does it come when the first animal, however insignificant, sustains the first identifiable toxic damage, however small? If 10% of one species at a station shows some reduction in egg production, how much of the assimilative capacity has been used? Or, if all of one species shows a 10% reduction in egg production how much has been used? Or, if all species show a 10% reduction in egg production how much has been used? Is the answer that 100% of the assimilative capacity has been used in any or all cases, or is it 10%?

Additional questions have been raised. If the amount of some necessary metal such as zinc or copper in an animal liver is reduced below its normal reserve--even though there still seems to be enough to supply the enzymes--does that constitute damage? And, if the unused reserve is 50% of normal, what percent of the assimilative capacity has been used? If the liver of one species has 40% vacuolation instead of the acceptable 30% vacuolation, how much of the assimilative capacity has been utilized?

The above questions illustrate the conceptual bramble patch in which we find ourselves. Table 3 summarizes our results. At this writing we have not resolved these matters; therefore, we will decline, at least for the present, to set numbers on the assimilative capacity of any region. It may be that the concept of assimilative capacity is not translatable into useful numerical values.

Table 3. Assimilative capacity of the sea in the region around three contaminated stations.

Criteria	Contamination: High (7.3)	Intermediate (6.4)	Low (2.3)	Virtually None (Reference)
Proposed measurement				
Pathology (fish)				
• Gonads[a]				
Longspine combfish	11.0%	17.0%	4.0%	
Yellowchin sculpin	6.0%	20.0%	8.0%	b
• Liver[c]	70%	71%	83%	0%[b,d]
Spillover				
• Metals into ENZ	0	0	0	0
• CH metabolites into MT or ENZ	0	0	0	0
Other possibly useful data				
Metal levels in metallothionein	low	reduced	normal	normal
Ecological distance from control (infauna)[e]	0.50	0.44	0.34	control
Infaunal index number[f]	9.9	48.4	92.6	71 ± 4
Remaining assimilative capacity	?	?	?	?

[a] Percent impaired reproduction.
[b] Normal variation.
[c] Percent of fish with vacuolation (1.5 or greater rating) (40 species).
[d] Fish with less than 0.5 ppm TICH.
[e] Calculated by Bruce Thompson, SCCWRP.
[f] Bascom (1978).

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