13.2 Galveston Bay - *Development of a Rapid Bioassessment Method and Index of Biotic Integrity For Coastal Environments: Northwestern Gulf of Mexico Pilot Studies*

13.2.1 Study Objectives

A study was conducted on selected streams and bayous within Galveston Bay, Texas (Figure 13-1) coastal ecosystems, in order to characterize the expected fish assemblages of various types of waterbodies (with varying water and habitat quality) (Guillen 1995a). A second study objective was to develop a prototype rapid bioassessment technique similar to the Index of Biotic Integrity for the northwestern Gulf of Mexico. In order to meet the second objective, several criteria for the development of the method had to be met. First, the method had to be ecologically relevant, that is any metric or ranking system had to directly relate to ecological function and structure. Secondly, the method had to be taxonomically simple or kept to the broadest taxonomic/functional group of organisms that provide the most information. The methods also had to be simple (in terms of equipment, labor, and analysis) cost effective, easily standardized, subject to easy replication, and adaptable to a variety of environments.

13.2.2 Study Methods

The sampling design consisted of five bayous classified according to the potential for anthropogenic impact; i.e., urban versus rural, impaired versus unimpaired and salinity effects; i.e., lower portions of tributaries versus upper portions. Oyster Bayou, Dickinson Bayou, Texas City Hurricane Canal, Highland Bayou Diversionary Canal, and Cedar Lakes Creek were selected to fulfill these criteria. Oyster Bayou is a minimally impaired coastal bayou located in the middle portion of Galveston Bay and flowing south to East Bay. Oyster Bayou stations were characterized by a silty clay substrate. The moderately impaired Dickinson Bayou is located in the northeastern portion of Galveston County. Dickinson Bayou is characterized by sandy to silty clay substrates and is impaired by both point and nonpoint sources. The Texas City Hurricane Canal is an industrial canal that flows into the Texas City ship channel, and receives industrial and stormwater discharges. The majority of the canal banks possess a steep slope, and little bank vegetation, and the southern shoreline is an artificial levee. The Highland Bayou Diversionary Canal is an artificial waterbody created by the Army Corps of Engineers in 1983. The canal was created by channelization of the upper reach of Highland Bayou proper and construction of an earthen dam directly below the channelized portion, in order to reroute water through a dredged canal into Jones Bay. The canal is tidally influenced and receives effluent discharge from municipal wastewater treatment plants and runoff from surrounding agricultural grazing and pasture lands. Cedar Lake Creek is a minimally impaired rural bayou which extends 24-miles from its origin at the intersection of Cedar Lakes to the Gulf Intracoastal Canal. There are no active discharges in the watershed, however, an oilfield is present at its upper reaches. Predominant land use in the area is cattle grazing and the San Bernard Wildlife Refuge.

To summarize, two minimally impaired bayous (Oyster Bayou and Cedar Lakes

Creek) and three impaired waterbodies (Highland Bayou Diversionary Canal, Texas City Hurricane Canal and Dickinson Bayou) were surveyed during the study period. The impaired sites included two that were influenced by residential and municipal wastewater, and one effected by industrial effluent. Two of the waterbodies were highly channelized and/or man-made. Site investigations involved seasonal quarterly surveys made at all stations within each watershed. Sampling was conducted during summer, fall, and winter 1991; spring and summer 1992; and winter, spring, summer, and fall 1993.

In order to evaluate the relationship between water quality and fish communities, various hydrological, habitat, and biological data were collected concurrently. Qualitative habitat measurements including primary and secondary tributary depth, width, substrate type, and shoreline vegetation were noted at each station. A rapid field method for the evaluation of percent sand in sediments was also used to evaluate effects of sediment size on nekton populations. Measurements of surface and bottom temperature, dissolved oxygen, conductivity, salinity and pH were made. Surface water samples were also collected for the determination of total organic carbon, fecal coliforms, total and orthophosphate, nitrates, total ammonia, total suspended solids, and chlorophyll *a*. Individual water chemistry and habitat values were plotted against seasons and stations to evaluate temporal and spatial patterns.

In addition, Pearson's correlation coefficients and stepwise and direct discriminant analyses were used to determine the relationship between the variables and clustered groupings of stations. The analyses provided another tool for investigators to evaluate the relative influence of physicochemical variables on coastal nekton communities. Survey results showed that the majority of water quality variables were within previously documented tolerance limits of estuarine fish.

Nekton (fish and macrocrustacea) were collected using experimental gillnets, trawls, and seines. Gillnets were 200 x 8-ft experimental monofilament nets with eight panels of varying mesh sizes (0.5-4-in mesh). Seine collections (five replicates of 25-ft hauls) were made using a 15 x 4-ft common minnow seine with 1/8-in square mesh nylon netting. Trawls were made at main channel stations in each watershed, using a 10-ft otter trawl with 1-in mesh in the wings and 1/4-in mesh in the cod end. Four replicate trawls (five minute tows, each) were made at each of the mainstream stations. Nekton collected via all sampling methods were identified to the lowest possible taxon, enumerated, and measured.

13.2.3 Study Results

Several biological metrics were considered during the pilot study based on historical usage and recent recommendations in the literature. Community metrics generated from pilot study data included: total catch, log-transformed total catch, number of nekton taxa, Shannon-Wiener diversity index, Pielou evenness index, total number of taxa making up 90% of the catch, dominance ratio (ratio of most abundant species/total catch), number of crustacean species; number of "bottom taxa"; i.e., sciaenids, flatfish, blue catfish; number of predatory species; number of "minnow" taxa; i.e., Poeciliids and/or cyprinodonts; number of goby taxa; proportion of total catch as bay anchovy; proportion of total catch as "shad"; i.e., clupeids and engraulids, proportion of total catch as poeciliids; proportion of total catch as Penaeid shrimp; and proportion of total catch as palaemonid shrimp; i.e., grass shrimp. The rationale for each proposed metric is provided in Table 13-3.

Trawl, seine, and gillnet results were utilized in a cluster analysis, and then subjected to stepwise discriminant analyses. Observed seasonal and spatial patterns and/or temperature and salinity related correlations were used to determine whether seasonal or salinity-adjusted metrics were needed. In addition, the decision to include data from "impaired" sites in the derivation of metrics was also evaluated using these analyses. If initial statistical analyses failed to show differences between the reference sites and impaired sites, then all sites were pooled for derivation of metrics.

Due to the strong seasonal and/or spatial trends observed in various metrics using the seine data, cumulative percent distributions of each candidate metric were calculated by season for minimally impaired watersheds. Results of the distributions are presented in Table 13-4. Metrics were adjusted where distributions indicated truncated values using the following approach. If the distribution line could be extended to the 15^{th} or 85^{th} percentile value without crossing the Y axis, then that estimated value was used. If it could not, the metric was not used during that season and/or the metric rating was adjusted to reflect only two conditions (e.g., normal and excellent). This same procedure was used to derive a proposed metric system using trawl data (Table 13-5). A proposed list of prototype metrics using gillnet catch data was developed (Table 13-6); however, since gillnet design and deployment is variable, it may be difficult to compare metrics derived from the pilot study with other studies. Pilot study results indicated that it seems feasible that a prototype estuarine bioassessment system based on nekton community collections can be used to successfully document impacts from pollution. Analysis of potential metrics through discriminant analysis, graphical evaluation of cumulative distribution, frequencies and correlation analyses yielded the proposed metrics listed in Tables 13-4, 13-5 and 13-6. The categories utilized in the framework of the proposed system were based on the following protocol. Depending on the metric, those values less than the 15^{th} percentile were categorized as "concern". The interquartile values; i.e., 15-85^{th} percentile were categorized as "normal", and values exceeding the 85^{th} percentile were classified as "excellent". In some cases where high metric values denoted degraded conditions, the inverse of the proposed scheme was used; i.e., $<15^{th}$ percentile = "excellent". The classification system was based primarily on statistical distributions of the observed data. Where data was insufficient, a "not recommended" disclaimer was listed.

It was difficult to single out one water quality variable as having the most influence on community structure and the proposed metrics. Therefore, a conservative approach was taken by grouping by season and utilizing all data across various salinity levels.

The proposed Index of Biotic Integrity (IBI) metrics derived from the pilot study would be most confidently applied to situations where salinities range from 1-25-ppt. Continued calibration of this system with additional data sets is needed. The proposed metrics need to be evaluated against independent data sets including those in high (>25-ppt) salinity regimes.

Table 13-3. Rationale for the inclusion of proposed nekton community metrics.

Metric	Rationale
Total Catch	Total abundance is a rough measure of the total community population and as such gives no information on individual species population levels. Low abundances can be caused by various stressors. It should be noted that high abundances caused by individual opportunistic species can also indicate a disturbed community.
Log Total Catch	Due to the inherent variability of populations, the patchiness of fish schools and previously observed distributions of fish, many ecologists feel that the log-normal distribution fits the distribution of nekton populations better. Therefore log total catch may be a more appropriate indicator of total population levels. In order to handle zero catches, however, a log (catch + 1) transformation is needed.
Total Number of Nekton Taxa	The species richness of any community is extremely important. Reductions in species number may indicate an overall reduction in available habitat or the presence of environmental stressors. This may be due to the avoidance or death of sensitive species in an area. The number of taxa collected is a relatively economical measure. On a relative scale it is the cheapest information obtainable from catch data.
Cumulative Number of Nekton Taxa	The cumulative number of taxa is somewhat different than the total number of taxa in that it reflects the upper limit of the number of taxa one would expect to collect within a single replicate sample. Large discrepancies between mean and cumulative number of species may indicate high variability in habitat or distribution of species. Like the total number of taxa metric a low cumulative number of taxa can reflect limited habitat and/or the presence of environmental stressors.
Total Number of Fish Taxa	This metric is closely related to total nekton species numbers. However, it was added to address situations where only fish data is tabulated.
Nekton Species Diversity	The Shannon-Wiener diversity function was selected to evaluate nekton communities. This commonly used function (H') was developed to incorporate the two most important components of diversity, namely richness and evenness. Species richness is normally tabulated. However, species richness alone provides no information on how evenly individuals are distributed among species. The majority of communities studied by ecologists show a log-normal pattern of species abundance in which a relatively few species possess a rather large number of individuals and a rather large number of species possess few numbers of individuals. A diverse community is one in which species number and evenness are maximized. One problem with the use of H' is the fact that various combinations of species numbers and evenness can yield the same answer. Therefore diversity indexes should only be evaluated in the presence of species richness and evenness.

Table 13-3 (Cont'd). Rationale for the inclusion of proposed nekton community metrics.

METRIC	RATIONALE
Nekton Evenness	One factor that influences diversity directly is the evenness of the distribution of organisms between species. Populations possessing high numbers of taxa but with highly uneven distributions between taxa (e.g. highly dominant taxa) may reflect underlying habitat limitations, stressors or seasonal patterns. One of the most popular indexes used by marine biologists is the Pielou's evenness index (J). This index is defined as: J = H'/ln(S), where H' is the Shannon-Weiner index, ln is the log base (e) and S is equal to number of taxa This index expresses H' relative to the maximum value that H' can obtain when all of the species in the sample are perfectly even with one individual per species.
Number of Nekton Taxa = 90% Catch	This index is the number of taxa that together add up to at least or exceed 90% of the total catch. This is another measure of evenness. High values would indicate a community in which there is no clear dominant taxa. This index is influenced by the same factors which effect the evenness index.
Nekton Dominance Ratio	This has also been referred to as the Berger-Parker index. This is the ratio N_{max}/N, where N_{max} = number of individuals present in the most abundant taxa, and N is the total catch. This equation is computationally simple and can be easily programmed into spreadsheets. In addition, it is intuitively easy to understand. High dominance reactions reflects dominance of the community by a few individuals which relates to an uneven distribution of individuals within taxa resulting in poor diversity. This may be related to potential stressors and other factors cited under the discussion of Pielou's evenness.
Number of Crustacean Nekton Taxa	The number of crustacean taxa present in the nekton is largely a function of 4 principle groups. The first group are crab species including blue crab, *Callinectes sapidus*. The second group includes seasonally dominant groups of Penaeid shrimp which migrate into tidal creeks and bayous as postlarva and juveniles. The third group includes resident species of grass shrimp, genus *Palaemonetes*. The final group include freshwater prawns, genus *Macrobrachium*, and crayfish genus *Procambarus*. The presence of crustacean taxa indicates a healthy population of benthic herbivores and omnivores which serve as the primary food source for many estuarine fish. In addition, crustaceans are especially sensitive to organic pesticides.
Number of Predatory Fish Taxa	Predatory fish were defined as fish in the family Carangidae, Scombridae, and the genera *Paralichthys*, *Lepisosteus*, *Micropterus*, *Cynoscion*, *Morone* and the species *Sciaenops ocellatus*, *Synodus foetens* and *Elops saurus*. These species represent individuals at the top of the food chain. Impacts to other species they depend on may reduce these predators indirectly. In addition, through the process of biomagnification predators are more likely to bioconcentrate high levels of pollutants found in the lower portions of the food chain.

Table 13-3 (Cont'd). Rationale for the inclusion of proposed nekton community metrics.

METRIC	RATIONALE
Number of "Minnow" Taxa	The number of "minnow" taxa include resident species of Cyprinodontidae and Poeciliidae. These two groups of small fish represent the majority of resident species inhabiting marsh and shallow water environments. The majority of these species are not normally found offshore or in deeper waters due to predation. A high number of these taxa may reflect habitat suitability of a particular location to resistant species. Since these species are largely non-migratory, their presence or lack of may indicate long-term environmental perturbation. In contrast, high populations of these species may correlate the absence of larger predators and/or the presence of marginal habitat unsuitable for other less tolerant taxa.
Number of Goby Taxa	This is another group of resident taxa that are primarily carnivorous, feeding on small invertebrates. In addition, gobies are extremely territorial and tend to stay within a defined area. Most gobies are benthic. Reduced numbers of gobies would indicate localized impacts to habitat, water quality and secondary impacts on food sources namely, epibenthic invertebrates.
Proportion of Nekton Catch as Poeciliids	Poeciliids are a group of fish that are generally extremely tolerant to poor water quality. Notable examples include the mosquitofish (*Gambusia affinis*) and molly (*Poecilia latipinna*). These two species are often found in harsh habitats where few other species live. In addition, they are typically found in areas (e.g., shallow flats) which are difficult for predators to exploit. A predominance of Poeciliids in shoreline communities can therefore indicate degraded conditions and/or lack of predators.
Proportion of Nekton Catch as Penaeid Shrimp	One of the most important species ecologically and commercially are the Penaeid shrimp, including the estuarine white shrimp *Penaeus setiferus*, the brown shrimp *P. aztecus*, and the less abundant pink shrimp *P. duorarum*. Typically these species enter the estuaries as postlarvae. With continued migration they reach tidal creeks and bayous as juveniles and spend the early part of the first year in these areas prior to migrating back to the ocean to spawn. The proportion of catch as Penaeid shrimp may be an excellent ecological indicator. Penaeid shrimp can serve as a metric that addresses the nursery functions of a waterbody. It is also a lower food chain omnivore. Many species are dependent upon this invertebrate for food. Therefore, reduced numbers of shrimp can detrimentally effect the entire nekton community. In addition, since it is an arthropod it may serve as an excellent indicator of secondary impacts associated with pesticide use.

Table 13-4. Proposed seine metrics for use in an estuarine IBI along Texas coast.

Metric	Summer Value	Fall Value	Winter Value	Spring Value	Score
Category A					
(A) Total Catch	<200 200-450 >450	<50 50-400 >400	NA ≤900 >900	NA ≤700 >700	1 2 3
*(A) Log Catch	<.5 4.5-6.0 ≥6.0	<.9 3.9-5.8 ≥5.8	<4.2 4.2-6.4 >6.4	<1.5 1.5-6.3 >6.3	1 2 3
*Prop. Pen. Shrimp	<.01 0.01-0.3 >0.3	<25 .25-.56 >56	NA NA NA	NA ≤0.04 >0.04	1 2 3
Category B					
(B) Prop. Shad	>0.83 NA ≤0.83	>.60 .04-.60 ≤0.04	>.59 NA ≤.59	>.78 NA ≤.78	1 2 3
*(B) Prop. B. Anchovy If Bay A. = 0 then use 'Shad' metric	>0.8 NA ≤0.8	>.52 .04-.52 <.04	>.13 NA ≤.13	>.34 NA ≤.34	1 2 3
*Dominance Ratio	>0.88 0.44-0.88 <0.44	>.65 .40-.65 <.40	>.82 .26-.82 ≤.26	>.78 .27-.78 <.27	1 2 3
Category C					
*(C) Mean #Taxa	<6 6-11 >11	<6 6-10 >10	<6 6-10 >10	<5 5-10 >10	1 2 3
(C) Cum. #Taxa	<10 10-19 >19	<6 6-11 >11	<11 11-18 >18	<11 11-19 >19	1 2 3
(C) Mean #Fish Taxa	<3 3-7 >7	<3 3-7 >7	<3.5 3.5-7 >7	<4 4-8 >8	1 2 3
Total IBI Score					
Concern	5-7	5-7	4-5	7-9	
Normal	8-12	8-12	6-10	10-12	
Excellent	13-15	13-15	11-12	13-15	
Total IBI Score (WHEN INVERTS NOT USED)					
Concern	4-5	4-5	4-5	5-6	
Normal	6-10	6-10	6-10	7-10	
Excellent	11-12	11-12	11-12	11-12	

* Recommended metric; if mean log total catch or total catch = 0, then score = high concern.

Table 13-5. Proposed trawl metrics for use in an estuarine IBI along Texas coast.

Metric	Summer Value	Fall Value	Winter Value	Spring Value	Score
*Prop. Total Catch as P. Shrimp	* ≤0.45 >0.45	<0.42 .42- .83 >0.83	* * *	* ≤0.08 >0.08	1 2 3
*Prop Total Catch as Shad	>0.06 * ≤0.06	>0.08 * ≤0.08	* * *	>0.03 NA ≤0.03	1 2 3
Category A					
*Mean # Nekton Taxa	<1.8 1.8-9.3 >9.3	<4.3 4.3-9.9 >9.9	<4.4 4.4-8.8 >8.8	<4.1 4.1-7.7 >7.7	1 2 3
Mean # Fish Taxa	<2.2 2.2-6.3 >6.3	<4.2 4.2-6.6 >6.6	<2.1 2.1-6.8 >6.8	<1.6 1.6-4.9 >4.9	1 2 3
Total IBI Score					
Concern	4	3	1	4	
Normal	5-8	4-8	2	5-8	
Excellent	9	9	3	9	

NOTE: To avoid problems caused by division by zero use the following formulas: For shrimp and shad proportions let metric value = taxa group catch/(total catch + 1). Alternately if any one replicate total catch = 0, then an IBI score of 'concern' can be given.

NOTE: Avoidance of winter sampling is recommended due to lack of suitable metrics.

* Recommended metric; if mean log total catch or total catch = 0, then score = high concern.

Table 13-6. Proposed gillnet metrics for use in estuarine IBI along Texas coast.

Metric	Assigned Metric Score			
	0	1	2	3
1) Total Nekton Catch	0	1<26	26<47	≥47
2) Category 2 (Pick 1 of the 2 Metrics Listed)				
2a) Number of Nekton Taxa	0	1<7	7<8	≥8
2b) H'	*	<1.25	1.25<1.85	≥1.85
3) Category 3 (Pick 1 of the 2 metrics listed)				
3a) Evenness J	*	<.58	.58<.81	≥.81
3b) Number of Taxa = 90% Total Nekton Catch	*	<4	4<6	≥6
No. Crust. Spp.	*	Not Recom.	Not Recom.	Not Recom.
4) No. Pred. Taxa	*	0	1	>1
No. "Minnow" Taxa	*	Not Recom.	Not Recom.	Not Recom.
5) No. Scaenids/B. Cat. Taxa	*	0	1-2	>2
Total IBI Score (SUM OF ALL 5 METRIC CATEGORIES)	0	5-6	7-13	14-15
Total IBI Rank	HIGH CONCERN	CONCERN	NORMAL	EXCELLENT

Due to the lack of strong correlation between the seine and trawl-derived metrics, it is advisable that future studies use both gear types. Since gillnet derived metrics were least sensitive to water quality fluctuation, and gillnet use is labor intensive and difficult to replicate, gillnetting is the least favored approach for evaluating nekton community health.

A fish health index (FHI) was tested during the pilot study to evaluate its utility in assessing impacts on estuarine fish communities. The FHI methods mirrored those used by the Tennessee Valley Authority (Dycus and Meinert 1993, Dycus 1995). Further evaluation is needed to determine the discriminatory power; i.e., impaired versus unimpaired sites of the index. Proposed FHI values for Gulf Coast bioassessments are listed in Table 13-7. The FHI proved to be time and cost efficient, and yielded information that was complementary to the IBI.

Table 13-7. Proposed fish health index and condition factors for use in estuarine rapid bioassessments of Texas Gulf coast tidal tributaries.

FISH HEALTH INDEX

Species	Assigned FHI Rank		
	1	**2**	**3**
Blue Catfish FHI Score	>70	40-70	<40
Atlantic Croaker FHI Score	>50	30-50	<30
Sea Catfish "Hardhead" (least recommend) score	>30	*	≤30
Spot FHI Score	>61	32-61	<32
AVERAGE SPECIES FHI RANK	1-1.4	1.5-2.5	≥2.6
Total FHI Rank based on average scores of single species	CONCERN	NORMAL	EXCELLENT

CONDITION FACTOR

Species	Assigned Condition Factor (CF) Rank		
	1	**2**	**3**
Blue Catfish CF	<.78	.78-.97	>.97
Atlantic Croaker CF	<1.02	1.02-1.15	>1.15
See Catfish "Hardhead" CF	<.82	.82-1.10	>1.10
Spot CF	<1.25	1.25-1.44	>1.44
AVERAGE SPECIES CF RANK	1-1.4	1.5-2.5	≥2.6
Total CF Rank based on average scores of single species.	CONCERN	NORMAL	EXCELLENT

The application of estuarine rapid bioassessment techniques in studies of Gulf of Mexico coastal environments is warranted, based on results of the pilot study. Several of the methods tested in the study (including seine and trawl based IBI and FHI) would aid water quality and fisheries scientists in their evaluation of water and habitat quality impacts resulting from human activity. The pilot bioassessment methods meet the requirements for inclusion in routine monitoring programs including: low cost, low effort, readily obtainable equipment, relatively easy taxonomy, and replication of effort which is suitable for statistical analyses.

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