CHAPTER 7

TRAWL-CAUGHT FISH AND MEGAINVERTEBRATES

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INTRODUCTION

The soft-bottom habitat of Los Angeles Harbor is currently a mixture of clay, silt, sand, and dredge spoils. In general, a gradient of sandy silt to sand exists from the inner portion of the Outer Harbor southward to the outer portions of the Outer Harbor (see CLA, EMD 1994-2006). In the same manner, the depth ranges from approximately 4 to 20 meters (some local areas have been recorded to near 30 meters after dredging activities associated with Pier 400 construction) from the inner to outer portions of the Outer Harbor. The combination of this depth and sediment gradient coupled with various point sources of potential contamination, e.g., the Dominguez Channel, various storm drains and industrial point-source discharges, and the tertiary effluent discharged from Terminal Island Water Reclamation Plant's [*on September 7, 2007, following the completion of the major operational upgrade of the Advanced Wastewater Treatment Facility (AWTF), the official name of the Terminal Island Treatment Plant was changed to the Terminal Island Wastewater Reclamation Plant (TIWRP)*] outfall, creates locally heterogeneous environments within the Harbor. Also, the San Pedro Breakwater, Middle Breakwater, and Pier 400, by adding topographic diversity to the environment and functioning as a substrate for the associated kelp beds, provide a complex combination of food, shelter, and a larger habitable area within the water column for fishes and invertebrates (see MEC 1988 for review). The fish species assemblages of these rocky substrate habitats are virtually indistinguishable from shallow rocky reefs (Allen 1985, Allen et. al. 2006) and contribute, often by transience, to the Los Angeles Harbor soft-bottom trawl assemblage. Additionally, sediment type or associated contaminants may exclude certain fish and epibenthic macroinvertebrates from an area either by precluding prey species (Cross *et al.* 1985), directly killing them, inhibiting settlement of their larvae, or driving certain species away, allowing more tolerant species to exploit these areas.

Due to these factors, the composition of demersal fish and epibenthic invertebrate populations varies between these ecologically distinct environments. The objective of the trawl program is to assess the demersal fish and epibenthic invertebrate assemblages in the vicinity of the TIWRP's wastewater outfall in order to partition out the relative anthropogenic and/or natural factors responsible for the biological patterns recognized in the Outer Los Angeles Harbor. To make this assessment, community indices were calculated, parsimony analyses of endemicity (PAE) [= most parsimonious distribution of character data (species)] analyses, and various ordinations were conducted in order to discern distributional patterns of trawl-caught organisms over space and time, and to determine community relationships among the trawl stations (communities) for the 2006-2007 biennial surveys.

Quarterly monitoring of the demersal (bottom living) fish and epibenthic macroinvertebrates (larger than 1.0 cm^2) was mandated in 1993 by the TITP NPDES Permit No CA0053856, Order No. 93-014. Modifications to the program were necessary in 1995 (Interim Monitoring Program) and 1996 (Post-Pier 400 Monitoring Program) due to Pier 400 construction activities and the final relocation of the TITP effluent discharge pipe. Additional monitoring requirement changes in both survey frequency (now semiannual) and trawl positions (due to additional construction activities) are reflected in the current TITP NPDES permit (CA0053856, Order No. R4-2005-0024) adopted in 2005.

MATERIALS AND METHODS

FIELD SAMPLING

Due to the presence of the Pier 400 Submerged Storage Site (P400 SSS), HT8 (15-17m) was permanently abandoned prior to the 2004 sampling period. Station HT7 was re-oriented from perpendicular to parallel with the discharge pipe and the trawl-line midpoint at the Outfall. Additionally, after consultation with LARWQCB, trawl alignment coordinates for both HT8 and HT11 were re-positioned to areas devoid of major bottom obstructions, determined from sonar reconnaissance, and renamed as HT12 (20-21 m) and HT13 (12-14 m), respectively (Figure 7-1).

In 2006, the NPDES-mandated trawls were conducted on February 22 and 23 (winter), and on September 6 and 13 (summer). The 2007 NPDES-mandated trawls were executed on March 6 (winter), and on August 30 (summer).

Coordinates were recorded for net over, on bottom (begin trawl), end trawl, and surface (on deck) during the course of each trawl to pinpoint the exact net location and direction. Additional descriptive trawl data (i.e., debris, depth, weather, etc.) were also recorded. An otter trawl net having a headrope length of 7.6 m with a 1.27 cm cod-end mesh was used. Trawls were towed at approximately two knots and due to the numerous navigational hazards within the trawl areas, the on-bottom time was restricted to five minutes.

All fish and megainvertebrates captured were examined for abnormalities (e.g., fin erosion, tumors, lesions, parasites, and color abnormalities), identified, counted, and weighed. All individuals of a species were collectively weighed to the nearest 0.1 kg. Individuals of different species weighing less than 0.1 kg were weighed together with other similar low-biomass species resulting in a composite weight value. Standard length size-classes (rounded up to the nearest 1.0 cm) were obtained for all fish. After identification and necessary measurements (length, weight) were taken for community analyses, the organisms were returned to the Harbor.

DATA ANALYSIS

All analyses are in accord with Appendix B of this 2006-2007 Los Angeles Harbor Biennial Assessment Report. Detailed descriptions and references are presented therein. In summary these include:

- Community parameters (species richness, abundances, traditional biodiversity indices, and phylodiversity indices)
- Parsimony Analysis of Endemicity (PAE) showing relationships of stations or sampling events (Q-mode) based on their taxonomic/species inventories
- Non-metric multi-dimensional scaling (NMDS) of stations derived from PAE patristic distances
- Parsimony Analysis of Co-occurring Species (PACOS) showing taxonomic/species relationships (R-mode) based on their station inventories (occurrences).

The most parsimonious cladograms, showing the relationships of the station objects (Q-analysis, Q-mode) under study were generated using the heuristic search Tree-Bisection and Reconnection and the Branch and Bound algorithm. Alternatively,

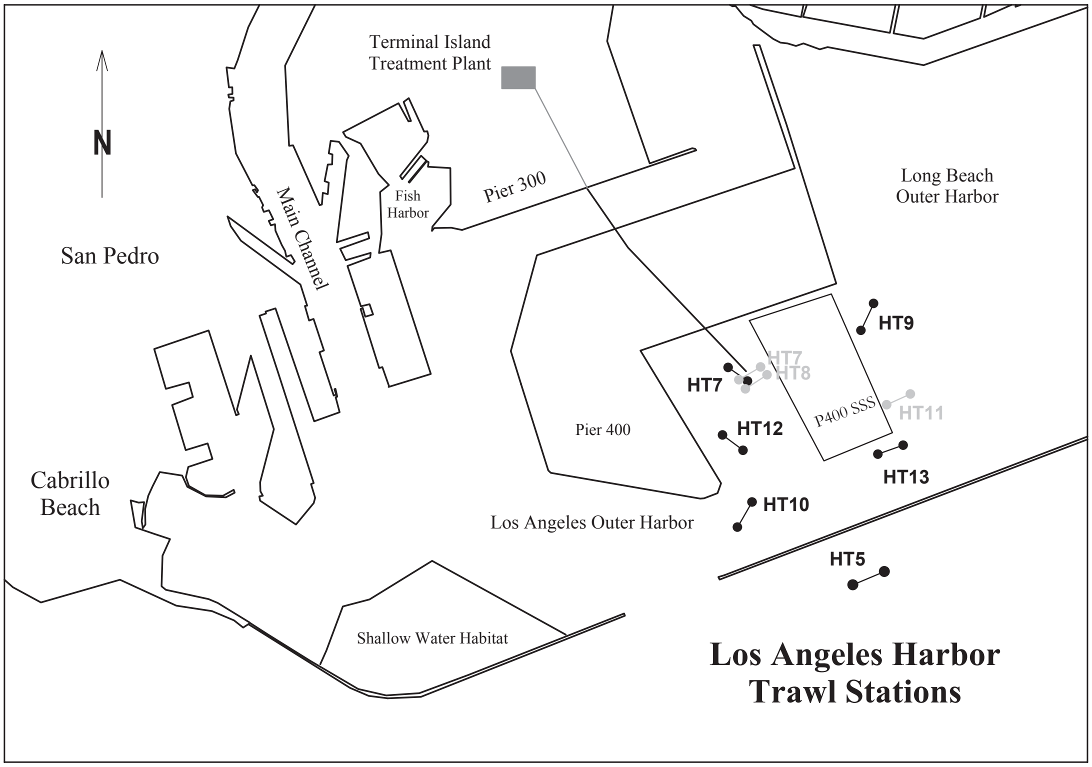

Figure 7-1. Trawl sampling stations in Los Angeles Harbor. Abandoned or former station positions are depicted in gray.

cladograms of species groups, showing the association or co-occurrence of species with one another (R-analysis, R-mode), were also produced for all trawl-caught organisms. This parsimony analysis of co-occurring species has been coined "PACOS" herein. All analyses were performed with the computer program PAUP* - Phylogenetic Analysis Using Parsimony (* and other methods) version 4.0b10 (Swofford 2000). Methods of calculations for measure of fit indices are presented in Appendix B and references therein.

Non-metric multidimensional scaling (NMDS) was applied, using PRIMER v6 software (Clarke and Gorley 2006), to the patristic distance (branch-length) pair-wise matrix derived from the cladistic analyses (the cladogram). NMDS is a highly recommended multivariate ordination method that works on any similarity or distance matrix (Warwick and Clarke 1995). Patristic distances were chosen as it has been shown (Smith 1994) that pairwise similarity or distance is underestimated by the conventionally used phenetic distance methods (e.g., Bray-Curtis). Pairwise comparisons using cladistic methods, which include all changes (including homoplasy or lack of fit) along the branches, is a better estimator or representation of the data (Smith 1994).

All taxa were used to calculate community parameters, traditional diversity indices, and phylodiversity indices and to generate the cladograms (parsimony analyses) and subsequent NMDS ordinations. Recent literature has shown that deleting rare species can damage the sensitivity of community-based methods to detect ecological changes (Cao *et al.* 1998 and 2001), and that taxon autochthony may be more informative than their abundance, especially in parsimony analyses (Perochon *et al.* 2001). Additionally, recent work underscores that it is the rare species, not the common and abundant taxa, which respond or are affected by varying aspects of habitat change or modification (Goodsell and Connell 2002).

RESULTS

FISH

Community Parameters

Demersal fishes collected in Los Angeles Harbor represent a moderately diverse, albeit uneven assemblage. No epidermal tumors or fin erosions were observed on fishes collected during this survey period. However, ambicoloration was observed from a 26 cm California halibut on 6 September 2006 at HT9, a 16 cm spotted turbot on 30 August 2007 at HT5, and from a 10 cm speckled sanddab on 30 August 2007 from HT7.

There were 1,222 fish representing 14 species collected in the winter 2006 survey and 6,110 fish comprising 16 species collected in the 2006 summer survey, constituting a total of 18 species and 7,332 individuals. The 2007 winter survey yielded a total of 1,261 fish consisting of 20 species while 3,124 fish contained within 15 species comprised the 2007 summer survey.

There were 7,332 and 4,385 fish collected in 2006 and 2007, respectively, constituting a total of 11,717 individuals representing 24 taxa. The total number of species of fish collected by EMD since the inception of this program in 1993 now equals 53.

Since unsuccessfully completed trawling events over different sampling periods may yield results difficult to assess, the catch per unit effort (CPUE) may be a better indicator or comparator over time. This measure is calculated by simply dividing the total abundance for the year by the number of sampling efforts. Thus, 2001's CPUE for the fish was 1,833/24 = 76, 2002's CPUE was 1,497/19 = 79, 2003's CPUE was 2,680/11 = 243, 2004's CPUE was 5,877/19 = 309, 2005's CPUE was 5,055/18 = 281, and the CPUE for 2006 and 2007 was 3,310/12 = 276 and 3,470/12 = 289, respectively.

The most fish-species rich sampling events (Table 7-1), having 10 or more species, were HT10 2007 Winter and HT13 2007 Winter both with 10 species, HT7 2006 Summer with 11 species, and HT7 2007 Winter with 12 species. The least species rich, having five or less species, were all four sampling events from HT5. The catch from HT5 2007 Winter yielded five species while the remaining 3 cohorts totaled a depauperate 4 species each. The remaining sampling events within the Outer Harbor ranged from 6 to 9 species with an average of 7.5.

The top seven most fish-abundant sampling events (Table 7-1) were HT9 2006 Summer (a whopping 4,892 individuals), HT12 2007 Summer (2,819), HT10 2006 Winter (962), HT10 2007 Winter (626), HT12 2006 Summer (565), HT12 2007 Winter (346), and HT10 2006 Summer (327), in decreasing order. The least abundant events were all four sampling events from Station HT5 outside of the Harbor ranging from 27 to 46 individuals.

Community Composition

There were 18 fish species collected in 2006 and 21 fish species collected in 2007 (24 total over the two year period) (Table 7-1), compared to 27, 26, 28, and 34 in the years 2002, 2003, 2004, and 2005, respectively. The five most abundant species over the 2006-2007 biennium were *Genyonemus lineatus* (white croaker; 6,780 = 57.9% of the total fish trawled), *Seriphus politus* (queenfish; 3,862 = 32.9%), *Citharichthys stigmaeus* (speckled sanddab; 502 = 4.3%), *Synodus lucioceps* (California lizardfish; 154 = 1.31%), and *Symphurus atricaudus* (California tonguefish; 90 = 0.77%) constituting 97.2% of the total abundance for the biennium. The most widely occurring fish species from the 24 sampling events were *C. stigmaeus*, *S. atricaudus*, and *S. lucioceps* all with 19 occurrences, *G. lineatus* and the California halibut *Paralichthys californicus* both collected 17 times, the hornyhead turbot *Pleuronichthys vericalis* 15 times, *S. politus* 13 times, and the specklefin midshipman *Porichthys myriaster* occurred 10 times. The remaining sixteen species of fish (66.6%) occurred nine times or less.

The species by sample-event data matrix shown in Table 7-1 reveals not only specific catch numbers per

Table 7-1. Raw abundance data matrix for fish species during the 2006-2007 biennium.

	Chitonotus pugetensis	*Citharichthys stigmaeus*	*Cymatogaster aggregata*	*Genyonemus lineatus*	*Icelinus quadriseriatus*	*Lepidogobius lepidus*	*Paralabrax nebulifer*	*Paralichthys californicus*	*Phanerodon furcatus*	*Pleuronectes vetulus*	*Pleuronichthys ritteri*	*Pleuronichthys verticalis*	*Porichthys myriaster*	*Porichthys notatus*	*Raja inornata*	*Scorpaena guttata*	*Sebastes miniatus*	*Seriphus politus*	*Symphurus atricaudus*	*Syngnathus leptorhynchus*	*Synodus lucioceps*	*Urobatis halleri*	*Xystreurys liolepis*	*Zaniolepis latipinnis*	**Total Abundance/Event**	**Number of Taxa**
HT5_2006_Winter	0	23	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	1	**33**	**4**
HT5_2006_Summer	0	18	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	5	0	0	0	**27**	**4**
HT5_2007_Winter	0	21	0	0	0	0	0	4	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	4	**32**	**5**
HT5_2007_Summer	0	42	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	**46**	**4**
HT7_2006_Winter	0	44	0	0	0	0	0	5	10	0	0	1	0	0	0	0	0	0	1	0	14	0	2	0	**77**	**7**
HT7_2006_Summer	0	14	2	100	0	0	3	6	28	0	0	1	0	0	0	1	0	6	2	0	19	0	0	0	**182**	**11**
HT7_2007_Winter	0	66	0	13	0	0	0	5	8	0	0	5	2	0	1	0	0	2	1	0	2	7	4	0	**116**	**12**
HT7_2007_Summer	0	45	0	3	0	0	0	3	1	0	0	0	1	0	1	0	0	0	4	0	0	0	0	0	**58**	**7**
HT9_2006_Winter	0	0	0	2	0	0	0	6	0	0	0	2	0	0	1	0	0	0	0	0	12	0	3	0	**26**	**6**
HT9_2006_Summer	0	1	0	1,652	0	0	0	3	0	0	0	4	1	0	0	0	0	3,226	4	0	1	0	0	0	**4,892**	**8**
HT9_2007_Winter	0	1	0	26	0	1	0	5	0	0	0	3	0	0	0	0	0	0	3	0	1	0	1	0	**41**	**8**
HT9_2007_Summer	0	0	0	54	0	0	0	18	0	0	0	1	3	0	2	0	0	10	6	0	2	0	0	0	**96**	**8**
HT10_2006_Winter	0	4	0	688	0	0	0	0	0	0	0	0	0	0	0	0	0	256	4	0	6	0	0	4	**962**	**6**
HT10_2006_Summer	0	23	0	286	0	0	0	1	0	0	0	3	0	0	0	1	0	4	4	1	4	0	0	0	**327**	**9**
HT10_2007_Winter	1	26	1	330	0	0	0	0	0	0	0	0	1	0	0	1	0	234	3	0	1	0	0	28	**626**	**10**
HT10_2007_Summer	0	11	0	18	4	0	0	0	0	0	0	0	0	0	0	1	0	3	3	0	0	0	0	2	**42**	**7**
HT12_2006_Winter	0	0	0	44	0	0	0	0	0	0	0	0	5	0	0	0	0	3	12	0	9	0	0	2	**75**	**6**
HT12_2006_Summer	0	0	0	529	0	0	0	1	0	1	0	0	3	0	0	0	0	27	3	0	0	0	1	0	**565**	**7**
HT12_2007_Winter	0	6	0	227	0	0	0	6	0	0	0	2	0	1	0	0	0	80	22	0	1	0	0	1	**346**	**9**
HT12_2007_Summer	0	0	0	2,785	0	0	0	0	0	0	0	2	16	0	0	1	0	10	5	0	0	0	0	0	**2,819**	**6**
HT13_2006_Winter	0	22	5	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	16	0	1	1	**49**	**9**
HT13_2006_Summer	0	38	8	9	4	0	0	0	4	0	0	6	1	0	0	0	0	0	1	0	46	0	0	0	**117**	**9**
HT13_2007_Winter	0	73	0	0	2	0	0	1	0	0	0	1	0	0	0	1	1	0	2	0	6	0	2	11	**100**	**10**
HT13_2007_Summer	0	24	4	14	0	0	0	0	6	0	0	3	1	0	1	1	0	0	9	0	0	0	0	0	**63**	**9**
Total Abundance/Taxon	**1**	**502**	**20**	**6780**	**11**	**1**	**3**	**71**	**57**	**1**	**1**	**38**	**34**	**1**	**6**	**7**	**1**	**3,862**	**90**	**1**	**154**	**7**	**14**	**54**	**Grand Total Abundance**	**Total number of Taxa**
Number of Occurrences	**1**	**19**	**5**	**17**	**4**	**1**	**1**	**17**	**6**	**1**	**1**	**15**	**10**	**1**	**5**	**7**	**1**	**13**	**19**	**1**	**19**	**1**	**7**	**9**	**11,717**	**24**

species, but also illuminate the axiomatic skewness of community structure, that very few species are highly abundant and widely occurring with much greater spatiotemporal exclusivity exhibited by the remaining cohorts.

Genyonemus lineatus remained (as seen in previous reports) the most abundant species, followed by *Seriphus politus, Citharichthys stigmaeus, S. lucioceps,* and *Symphurus atricaudus*. Together, the two sciaenids (white croaker and queenfish) comprised 90.8% of the total abundance of the trawled-fish, while the previous two-year's values were 91.7% and 87.9%, respectively.

The highest abundance of white croaker for both years occurred in the summer surveys primarily from young of the year in the 5-7 cm standard length (SL) size class (53%). For 2006, juveniles from 5-7 cm totaled 1,236 individuals with the highest numbers from station HT9. For 2007, juveniles in the same size class range totaled 2,280 individuals, mostly from station HT12. White croaker spawn from December to April with usual peaks in March. The newly hatched young transform from the larval stage to juveniles at a very small size, (approximately 1.7 cm for white croaker and about 1.6 cm for queenfish) and quickly settle out to the bottom of the nearshore and protected waters (Moser, 1996). Juveniles feed on polychaetes, small shrimp, crabs, and mollusks. White croaker mature at 13-15 cm in length (Maxwell, 1975, DeMartini *et al.*, 1985), feeding on benthic invertebrates and other fish, while being preyed upon by seals, sea lions, sharks, and other fishes (www.fishbase.org). A combined total of 6,780 individuals were captured from both years (3,310 in 2006 and 3,470 in 2007), and the majority of fish trawled were immature fish less that 15 cm in length. Of the total fish collected for both years, 1490 (22%) were in the young adult size range of 13-15 cm SL. At station HT10, winter 2006, 454 individuals were collected in this size range, and 331 fish were trawled at station HT9 in the summer of 2006. In the winter of 2007, 260 individuals were counted, again from station HT10. These three samples totaled 1,045 fish for the 13-15 cm size class of the total 2006-2007 of 1,490, or 70% of the young adult catch (Figure 7-2). There were no white croaker taken outside of the breakwater, station HT5. White croaker live in close association with queenfish and are important components of the Los Angeles Harbor fish community.

The most abundant size class (SC) for queenfish (Figure 7-3) was the juvenile young-of-the-year (YOY), primarily between 4-6 cm SL (4 cm, 693; 5 cm, 2,299, and 6 cm, 158 individuals), captured at station HT9 during the summer trawl 2006, totaling 3,150 individuals, or 82% of the total catch for both years combined (note that the abundance scale is logarithmic and thus does not plot an occurrence of a single individual. The total queenfish catch for 2006-2007 was 3,862 fish with an occurrence of 13 out of 24 sampling events (trawls) yielding a CPUE of 54%. The largest catch of queenfish over the two-year period, excluding the YOY at station HT9, was at station HT10 with 256 individuals for the winter 2006 surveys, followed again by station HT10 with 234 individuals trawled during the winter of 2007, mostly sub-adults at 15 cm SL or less. There were only 23 queenfish recorded for all stations during the summer of 2007. For the 2006-2007 sampling events, there were no queenfish taken at HT5-the only station outside of the Los Angeles Breakwater (Table 7-1).

Queenfish, second in abundance following white croaker for 2006-2007, ranked seventh in frequency of occurrence. If the YOY for 2006 (4-6 cm SL), or the 3,150 individuals, were removed from the total catch of 3862 for both years, they would still rank second in abundance behind white croaker and ahead of speckled sanddabs. Queenfish spawn from February into October, peaking in May (Moser 1996). The YOY counts were high for one station during one season, reflecting the fact that post-larval queenfish were occupying this portion of the Outer Los Angeles Harbor, even if only transitional. Queenfish are an important nearshore species and, while the abundance is high for the single occurrence of young individuals in space and time, these numbers may not directly translate into high numbers of young being recruited into the adult fishery. These are the highest numbers recorded

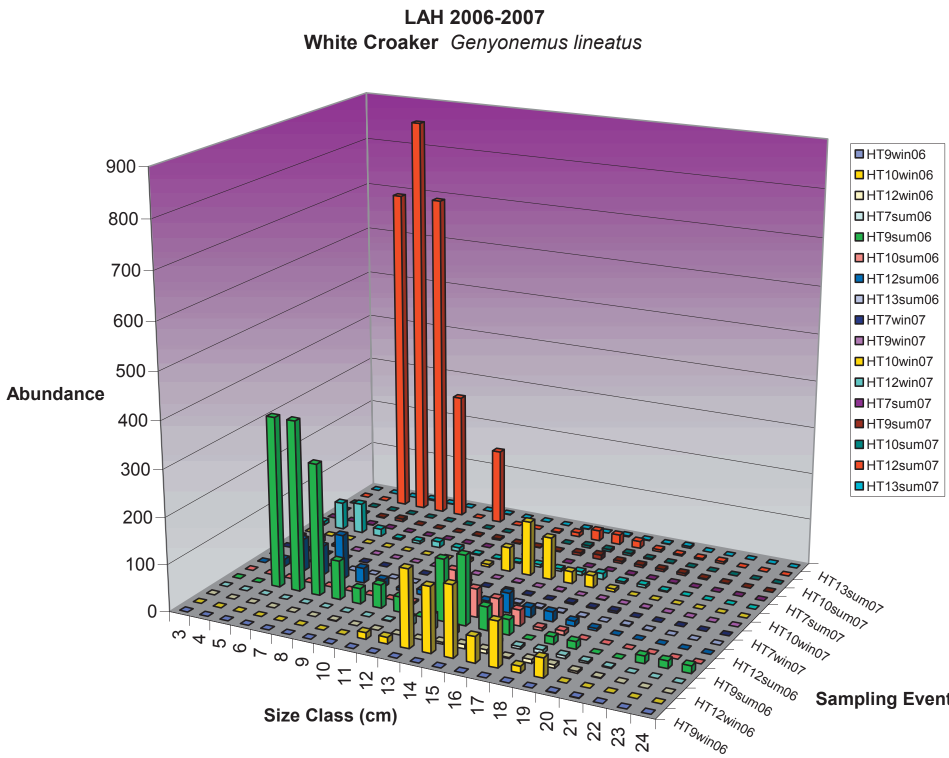

Figure 7-2. Size-class distribution of Genyonemus lineatus during the 2006-2007 biennium.

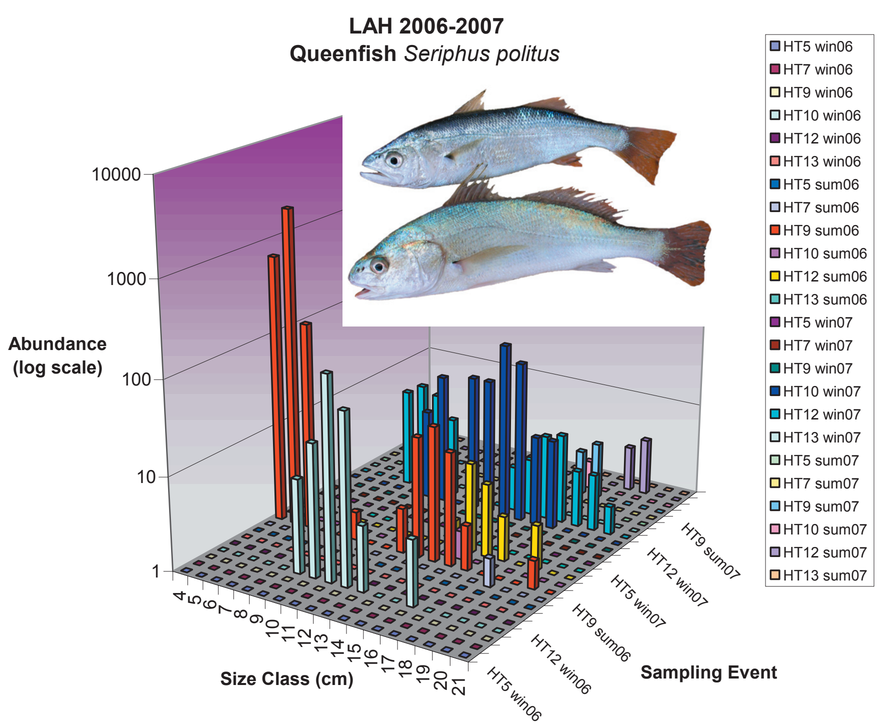

Figure 7-3. Size-class distribution of Seriphus politus during the 2006-2007 biennium. Inset showing differences between queenfish (top) and white croaker (bottom).

in the past several years for young queenfish and although it could just reflect movement of a school of adults, it may be a reflection on the overall future health of the harbor.

White croaker and queenfish are the two most abundant sciaenid species collected in the CalCOFI ichthyoplankton surveys (Moser 1996). Both species are listed as a sportfish (CDFG 1987), and as minor commercial fishery (www.fishbase.org; where queenfish are listed as queen croaker). Queenfish feed on crustaceans and small fishes and in turn are preyed upon by seals, sea lions, and other fishes (www.fishbase.org).

MEGAINVERTEBRATES

Community Parameters

Epibenthic megainvertebrates collected at the trawl sites in Los Angeles Harbor represent an uneven and less abundant assemblage relative to their piscine counterparts. For the 2006-2007 biennium, there were a total of 597 megainvertebrate individuals collected and distributed among 36 taxa out of a CLAEMD historical total of 116.

Separation of years results in a total of a relatively depauperate 159 individuals among 25 taxa for 2006 (Table 7-2) and 438 among 21 taxa for 2007 (Table 7-3). Some station samples possessed only a single invertebrate taxon such as: the 5 *Philine auriformis* collected at HT13 Summer 2006, the 21 *Lytechinus pictus* collected at HT5 Summer 2006, and the single *Pisaster brevispinis* from HT7 Summer 2007. This depauperate and poorly biodiverse situation may be due to the excessive sedimentation witnessed at various times throughout the biennium and possibly coupled with variation in temperature regime. Indeed, 14 of the 24 trawls captured only four or fewer species of megainvertebrates (see Tables 7-3 and 7-4). The CPUE for the megainvertebrate catch in 2001 was 408/24 = 17, 2002's CPUE was 452/19 = 24, 2003's CPUE was 236/11 = 21, 2004's CPUE was 403/19 = 21, 2005's CPUE was 387/18 = 22, 2006's CPUE was 159/12 = 13, and 2007's CPUE was 438/12 = 37.

The most species-rich sampling events were HT12 2007 Winter and HT13 2007 Winter with eight and nine invertebrate species collected, respectively (Table 7-3). The most abundant sampling event was HT12 2007 Winter with 264 individuals, attributable to 62 blackspotted bay shrimp *Crangon nigromaculata* and 172 ridge-back rock shrimp *Sicyonia ingentis*.

Community Composition

Tables 7-2 and 7-3 represent the raw megainvertebrate taxa data by sample event matrices for 2006 and 2007, respectively. The most widely occurring megainvertebrate taxa for the biennium were *C. nigromaculata* (15 times), *P. auriformis* (14), and both *Pyromaia tuberculata* and *S. ingentis* (10 times). Regardless of abundance, 20/36 = 56% of the species occurred only once. In 2007, station HT12 Winter contributed the vast majority (172) of *S. ingentis* to the biennium total of 228 individuals for this species.

As for fish, megainvertebrate spatiotemporal trends are once again difficult to discern with such variable data this year, especially due to the various ongoing construction activities and their effects in the Outer Los Angeles Harbor (see Chapter 1: Introduction of this report).

COMBINED FISH AND MEGAINVERTEBRATES

Assessing the combination of megainvertebrates and fish, there were a total of 12,314 animals collected and distributed among 60 taxa (24 fish taxa, 36 invertebrate taxa) during the 2006-2007 sampling period. There have been 169 CLAEMD historically sampled taxa from the Harbor since 1993. Segregating years, there were 7,491 animals collected in 2006 and 4,823 collected in 2007.

Biomass values (not presented herein) were quite uniform with elevated values associated with the high numbers of sciaenids (*G. lineatus* and *S. politus*),

Table 7-2. Raw abundance data matrix for megainvertebrate species during the 2006 sampling period.

	HT5 2006 Winter	HT5 2006 Summer	HT7 2006 Winter	HT7 2006 Summer	HT9 2006 Winter	HT9 2006 Summer	HT10 2006 Winter	HT10 2006 Summer	HT12 2006 Winter	HT12 2006 Summer	HT13 2006 Winter	HT13 2006 Summer	Total Abundance/Taxon	Number of Occurrences
Armina californica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astropecten verrilli	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Cancer antennarius	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Cancer anthonyi	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Cancer gracilis	0	0	0	1	0	0	0	0	0	0	0	0	1	1
Conus californicus	0	0	0	1	0	0	0	0	0	0	0	0	1	1
Crangon nigromaculata	3	0	2	0	2	0	4	4	10	12	0	0	37	7
Dendronotus frondosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendronotus iris	0	0	3	1	0	0	0	0	0	0	0	0	4	2
Eualus lineatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Farfantepenaeus californiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flabellina pricei	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemisquilla ensigera californiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heptocarpus palpator	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Heterocrypta occidentalis	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Janolus barbarensis	0	0	1	1	0	0	0	0	0	0	0	0	2	2
Loligo opalescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lophopanopeus digensis	0	0	0	0	0	0	0	0	0	0	2	0	2	1
Loxorhynchus crispatus	0	0	0	0	0	0	0	0	0	4	0	0	4	1
Lytechinus pictus	24	21	0	0	0	0	0	0	0	0	0	0	45	2
Nassarius fossatus	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Ocinebra gracillima	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Octopus rubescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiothrix spiculata	0	0	0	0	0	0	0	2	0	0	0	0	2	1
Pachycheles rudis	0	0	0	0	0	0	0	2	0	0	0	0	2	1
Pagurus spilocarpus	0	0	0	0	0	0	1	0	0	0	0	0	1	1
Panulirus interruptus	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Philine auriformis	1	0	7	2	6	0	0	0	1	0	5	5	27	7
Pisaster brevispinis	2	0	0	0	0	0	0	0	0	0	0	0	2	1
Portunus xantusii	0	0	0	1	0	0	0	0	0	0	0	0	1	1
Pteropurpura sp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyromaia tuberculata	0	0	0	0	0	1	1	0	0	0	0	0	2	2
Sicyonia ingentis	0	0	0	0	0	0	5	4	5	2	1	0	17	5
Sicyonia penicillata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stylatula elongata	0	0	0	0	0	1	0	0	0	0	0	0	1	1
Triopha maculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Abundance/Event	31	21	14	7	8	2	11	15	17	18	10	5	76	6
Number of Taxa	5	1	5	6	2	2	4	7	4	3	5	1	24	6

Table 7-3. Raw abundance data matrix for megainvertebrate species during the 2007 sampling period.

	HT5 2007 Winter	HT5 2007 Summer	HT7 2007 Winter	HT7 2007 Summer	HT9 2007 Winter	HT9 2007 Summer	HT10 2007 Winter	HT10 2007 Summer	HT12 2007 Winter	HT12 2007 Summer	HT13 2007 Winter	HT13 2007 Summer	Total Abundance/Taxon	Number of Occurrences
Armina californica	3	0	0	0	0	0	0	0	0	0	0	0	3	1
Astropecten verrilli	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Cancer antennarius	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cancer anthonyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cancer gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conus californicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crangon nigromaculata	3	0	8	0	13	0	5	3	62	0	3	3	100	8
Dendronotus frondosus	1	0	0	0	0	0	0	0	0	0	1	0	2	2
Dendronotus iris	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eualus lineatus	0	0	0	0	0	0	0	0	5	0	0	0	5	1
Farfantepenaeus californiensis	0	0	3	0	11	1	0	0	8	0	4	0	27	5
Flabellina pricei	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Hemisquilla ensigera californiensis	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Heptocarpus palpator	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterocrypta occidentalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Janolus barbarensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loligo opalescens	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Lophopanopeus digensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Loxorhynchus crispatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lytechinus pictus	0	4	0	0	0	0	0	1	0	0	0	0	5	2
Nassarius fossatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ocinebra gracillima	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Octopus rubescens	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Ophiothrix spiculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pachycheles rudis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagurus spilocarpus	0	0	0	0	0	0	0	2	0	0	0	0	2	1
Panulirus interruptus	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Philine auriformis	0	0	3	0	22	3	0	1	11	0	5	1	46	7
Pisaster brevispinis	0	0	0	1	0	1	0	0	0	0	0	0	2	2
Portunus xantusii	0	0	0	0	2	0	0	0	0	0	0	0	2	1
Pteropurpura sp	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Pyromaia tuberculata	0	0	3	0	4	4	2	0	2	1	2	1	19	8
Sicyonia ingentis	0	0	0	0	0	0	17	2	172	15	5	0	211	5
Sicyonia penicillata	0	0	0	0	0	0	0	0	3	0	2	0	5	2
Stylatula elongata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triopha maculata	0	0	0	0	0	0	1	0	0	0	1	0	2	2
Total Abundance/Event	8	5	19	1	52	9	25	10	264	16	24	5	344	6
Number of Taxa	4	2	6	1	5	4	4	6	8	2	9	3	32	6

the yellowleg shrimp *Farfantepenaeus californiensis*, and ridgeback rock shrimp *Sicyonia ingentis*, as well as the collection of single specimens of the short-spined sea star *Pisaster brevispinus* and the spiny lobster *Panulirus interruptus*.

The total number of combined fish and megainvertebrate taxa or taxa richness (S), total number of individuals (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Wiener index of diversity (H'), Simpson's dominance (1-λ'), phylodiversity indices [taxonomic diversity (Δ), taxonomic distinctness (Δ*), average taxonomic distinctness (Δ^+), total taxonomic distinctness ($S\Delta^+$), variation in taxonomic distinctness (Λ^+), average phylogenetic diversity (Φ^+), and total phylogenetic diversity ($S\Phi^+$),] are provided for the 2006-2007 biennium surveys in Table 7-4.

The five most taxa-rich sampling events (Table 7-4), having 16 or more taxa, were HT13 Winter 2007 (19 taxa), HT7 Winter 2007 (18), HT7 Summer 2006 and HT12 Winter 2007 (17), and HT10 Summer 2006 (16). The least taxa-rich sampling events, having less than ten taxa, were all four of the samples from outside of the breakwater HT5 Winter 2006, HT5 Summer 2006, HT5 Winter 2007, and HT5 Summer 2007 with 9, 5, 9, and 6 taxa, respectively. Three samples possessed 8 taxa each, namely HT7 Summer 2007, HT9 Winter 2006, and HT12 Summer 2007.

Mapping the biodiversity and phylodiversity indices (not shown herein) onto the cladogram (see below) did not yield any striking patterns.

The most widely occurring taxa were *Synodus lucioceps*, *Citharichthys stigmaeus*, and *Symphurus atricaudus* collected 19 times each, followed by *Paralichthys californicus* and *Genyonemus lineatus* (17), the blackspotted bay shrimp *Crangon nigromaculata* (15), and the New Zealand paperbubble *Philine auriformis* collected 14 times. As with either the separate fish or megainvertebrates, the combination of the two groups does not reveal any conspicuous spatiotemporal pattern or outfall signal.

Rank abundance and occurrence values for fish, megainvertebrates, and their combined species exhibit a characteristic species abundance pattern; only a few species are highly abundant. A few species possess moderate to high abundance while the majority of species are represented by very few or a single individual. The distributional abundance shape (Chapter 7, CLA, EMD 2004) for all trawl stations continues to mimic the axiomatic logistic-J distribution (Dewdney 2003), with a few highly abundant, widely occurring species, followed by a very long tail of exclusively distributed (hierarchically nested) taxa.

CLADISTIC ANALYSIS AND NON-METRIC MULTIDIMENSIONAL SCALING

The generation of a pattern accurately representing the environmental conditions of a study area is ultimately the goal in any type of monitoring endeavor. Without a pattern, regardless of its apparent randomness or non-randomness, science has little if anything to explain. Furthermore, one would be equally unlikely to achieve any understanding of these ecological processes without an understanding of the patterns they generate (Lambshead and Paterson 1986, Patterson 1980). Several theories and methods to generate patterns are currently in practice. The method now dominating systematics (classification) is cladistics. This methodology is employed herein as an ecomonitoring tool.

Biennial Analysis - Trawled Fish Plus Megainvertebrates

As in the previous Chapter, Macrofaunal Assemblages, the station or sampling events outside the Middle Breakwater, in the case of trawling, HT5 events, were defined as the outgroup to function as the root by which all the data are polarized. The resulting parsimony analysis of endemicity (PAE) cladogram (Figure 7-4) had a tree length of 143.66, a consistency index of 0.4785, and a retention index of 0.4763. The cladogram displays a fair degree of site fidelity with all four of the 16 m HT5 samples from outside of the Harbor grouping together at the base of the cladogram. Likewise, the 22 m

Table 7-4. Los Angeles Harbor 2006-2007 biennium community parameters for combined fish and megainvertebrates. Community parameters: total number of species (S), total number of individuals (N), Margalef's species richness (d), Pielou's evenness (J'), Shannon-Wiener index of diversity (H'), Simpson's dominance (1-λ'), Benthic Response Index (BRI), and phylodiversity indices [taxonomic diversity (Δ), taxonomic distinctness (Δ*), average taxonomic distinctness (Δ+), total taxonomic distinctness (SΔ+), variation in taxonomic distinctness (Δ+),average phylogenetic diversity (Δ+), and total phylogenetic diversity (SΔ+)].

	S	N	d	J'	H'	1-λ'	Δ	Δ*	Δ^+	$s\Delta^+$	Λ^+	Φ^+	$s\Phi^+$
HT5 2006 Winter	9	64	1.92	0.70	1.55	0.73	64.32	88.51	88.17	793.53	475.36	71.73	645.55
HT5 2006 Summer	5	48	1.03	0.76	1.23	0.67	57.12	85.57	64.25	321.25	956.70	60.72	303.59
HT5 2007 Winter	9	40	2.17	0.73	1.61	0.71	48.55	68.73	81.62	734.57	718.86	60.28	542.50
HT5 2007 Summer	6	51	1.27	0.40	0.72	0.32	23.59	73.90	74.28	445.68	881.72	62.55	375.29
HT7 2006 Winter	12	91	2.44	0.69	1.72	0.73	47.74	65.67	77.87	934.48	860.23	52.34	628.12
HT7 2006 Summer	17	189	3.05	0.59	1.67	0.68	34.02	49.78	75.49	1283.32	763.44	48.14	818.33
HT7 2007 Winter	18	135	3.47	0.69	2.00	0.74	48.78	65.79	77.10	1387.77	692.80	49.53	891.46
HT7 2007 Summer	8	59	1.72	0.47	0.97	0.41	19.10	46.09	65.19	521.52	562.47	57.74	461.90
HT9 2006 Winter	8	34	1.99	0.86	1.80	0.82	60.65	74.13	75.36	602.90	659.33	65.95	527.58
HT9 2006 Summer	10	4894	1.06	0.29	0.67	0.45	7.94	17.58	66.75	667.48	742.15	55.95	559.48
HT9 2007 Winter	13	93	2.65	0.79	2.02	0.83	73.07	87.66	74.62	970.07	891.29	49.57	644.47
HT9 2007 Summer	12	105	2.36	0.66	1.64	0.70	40.89	58.72	79.47	953.65	615.66	62.38	748.52
HT10 2006 Winter	10	973	1.31	0.33	0.76	0.43	10.46	24.26	74.16	741.56	813.81	51.11	511.14
HT10 2006 Summer	16	342	2.57	0.29	0.80	0.30	18.75	63.32	78.65	1258.39	784.36	51.36	821.78
HT10 2007 Winter	14	651	2.01	0.46	1.21	0.61	22.50	36.86	72.67	1017.37	705.89	52.29	732.07
HT10 2007 Summer	13	52	3.04	0.81	2.07	0.83	57.03	68.74	82.64	1074.36	670.31	57.34	745.46
HT12 2006 Winter	10	92	1.99	0.74	1.70	0.73	51.88	70.77	80.79	807.93	638.81	61.28	612.76
HT12 2006 Summer	10	583	1.41	0.20	0.45	0.17	8.99	51.59	69.79	697.91	868.76	47.58	475.83
HT12 2007 Winter	17	610	2.49	0.60	1.71	0.75	58.63	77.80	78.54	1335.16	798.18	48.69	827.80
HT12 2007 Summer	8	2835	0.88	0.06	0.12	0.03	2.12	60.62	70.19	561.54	722.60	55.31	442.50
HT13 2006 Winter	14	59	3.19	0.71	1.88	0.78	53.94	68.93	74.64	1045.02	806.08	49.77	696.77
HT13 2006 Summer	10	122	1.87	0.73	1.68	0.75	41.97	55.89	59.05	590.52	473.11	52.91	529.11
HT13 2007 Winter	19	124	3.73	0.59	1.74	0.64	47.41	73.88	79.37	1508.00	817.46	43.36	823.76
HT13 2007 Summer	12	68	2.61	0.78	1.93	0.81	45.64	56.27	73.44	881.25	646.84	56.90	682.84

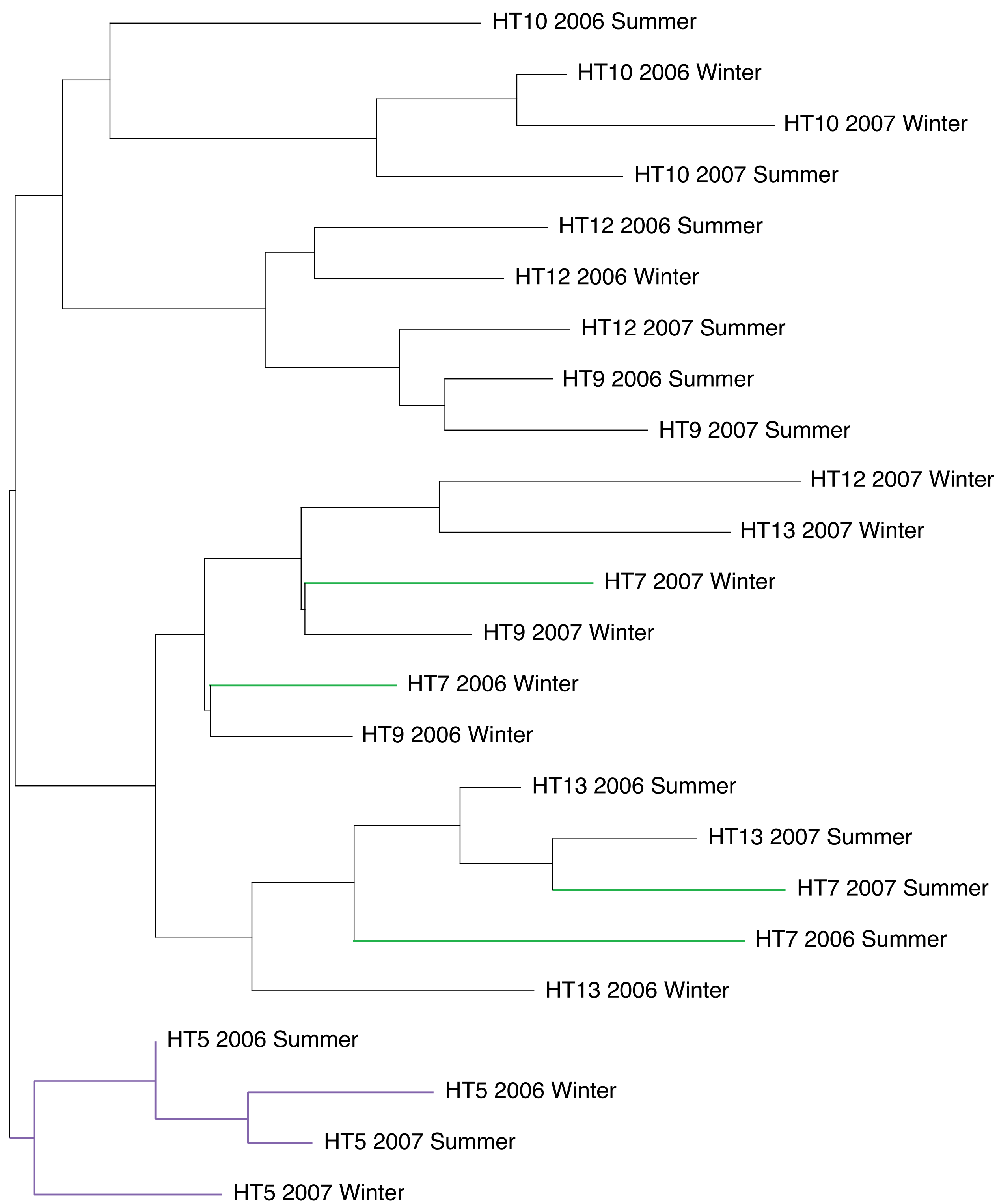

Figure 7-4. Parsimony analysis of endemicity (PAE) q-mode cladogram showing the sampling event relationships based on the combined fish and megainvertebrate taxa inventories for the 2006-2007 biennium.

samples from station HT10 all group in the same small subclade at the top of the cladogram. The sister clade to this HT10 subclade groups three of the four samples from Station HT12 and two of the samples from HT9. Viewing the cladogram in its entirety reveals that much of the grouping is heavily influenced by season. The subclade bordered by samples from Station HT13 2006 Winter and HT13 2006 Summer is composed of 4 Summer samples and only 1 Winter sample. The sister clade to that is composed of all Winter samples, the next subclade bordered by samples from Station HT9 2007 Summer and HT12 2006 Summer is composed of 4 out of 5 Summer samples. The 4 samples from Outfall Station HT7 do not group together.

Employing the trace character history module from Mesquite version 1.05 build g24 (Maddison and Maddison 2005) allows one to map every species' distribution onto the cladogram creating a highly informative heuristic visualization of what species are responsible for the sample groupings present in the cladogram. The tight grouping of the samples from Station HT5 is due to the presence of *Astropecten verrilli, Lytechinus pictus, Hemisquilla californiensis, Armina californica*, and *Pleuronichthys ritteri*. The lower subclade bordered by HT13 2006 Winter and HT13 2006 Summer is held together in part by the presence of *Cymatogaster aggregata*, *Farfantapenaeus californiensis* links up the subclade of all Winter samples bordered by HT9 2006 Winter and HT12 2007 Winter, and finally, *Sicyonia pencillata* is responsible for grouping the two samples from HT12 2007 Winter and HT13 2007 Winter.

The sample groupings produced from the 3-D NMDS ordination (Figure 7-5) (derived from the patristic distances of the PAE cladogram) mirror the groupings seen in the cladogram. Again, a subset of the samples from station HT5 located outside the Harbor group away from the remaining samples collected from stations located within the Harbor.

The parsimony analysis of co-occurring species (PACOS) cladogram (Figure 7-6) resulted in multiple albeit nearly identical cladograms with a tree length of 120, a consistency index of 0.200, and a relatively high retention index (a measure of branch support) of 0.625. The cladogram reveals which species occur together. For example, the sciaenids, *G. lineatus* and *S. politus*, were almost always collected together during the biennial sampling, thus they are found grouped together within the elongate clade. The long branch-lengths leading to the species group bordered by *Genyonemus lineatus* and *Citharichthys stigmaeus* represent the relative number of sampling events from which these species were collected. Hence, this grouping of species represents the most widely occurring species from our biennial sampling survey.

DISCUSSION

The results of the trawl-caught fish and megainvertebrate program for the 2006-2007 biennium suggests a somewhat diverse community of fish and megainvertebrates exists with many samples recording the number of taxa collected in the mid- to high-teens. Although, the progression of deposition of dredged Los Angeles Harbor sediments and removal of these stored sediments as fill material for continuing Los Angeles Harbor construction projects continues, more pattern was discernible in this biennial report than the previous report. The cladogram of the combined fish and megainvertebrate community data grouped like-station samples together, such as all HT10 samples, all HT5 samples, 3 of the 4 HT13, and 3 of the 4 HT12 samples. This grouping of like stations is an indication of species-site fidelity and suggests the possible recovery of the environment from previous perturbation. Additionally, there also was evidence of grouping by season in the cladogram, further suggesting the environment is having a larger role in structuring the local community than the constant construction within the Harbor over the previous years. Additionally, although the Terminal Island Water Reclamation Plant's Outfall Station HT7 had highly variable species richness with values of 8, 12, 17, and 18, it should be noted that the taxa counts of 17 and 18 represent some of the most diverse samples collected during the biennium.

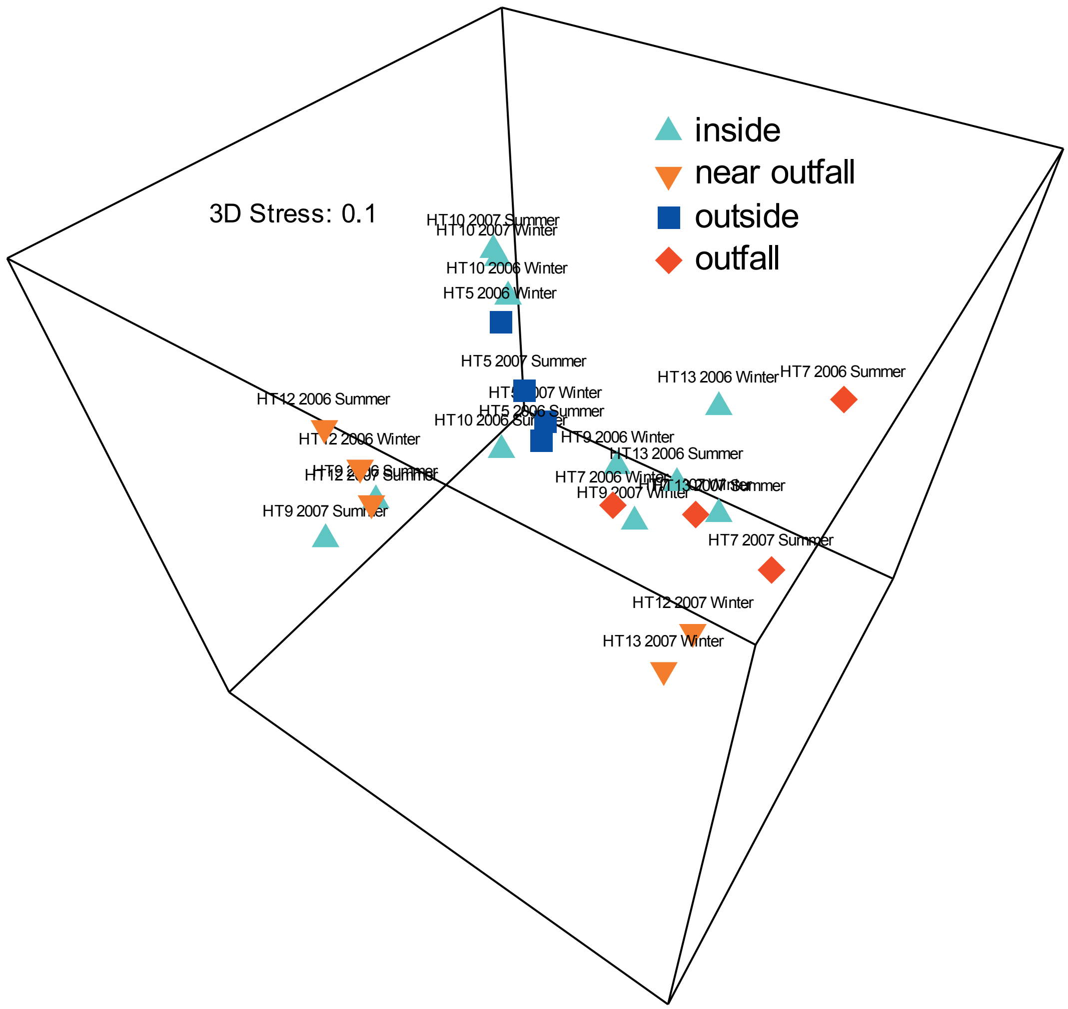

Figure 7-5. Non-metric multi-dimensional scaling (NMDS) of patristic distances derived from the parsimony analysis of endemicity (PAE) cladogram for the 2006-2007 biennium. Four treatment levels of a location factor are employed.

Indeed, the Winter sample from 2007 scored the highest phylogenetic diversity value for the entire biennium.

Adult fish populations in Los Angeles Harbor have been studied in the past using otter trawls, gill nets, purse seines, and divers (MEC 1988). The sampling devices most frequently used were otter trawls of various sizes, and it has been shown that catch efficiency of otter trawls is highly variable (8-52%) depending on trawl size, fish size, and fish species (MEC 1988). Hence, it is difficult to assess how quantitatively comparable previous reports are with our results reported herein. The aforementioned variability reported from our community parameters over the last few years (Tables 7-1, 7-2, and 7-3) continue to bear testimony to this concept (CLA, EMD 1994 - present chapter).

Within the 24 sampling events over the 2006-2007 biennium, the same small group of fish and invertebrate species that typically dominate sampling period after sampling period were recorded. Fish species had variable abundances punctuated at several sampling events driven by a few species. The dominant species were, once again, *Genyonemus lineatus*, *Seriphus politus, Citharichthys stigmaeus*, *Synodus lucioceps,* and *Symphurus atricaudus*. However, in contrast to years prior to 2003, *Paralichthys californicus* appears to be emerging as a prominent species as it occurred in 11 out of 11 events in 2003, 15 out of 19 events in 2004, 7 out of 18 events in 2005, and 17

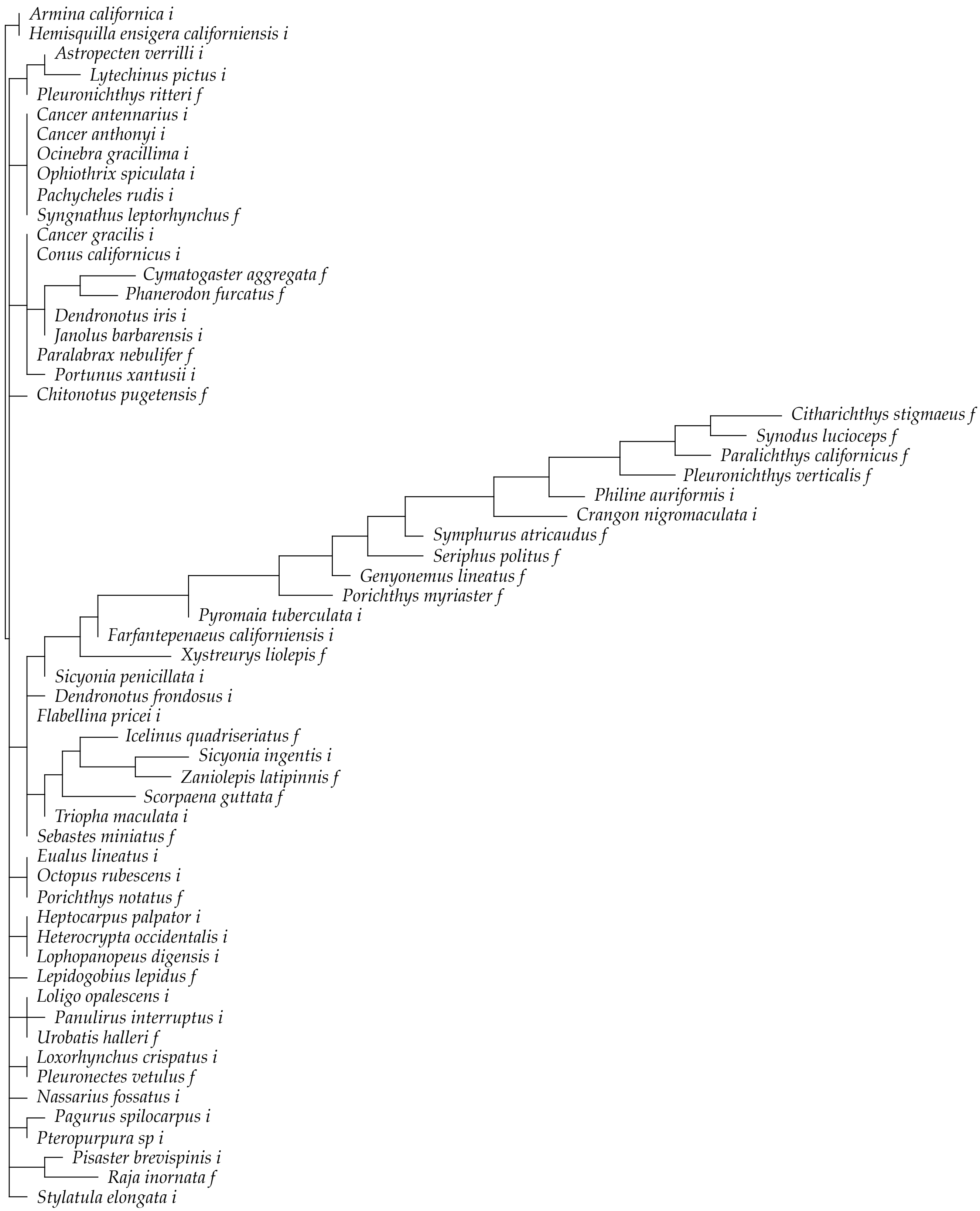

Figure 7-6. Parsimony analysis of co-occurring species (PACOS) cladogram showing the associations of combined fish and megainvertebrates based on where they occurred during the 2006-2007 biennium.

out of 24 events over the 2006-2007 bienniumn. For megainvertebrates, *Crangon nigromaculata* followed by *Philine auriformis* have dominated the catch both in abundance and occurrence in previous years. This co-occurring pair remained the most widely occurring in 2006-2007. However, by far the most abundant megainvertebrate was *S. ingentis* with 228 individuals, primarily at HT12. This species' abundance pattern was challenged by that of *C. nigromaculata* (137 individuals) for the biennium, suggesting an equitable niche for these species. In general, megainvertebrates occurred in low numbers of species and abundances relative to other nearshore soft-bottom habitats and to previous years. Additionally, megainvertebrate taxa tend to fluctuate more dramatically in Los Angeles Harbor from year to year in the overall context of their historical master species list as seen between 2006 and 2007.

Additionally, it has been hypothesized that establishing monitoring programs in spatially open systems such as the open ocean using highly mobile organisms (e.g., fish) can impose formidable problems when trying to assess local effects and changes (Thomas 1993). However, in spatially captive systems, such as the Los Angeles Harbor, the mobility of fish may in effect increase information sensitivity. Fish have the immediate capability in both space and time to avoid or exploit these minimally impacting perturbations such as tertiary effluent in spatially captive environments. Antithetically, this type of data may yield finer pattern resolution than other biological data sets (i.e., infauna) in these unique (captive and relatively homogeneous) situations.

Although Pier 400 construction is complete, current activities including proximate dredging and filling of spoils remain (i.e., Pier 400 Submerged Storage Site). This, combined with the previous construction, dredging, and fill activities, appear to constitute a lasting effect upon the behavior and, therefore, the distribution of species often captured in our monitoring program. Hence, any message obtained from the data analysis tends to still be a bit garbled, altered, and not informative relative to the objective of the Los Angeles Harbor Monitoring Program: to investigate potential effects of the effluent discharged from the Terminal Island water Reclamation Plant's outfall on the biological communities (i.e., benthic infauna, trawled fish and invertebrates, and sportfish) in the Los Angeles Harbor. Hence, we must continue to recommend that the results from the trawling program be viewed with extreme caution until the Los Angeles Harbor environment becomes more stabilized.

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