# BIOLOGICAL MONITORING OF THE CHEVRON DIFFUSER BARBERS POINT, O'AHU --- 2010

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## **Summary**

Surveys of corals, micromollusks and fishes were conducted at permanent monitoring areas on 28 July 2010 in compliance with the requirements of a Zone of Mixing Permit issued by the Hawai'i State Department of Health to the Chevron Oil Refinery. We report the following:

- Coral saddle-top population mortality averaged 5%. Three additional colonies, primarily on the sides of the saddles, were measured for growth estimates in the coming years. One new recruit to the tops of the saddles was seen, and there are numerous small colonies on the sides of the saddles. Average growth for *Pocillopora meandrina* colonies from 2009 to 2010 was 107 cm<sup>2</sup>.
- The micromollusk abundance and species numbers for 2010 were similar to numbers from 2002-2009. In 2010, a total of 5,846 micromollusks belonging to 176 mollusk taxa were collected. Species indicative of habitat degradation were not found or present in very low numbers in the vicinity of the pipeline. No individuals of *Finella pupoides*, characteristic of anaerobic conditions, were recorded in this study. At all four stations, pyramidellids and infaunal bivalves (indicators of enriched conditions) were present but in low numbers. *Isognomon*, a genus characteristic of lowered salinity conditions, were not present at the Pipeline (T1) and Control sites but were found in extremely low numbers at T2 and T3.
- The total number of individual fishes was lower at the Pipeline as compared to the previous year but higher at T2, T3 and the Control sites. However, a higher number of fishes were quantified at the Pipeline (137) as compared to the Control site (101) in 2010. This pattern was also observed with the number of species recorded at the Pipeline (17) and the Control (12) sites. The richness or number of species recorded was higher at T2 and the Control site as compared to 2009 but lower at the Pipeline and T3 (Appendix 3). An ordination analysis suggests that T2, T3 and the Control sites are most similar to one another based on number of fish species, numerical abundance and biomass densities. These sites had fewer fish of smaller size and less species than recorded at the Pipeline. The Pipeline is clearly separated from the other three sites. This is consistent with previous years where fish factors were considerably higher at the Pipeline than at the other sites. No evidence of negative impacts to fish populations due to the Pipeline or effluent was found.

## Introduction

The Chevron monitoring program at Barbers Point, O'ahu was initiated in 1982 to comply with the requirements of a Zone of Mixing Permit issued by the Hawai'i State Department of Health. Censuses of corals on the pipeline saddle, micromollusks from sediments near the discharge pipe, and fishes in the vicinity of the pipeline have been conducted yearly with the exception of an 18-month (1983-1984) and 16-month (1999-2000) hiatus. In 1996 the zone of mixing was expanded, and two additional sites within the zone and an outside control site were added to the surveys (Figure 1). We report here the measured parameters of coral growth and population dynamics for the Pipeline saddle-top populations and micromollusk and fish counts for all surveyed sites for the year 2010.

# **Pipeline**

The pipeline (T1, Figure 1) carrying the effluent discharge extends a distance of 364 m (1200 ft) from the shore to a depth of 7 m (23 ft). The discharge consists of process effluent and cooling water with temperatures 3° to 4° above ambient, and DO and pH slightly different from ambient (Kay and Smalley 1982). The discharge is rapidly diffused, and the receiving water falls well within ambient limits within a few seconds of discharge (Kay 1981).

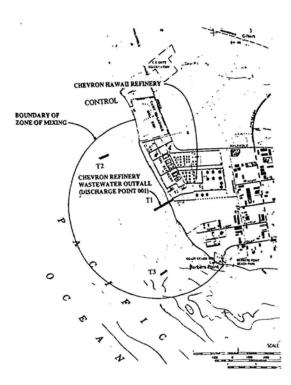


Figure 1: Biological monitoring sites for the Chevron Refinery wastewater outfall.

The pipeline sits on a topographically homogeneous limestone shelf which experiences continuous surge, varying in intensity relative to surf conditions, and a long-shore current that

frequently changes speed and direction. The shelf is subject to continual sand abrasion and the water to relatively high turbidity, with visibility typically from 1.5-6 m due to the sediment load in the water column.

The diffuser is anchored by eight large concrete saddles (approximately 1.5 m x 1.5 m x 1.5 m) though which the pipeline passes. The seaward-most saddle is in 7 m (23 ft) of water, and the other saddles are in progressively shallower water as the pipe approaches shore. Approximately 50 m shoreward of the end of the diffuser several bags of concrete (ca 75 lb) have been dumped under and around the pipe. The pipe, saddles, and concrete bags significantly increase the structural complexity of an otherwise two-dimensional habitat.

The macrobiota reflects the physical conditions of the environment. The limestone shelf is interrupted by pockets and crevices, some with sand, and is covered by a sparse algal turf. Scattered encrusting *Porites* and *Montipora* corals are present, along with low-level branching colonies of *Pocillopora meandrina*. Corals are present on the pipeline itself, with the dominant species being *P. meandrina*. Other obvious components of the biota are several species of fish and sea urchins (*Echinometra*) that are found around the pipeline.

# **Experimental Sites**

In 1996, two additional experimental sites (T2 and T3, Figure 1) within an expanded zone of mixing (ZID) were designated. Location, proximity and greatest similarity to the pipeline in terms of topographic relief and macrobiota were the basis for the selection (Kay et al. 1996). T2 is approximately 600 m northwest of the pipeline and roughly 250 m southeast of the Barbers Point Harbor. It consists of approximately 40-70% living coral cover in the form of large colonies of *Porites lobata* (and some *P. evermanni*) along with *P. compressa* and various *Montipora* spp. Massive three-dimensional colonies and accretions provide complex habitat for fish that is reasonably comparable to the saddle structures of the diffuser pipeline, given the limitations of habitat within the ZID.

The second site, T3, is approximately 600 m south of the diffuser pipeline in 9-11 m of water and consists of fractured and contoured limestone shelf with an abrupt 2 m drop and gradual rise, and several large apparently carbonate boulders. Coral cover, although estimated at less than 20%, is greater than that found in the inshore area surrounding the pipeline. *P. lobata* (included server large heads) and *P. meandrina* are the most common species. Numerous encrusting corals, including *Montipora patula*, *M. flabellata*, *M capitata* and *Pavona varians*, are also present. The area appears impacted by occasional heavy swell that may serve to limit expansion of coral cover and upright growth of all but the *P. meandrina* and *P. lobata* heads.

## **Control Site**

A control site (Figure 1), outside the ZID, was also established in 1996. The site is approximately 600-700 m north of the Barbers Point Harbor entrance and 400-500 m south of the Ko'Olina Resort, at a fairly consistent depth of about 8 m. The bench is topographically complex, with numerous caves, crevices, and an apparent spur and groove network. The grooves are estimated to be 2-4 m wide, with an abruptly vertical northernmost wall approaching 3 m in height and a southernmost wall sloping more gradually to the bench above. Each groove contains scattered sand deposits. Live coral cover in the area is estimated to be less than 10%. Dominant species include *P. meandrina* and *P. lobata* (including both encrusting and large heads). Other

scleractinians include *P. varians*, *M. capitata*, *M. flabellata* and *Cyphastrea ocellina* (all encrusting).

#### Methods

## **Transects**

The permanent monitoring locations (Pipeline [T1], T2, T3 and Control) were relocated using GPS and surveyed on 28 July 2010. Fish surveys and sediment collections occurred along a 50 m transect laid perpendicular to shore at T2, T3 and the Control site. The pipeline between and including the 4 outermost (makai) saddles served as the permanent transect for surveys of coral and fish and sediment sampling at T1.

#### Corals

Length (the longest curved dimensions of live coral colony skeleton structure in a direction perpendicular to the pipeline) and width (longest curved width of live coral colony skeletal structure in a direction parallel to the pipeline) measurements were made using a flexible measuring tape on colonies of *P. meandrina* on the tops of the 4 outermost saddles of the diffuser pipeline. These included previously measured colonies and new colonies to replace those suffering from high levels of partial or total mortality. Coral recruits and the position of all live and dead colonies on each saddle-top were mapped.

#### Micromollusks

Micromollusks (mollusks with shells less than 10 mm in greatest dimension) were sorted from sediments collected from sand-accumulations within 3 m of each of the four saddles on limestone bench adjacent to the Pipeline. Sediments were also collected within 3 m of the 0, 17, 34 and 50 m marks on the transect lines at T2, T3, and Control sites. The sediments were put through two 95% alcohol washes, air dried, and only fresh shells were removed from aliquots of 25 ml by sorting under a dissecting microscope. The shells were identified to the lowest taxonomic level possible using Kay (1979). The shells were counted and counts were analyzed for abundance, habitat and trophic information (Kay 1979, Beesley et al. 1998).

#### Fish

Visual fish transects were conducted using SCUBA on 28 July 2010 at the four sites previously established. For each transect, fishes were counted within 2 m on either side of a 50 m transect line. At the pipeline site, this included the areas under the pipeline and within the concrete stanchions.

# Results

# **Corals**

A map of the colonies measured in July 2010 and summary data are shown in Appendix 1. Mortality of colonies occurred only on saddle 1 (1 colony of 5 mapped), but was on average

low (5%). There has been continued mortality to colonies on the tops of these saddles over time, which is probably attributable to the determinate growth of P. meandrina. Growth rates, calculated in 2010, are similar to past recorded growth rates (average  $107 \, \mathrm{cm}^2$ , standard error  $21.4 \, \mathrm{cm}^2$ , n = 24, note – due to high surge, one colony was not accurately measured and has not been included with these data). One new recruit to the top of the saddles was noted. Three additional colonies, mostly on the sides of the saddles, were measured for additional growth measurements.

#### Micromollusks

The micromollusks in the Chevron biomonitoring samples for 2010 were representative of various habitats and trophic structure (Kay, 1979; Beesley et al., 1998). A total of 5,846 micromollusks belonging to 176 mollusk taxa were counted (Appendix 2). For all sites, Gastropods made up 90.4% of the total number of specimens, while bivalves (9.5%) and Polyplacophora (0.1%) made up the rest. The high ratio of gastropods to bivalves is said to result from the lack of expanses of nutrient-rich, silty sand ocean substrata (Kay 1967). The dominant taxa for 2010 belonged to the families Rissoidae (1,611), and Cerithiidae (551). *Rissoina cerithiiformis* (854) was the dominant species, followed by *Tricolia variabilis* (545).

The overall abundance for 2010 was 5,846 micromollusks. The highest abundance of micromollusks for 2010 was at T2 (3,554), followed by T1 pipeline (970), T3 (801), and Control site (521) (Figure 1, Appendix 2).

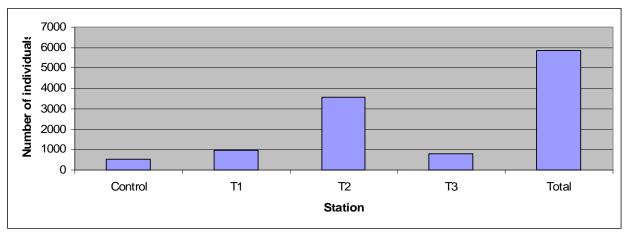


Figure 1: Abundance of all micromollusks at the 4 sites for 2010.

The total abundance for 2010 (5,846) is similar to abundances for 2002 (3,266), 2003 (4,763), 2004 (4,772), 2005 (5,781), 2006 (4,798), 2007 (4,589), 2008 (4,377) and 2009 (4,244). In 2005, there was an increase in abundance at the Control site. In 2006, the abundance at the Control site exhibited a major decrease then in 2007, the abundance returned to the ranges observed between the years 2002-2005 and continues in this range for 2008, 2009 and 2010 (Figure 2).

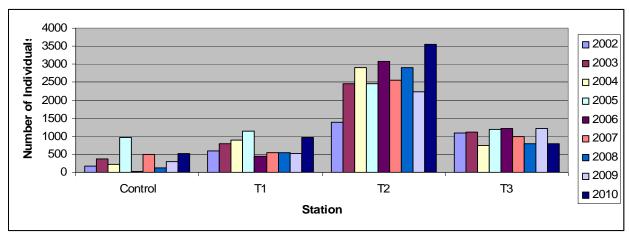


Figure 2: Abundance of all micromollusks at the 4 sites over 2002-2010

The distribution of micromollusks for 2010 among sites (Figure 3) was similar to the pattern seen in previous years. Specifics on the abundance and species composition are shown in Appendix 2.

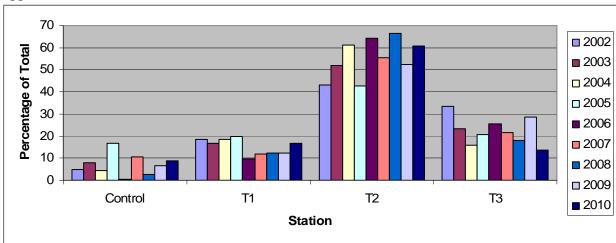


Figure 3: Distribution of micromollusks at the 4 sites over 2002-2010 (percentage of total samples).

There were 176 taxa for 2010 (Figure 4), which is similar to the numbers of taxa for 2003 (171), 2004 (151), and 2005 (156), but slightly higher than 2002 (144), 2006 (130), 2007 (144), 2008 (135) and 2009 (139). There are noticeable decreases in the number of taxa for the 2006 Control site, and 2007 station T3. The total numbers of taxa for 2010 are slightly higher than the range of 130 to 171 for 2002 to 2009 (Figure 5). This increase in number is due to identification of some previously unidentified taxa.

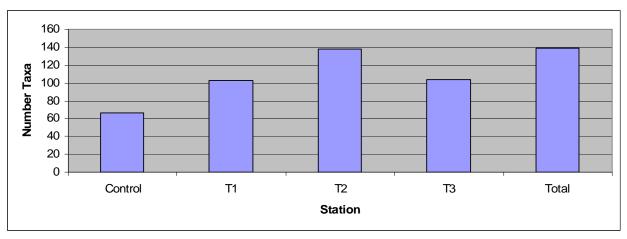


Figure 4: Number of taxa at the 4 sites for 2010.

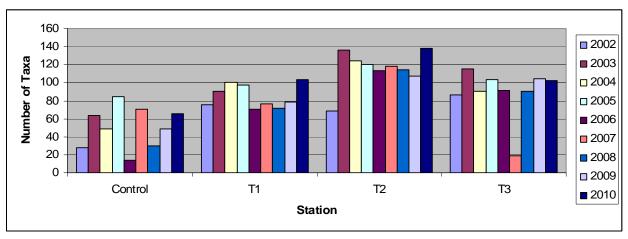


Figure 5: Number of taxa at the 4 sites over 2002-2010

For all taxa present at the 4 sites for 2010, epifaunal species [i.e. species associated with rocks, gravel, or other hard substrates] made up 88.5% of the total. Epifaunal species comprise 89.3% of micromollusks observed at T1 pipeline, 88.7% at the Control site, 88.7% at T2 and 87.0% at T3. Infaunal species (i.e. species that burrow or live in bottom deposits of the ocean) 6.4%, parasitic species 3.6%, commensal species 1.0%, and unknown 0.5% comprised the rest of the habitat types at all sites combined in 2010 (Figure 6).

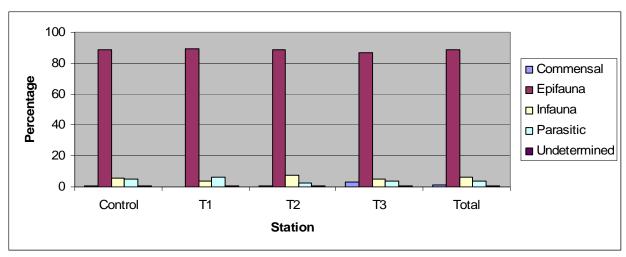


Figure 6: Habitat distribution for 2010.

At the Control site, for all taxa enumerated, detritivores were most common (59.5% of all individuals), followed by filter feeders (13.2%), herbivores (11.9%), carnivores (10.0%), parasitic mollusks (4.8%), and unknowns (0.6%). At Pipeline (T1), detritivores (49.9%) were followed by herbivores (26.5%), filter feeders (12.7%), parasitic mollusks (6.4%) carnivores (4.1%), and unknowns (0.4%). At the T2 site, herbivores (38.4%) were slightly more abundant than detritivores (37.6%). They were followed by filter feeders (14.9%), carnivores (4.7%), parasitic mollusks (3.6%), and unknowns (0.6%). Finally at T3, detritivores (41.2%) were followed by herbivores (35.6%), filter feeders (12.0%), carnivores (6.6%) parasitic mollusks (3.7%), unknowns (0.7%) and commensal (0.1%) (Figure 7).

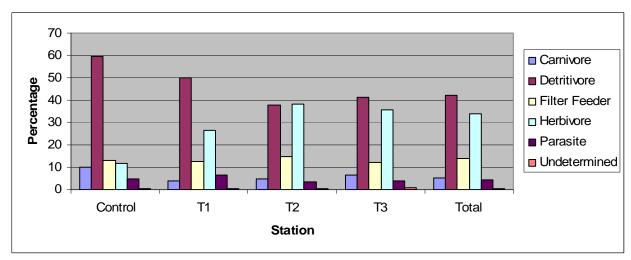


Figure 7. Trophic distribution of micromollusks for all 4 sites for 2010

In the 2010 samples, detritivores (44.4%) made up a major portion of the epifauna: Control (67.1%), T1 pipeline (53.6%); T3 (43.9%); and T2 (38.7%). For all epifaunal micromollusks, detritivores were followed by herbivores (37.5%), filter feeders (11.6%), carnivores (5.7%), and parasites (0.7%) (Figure 8).

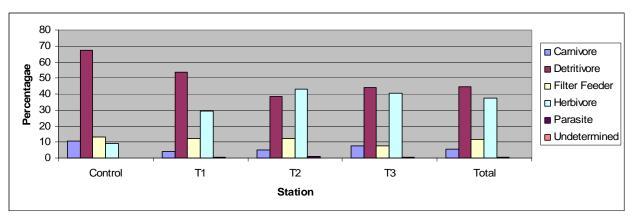


Figure 8: Epifaunal trophic structures at the 4 sites for 2010.

The family Rissoidae (1,589), which feeds on diatoms and algal filaments, was the most abundant group present: T2 (1,152); T3 (228); T1 pipeline (151); and Control (58) (Figure 9). The rissoid, *Rissoina cerithiiformis* (854), was the most abundant species present: T2 (697); T3 (114); T1 pipeline (41); and Control (2). The herbivore, *Tricolia variabilis* (545), was the second most abundant species: T2 (301); T1 pipeline (152) and T3 (92). However, no *T. variabilis* were found at the Control site. The sponge feeding triphorids were most abundant at T2 (108) followed by Control (28), T3 (21), and T1 pipeline (18).

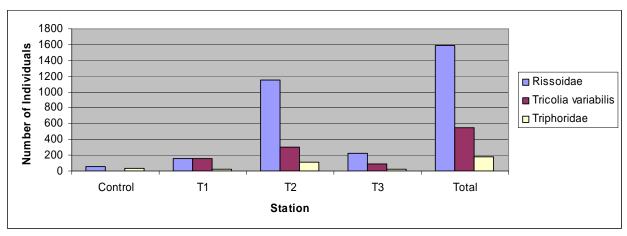


Figure 9: Dominant species at the 4 sites for 2010.

The classic model of pollution or of deleterious effects of land-based outfalls predicts a decline in species richness at the impact site and/or an increase in abundance of a few pollution tolerant organisms. The Pipeline (T1) has a species richness value of 103, which is higher than the Control (66). No individuals of *Finella pupoides*, characteristic of anaerobic conditions, were recorded for the 2010 study (Figure 10). Pyramidellids and infaunal bivalves, indicative of enriched conditions were present in low percentages [pyramidellids: T1 (4.9%); Control (3.8%); T3 (3.7%); and T2 (3.4%)] [infaunal bivalves: T2 (3.8%); T3 (2.1%); T1 pipeline (1.6%); and Control (1.2%)]. Bivalves in the family Lucinidae, indicative of anoxic conditions (i.e. low nutrients and often high sulphide content environments, Reid & Slack-Smith, 1998), were present at low percentages at the Pipeline (T1) (0.1%) and T2 (0.1%) sites. However, no lucinid

bivalves were recorded for Control and T3 [Figure 9]. Mollusk species in the genus *Planaxis*, characteristic of lowered salinity, was present only at T2 (1). Juvenile shells of the genus *Isognomon*, also characteristic of lowered salinity conditions, were present at station T2 (14), and T3 (2), with none present at Pipeline (T1) or the Control.

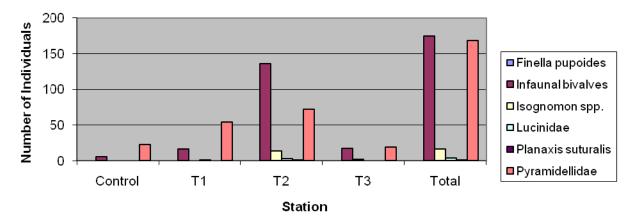


Figure 10: Indicator species at the 4 sites in 2010.

## **Fish**

Numbers of individual species are shown in Appendix 3. Total numbers of individual fishes were slightly higher in 2010 (411) when compared to previously measured transects in 2009 (399). Fish numerical abundances in 2010 were not statistically different from the prior 13 years of census data at any of the four sites (Single Specimen Compared to a Sample, P > 0.05). Species richness average across sites was lower than the average for the previous 12 years (14.2 versus 21.7 across all sites; Appendix 3, Table 1). This is probably due to high variability. However, species richness was not significantly different from previous surveys.

Table 1: Comparison of 2010 data with earlier data. Total number of individuals:

date	pipeline	Т3	T2	Control
Aug 96	369	229	246	134
Aug 97	386	174	209	126
Aug 98	364	82	134	86
Sep 99	274	143	81	290
Apr 01	197	121	97	113
Apr 02	344	228	172	128
Average –	322	163	156	146
Mohlmann data				
Aug 03	142	56	116	87
Nov 04	202	201	131	94
Aug 05	170	175	129	71
Aug 06	184	105	111	73

July 07	168	19	64	63
Aug 08	53	32	95	67
Aug 09	234	50	52	63
July 10	137	94	<b>79</b>	101

Total Number of Species:

Date	pipeline	Т3	T2	Control
Aug 96	38	26	44	24
Aug 97	35	39	26	21
Aug 98	28	20	23	17
Sep 99	32	31	21	22
Apr 01	26	28	23	17
Apr 02	30	26	23	19
Average –	32	28	27	20
Mohlmann data				
Aug 03	24	16	21	18
Nov 04	14	24	17	16
Aug 05	25	27	20	15
Aug 06	18	16	20	13
July 07	21	9	11	10
Aug 08	13	14	12	10
Aug 09	23	17	14	10
July 10	17	13	15	12

As in all previous years since 1996 except for 2008, there were a considerably higher number of fishes at the Pipeline than at the Control site. The 2008 anomaly was due to poor visibility at the Pipeline. Species richness also followed the same trend in 2010 with a larger number of fish species recorded at the Pipeline than at the Control site in all previous years since 1996 with the exception of 2004. Fish biomass at the Pipeline (16.44 Kg) was considerably higher than at the Control site (2.83 Kg), T2 (1.79 Kg) and T3 (3.47 Kg). The arrangement of the four sites in multi-dimensional space for the 2010 survey show no tight clustering based on species richness, numerical abundances and biomass densities combined (Figure 10). As in the majority of previous years, the Pipeline site is remote in ordination space from the other three sites due to high fish numbers, biomass, and species quantified.

# 2010 Principal Components Analysis-Community Fish Factors

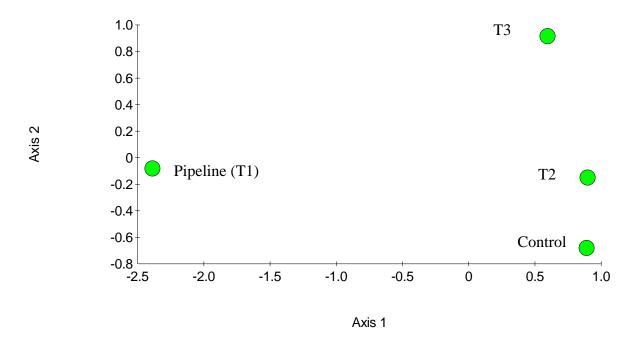


Figure 10. Multivariate ordination of fish assemblage characteristics for four Chevron sites: T-1 (pipeline), T-2, T-3 and Control.

Eight species counted during 2010 were not seen on previous 2009 transects. This was most likely due to the transient and mobile nature of fishes. Twelve species that were recorded in 2009 were not seen in 2010. The fish species recorded (32) in this survey are either endemic or indigenous with the exception of *Lutjanus fulvus* (to'au). No introduced species were recorded in 2009. No unusual species were recorded on transects in 2010. Large schools of fishes were recorded at all four transects. These included *Mulloides vanicolensis* (weke ula) and *Acanthurus triostegus* (manini) at the Pipeline and *Acanthurus olivaceus* (na'ena'e) at T3. *Acanthurus nigrofuscus* (mai'i'i) was found in large numbers on all transects except T3.

The Pipeline site had a considerably higher number of individuals and species as compared to all other sites. Numbers of individuals were higher in 2010 at T3, T2 and the Control site as compared to numbers in 2009. Number of species of fishes observed was higher at T2 and the Control in 2010.

Higher topographic relief is positively correlated with these fish community characteristics. The pipeline and stanchions and sites with large coral colonies provide additional substrate for fishes. Fishes are normally concentrated around and within the stanchions providing protection, shelter, and food. Prior research has recognized the importance of topographic relief in the structure of fish assemblages throughout the world and in Hawai'i. It is evident that fish populations are highly associated with spatial relief for several reasons.

- Increased substrate provides habitat for benthic invertebrates, which serve as the main diet of many species of fishes, which in turn are utilized at other trophic levels.
- Increase in coral cover associated with rugosity provides more food for obligate corallivores.
- Spatial complexity increases habitat heterogeneity, providing increased areas of refuge for fish populations from predation and competition.
- Topographical relief can expand the availability of resources and their production rate.
- Increased relief results in higher heterogeneity, creating habitat complexity that increases fish diversity.

Fish populations are highly variable, requiring numerous transects to quantify absolute values of fish communities. A large sample size is necessary due to the high variability among fish assemblages. Many rare, cryptic or mobile species can be under reported and the power to accurately detect absolute fish abundances can be extremely low. Although fish populations vary considerably both spatially and temporally, relative comparisons can be made between sites with few transects over time. This dataset currently includes 14 years of fish data increasing the statistical power to detect differences when present.

## **Discussion**

## **Corals**

The continuing decline in the coral population on the saddles reflects the age of the colonies on these saddles. Many of these colonies are close to the maximum size of colonies of *Pocillopora meandrina* (Grigg and Maragos 1974, Kolinski and Cox, personal observations). Although there was only one recruit to the tops of the saddles during 2009 to 2010, recruitment of corals in Hawai'i is highly variable in both time and space (Kolinski 2004, Coles and Brown 2007, Brown and Friedlander 2008, Basch et al. 2008). Coles and Brown (2007) followed coral coverage around the Kahe Power Plant (to the west of this study area) over a long time span and reported that irregular recruitment had the greatest impact on recovery of coral coverage following hurricanes. It should be noted that there are numerous small colonies growing on the sides of these saddles.

Remaining colonies on these saddles are showing fairly consistent rates of growth, indicating that this environment is suitable for growth.

#### Micromollusks

The high species richness value at the impact site Pipeline T1, absence of individuals of *Finella pupoides* (indicative of nutrient rich conditions), and very low abundances of species indicative of anoxic conditions, along with the high ratio of gastropods to bivalves, strongly suggest effluent released at the Pipeline (T1) is not negatively impacting or shifting

micromollusk communities in the region. High species numbers and abundances at T2, Pipeline (T1) and T3, in comparison to the Control populations, support this conclusion.

The classic model of pollution or of deleterious effects of land-based outfalls predicts a decline in species richness at the impact site and/or an increase in abundance of a few pollution tolerant organisms. The Pipeline (T1) has a species richness value of 103, which is higher than the Control (66). No individuals of *Finella pupoides*, characteristic of anaerobic conditions, were recorded in this study. Pyramidellids and infaunal bivalves, indicative of enriched nutrient conditions, were recorded but at very low percentages. Only one individual of the mollusk species in the genus *Planaxis*, characteristic of lowered salinity, was present at T2. Juvenile shells of the genus *Isognomon*, also characteristic of lowered salinity conditions, were present in low numbers at station T2 (14) and T3 (2), with none present at the Pipeline (T1) or the Control.

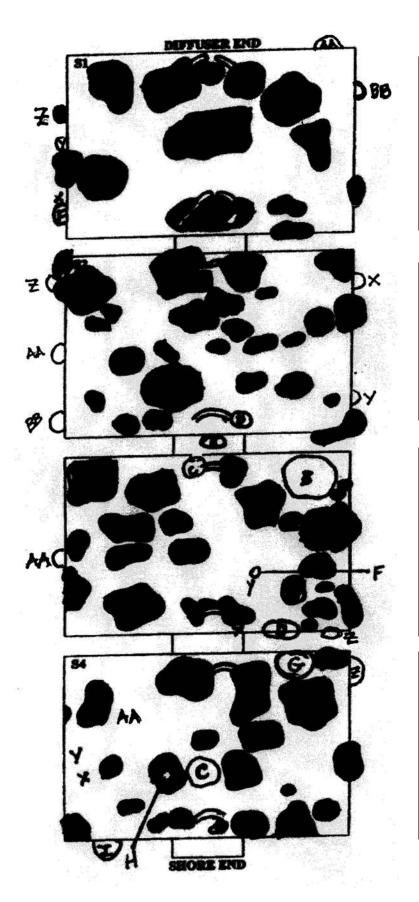
#### **Fish**

Total numbers of fishes, biomass, and species varied, but did not differ statistically from estimates made over the past 13 years. Variation in numbers can be attributed to differences in visibility and natural fluctuations that are typically observed in temporally spaced censuses of highly mobile reef organisms. As in previous years, species richness and fish numerical and biomass abundance at the Pipeline were much higher than at the Control site. There is no evidence to suggest that the Pipeline or effluent negatively impact fish populations (as measured) within the zone of mixing (ZID).

## **Literature Cited**

- Basch, L, J. White, A. Leemhuis and W. Walsh. 2008. Recruitment dynamics of scleractinian corals in a network of national parks and marine protected areas: West Coast Hawai'i Island. 2008 Hawai'i Conservation Conference, published abstract.
- Beesley, P.L., G.J.B Ross and A. Wells (ed.). 1998. Mollusca: The Southern Synthesis. Fauna of Australia. Vol. 5. CSIRO Publishing: Melbourne, Part A xvi 563 pp., Part B viii 565-1234 pp.
- Brown, E. and A. Friedlander. 2008. Marine benthic and fish communities in Hanalei Bay, Kauai since 1992: Spatial and temporal trends in a resilient Hawaiian coral reef ecosystem. 2008 Hawai'i Conservation Conference, published abstract.
- Castro, P. and Huber, M.F. 2007. Marine Biology, Sixth Edition, McGraw-Hill, New York; 460 pp.
- Coovert, G.A. 1987. Marginellidae of Hawaii: Volvarina. Hawaiian Shell News, June 1987: 9
- Coles, S. L. and E. K. Brown. 2007. Twenty-five years of change in coral coverage on a hurricane impacted reef in Hawai'i: the importance of recruitment. Coral Reefs 26:705-717.
- Cox, E. F., K. Rodgers, and R. Kawamoto. 2009. Biological monitoring of the Chevron diffuser, Barbers Point, Oahu 2009. Report for Chevron.
- Cox, E. F., K. Rodgers, and R. Kawamoto. 2008. Biological monitoring of the Chevron diffuser, Barbers Point, Oahu 2008. Report for Chevron.
- Cox, E. F., K. Rodgers, R. Kawamoto and E. A. Kay. 2007. Biological monitoring of the Chevron diffuser, Barbers Point, Oahu 2007. Report for Chevron.
- Cox, E. F., K. Rodgers, R. Kawamoto and E. A. Kay. 2006. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu 2006. Report for Chevron.
- Kay, E. A. 1967. The composition and relationships of the marine molluscan fauna of the Hawaiian Islands. Venus 25: 96-104.
- Kay, E.A. 1979. Hawaiian Marine shells. Reef and Shore Fauna of Hawaii, Section 4: Mollusca. BPBM Spec. Publ. 64(4): 653 pp.
- Kay, E. A. 1981. An assessment and recommendations for a zone of mixing permit for the Chevron USA Hawaiian Refinery. Report for Chevron.
- Kay, E. A. and T. Smalley. 1982. Biological monitoring of the Chevron diffuser pipeline.

- Barbers Point, Oahu -- 1982. Report for Chevron.
- Kay, E. A., D. Gulko, S. Kolinski, and M. Mohlmann. 1996. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu -- 1996. Report for Chevron.
- Kay, E. A., S. Kolinski, M. Mohlmann and R. Kawamoto. 2002. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu 2002. Report for Chevron.
- Kolinski, S. P. 2004. Sexual reproduction and the early life history of *Montipora capitata* in Kaneohe Bay, Oahu, Hawaii. Ph.D. Dissertation, University of Hawai'i, 152 pp.
- Kolinski, S., F. Cox, R. Kawamoto and E. A. Kay. 2003. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu 2003. Report for Chevron.
- Kolinski, S., K. Rodgers, R. Kawamoto and E. A. Kay. 2004. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu 2004. Report for Chevron.
- Kolinski, S., K. Rodgers, R. Kawamoto and E. A. Kay. 2005. Biological monitoring of the Chevron diffuser. Barbers Point, Oahu 2005. Report for Chevron.
- McCormick, M. 1994. Comparision of field methods for measuring surface topography and their associations with a tropical reef fish assemblage. Marine Ecology Progress Series 112: 87-96.
- Pittman, C. and Fiene, P. "Sea Slugs of Hawaii". <a href="www.seaslugsofhawaii.com">www.seaslugsofhawaii.com</a> (accessed 25 August 2010).
- Stansic, John 1998. Family Ancylidae. Pp. 1071-1072, , *in* Beesley, P.L., Ross, G.J.B. & Wells, (eds.) Molluscas: The Southern Synthesis. Fauna of Australia. Vol. 5. CSIRO Publishing: Melbourne, Part B viii 565 1234 pp.
- Wells, F. E. 1998. Family Triphoridae. Pp. 809 811, *in* Beesley, P.L., Ross, G.J.B. & Wells, (eds.) Molluscas: The Southern Synthesis. Fauna of Australia. Vol. 5. CSIRO Publishing: Melbourne, Part B viii 565 1234 pp.
- Wilkinson, C. R. 1993. Coral reefs of the world are facing widespread devastation: can we prevent this through sustainable management practices. Proceedings of the Seventh International Coral Reef Symposium, Guam 1: 11-21.



## Saddle 1

F 15 x 14 cm gro X 6 x 7 cm gro Y 6 x 7 cm gro Z 8 x 10 cm gro AA 46 x 45 cm gro

New

growth 69 cm<sup>2</sup> growth 23 cm<sup>2</sup> growth 1 cm<sup>2</sup> growth 22 cm<sup>2</sup> DEAD

growth 22 cm<sup>2</sup>

#### Saddle 2

BB 5 x 5.5 cm

D 34 x 29 cm growth 121 cm<sup>2</sup>
E 17 x 19 cm growth 106 cm<sup>2</sup>
X 11 x 10 cm growth 45 cm<sup>2</sup>
Y 7 x 6.5 cm growth 20 cm<sup>2</sup>
Z 35 x 34 cm growth 297 cm<sup>2</sup>
AA 24 x 20 cm growth 110 cm<sup>2</sup>
BB 19 x 16 cm growth 93 cm<sup>2</sup>

# Saddle 3

B incorrectly measured

New

Z 30 x 34 cm AA 12 x 12 cm

#### Saddle 4

C 37 x 33 cm growth 93 cm<sup>2</sup>
G 48 x 48 cm growth 259 cm<sup>2</sup>
H 23 x 20 cm growth 130 cm<sup>2</sup>
I 41 x 43 cm growth 129 cm<sup>2</sup>
X 9 x 7l4 cm growth 33 cm<sup>2</sup>
Y 10 x 11 cm growth 67 cm<sup>2</sup>
Z 35 x 35 cm growth 54 cm<sup>2</sup>

New

AA 8 x 8 cm

Appendix 2: Micromollusk data for Chevron stations, 2010.

11	Taxon	Habit	Trophic	Control	Pipeline T1	T2	T3	Total
	BIVALVIA							
Arcidae	Acar sp. cf. plicata	Epifaunal	Filter	0	0	0	0	0
Arcidae	Arcidae spp.	Epifaunal	Filter	0	0	1	0	1
Arcidae	Barbatia divaricata	Epifaunal	Filter	6	22	22	2	52
Arcidae	Barbatia nuttingi	Epifaunal	Filter	8	19	105	14	146
Carditidae	Cardita spp.	Nestlers	Filter	0	0	0	0	0
Condylocardiidae	Carditella hawaiensis	Infaunal	Filter	1	3	9	5	18
Propeamusiidae	Chlamydella sp. A	Epifaunal	Filter	0	0	12	0	12
Philobryidae	Cosa waikikia	Epifaunal	Filter	0	0	0	0	0
Mytilidae	Crenella spp.	Epifaunal	Filter	1	1	4	4	10
Lucinidae	Ctena bella	Infaunal	Symbiotic/ Filter	0	1	3	0	4
Lucinidae	Epicodakia spp.	Infaunal	Filter	0	0	0	0	0
Mesodesmatidae	Ervilia bisculpta	Infaunal	Filter	1	0	0	0	1
Cardiidae	Fragum mundum	Infaunal	Filter	0	6	25	0	31
Galeommatidae	Galeommatidae spp.	Commensal	Commensal	0	0	0	0	0
Hiatellidae	Hiatella arctica	Infaunal	UNDETER	0	0	8	0	8
Veneridae	Irus spp.	UNDETER	UNDETER	0	0	0	0	0
Isognomonidae	Isognomon legumen	Epifaunal	Filter	0	0	0	0	0
Isognomonidae	Isognomon perna	Epifaunal	Filter	0	0	0	0	0
Isognomonidae	Isognomon spp.	Epifaunal	Filter	0	0	14	2	16
Galeommatidae	Kellia hawaiensis	Commensal	Filter	0	2	28	25	55
Galeommatidae	Kellia spp.	Commensal	Filter	2	0	0	1	3
Galeommatidae	Kona symmetrica	Infaunal	Filter	0	0	4	0	4
Pectinidae	Laevichlamys irregularis	Epifaunal	Filter	0	0	2	0	2
Galeommatidae	Leiochasmea elongata	Commensal	Commensal	0	0	0	1	1
Limidae	Limidae spp.	Epifaunal	Filter	0	0	0	0	0
Malleidae	Malleus regula	Epifaunal	Filter	0	3	4	2	9
Malleidae	Malleus spp.	Epifaunal	Filter	0	0	0	0	0
Nuculidae	Nucula hawaiensis	Infaunal	Filter	1	0	29	3	33
Ostreidae	Ostreidae spp.	Epifaunal	Filter	1	2	44	0	47
Pteriidae	Pinctada spp.	Epifaunal	Filter	1	1	13	0	15
Pteriidae	Pteriidae spp.	Epifaunal	Filter	0	0	0	0	0
Mesodesmatidae	Rochefortina sandwichensis	Infaunal	Filter	2	5	39	8	54
Semelidae	Semelangulus crebrimaculatus	Infaunal	Detritus	0	0	0	0	0
Mytilidae	Septifer bryanae	Infaunal	Filter	1	1	18	1	21
Tellinidae	Tellina crucigera	Infaunal	Deposit/ Suspension	0	0	1	0	1
Bivalvia	Bivalvia spp.	UNDETER	UNDETER	0	1	11	0	12
Scaphandridae	GASTROPODA Acteocina hawaiensis	Infaunal	Carnivore	0	0	3	0	3
1								

Scaphandridae	Acteocina sandwicensis	Epifaunal	Herbivore	0	0	0	0	0
Scaphandridae	Acteocina spp.	Infaunal	Carnivore	0	1	0	0	1
Trochidae	Alcyna ocellata	Epifaunal	Detritus	51	13	143	5	212
Trochidae	Alcyna subangulata	Epifaunal Epifaunal	Detritus	1	12	17	0	30
Rissoidae	Alvania isolata	Epifaunal	Detritus	2	7	3	1	13
Ancylidae	Ancylidae spp.	Epifaunal	UNDETER	0	0	1	0	1
Hipponicidae	Antisabia foliacea	Epifaunal	Filter	39	29	67	14	149
Aplysiidae	Aplysiidae spp.	Epifaunal	Herbivore	0	0	0	0	0
Muricidae	Aspella producta	Epifaunal	Carnivore	0	0	0	0	0
Atyididae	Atys semistriata	Infaunal	Herbivore	0	0	3	0	3
Eulimidae	Balcis brunnimaculata	Parasitic	Parasitic	0	0	1	3	4
Eulimidae	Balcis spp.	Parasitic	Parasitic	2	2	25	6	35
Barleeidae	Barleeia brevilabiosa	Epifaunal	Detritus	0	0	0	0	0
Barleeidae	Barleeia labiosa	Epifaunal	Detritus	6	6	4	3	19
Barleeidae	Barleeia spp.	Epifaunal	Detritus	5	2	0	0	7
Cerithiidae	Bittium impendens	Epifaunal	Detritus	1	7	52	9	69
Skeneidae	Brookula iki	Epifaunal	Detritus	0	0	15	0	15
Buccinidae	Buccinidae spp.	Epifaunal	Carnivore	0	0	0	0	0
Bullidae	Bulla vernicosa	Infaunal	Herbivore	0	0	0	0	0
Buccinidae	Caducifer decapitata	Epifaunal	Carnivore	0	0	1	0	1
Caecidae	Caecum arcuatum	Infaunal	Detritus	0	13	43	13	69
Caecidae	Caecum glabriformis	Infaunal	Detritus	0	0	0	0	0
Turridae	Carinapex minutissima	Epifaunal	Carnivore	1	8	20	19	48
Turridae	Carinapex papillosa	Epifaunal	Carnivore	1	0	1	0	2
Turridae	Carinapex spp.	Epifaunal	Carnivore	0	0	0	1	1
Cephalaspidea	Cephalaspidea spp.	Infaunal	Carnivore	0	1	3	0	4
Dialidae	Cerithidium diplax	Infaunal	Detritus	0	1	3	1	5
Dialidae	Cerithidium perparvulum	Epifaunal	Detritus	0	16	79	2	97
Cerithiopsidae	Cerithiopsis spp.	Epifaunal	Carnivore	2	6	13	4	25
Cerithiidae	Cerithium atromarginatum	Epifaunal	Detritus	0	5	1	2	8
Cerithiidae	Cerithium columna	Epifaunal	Detritus	0	0	4	0	4
Cerithiidae	Cerithium egenum	Epifaunal	Detritus	1	4	26	10	41
Cerithiidae	Cerithium interstriatum	Epifaunal	Detritus	0	2	16	3	21
Cerithiidae	Cerithium matukense	Infaunal	Detritus	0	0	0	0	0
Cerithiidae	Cerithium nesioticum	Infaunal	Detritus	0	3	39	6	48
Cerithiidae	Cerithium rostratum	Infaunal	Detritus	0	0	0	0	0
Cerithiidae	Cerithium zebrum	Epifaunal	Detritus	0	50	72	33	155
Cerithiidae	Cerithium spp.	Epifaunal	Detritus	13	8	5	0	26
Turridae	Ceritoturris bittium	Epifaunal	Carnivore	1	0	0	0	1
Calyptraeidae	Cheilea equestris	Epifaunal	Filter	0	0	0	0	0
Turridae	Clavus laeta	Epifaunal	Carnivore	0	0	0	0	0

Turridae	Clavus mighelsi	Epifaunal	Carnivore	0	0	1	0	1
Turridae	Clavus pusilla	Epifaunal	Carnivore	1	0	0	0	1
Turridae	Clavus spp.	Epifaunal	Carnivore	0	1	2	0	3
Turbinidae	Collonista candida	Epifaunal	Forage	0	14	13	11	38
Columbellidae	Columbellidae spp.	Epifaunal	Detritivore: Omnivore	1	2	2	0	5
Conidae	Conus spp.	Epifaunal	Carnivore	0	0	0	0	0
Coralliophilidae	Coralliophilidae spp.	Parasitic: on coral	Parasitic: on coral	0	0	0	0	0
Costellariidae	Costellariidae spp.	Infaunal; Epifaunal	Carnivore	0	0	0	0	0
Calyptraeidae	Crepidula aculeata	Epifaunal	Filter	0	3	0	1	4
Skeneidae	Cyclostremiscus emeryi	Epifaunal	Detritus	0	9	36	16	61
Skeneidae	Cyclostremiscus striatus	Epifaunal	Detritus	5	0	0	1	6
Scaphandridae	Cylichna pusilla	Infaunal	Carnivore	1	0	0	0	1
Marginellidae	Cystiscus huna	Epifaunal	Carnivore	0	0	0	0	0
Turridae	Daphnellinae spp.	Epifaunal	Carnivore	0	0	0	0	0
Vermetidae	Dendropoma spp.	Epifaunal	Filter	0	22	75	11	108
Marginellidae	Dentimargo pumila	Epifaunal	Forage	98	0	0	0	98
Dialidae	Diala semistriata	Epifaunal	Detritus	0	0	2	1	3
Aytididae	Diniatys dentifer	Infaunal	Herbivore	0	0	0	0	0
Fissurellidae	Diodora granifera	Epifaunal	Herbivore	0	1	9	4	14
Fissurellidae	Emarginula spp.	Epifaunal	Herbivore	2	0	0	0	2
Epitoniidae	Epitoniidae spp.	Infaunal	Carnivore: Cnidaria	0	0	2	1	3
Triviidae	Erato sandwicensis	Epifaunal	Carnivore	0	0	0	0	0
Turridae	Etrema acricula	Epifaunal	Carnivore	0	0	2	0	2
Trochidae	Euchelus gemmatus	Epifaunal	Herbivore	0	1	15	4	20
Trochidae	Euchelus spp.	Epifaunal	Herbivore	4	3	2	0	9
Columbellidae	Euplica varians	Epifaunal	Omnivore	0	0	0	0	0
Pyramidellidae	Evalea peasei	Epifaunal	Detritus	0	0	2	0	2
Obtortionidae	Finella pupoides	Infaunal	Detritus	0	0	0	0	0
Trochidae	Gibbula marmorea	Epifaunal	Herbivore	0	11	45	6	62
Marginellidae	Granula sandwicensis	Epifaunal	Forage	14	10	9	6	39
Marginellidae	Granulina vitrea	Epifaunal	Forage	0	1	5	1	7
Atyididae	Haminoea curta	Infaunal	Herbivore	0	0	0	0	0
Atyididae	Haminoea spp.	Infaunal	Herbivore	0	0	0	0	0
Architectonicidae	Heliacus implexus	Epifaunal	Carnivore	0	0	0	1	1
Pyramidellidae	Herviera gliriella	Parasitic	Parasitic	0	7	30	2	39
Pyramidellidae	Herviera patricia	Parasitic	Parasitic	0	4	4	0	8
Pyramidellidae	Hinemoa indica	Parasitic	Parasitic	1	1	3	0	5
Hipponicidae	Hipponix australis	Epifaunal	Detritus	0	1	4	2	7
Hipponicidae	Hipponix pilosus	Epifaunal	Filter	0	4	9	0	13
Cerithiidae	Ittibittium parcum	Epifaunal	Detritus	4	56	102	16	178
Juliidae	Julia exquisita	Epifaunal	Herbivore	7	6	17	1	31

Juliida	e	Juliidae spp.	Epifaunal	Herbivore	1	2	9	0	12
Turrida	ae	Kermia aniani	Epifaunal	Carnivore	1	0	3	0	4
Turrida	ae	Kermia pumila	Epifaunal	Carnivore	0	0	2	1	3
Turrida	ae	Kermia spp.	Epifaunal	Carnivore	1	0	0	0	1
Turbin	idae	Leptothyra rubricincta	Epifaunal	Detritus	0	35	9	12	56
Turbin	idae	Leptothyra verruca	Epifaunal	Detritus	47	34	51	25	157
Turrida	ae	Lienardia mighelsi	Epifaunal	Carnivore	13	0	0	0	13
Skenei	dae	Lophocochlias minutissimus	Epifaunal	Detritus	0	10	77	14	101
Skenei	dae	Lophocochlias sp. A	Epifaunal	Detritus	0	55	37	23	115
Turrida	ae	Macteola segesta	UNDETER	Carnivore	1	1	0	0	2
Rissoid	dae	Merelina granulosa	Epifaunal	Detritus	0	1	0	1	2
Rissoid	dae	Merelina hewa	Epifaunal	Detritus	0	10	103	5	118
Rissoid	dae	Merelina wanawana	Epifaunal	Detritus	14	8	14	9	45
Tripho	ridae	Metaxia albicephala	Epifaunal	Carnivore	0	2	1	0	3
Tripho	ridae	Metaxia brunnicephala	Epifaunal	Carnivore	0	0	5	0	5
Tripho	ridae	Metaxia spp.	Epifaunal	Carnivore	0	0	7	0	7
Turrida	ae	Microdaphne trichodes	Epifaunal	Carnivore	0	0	1	0	1
Pyrami	idellidae	Miralda paulbartschi	Parasitic	Parasitic	0	6	11	4	21
Pyrami	idellidae	Miralda scopulorum	Parasitic	Parasitic	0	19	11	4	34
Pyrami	idellidae	Miralda spp.	Parasitic	Parasitic	11	0	1	0	12
Mitrida	ae	Mitra spp.	Epifaunal	Carnivores: exclusively on sipunculids	0	0	0	0	0
Colum	bellidae	Mitrella loyaltensis	Epifaunal	Detritus	0	1	1	0	2
Colum	bellidae	Mitrella margarita	Epifaunal	Detritus	0	0	0	0	0
Colum	bellidae	Mitrella rorida	Epifaunal	Detritus	0	0	0	0	0
Colum	bellidae	Mitrella spp.	Epifaunal	Carnivore	0	1	3	2	6
Turrida	ae	Mitrolumna metula	Epifaunal	Detritus	0	1	1	1	3
Turrida	ae	Mitrolumna spp.	Epifaunal	Detritus	0	1	4	0	5
Moduli	idae	Modulus tectum	Epifaunal	Detritus	0	0	1	0	1
Thaidid	dae	Morula spp.	Epifaunal	Carnivore	0	0	1	0	1
Murici	dae	Muricidae spp.	Epifaunal	Carnivore	0	0	2	1	3
Nassar	riidae	Nassariidae spp.	Epifaunal	Carnivore	0	0	0	0	0
Naticio	lae	Naticidae spp.	Infaunal	Carnivore	0	0	0	0	0
Neritid	lae	Neritidae spp.	Epifaunal	Herbivore	0	0	0	0	0
-	idellidae	Odostomia gulicki	Parasitic	Parasitic	0	0	0	0	0
	idellidae	Odostomia stearnsiella	Parasitic	Parasitic	0	17	2	4	23
-	idellidae	Odostomia spp.	Parasitic	Parasitic	4	0	3	4	11
	gyridae	Omalogyra japonica	Epifaunal	Herbivore	0	0	8	4	12
Epiton	iidae	Opalia attenuata	Epifaunal	Carnivore	0	0	0	0	0
	stellidae	Orbitestella regina	Epifaunal	Detritus	0	3	75	7	85
	stellidae	Orbitestella spp.	Epifaunal	Detritus	7	0	7	0	14
Pyrami	idellidae	Otopleura mitralis	Parasitic	Parasitic	0	0	0	0	0

Rissoidae	Parashiela beetsi	Epifaunal	Detritus	0	7	40	3	50
Littorinidae	Peasiella tantilla	Epifaunal	Herbivore/Detritus	1	0	0	0	1
Fasciolariidae	Peristernia chlorostoma	Epifaunal	Detritus	0	2	0	3	5
Haminoeidae	Phanerophthalmus cylindricus	Epifaunal	Herbivore	0	0	0	1	1
Phenacolepadidae	Phenacolepas scobinata	Epifaunal	Herbivore	0	0	1	0	1
Architectonicidae	Philippia oxytropis	Infaunal	Carnivores	0	1	0	0	1
Planaxidae	Planaxis suturalis	Epifaunal	Herbivore	0	0	1	0	1
Cerithiidae	Plesiotrochus luteus	Epifaunal	Detritus	0	0	1	0	1
Naticidae	Polinices tumidus	Infaunal	Carnivore	0	1	0	0	1
Pupillidae	Pupillidae spp. [Terrestrial]	UNDETER	UNDETER	0	0	0	0	0
Rissoidae	Pusillina marmorata	Epifaunal	Herbivore	0	17	144	29	190
Pyramidellidae	Pyramidellidae sp. C	Parasitic	Parasitic	0	0	2	0	2
Pyramidellidae	Pyramidellidae spp.	Parasitic	Parasitic	2	0	0	0	2
Eulimidae	Pyramidelloides gracilis	Epifaunal	Parasitic	0	3	4	1	8
Eulimidae	Pyramidelloides suta	Epifaunal	Parasitic	0	0	0	0	0
Pyramidellidae	Pyrgulina oodes	Parasitic	Parasitic	0	0	0	0	0
Rissoellidae	Rissoella confusa	Epifauna	Algal/Detritus/Diatoms	0	0	0	0	0
Rissoellidae	Rissoella longispira	Epifaunal	Parasitic	0	2	0	0	2
Rissoellidae	Rissoella spp.	Epifaunal	Parasitic	0	0	25	1	26
Rissoidae	Rissoidae spp.	Epifaunal	Detritus	4	5	0	0	9
Rissoidae	Rissoina ambigua	Epifaunal	Detritus	2	22	34	34	92
Rissoidae	Rissoina cerithiiformis	Epifaunal	Herbivore	2	41	697	114	854
Rissoidae	Rissoina costata	Epifaunal	Detritus	14	13	16	11	54
Rissoidae	Rissoina imbricata	Epifaunal	Detritus	15	0	0	0	15
Cingulopsidae	Rufodardanula ponderi	Epifaunal	Detritus	0	1	3	2	6
Cingulopsidae	Rufodardanula spp.	Epifaunal	Detritus	0	0	1	1	2
Rissoidae	Sansonia kenneyi	Epifaunal	Filter	5	0	6	3	14
Scaliolidae	Scaliola spp.	Epifaunal	Detritus	1	0	1	0	2
Rissoidae	Schwartziella ephamilla	Epifaunal	Detritus	0	0	44	1	45
Rissoidae	Schwartziella triticea	Epifaunal	Detritus	0	9	32	15	56
Scissurellidae	Scissurella lamellata	Epifaunal	Herbivore	11	0	0	0	11
Scissurellidae	Scissurella pseudoequatoria	Epifaunal	Detritus	0	4	35	7	46
Scissurellidae	Scissurellidae spp.	Epifaunal	Detritus	4	0	0	0	4
Columbellidae	Seminella peasei	Epifaunal	Detritus	0	1	0	2	3
Columbellidae	Seminella smithi	Epifaunal	Detritus	0	0	0	1	1
Columbellidae	Seminella spp.	Epifaunal	Detritus	0	1	0	2	3
Vermetidae	Serpulorbis spp.	Epifaunal	Filter	0	0	0	0	0
Scissurellidae	Sinezona insignis	Epifaunal	Herbivore	0	1	21	16	38
Siphonariidae	Siphonaria normalis	Epifaunal	Herbivore	7	0	0	0	7
Rissoidae	Stosicia hiloense	Epifaunal	Detritus	0	11	19	2	32
Caecidae	Strebloceras subannulatum	Infaunal	Herbivore	21	1	1	1	24

Strombidae	Strombus spp.	Epifaunal	Herbivore	0	0	0	0	0
Dialidae	Styliferina goniochila	Infaunal	Detritus	0	1	31	3	35
Stomatellidae	Synaptocochlea concinna	Epifaunal	Herbivore	0	9	4	1	14
Pyramidellidae	Syrnola lacteola	Parasitic	Parasitic	5	0	0	0	5
Costellariidae	Thala spp.	Infaunal	Carnivore	0	0	0	0	0
Phasianellidae	Tricolia variabilis	Epifaunal	Herbivore	0	152	301	92	545
Triphoridae	Triphora coralina	Epifaunal	Carnivore	28	0	21	3	52
Triphoridae	Triphora spp.	Epifaunal	Carnivore	0	11	64	11	86
Trochidae	Trochus intextus	Epifaunal	Herbivore	2	0	9	1	12
Turbinidae	Turbo sandwicensis	Epifaunal	Herbivore	0	9	14	3	26
Pyramidellidae	Turbonilla cornelliana	Parasitic	Parasitic	0	0	0	0	0
Pyramidellidae	Turbonilla spp.	Parasitic	Parasitic	0	0	3	1	4
Turridae	Turridae spp.	Parasitic	Forage	0	2	1	1	4
Vanikoridae	Vanikoro spp.	Epifaunal	Detritus	0	4	2	3	9
Vermetidae	Vermetidae spp.	Epifaunal	Filter	0	0	1	0	1
Costellariidae	Vexillum diutenera	Epifaunal	Carnivore	0	0	0	0	0
Costellariidae	Vexillum interruptum	Epifaunal	Carnivore	0	0	0	0	0
Costellariidae	Vexillum tusum	Epifaunal	Carnivore	0	1	0	1	2
Costellariidae	Vexillum spp.	Epifaunal	Carnivore	0	0	0	1	1
Triphoridae	Viriola spp.	Epifaunal	Carnivore	0	5	10	7	22
Marginellidae	Volvarina fusiformis	Epifaunal	Carnivore	1	0	0	0	1
Marginellidae	Volvarina spp.	Epifaunal	Carnivore	0	0	0	0	0
Siphonariidae	Williamia radiata	Epifaunal	Herbivore	0	1	49	0	50
Rissoinidae	Zebina bidentata	Epifaunal	Herbivore	0	0	9	1	10
Rissoinidae	Zebina tridentata	Epifaunal	Herbivore	2	1	2	5	10
Rissoinidae	Zebina spp.	Epifaunal	Herbivore	2	0	0	0	2
Gastropoda	Gastropoda sp. A	UNDETER	UNDETER	0	3	2	6	11
Gastropoda	Gastropoda spp.	UNDETER	UNDETER	3	0	1	0	4
	POLYPLACOPHORA							
Polyplacophora	Polyplacophora spp.	Epifaunal	Herbivore	0	1	5	2	8
	Total No. of Individuals			521	970	3554	801	5846
	Total No. of Individuals/cm3			5.2	9.7	35.5	8.0	14.6
	Total No. of Taxa			66	103	138	102	176

APPENDIX 3: Numbers of individuals by species at T-1 – T-3 and Control sites, 2010.

	Pipeline			
Species	(T1)	T2	T3	Control
Acanthuridae				
A. leucopareus	1			
A. nigrofuscus	25	30	5	41
A olivaceous	7		42	
A. triostegus	24		13	
C. strigosus		17		5
Naso lituratus				1
Zebrasoma flavescens		10		
Balistidae				
Melichthys niger	1	2	1	3
Rhinecanthus rectangulus	1	1	1	1
Sufflamen bursa		1	1	1
Chaetodontidae				
C. lunula	4			
C. miliaris	3			
Forcipiger flavissimus			1	
Cirrhitidae				
Cirrites pinnulatus	1			
Paracirrhites arcatus		1	3	
Labridae				
Bodianus bilunulatus	2			2
Gomphosus varius	_	1		3
Labroides phthirophagus	2	•		ŭ
Stethojulis balteata	_			1
Thalassoma duperrey	14	3	10	28
Lutjanidae		· ·		20
Lutjanus fulvus			1	
Monacanthidae			•	
Cantherhines dumerilii	1			
Mullidae				
M. vanicolensis	40			
Parupeneus multifasciatus	2	1	14	6
P. porphyrus	1	1	17	U
Pomacentridae	Ī			
Abudefduf abdominalis	8			
Chromis hanui	O	1		
		1	4	
Coris gaimard		4	1	
P. johnstonianus		1		
Stegastes fasciolatus		1		
Scaridae		•		
Scarus juveniles		6		
Tetraodontidae			4	_
Canthigaster jactator	40-	1	1	5
Total per site	137	77	94	97
Number of species	17	15	13	12