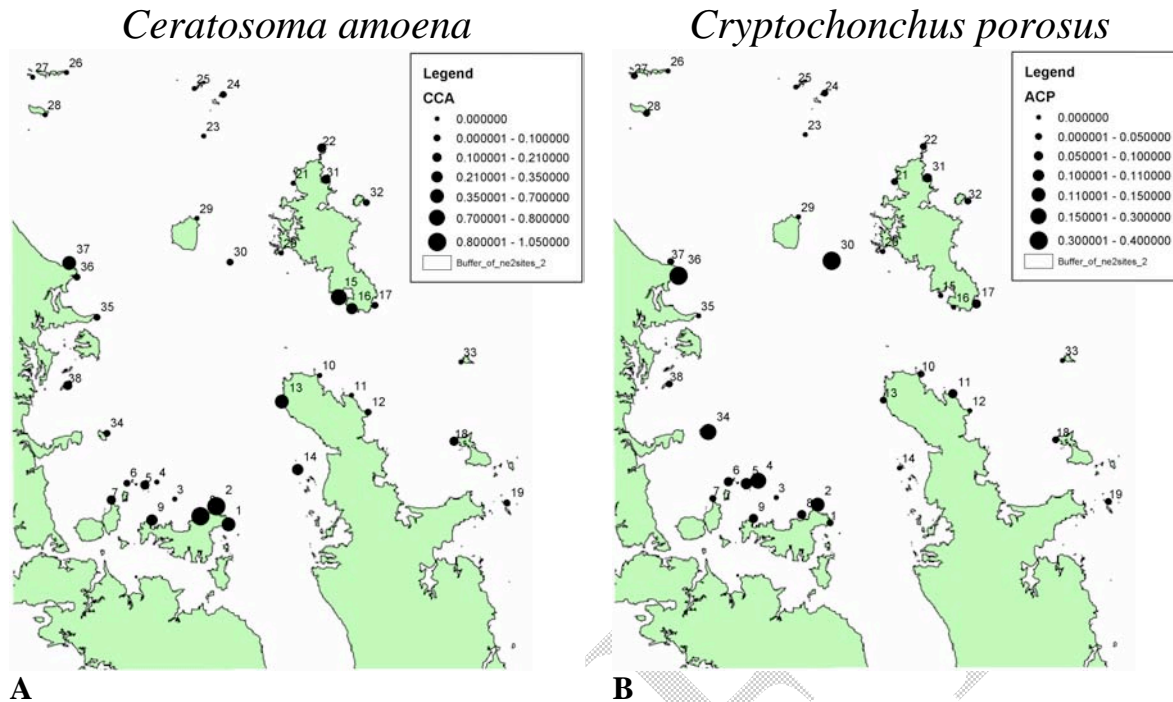


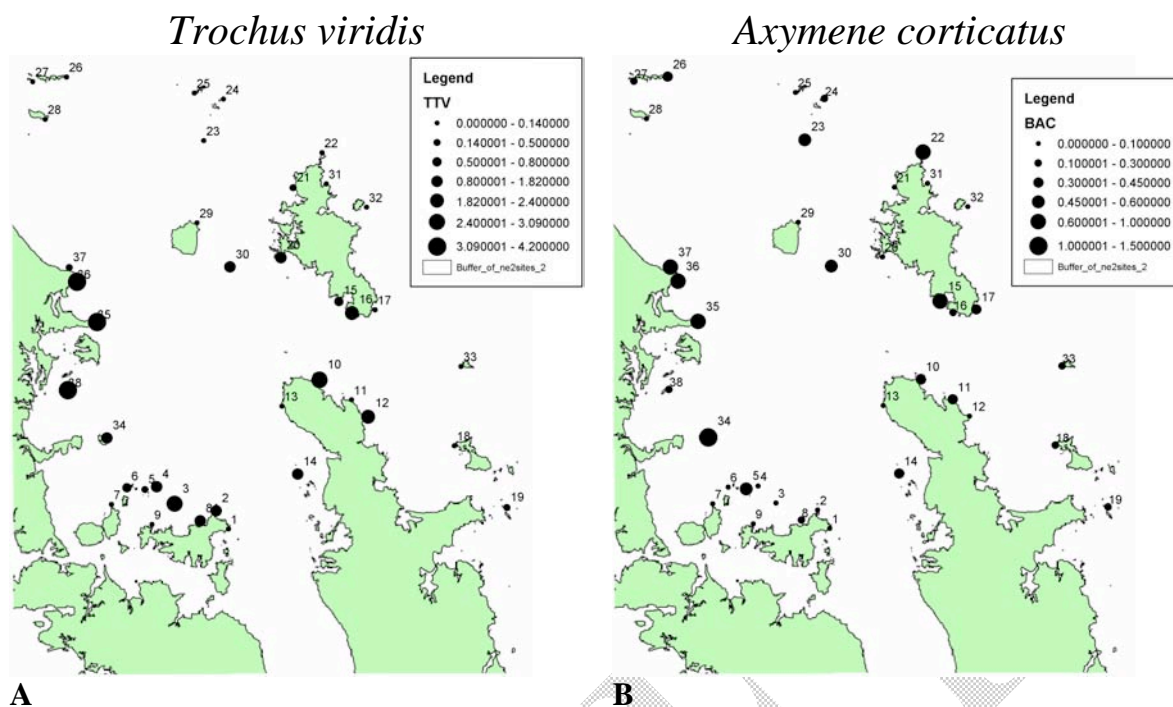
**Figure 14.** Spatial pattern of mobile invertebrate consumers (A) large hermit crabs and (B) the spotted topshell, *Calliostoma (Maurea) punctulatum*.

The clown nudibranch, *Ceratosoma amoena*, showed several isolated sites of high abundance within the Gulf but tended to have low abundance in most parts of the outer Gulf (Figure 14A). The butterfly chiton, *Cryptochonus porosus*, tended to be most abundant at inner to middle Gulf sites, with peak abundances at sites 2 (Thumb Point), 4 (Ahaaha Rock), 30 (Horn Rock), 34 (Shag Rock), and 36 (Takatu Point)(Figure 14B).



**Figure 15.** Spatial pattern of mobile invertebrate consumers (A) the clown nudibranch, *Ceratosoma amoena* and (B) the butterfly chiton, *Cryptochonchus porosus*.

*Distribution and Abundance of Small Gastropods+ Hermit Crabs.* Abundance estimates were obtained for about 14 species of small gastropods and hermit crabs that could be reliably identified. Many species were patchily distributed throughout the Gulf, however two species (*Trochus viridis* and *Axymene corticatus*) were sufficiently abundant and widespread to allow statistical modelling of relationships between physical environmental variables. The green topshell, *Trochus viridis*, had an average density of 0.95 individuals per 0.25 m<sup>2</sup> with a maximum of 4.2 individuals per 0.25 m<sup>2</sup> (i.e. site 36, the Watchman). *Trochus* tended to be most abundant in the inner Gulf and areas on the western side of Great Barrier Island (Figure 16A). Exceptions to this overall pattern occurred along the northeast Coromandel Peninsula (i.e. sites 10 and 12) and Horn Rock (site 30). The small whelk, *Axymene corticatus*, was most abundant in mid to outer areas of the Gulf, including the Leigh Coast (sites 34 to 37) and also had pockets of high abundance along the northeast Coromandel Peninsula and around Great Barrier Island (e.g. sites 15 and 22)(Figure 16B).



**Figure 16.** Spatial pattern of small gastropod abundance of (A) the green topshell, *Trochus viridis* and (B) the small whelk, *Axymene corticatus*.

*Statistical Modelling of Biological Patterns.* Multiple regression (GAM) analyses revealed a broad range of statistical relationships for the different response variables, involving different predictor variables (Table 3). Several of these relationships involved numerous predictor variables (e.g. species density, hermit crabs), while other models involved only singular variables (e.g. turnover diversity and *Fosterygerion flavonigrum*). Several of the models did not establish any relationships with the available predictor variables, including triple fins *Ruanoho whereo* and *Fosterygerion varium*, and mobile invertebrates *Ceratosoma amoena* and *Axymene corticatus* (Table 3).

Species density exhibited a positive relationship between mean depth in a 1000 m radius, a positively monotonic relationship to the mean SST, a tapering negative relationship to the monthly standard deviation of SST, and a saturating function to increasing SST annual amplitude (Appendix IVa). For the standard deviation of species density, there was a positive relationship between maximum orbital velocity (i.e. 95<sup>th</sup> percentile) and annual amplitude of SST showed a flat-lined function until about an amplitude of 3.6 and then decreased, indicating a type of threshold where sites of high amplitudes of SST had lower standard deviations of density (Appendix IVb).

Turnover diversity, measured as Routledge's  $\beta_i$  index, showed a positive relationship with increasing maximal orbital wave velocity (Appendix IVc). The observed species

richness showed similar trends to the estimated species richness (Chao 2), with relationships to mean depth within a 1000 m radius, mean SST and the monthly standard deviation of SST (Appendix IVd, e). In addition, estimated species richness also showed a positive relationship with maximal orbital wave velocity and the semi-annual amplitude of SST. It is interesting to note that the mean depth within a 1000 m radius from these two models differed slightly, with a curvilinear relationship for  $S_{\text{obs}}$  and a more rectilinear function for Chao 2, both increasing with increasing depth (Appendix IVd, e). The relationship to the standard deviation of monthly SST was a monotonic decreasing function for both models, and the relationship to seabed profile was a wavy decreasing function with increasing seabed steepness.

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**Table 3.** Summary of modelling results of the Generalised Additive Models (GAMs) for aspects of epifaunal species diversity, cryptic fishes and mobile invertebrate consumers. NS = non significant model result.

Ser	Description	Equation
1	Mean species density/0.25 m <sup>2</sup>	gam(formula = YYY\$Density ~ s(bathy.haur, 3) + s(sst.mean, 3) + s(sst.mth.std, 3) + s(sstanamp, 3))
2	Standard Deviation of species density/0.25 m <sup>2</sup>	gam(formula = YYY\$StdevD ~ s(orbv.95, 3) + s(sstanamp, 3))
3	Turnover diversity (Routledge's B <sub>1</sub> index)	gam(formula = YYY\$RoutBi ~ s(orbv.95, 3))
4	Estimated species richness (Chao 2)	gam(formula = YYY\$Chao2 ~ s(bathy.haur, 3) + s(orbv.95, 3) + s(sst.mth.std, 3) + s(sstsanamp, 3))
5	<i>Ruanoho whero</i>	NS
6	<i>Notoclinops segmentatus</i>	gam(formula = YYY\$xfmTNS ~ s(sst.mean, 3))
7	<i>Fosterygerion malcolmi</i>	gam(formula = YYY\$xfmTFM ~ s(sst.mth.std, 3) + s(sstanph, 3) + s(sstsanamp, 3))
8	<i>Fosterygerion varium</i>	NS
9	<i>Fosterygerion flavonigrum</i>	gam(formula = YYY\$xfmTFF ~ s(sst.mean, 3) + s(sst.mth.std, 3) + s(sstanamp, 3) + s(tidcurmax1, 3))
10	<i>Optivus elongatus</i>	gam(formula = YYY\$xfmTOE ~ s(sstsanamp, 3))
11	<i>Scorpaena papillosus</i>	gam(formula = YYY\$xfmSSP ~ s(sst.mean, 3) + s(sstanph, 3) + s(tidcurmax1, 3))
12	<i>Parablennius laticlavus</i>	gam(formula = YYY\$xfmBPL ~ s(orbv.95, 3) + s(sst.mean, 3))
13	<i>Fosterygerion lapillum</i>	gam(formula = YYY\$xfmTFL ~ s(sstanph, 3))
14	<i>Evechinus chloroticus</i>	gam(formula = YYY\$xfmEEC ~ s(orbv.95, 3) + s(sst.mean, 3) + s(sstanamp, 3))
15	<i>Cookia sulcata</i>	gam(formula = YYY\$xfmTCS ~ s(sstsanamp, 3))
16	<i>Dicathais orbita</i>	gam(formula = YYY\$xfmCDO ~ s(sstanamp, 3))
17	<i>Stichopus mollis</i>	gam(formula = YYY\$xfmSSM ~ s(sstsanamp, 3))
18	Paguridae (Hermit crabs)	gam(formula = YYY\$xfmPHC ~ s(sst.mean, 3))
19	<i>Maurea punctulata</i>	gam(formula = YYY\$xfmTMP ~ s(sstsanamp, 3))
20	<i>Ceratosoma amoena</i>	NS
21	<i>Cryptochonchus porosus</i>	gam(formula = YYY\$xfmACP ~ s(sst.mth.std, 3))
22	<i>Trochus viridis</i>	gam(formula = YYY\$xfmTTV ~ s(orbv.95, 3) + s(sst.mth.std, 3) + s(sstsanamp, 3))
23	<i>Axymene corticatus</i>	NS

Statistical models for the cryptic fishes ranged from complex relationships between multiple factors (e.g. *Fosterygerion malcolmi*) to simple monotonic relationships with a single key factor (e.g. *Notoclinops lapillum*)(Table 3). Two species of fish revealed non-significant relationships, including the spectacled triplefin *Ruanoho whero* and the variable triplefin

*Fosterygion varium* (Table 3). The blue-eyed triplefin, *Notoclinops segmentatus*, showed a significant relationship to mean SST as a near-linear increasing trend (Appendix IVf). The mottled triplefin, *Fosterygion malcolmi*, showed relationships with several variables, including a curvilinear relationship with the monthly standard deviation of SST, SST annual phase and SST annual amplitude (Appendix IVg). The relationship of physical environmental variables and the abundance of *Fosterygion flavonigrum* showed a near-linear positive relationship to mean SST, a decreasing function of monthly standard deviation of SST, an increasing curvilinear relationship to SST annual amplitude, and a decreasing function of maximum tidal current (Appendix IVh).

The slender roughy, *Optivus elongatus*, showed a non-linear decreasing function of SST semi-annual amplitude, where annual amplitudes greater than 0.25 showed the lowest abundance (Appendix IVi). The scorpion fish, *Scorpaena papillosus*, showed relationships with three physical factors, including mean SST, SST annual phase, and maximum tidal current (Table 3). Areas with maximum tidal currents higher than  $0.4 \text{ m}\cdot\text{s}^{-1}$  had higher abundance for *S. papillosus* (Appendix IVj). *Parablennius laticlavus* showed a relationship to maximum orbital velocity and mean SST, where the mean SST was a positive increasing relationship, with a sharp increase in temperatures above  $17.4^\circ \text{C}$  (Appendix IVk). Maximum orbital velocities had considerable error with values beyond  $50 \text{ cm}\cdot\text{s}^{-1}$ , most likely due to few observations beyond this point.

Statistical modelling indicated that the abundance of the sea urchin *Evechinus chloroticus* was associated with extreme orbital velocity, mean SST, and SST annual amplitude (Table 3). Urchin abundance tended to be related to these factors in a non-linear fashion, with an increasing function of extreme orbital velocity to about  $50 \text{ cm}\cdot\text{s}^{-1}$  where it decreases steadily (Appendix IVl). The relationship with SST statistics also showed curvilinear relationships, with an increasing function at temperatures  $> 17.2^\circ \text{C}$  and a decreasing function from 3.0 to  $3.2^\circ \text{C}$  annual amplitude. The abundance of *Cookia*, hermit crabs, and *Cryptochonchus* showed relationships to aspects of SST, including the semi-annual amplitude, mean, and monthly standard deviation, respectively (Table 3). The abundance of *Cookia sulcata* also decreased as a linear function of the semi-annual amplitude of SST, suggesting that this species was associated with more stable oceanographic conditions within the Gulf (Appendix IVm).

*Dicathais orbita* showed a relationship with only one physical environmental variable, the annual amplitude of SST (Table 3). This pattern was curvilinear, with a positive relationship to *Dicathais* abundance which tapering off and SST annual amplitude values of

about 3.7 °C, which then decreased (Appendix IVn). Patterns for the sea cucumber, *Stichopus mollis*, also showed a relationship to only one physical environmental factor, the semi-annual amplitude of SST (Table 3). This pattern showed a nearly flat relationship to semi-annual amplitudes of about 0.35 °C, where the pattern becomes positive, with a relatively large increase in the predicted abundance of *Stichopus* (Appendix IVo).

Statistical relationships between large hermit crabs and physical environmental factors showed only one variable, mean SST, to be associated with hermit crab abundance (Table 3). This relationship was negative, tapering off at temperatures of about 17.4 °C (Appendix IVp). *Calliostoma (Maurea) punctulata* also showed a relationship to a single physical environmental variable, the semi-annual amplitude of SST (Table 3), which was characterised by a curvilinear relationship, increasing to about 0.27 °C and then decreasing to about 0.35 °C (Appendix IVq). Abundance of the butterfly chiton, *Cryptochonchus porosus*, showed a statistical relationship to the monthly standard deviation of SST (Table 3). This relationship was curvilinear, characterised by a decreasing function to about 0.56 °C and then increasing slightly to about 0.64 °C (Appendix IVr). *Trochus viridis* abundance was related to three physical environmental variables, including extreme wave orbital velocity, the monthly standard deviation of SST and the semi-annual amplitude of SST (Table 3). The relationship between extreme orbital velocity was a strong negative function which levelled off at about 50 cm·s<sup>-1</sup>; SST monthly standard deviation was decreasing to about 0.58 °C and then increased; and SST semi-annual amplitude was a decreasing linear function (Appendix IVs).

## Discussion

*Patterns of Rocky Reef Epifaunal Diversity.* Patterns of rocky reef epifaunal species diversity showed a general trend of increasing species density and richness from inner to outer Gulf (Figures 3, 4 and 5). For species density (i.e. number of species per 0.25 m<sup>2</sup> quadrat), there was an average of approximately 11.7 species per 0.25 m<sup>2</sup> for inner Gulf sites, while there was approximately 15.5 species per 0.25 m<sup>2</sup> in outer Gulf. This represents approximately 25% higher species density at sites in the outer Gulf. As species interactions, such as spatial competition, are likely to be important at high species densities, it is likely that the species assemblages in outer Gulf areas represent more interactive communities. If inner Gulf assemblages are less interactive, it is likely that these species assemblages may be more reliant on regional scale, rather than local scale, processes (Cornell and Lawton 1992).

The variation of species density, an indicator of the patchiness of the species assemblages, did not show a clear pattern from inner to outer Gulf (Figures 3A). The lack of

clear spatial trend may reflect local variation in topography and substrate characteristics. For example, site 13 (Fantail Bay) and site 25 (Stack “H”) were characterised by highly irregular topography and high variation in species density. The variation of species density may also be influenced by larger-scale disturbance regimes. The particularly low variation at site 17 (Rosalie Bay) may have been due to the high density of sea urchins at that site (Figure 11A). Such relationships between the abundance of key consumers (e.g. such as sea urchins) may account for some of the observed variation in species diversity as well as aspects of the physical environment.

Measures of species turnover, calculated as Routledge’s  $\beta_1$ , showed a tendency for lower turnover at inner Gulf sites (mean = 0.75) and higher turnover at outer Gulf sites (mean = 0.80)(Figure 4B and 6A). This pattern was, however, highly variable with some sites, such as sites on the northeast tip of Coromandel Peninsula (sites 10 – 12), showing regional peaks in turnover diversity. There were two extreme outliers in terms of their turnover diversity. Stack “H” in the Mokohinaus (site 25) had a  $\beta_1$  of 1.39, and the site within the Leigh Marine Reserve (i.e. site 37) had a  $\beta_1$  of 0.03. In terms of the differences between quadrats at those sites, this means that there was extreme variation in the community composition at the quadrat level at Stack “H”, and the composition at Goat Island was extremely low. Although the multiregression analysis only identified one physical variable related to this pattern (i.e. extreme orbital velocity), it is difficult to explain the observed difference between these two sites solely in terms of wave exposure. As the information on the variation of species density suggests that there is substantial heterogeneity in the number of species per quadrat, the complimentary information from the  $\beta_1$  index also indicates that the individual patches are also of distinct community composition. Understanding the relationship between turnover diversity and biological factors (e.g. such as the abundance of key consumers) may help in better understanding these patterns, rather than interpreting differences in turnover diversity or species composition based on physical processes alone.

Observed species richness and the Chao 2 species richness estimator showed similar patterns, with a considerable increase in richness moving from inner to outer Gulf sites (Figure 4C). There is an estimated 29 - 36 % difference in the number of species from inner to outer Gulf sites, with the largest changes observed between site 38 (Motuora Island) and site 35 (Takatu Point) on the western edge of the Gulf and between site 13 (Fantail Bay) and site 10 (Poley Bay) on the Coromandel side of the Peninsula (Figure 5). As previously noted, Rosalie Bay (site 17) on the eastern side of Great Barrier Island had comparatively low species richness and thought to be related to the density of sea urchins (*Evechinus*



*chloroticus*). Rosalie Bay may be representative of many reef sites along the east coast of Great Barrier Island, from the southern-most tip at least to Arid (Rakitu) Island (Mick & John Ellwood, *pers. comm.*). However, further investigation is required in order to confirm this pattern.

The compositional changes in the epifaunal assemblages that accompany these changes in diversity indicate that the inner Gulf reefs are dominated by encrusting sponges and the tubeworm “*Chaetopteros*”, with few cnidarians (i.e. hydroids and anemones)(Appendix I). At inner Gulf sites, there was a considerable amount of sediment present on the reefs, in particular those with “*Chaetopteros*” aggregations. How sediment cover in these areas influences the epifaunal communities should be assessed. In contrast to the majority of inner Gulf sites, outer Gulf reefs were dominated by encrusting and massive sponges, many species of cnidarians, ascidians and bryozoans. There were several inner Gulf sites that have a significant number of sponge species, for example at Billy Goat Point (site 7) and Fantail Bay Reef (site 13). Strong tidal currents may increase growth and survivorship of suspension-feeders (e.g. Lesser, et al. 1994, Ginn, et al. 2000), however the general absence of these assemblages in the vicinity of Waiheke Island suggests that other factors, such as larval supply, may be important for determining their distribution and abundance.

The contribution of rare species to the total average richness of reefs indicates that between 36.3 and 46.2% of the total species richness was made up of rare species (i.e. the sum of species that were observed once or twice along a transect). Patterns of rarity across the Hauraki Gulf showed a trend of increasing rarity from inner to outer Gulf. Reefs with the highest number of rare species, site 10 (Poley Bay), site 15 (Tryphena Harbour) and site 16 (Dolphin Bay), suggest that areas near the constriction at Colville Channel, between the Coromandel Peninsula and the southern tip of Great Barrier Island, are of special character within the region. In the inner reaches of the Hauraki Gulf, there was constantly low numbers of rare species, compared to areas in the outer Gulf. Fantail Bay (site 13) was the only exception to this pattern, with a larger number of rare species. There is a certain amount of heterogeneity with respect to the number of rare species occurring on reefs in the outer Gulf, with most sites having comparatively higher numbers of rare species and some areas with considerably lower numbers of rare species (e.g. site 17 (Rosalie Bay)). However, as expressed as a percentage total of species present, it appears the species complement is made up of a similar percentage of rare species. For example, Rosalie Bay (site 17) and Dolphin Bay (site 16) have large differences in the number of species (16 vs. 49  $S_{obs}$  respectively), but they have a similar percentage total of rare species (49 vs. 56% of  $S_{obs}$  respectively). This

suggests that similar physical structuring agents at these sites may influence the percentage of rare species at these sites, while biological processes at these sites may influence the total number of species present. Further modelling of the relationships between physical and biological patterns at these sites is likely to provide insight into these alternative hypotheses.

Overall, the high percentage of the total epifaunal diversity of rocky reefs represented by few individuals (or individual colonies) has implications for the viability or reproductive success of populations at individual reef sites. Many of these sessile epifaunal organisms are characterised by relatively short-lived larvae, including sponges (Bergquist 1978, Ayling 1980), ascidians (Olson 1985, Grosberg 1987), bryozoans (Ryland 1970), solitary corals (Gerrodette 1981), soft corals (Sebens 1986), and serpulid polychaetes (Keough and Downes 1982). Low population abundance of species at individual reef sites may potentially influence the susceptibility of populations to local extinction, whether caused by natural or human-induced impacts. Studies of life history traits and reproductive output of these organisms would provide valuable information regarding critical population sizes required to maintain populations within and among rocky reefs. The relative extent to which these sites are hydrographically connected may also have implications for population processes of rare species among reef localities. Additional information on the age and growth of these organisms may provide other information pertaining to the relative success of colonisation and fitness parameters for individual reef sites. Understanding the potential causes for the rarity and the potential influence of low abundance on the survivorship of these epifaunal organisms requires further study.

*Patterns of Cryptic Fish Abundance.* The abundance of cryptic reef fish showed several different patterns with respect to location within the Hauraki Gulf. Some species, such as the yellow-black triplefin, *Fosterygion flavonigrum*, and the crested blenny, *Parablennius laticlavus*, showed lower abundances at sites within the Gulf and higher relative abundances in the outer Gulf (Figure 8A, 9B). Other species, such as the common triplefin, *Fosterygion lapillum*, showed their highest abundance at inner Gulf sites, while outer Gulf sites were of low abundance (Figure 10). Other species, such as the spectacled triplefin, *Ruanoho whero*, and blue-eyed triplefin, *Notoclinops segmentatus*, showed highly variable abundances at sites throughout the Gulf (Figure 6). The distribution of the latter species contrasts with species that appear to have localised areas of high abundance, such as the slender roughy, *Optivus elongatus*, and the scorpion fish, *Scorpaena papillosus* (Figure 8B, 9A). These contrasting patterns suggest that certain species of cryptic fishes may be useful indicators of different

physical environmental conditions. As there is little previous information on the distribution and abundance of these species throughout the Gulf, it is uncertain to what extent these patterns are consistent in time, and for which species. Further investigation is required to understand the factors that cause and, potentially, maintain populations of species that show localised areas of high abundance, such as the scorpion fish, *Scorpaena papillosus* (Figure 9A). Although the statistical modelling provides some insight into the physical conditions at those sites, whether or not those factors are responsible for causing the pattern requires further validation work (see discussion below). Interpretation of these results should also consider trophic relationships of these species and potential behavioural influences (e.g. habitat selectivity or territoriality) on these patterns. Linkages between the information from the benthic quadrats, and potentially, macroinvertebrate abundance at sites may also explain some of the observed variation in cryptic fish abundance.

*Patterns of Mobile Invertebrate Consumers.* The abundance of mobile invertebrate consumers also showed several different spatial patterns. The abundance of species such as the sea urchin, *Evechinus chloroticus*, showed a clear trend of low numbers within the Gulf and higher numbers at sites in the outer Gulf (Figure 11A). In contrast, species such as the sea cucumber, *Stichopus mollis* - a deposit feeder, showed an opposite trend of higher relative abundances within the Gulf and lower abundances in regions of the outer Gulf (Figure 12B). Other species showed more variable spatial distributions. For example, *Calliostoma (M.) punctulatum*, had isolated sites of high abundance in the inner Gulf and outer Gulf regions (Figure 13B). As with the cryptic fishes, benthic invertebrate species with distinct distribution patterns suggest that these species may be useful indicators of physical environmental conditions.

The collection of small gastropods and hermit crabs provided an additional data set that could be compared with that for the larger mobile consumers. The pattern of *Trochus viridis*, a generally common and widespread grazer, showed particularly low abundances at offshore islands, from Rodney Point, Little Barrier Island and the northern areas of Great Barrier Island (Figure 15A). There were several sites on the eastern side of the Coromandel Peninsula (sites 10 and 12) that had a relatively high abundance of *Trochus*. The small predatory whelk, *Axymene corticatus*, showed a much more variable distribution throughout the Gulf, with a region of relatively high abundance along the shoreline north of Auckland and at several sites around Great Barrier Island (Figure 15B). Although information on the distribution of these smaller invertebrates in the shallow subtidal is lacking for much of the

New Zealand coastline, establishing relationships to physical environmental variables of the Marine Environment Classification provides a valuable predictive tool for understanding their broader geographic distributions. As these data and the relationship to physical factors relate to depths at approximately 15 m depth, how these patterns may change across a depth gradient should also be considered in any future development of this work.

*Statistical Modelling Aspects.* Statistical modelling of community-level parameters of the suspension-feeding sessile invertebrate communities showed that aspects of the mean and variation of Sea Surface Temperature (SST), and aspects of bottom topography were related to patterns of species diversity (Table 3). Species density and estimated species richness (i.e. Chao 2) showed complex relationships to predictor variables, including opposing near-linear trends with SST statistics and wave exposure (Appendix IVe). The curvilinear relationship between the Chao 2 index and water depth in the vicinity of the sampling site indicated a flat trend from 10 to approximately 25 m depth, where it then increases as a linear trend to approximately 60 m depth. This non-linear relationship between species richness and the depth proximal to the sampling site (i.e. within 1000 m) suggests that there may be a switch in ecological conditions at approximately 25 m depth. Being able to verify these relationships could help establish a useful environmental indicator. For example, the possibility of enhanced larval supply from deeper areas to shallow subtidal reefs where areas deeper than 25 m are in proximity could be one possible mechanism. Such reefs may therefore have different dynamics of species recruitment rates and may be more resilient to disturbance.

Overall, this implies that in terms of the physical environmental variables associated with patterns of epifaunal diversity, the multiregression analysis selected factors that are generally smoothly varying variables throughout the Hauraki Gulf. Aspects of bottom topography are mostly a trend associated with the coastline, although there is also a broad topographic trend from the inner to outer Gulf (Hadfield, et al. 2002). Even though the confidence bands surrounding the smooth functions of the GAM are reasonably small, there are regions of the regression where the confidence bands are considerably wider. This error in the regression may be associated with high variance within the biological patterns, or, alternatively, this could be associated with errors in the physical environmental layers at sampling locations. For example, there can be considerable variation associated with SST statistics derived from satellite imagery near the coast, islands and finer scale reef formations that were sampled during the survey not may be well represented in the coverage of this layer.

Alternatively, these smaller features may also not be well resolved at a grid cell size of 250 m, which may also account for broader confidence bands associated with levels of diversity.

There were a number of contrasting physical variables that were selected for cryptic fishes. For example, *Parablennius laticlavus* abundance was related to extreme orbital velocity and mean SST, while *Fosterygion flavonigrum* abundance was related to a combination of four SST variables and maximum tidal current velocity (Table 3, Appendix IVh, k). These contrasting relationships imply that individual species within this assemblage are responding differently to the same suite of physical environmental factors. It is also important to note that the statistical models were based on the relative abundance, rather than the presence or absence of a species at a given site. As modelling results may differ with the use of presence-absence data only, it would be useful to distinguish between environmental factors which restrict a species from occurring at a site and those which influence the overall abundance. Additional tests for understanding the relationships between physical environmental parameters and overall patterns of community structure would also be valuable information to better understand the most relevant physical environmental variables.

It should be stressed that although the statistical relationships established with the multiregression (GAMs) analysis can provide insight into how species abundances are related to the physical conditions at those sites, it remains an open question as to whether or not those factors are actually responsible for causing the pattern. There are several reasons why it is necessary to separate the *causal* factors and those that are spatially related. Firstly, in Hutchinson's formulation of the niche concept there was a distinction between a species' fundamental niche and its realised niche (Pulliam 1988). That is, although the conditions may be adequate for a species to establish viable populations, there are other factors that may prevent a species from occurring at such a locale (i.e. realised niche is smaller than its fundamental niche). There is also evidence that species may also occur where they are not able to establish viable populations (i.e. in the case of sink habitats, where the species' fundamental niche is smaller than its realised niche (Pulliam 1988)). Additional research is required to establish causal relationships. This may potentially involve ecological experiments with the collection of physical data at the local level. These types of studies are required before the physical factors indicated in this report can be confirmed as the agents creating and/or maintaining the observed patterns in species distribution and abundance.

The summary of the physical variables that are related to aspects of the distribution and abundance of species, indicate that there is much variation, both in terms of the number and combination, of the final selection of physical variables (Table 3). One method of

providing a summary of the importance of variables would be to tabulate them and place them in rank order (e.g. Image, et al. 2003). A collective analysis between the different variables representing community and species-levels of biological organisation for rocky reefs and those aspects of finfish, plankton, and soft-sediment assemblages would further support the selection of physical environmental variables that make up the final classification.

*Spatial Predictions.* The relationships established from the multiregression analyses can be used to map predicted patterns of species distribution and abundance in geographic space. These predictive surfaces can be used as a tool to identify potential overlap in species distribution or sensitive areas for management purposes. Although these predictions can be mapped as a continuous surface across the Hauraki Gulf, the predictions only pertain to areas of rocky reef in the shallow subtidal at approximately 15 m depth. As the habitat or depth changes, it is likely that the nature of the statistical relationship also changes, although it is yet to be determined the extent to which these predictions correspond to observed patterns in other habitats or depths. It should also be noted that because the spatial extent of the physical layers excluded some offshore areas (such as outer Great Barrier Island and Coromandel Peninsula), biological information from those sites has not contributed to the modelling results. As these sites potentially represent one end of a gradient in physical conditions, the inclusion of those sites in the multiregression analysis may have made an important contribution to the outcome of the statistical modelling. Whether or not the physical information for the Hauraki Gulf can be extended to include these (and potentially other sites) in the region should be assessed. Alternatively, it may be possible to use some of the physical information available at the 1 km scale for modelling purposes, although this would require additional consideration and interpretation of the outcomes.

Modelled patterns of species density of epifaunal invertebrates indicated that areas in the outer Gulf had the highest density (Appendix Va). Areas where high species density predictions intersect the coast include outer Great Barrier and Little Barrier Islands. In the inner Gulf, predicted species density showed pockets of relatively low species density, around Waiheke Island, in the Firth of Thames and the western side of the Coromandel Peninsula (Appendix Va). As there was little rocky reef habitat found at 15 m in these areas, it is uncertain if these predictions are accurate. The predictions for the variation of species density of epifaunal invertebrates showed a pattern of relatively low variation in the innermost reaches of the Gulf, while areas past Waiheke Island and north Auckland have relatively high variation (Appendix Vb). Again, as there was little rocky reef habitat in those regions, it is

difficult to know how these predictions reflect actual biological patterns. The ability to be able to delimit rocky reef habitats in future modelling would be advantageous.

Patterns of predicted species richness of epifaunal invertebrates indicated higher richness near the coastal fringe and lower richness in deeper regions and regions in the inner Firth of Thames (Appendix Vc). Predicted areas of high species richness included the coastal fringe of Great Barrier Island, Little Barrier Island, the Coromandel Peninsula, and areas around Leigh. It is interesting to note that the region around Waiheke Island was also identified as having relatively high species richness (Appendix Vc). Predicted abundance for the spectacled triplefin, *Ruanoho whero*, indicated a pattern of lower predicted abundance near the coastal fringe of offshore islands and areas of the outer Gulf, with higher predicted densities in deeper regions and areas of the inner Gulf (Appendix Vd). As predictions are not likely to be valid beyond the 20 m depth contour, the areas where these contours of high abundance intersect the coastal fringe, such as areas around Great Barrier Island, are more likely to be closer to observed densities in the field.

Predicted abundance of the blue-eyed triplefin, *Notoclinops segmentatus*, showed a similar pattern to *Ruanoho whero* (Appendix Ve), with lower predicted abundance in the offshore island groups (e.g. Hen & Chickens, Mokohinaus, and Little Barrier) and coastal headlands (e.g. north tip of the Coromandel Peninsula, northeast tip of Waiheke Island and Cape Rodney), and higher abundance in deeper areas away from the coastal fringe (Appendix Ve). There are areas where higher predicted abundance intersects the coastal fringe, including areas around Great Barrier Island and the east coast of the Coromandel Peninsula. In contrast, the predicted abundance of the mottled triplefin, *Fosterygion malcolmi*, showed a smooth gradient with lower predicted abundance in the inner Gulf region and higher abundance in the outer Gulf (Appendix Vf). It is interesting to note that the predicted contours of high density extend to the lower reaches of the western edge of the Coromandel Peninsula, south to Deadman's Point, while on the opposite side of the Gulf, the predicted contours of high density do not extend much further beyond Takatu Point. There is also a region in the northern portion of Waiheke Island that is predicted to have higher relative abundance than surrounding areas (Appendix Vf).

The predicted abundance of the yellow-black triplefin, *Fosterygion flavonigrum*, showed a gradient with lower abundance in inner gulf regions and generally higher abundance in outer Gulf regions, particularly surrounding the Mokohinaus, Little Barrier, and the northern region of Great Barrier Island (Appendix Vg). There are several deviations to this pattern, with a lower predicted abundance along the western edge of the Coromandel

Peninsula, and areas of relatively lower abundance on the western edge of Great Barrier Island. The northern region of Waiheke Island, the region around Deadman's Point and the northern tip of the Coromandel Peninsula are predicted to have a relatively higher abundance of *Fosterygion flavonigrum* than surrounding areas (Appendix Vg). The predicted abundance of the slender urchin, *Optivus elongatus*, showed a peak in abundance towards the centre of the Gulf, with areas of higher relative abundance surrounding the coastal fringe of Great Barrier, the northern tip of the Coromandel Peninsula, areas near Takatu Point and Deadman's Point (Appendix Vh). As the predictions for this species are not likely to be valid for the areas away from the coastal fringe, it is unlikely that the predicted abundance of *Optivus elongatus* in the centre of the Gulf is accurate. Places where these contours intersect the coast are likely to provide the most accurate prediction for its abundance.

The statistical modelling for the scorpion fish, *Scorpaena papillosus*, indicated a general trend of decreasing abundance from inner to outer Gulf regions, with deviations to this pattern in the areas of the offshore islands, the northern region of the Coromandel Peninsula and Great Barrier Island (Appendix Vi). There appears to be a general tendency for relatively lower abundance in the south or southwest sides of islands, such as Waiheke and Little Barrier Island. The spatial predictions for the crested blenny, *Parablennius laticlavus*, showed a pattern of low densities in areas of the inner Gulf, Firth of Thames and south of Waiheke Island, and relatively low abundance around the northern tip of Great Barrier Island, Mokohinaus and Hen & Chickens (Appendix Vj). The region of highest abundance tended to occur along the western edge of the Coromandel Peninsula, the northern tip of Waiheke Island and Takatu Point.

Predicted distributions of the sea urchin, *Evechinus chloroticus*, showed a general trend of decreasing abundance with increasing distance offshore (Appendix Vk). Areas such as the northern tip of Great Barrier Island, the Hen & Chickens, and areas around Little Barrier Island had relatively higher abundances predicted along the coastal fringe (Appendix Vk). The spatial predictions for the abundance of Cook's turbin, *Cookia sulcata*, showed a general trend of decreasing abundance from inner to outer Gulf, with areas of predicted high abundance in the northern tip of Waiheke Island, Cape Rodney and Takatu Point, and the western and northern tip of the Coromandel Peninsula (Appendix Vl). Offshore islands in the north were also predicted to have higher abundance of *Cookia sulcata* (Appendix Vl).

Predicted abundance for the ribbed rock shell, *Dicathais orbita*, showed a trend of decreasing abundance from inner to outer Gulf with areas of high abundance around the offshore islands (e.g. the Hen & Chickens, Mokohinaus, Little Barrier Island and around



Great Barrier Island (Appendix Vm)). Predictions for the abundance of the sea cucumber, *Stichopus mollis*, showed a general trend of decreasing abundance from inner to outer Gulf (Appendix Vn). The model also predicted relatively lower abundance in the region surrounding and north of Waiheke, in the vicinity of the Noises and rock islands towards the Port of Auckland, the area west of the Coromandel Peninsula, and the area surrounding Cape Rodney and Takatu Point (Appendix Vn). The highest predicted abundances for *Stichopus mollis* occurred in embayments and shallow water areas of the Firth where there was no empirical sampling.

The predicted abundance of large hermit crabs showed a pattern of generally high abundance throughout the Gulf, with areas of particularly low abundance in the vicinity of rock stacks and areas along the northern tip of the Coromandel Peninsula and Waiheke Island (Appendix Vo). The pattern of predicted abundance also shows the area north of Cape Rodney as also having relatively low abundance of hermit crabs. Predicted abundance of *Calliostoma (Maurea) punctulatum* showed a pattern of generally high abundance throughout the Gulf, with areas of relatively lower abundance in the southwest coast of Great Barrier Island, Takatu Point, and shallow embayments and the Firth of Thames (Appendix Vp). Predicted areas of relatively high abundance for *Calliostoma (M.) punctulatum* include the region surrounding the eastern and northern portion of Great Barrier Island, to the south of the tip of the Coromandel Peninsula, and a region surrounding Waiheke Island (Appendix Vp).

Spatial predictions for the abundance of the butterfly chiton, *Cryptoconchus porosus*, showed relatively low abundance throughout the Gulf, with the exception of the outer region of Great Barrier Island (Appendix Vq). The predictions for *Trochus viridis* showed areas of high abundance towards areas of the outer Gulf, particularly around Great Barrier Island, northern tip of the Coromandel Peninsula, and around Takatu Point (Appendix Vr). Areas in the inner Gulf, particularly in the vicinity of Waiheke Island and coastal embayments show relatively lower predicted abundance. There is one area of the Firth of Thames that also has a relatively higher predicted abundance, however as there was little rocky reef habitat found in these areas, these predictions are likely not to apply to this area of the Gulf.

Although the spatial predictions provide a valuable tool in order to visualise general tendencies in the distribution and abundance of species throughout the Hauraki Gulf and can have numerous applications for planning and management, it is important to validate the robustness of these patterns and the accuracy of the predictions. The correlation between predicted and observed abundance and species distributions can be made through an independent ground-truthing of the spatial patterns by surveying a number of new sites. This

not only provides the base information to validate the predictions, but the additional information can also be incorporated into the overall dataset and improve the predictive models.

### **General Summary and Recommendations**

Patterns of epifaunal species density and richness showed a tendency for higher numbers of species in outer Gulf regions, and these patterns were related to aspects of Sea Surface Temperature (SST) and bottom topography. Spatial predictions of these modelling results showed that areas surrounding the Coromandel Peninsula and Great Barrier Island are of relatively higher epifaunal species abundance. Turnover diversity of the epifaunal assemblages did not show any clear spatial trends and was significantly related to maximum orbital wave velocity. Several sites included in the surveys could not be included in the statistical modelling due to falling outside of the environmental grids. These sites may have contributed to the outcome of the modelling, as they potentially represent extremes in the environmental gradient across the Gulf.

Patterns of small benthic fishes, such as triplefins and blennies, and mobile invertebrate consumers, such as sea urchins and gastropods, showed several contrasting spatial patterns across the Hauraki Gulf. Some species showed a tendency for higher relative abundance within inner Gulf sites, with others showing higher relative abundance in outer Gulf sites. These species abundance patterns tended to have statistical relationships with smoothly varying environmental factors, such as SST, while others were more closely related to depth and aspects of bottom topography that vary over shorter spatial extents. Other species showed more localised patterns of high abundance, particularly in the area of the north tip of the Coromandel Peninsula and Great Barrier Island. These species showed a relationship to a variety of physical environmental factors, such as tidal currents, orbital velocity, and aspects of bottom topography. Spatial predictions largely reflect the tendency revealed in the abundance, with some indication of areas of higher relative abundance than surrounding areas. Great Barrier Island, the northern tip of the Coromandel and the Leigh coastline are regions where there was a confluence of abundance patterns for numerous species.

Several aspects of this work could be developed in terms of fine-tuning the statistical models and an exploration into the interaction between biological and physical environmental factors. Ground-truthing of the spatial predictions would also provide a means to assess the utility of the physical layers to predict biological pattern, and this exercise can also provide

new information that can be incorporated to improve the statistical models. Understanding the uncertainties associated with the base physical layers and the error associated with the statistical models would enable better interpretation of the modelling outcomes. A compilation of these modelling results with aspects of the planktonic, soft sediment and fish assemblages conducted by NIWA would also provide a more holistic overview of the structure and function of the Hauraki Gulf system and its relation to the physical environmental parameters. It will be important to consider these aspects when trailing the utility of the Marine Environment Classification for different management applications.

### **Acknowledgements**

Many thanks are extended to the captain and crew of the M.V. *Whai* (Mick and John Ellwood) for their support and sharing with their experiences in the Gulf. Dulcie Ellwood (Marine Adventures Ltd., Whitianga) assisted in logistical organisation the preparation for the trip. Lindsay Chadderton, Clinton Duffy and Leane Makey (DoC, Northern Regional Office), Megan Graeme (Natural Solutions, Coromandel), and Shane Kelly (Auckland Regional Council) assisted in the collection of additional biological data along the transects and warrant a special mention for their efforts. Auckland Conservancy also provided additional vessel support required for this work aboard the MV *Hauturu*. Fanny Lariviere, Critchlow Associates, helped with producing the predictive maps used in this report. Work associated with the development of the physical environmental layers and extractions from NIWA, Christchurch should also be acknowledged, including Ton Snelder, Mark Weatherhead, Keri Niven and Katie Image. This work was funded out of the Marine Environment Classification project (3443) of the Department of Conservation, Science & Research Division.

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## Appendix I. General Site Descriptions

- (1) Kauri Point, East Waiheke Island. Topography consisted of a short reef terrace located near the centre of the channel, transect running on the east-facing wall. Epifauna characterised by *Ostrea*-type bivalves, large massive and encrusting sponges (e.g. *Ancornia*, *Cliona*), and few bryozoans (e.g. ?*Galeopsis*). Rocks slightly fouled with sediment. The top of the reef covered with sparse *Ecklonia* forest. Current quite strong at the surface, but more sheltered towards the reef. Reef bottom at approximately 17 m with gently sloping, coarse sandy bottom.
- (2) Thumb Point, North Waiheke Island. Transect was placed along the northeast end of the reef, in between two reef spurs separated by a sand channel. Reef top covered with thick *Ecklonia*, some *Sargassum* and *Carpophyllum*. Substrate covered with some flocculent and sediment. Epifauna consisted of sparse bryozoans and sponges.
- (3) D'Urville Rock. Shattered rock reef covered in thick sediment, transect running on the south-facing edge. Few sponges and solitary ascidians (*Cnemidocarpa*) and many *Chaetopterous* aggregations along exposed rock faces and embedded in sediment. Sparse *Ecklonia* were present with some *Sargassum*/*Carpophyllum*. Contours gently sloping to approximately 12 m where it becomes steeper. At 24 m, it becomes gently sloping again to a sediment plain. There are isolated rocks throughout.
- (4) Ahaaha Rock. Transect running along the south-facing edge. Site covered in very heavy flocculents and sediment. Reef broken and separated by sand channels, fouled by monofilament. Epifauna consisted of few bryozoans, solitary ascidians (blue *Pyura*), and some erect sponges (e.g. *Axinella*).
- (5) David Rocks, the Noises. Survey along the north-facing edge of a steep reef covered with *Ecklonia*. Epifauna consisted of some large sponges, sprawling *Cliona*, and some cup sponges (like *Ancorina*), few bryozoans, hydroids, and blue *Pyura*.
- (6) Orarapa "Motohurupapa" Rock. Transect was placed along an outcrop along the western extension of the island, separated from other contours. Top of the reef was at 12 m and drops steeply to 20 m, sheer on the western extension and more gently sloping towards the east and southeast of the point. Bottom was at about 22 m and consisted of silty sand. Walls covered in small clumps of bryozoans (?*Galeopsis*) and small sponge colonies (e.g. *Cliona*, *Ircinia*).
- (7) Billy Goat Point. Sampled along the bottom of a steep, shallow reef with several large rock faces. Currents reasonably strong through the channel, sampled along the northwest-facing ledge passing through a deep gut sheltered to the northwest. Epifauna consisting of many different sponges, with clumps of *Tethya*, *Aaptos*, large *Ancorina*, *Cliona*, and upright branching *Raspadia*. Some solitary corals were present (*Flabellum*, *Culicea*) and several large hydroid colonies.
- (8) Splash Rock, North Waiheke Island. Survey along the north side of the reef about 200 m from the marker buoy, transect running clockwise from the start of the reef wall around to the gut separated by a deep sand channel. Some large sponges present, bryozoans, *Chaetopterous*. *Ecklonia* was present as isolated plants along the top of the reef.
- (9) Hakaimango Point, North Waiheke Island. Reef flat-topped with sparse kelp and large hydroid colonies. Many different types of sponges (*Tethya*, *Ancorina*) were present. Bottom of the reef consisted of a sloping sand bottom, with lots of *Ecklonia* wrack along the lower extent of the reef. The western extension of the reef characterised by a steep wall with many bryozoans, solitary corals and hydroids.
- (10) Poley Bay "the Pinnacles". Reef consisting of steeply sloping bedrock with many caves and undercut faces. Many species sponges, ascidians (e.g. *Didemnum*), and bryozoans were present.

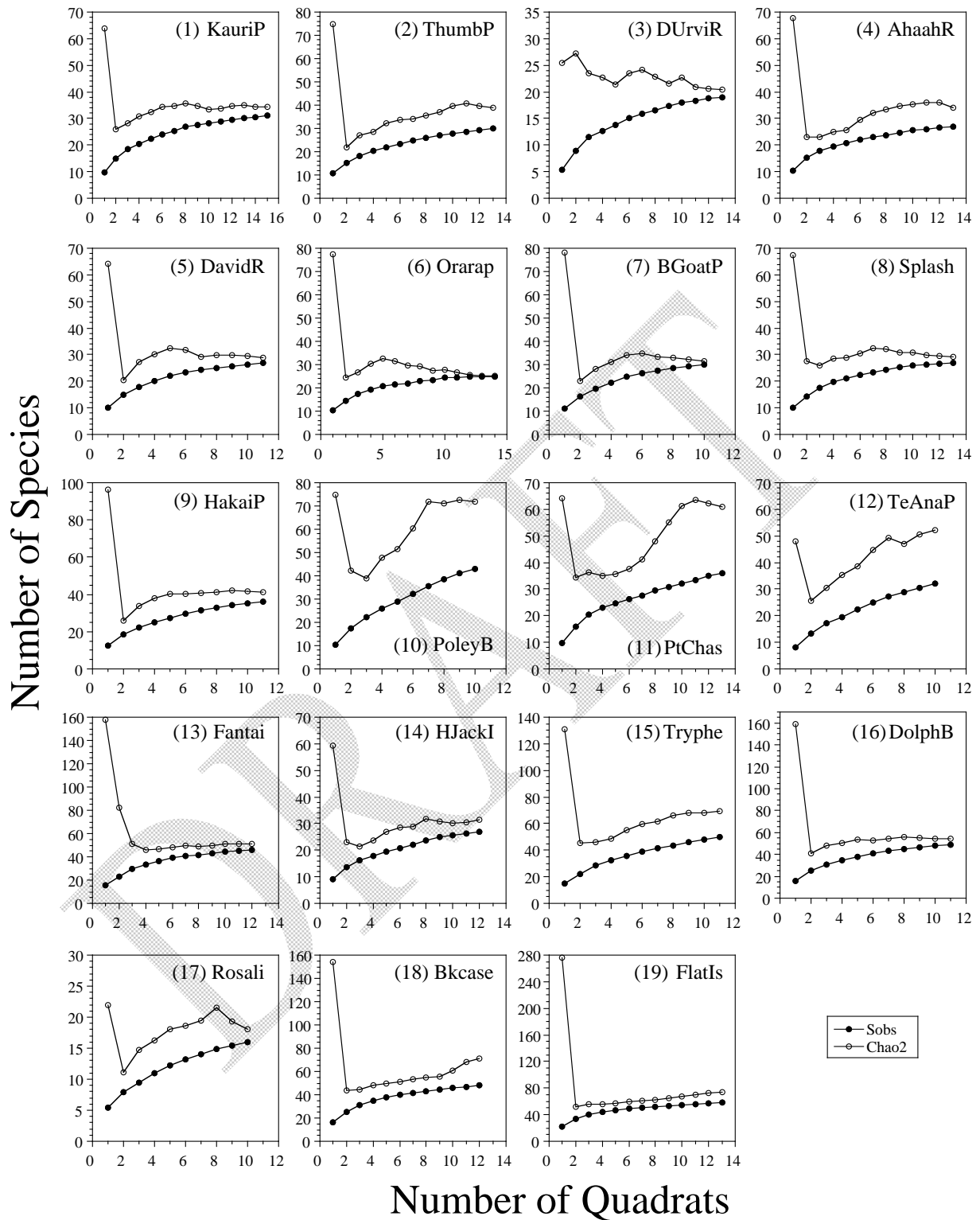
- (11) Port Charles Lighthouse. Topography consisted of a sloping reef with large sponges (e.g. *Ancorina* and *Polymastia*), anemones (*Anthothoe*, *Corynactis*) and large cover of encrusting and upright calcareous algae. Transect placed along a steep terrace at 15 m depth.
- (12) Te Anaputa Point, just north of Waikawau, Coromandel Peninsula. Reef consisted of vertical faces, bluffs and boulders. Walls largely covered with encrusting calcareous algae and small anemones (*Anthothoe*) with many isolated sponge colonies. Many small sea urchins (*Evechinus*) were present.
- (13) Fantail Bay Reef, Coromandel Peninsula. Reef system consisted of isolated rock outcrops and terraces surrounded by sloping coarse sediment and shell hash bottom in an area of swift tidal currents. Transect started along the south-facing wall and extending to the northeast-facing extension of the reef. Sparse *Ecklonia* cover present on the top of the reef. Epifauna consisted of high cover of massive and branching sponges, encrusting and solitary ascidians, with some large bryozoan clumps.
- (14) Happy Jack Island “Motukahaua,” Coromandel Peninsula. Survey on the western-most tip of the island to a sandy and shell-hash bottom. Reef consisted of broken faces and rubble. Epifauna did not seem to have any obvious pattern of zonation, consisting of some large encrusting colonies of *Cliona* and small clusters of *Anthothoe*. Encrusting colonial ascidians also present (e.g. *Didemnum*, *Leptoclinides*).
- (15) Tryphena Bay Pinnacles “Modeo Rocks,” Great Barrier Island. Survey along southern-most pinnacle starting on the south facing edge and working along the contours to the northwest. Reef system consisting of irregular topography, caves, overhangs and isolated outcrops. Bottom of the reef system, at about 24 m, consists of light-coloured sand. Walls covered with anemones (*Corynactis*), hydroids, sponges, and bryozoans. Top of the reef covered with dense *Ecklonia*.
- (16) Dolphin Bay Point, Southern Great Barrier Island. Survey transect was placed along terraced reef faces underneath a dense *Ecklonia* kelp canopy. Epifauna consisting mainly of encrusting coralline algae with isolated sponges, occasional large vases, mounding ascidians (e.g. *Aplidium*), and bryozoans.
- (17) Rosalie Bay, Great Barrier Island. Survey along sheer bedrock terrace, largely covered with encrusting coralline algae, few kelp plants, and few epifaunal invertebrates. Many sea urchins (*Evechinus*) were present.
- (18) The “Bookcase,” Great Mercury Island. Transect started on western extension of the outcrop and traversed to the south-facing wall. Reef characterised of very steep topography with some broken reef outcrops. Shallow depths characterised with thick *Ecklonia* cover, becoming sparser with depth. Epifauna consisted largely of anemones (*Anthothoe*), hydroids (*Solandaria*), and encrusting sponges. There were some sparse bryozoan colonies present. The bottom of the reef ends in an extensive plain of white sand with some coarse sediment.
- (19) Flat Island, Mercury Islands. Survey dive off the south end of the island on the western-facing wall. Reef consisting of a steep dropoff from about 7 – 9 m depth, ending abruptly in a white sand plain at approximately 16 m depth. Epifauna consisted of a diverse assemblage of sponges (e.g. *Ancorina*, *Haliclona*), bryozoans (e.g. *Steginoporella*), ascidians (e.g. *Synoecium*), and anemones (e.g. *Anthothoe*). Several species of solitary coral were also present.
- (20) Junction Island, western Great Barrier Island. Transect set on broken reef face at 14 m depth of the northwest corner of the island just outside swash zone. Site covered with extremely long stiped *Ecklonia*. The base of the reef extends out onto coarse white sediment and shell hash. Very little on rock surfaces, mostly calcareous algae and few

- hydroids, some sparse *Ancorina* sponges, *Tethya*, *Axinella* and *Cliona celata*, few *Anthothoe*.
- (21) Ahuriri Point, northwest Great Barrier Island. Steep wall with large, open faces and angles with few crags. On deeper extensions of the reef, there are few isolated outcrops covered with *Steginoporella* and *Ecklonia*. Many ascidians at this site, with some large *Ancorina*, *Cliona* and *Polymastia* colonies. Most photoquadrats taken under the *Ecklonia* canopy. There were quite a few small *Evechinus* between 7 and 10 m depth.
- (22) Needles Point, northern Great Barrier Island. Dive along the north side of the furthest island/reef formation to the north. Reef a large hummock formation with broken extensions leading to the northeast. Transect set along the hummock and ran out towards the broken areas, running along the steep topography. Many encrusting bryozoans and brachiopods on the steep faces. Also, solitary ascidians, hydroids and anemones (*Corynactis* and *Anthothoe*) present.
- (23) Simpsons Rock, south of Mokohinau Island group. Dive along the northern face and following the contours towards the easternmost edge. Steep sloping and vertical rock faces, covered predominately with algae, crustose, erect corallines, browns and reds, with deep *Ecklonia* and *Carpophyllum*. Sponges mostly encrusting, with some *Alcyonium*, small *Corynactis* and *Anthothoe*, solitary ascidians (e.g. *Cnemidocarpa*), and large *Solanderia* colonies.
- (24) Maori Rocks, Eastern Mokohinau Islands. Dived the easternmost islet on the southeast edge. The south edge is a steep wall with some shelves and deeply cut terraces. Sheltered side was quite barren of benthic life, while around the corner, there was amazing *Ecklonia* cover and impressive colonies of *Cliona*, *Dendrilla*, and other encrusting sponges, and many bryozoan clumps (e.g. *Galeopsis*).
- (25) Stack "H", western Mokohinau Islands. Started transect along the smooth north-south running ledge, under dense *Ecklonia* cover. There were small vertical sections along wall, but mostly steeply sloping with vertically running crags. Bottom with few encrusting invertebrates, mostly encrusting calcareous algae with some large *Ancorina* and *Polymastia* colonies. Small colonies of *Solanderia*, *Bugula* (blue) and *Orthoscuticella*.
- (26) Coppermine Point, eastern point of Coppermine Island, Hen & Chicken Islands. Transect run along a steep wall, starting in a type of surge channel and extending out along a kelp forest and more gently sloping reef. Bottom consists of bricks and deep gullies, about 18 – 20 m depth and then drops off again. Visibility poor with moderate surge at shallow depths. Understorey cover of lush bryozoans, *Galeopsis*, *Cellaria* and low branching tufts. Large numbers of *Anthothoe*, *Solanderia* and numerous colonial ascidian species.
- (27) Mauitaha Island, southeast edge of island, Hen & Chicken Islands. Steep incline with a reef top at about 8 m depth, contours steep to about 10-12 m and then turns to broken boulders and reef spurs, steeply dropping to 18+ m. *Ecklonia* stipes covered with a fleshy *Beania*-type bryozoan, with smaller colonies of a *Hornera*-type bryozoan, *Celleporaria* and *Galeopsis*. Understorey mostly calcareous algae w/ some sparse *Ancorina* and *Aplisina* (yellow) and *Axinella* (orange).
- (28) The Pinnacles, south edge, Hen & Chicken Islands. Very steep topography, coming up from about 30 m depth, running the transect along the western edge across the southern face to the east. Swift currents present. Walls covered mostly with hydroids and few bryozoan clumps and clusters of *Anthothoe*. Some large *Cacospongiae* (blue) colonies present towards the eastern edge.
- (29) Ngatamahine Point, northeast Little Barrier Island. Transect set on reef outcrops at about 10-12 m depth. Reef very irregular with large spires and faces and some disjunct boulders. Sparse kelp on most of the faces, but thicker stands below. Quite a few *Solanderia*,

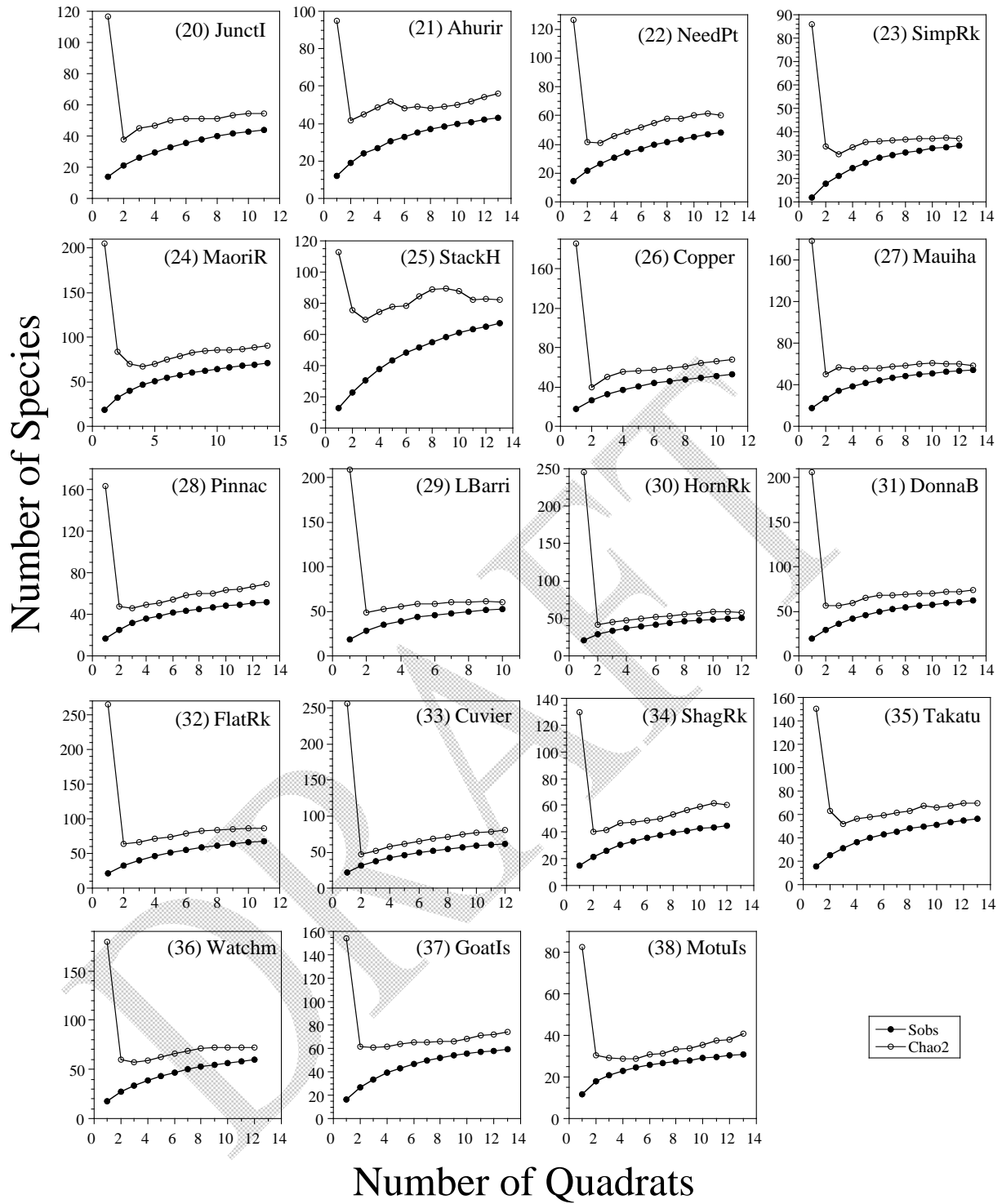


- Ancorina*, *Stellata* (orange cup sponge), *Tethya* and *Steginoporella* colonies. Sparse *Corynactis* and few patches of *Anthothoe*, with isolated colonies of *Celleporaria* and *Galeopsis*. *Cnemidocarpa* and *Asterocarpa* also present.
- (30) Horn Rock, central Hauraki. Set transect on eastern edge along steep topography, from 10 to about 20 m depth. Amazingly jagged reef and faces, with isolated stacks separated by broken rock and sediment. Some channels with deep ripples and shell debris. Reefs cloaked with *Ecklonia* and some *Sargassum*, *Carpophyllum* and understorey mostly encrusting calcareous algae with some bryozoans, *Ancorina*, *Tethya* and large *Cliona* colonies.
- (31) Donna's Bay, eastern Great Barrier Island. Amazing deep reefs out on the sediment plain, transect set on the edge of the coastal reef, steeply sloping with some terraces. Large colonies of *Celleporaria* and other encrusting species, large *Ancorina* colonies on the ridges and sides of boulders. Above the transect at about 12 m, there were amazing barrens w/ very little beyond encrusting colonies and some *Anthothoe*. A strange blue, stalked ascidian also there, common on the deeper sections of reef.
- (32) Flat Top Island. Set transect on the western side of the islet and ran along the north edge along the base of the reef. Swell quite heavy and difficult to steady the framer, shot paired photos on the base of the reef and along the transect. There is a sheer wall to the south, with clumps of *Corynactis* and hydroids. Bottom cover mostly encrusting calcareous algae with few sponges and little kelp cover.
- (33) Cuvier Island. Transect on the southwestern tip of the island. Reef habitat mostly disjunct boulders with some larger outcrops with vertical sections. Shot photoquadrats on the sides of boulders, largely covered with *Ecklonia*. Some sparse sponges, *Ancorina*, *Polymastia* and some *Steginoporella*.
- (34) Shag Rock, east of Tiritiri Matangi Island. Sampled on the seaward edge of the reef, with abrupt ledges and faces working towards the northwest. Walls covered with *Corynactis* and *Anthothoe*, with clumps of *Galeopsis* and various encrusting bryozoans. Some large patches of *Cliona celata* and some *Ancorina* colonies. Kelp sparse along the reef walls, but more common up shallow, particularly *Sargassum* belts at 3-5 m depth.
- (35) Elephant Point, south tip of Takatu Point, Tawharanui Peninsula. Transect set on the south-facing wall. Reef disjunct with numerous faces and outcrops, with large vertical faces in terrace formations, though largely disorganized. Strong current at the surface. Deeper areas had amazing sponges, *Ancorina*, *Stelleta*, and *Polymastia*. *Alcyonium* abundant with clumps of *Steginoporella* and stalked ascidians. Some degrading patches of *Ecklonia*.
- (36) The Watchman, just outside Leigh Harbour. Reef mostly broken with some outcrops and terraces. Dense *Ecklonia* cover. Transect ran over mostly vertical habitat along faces of the ridges with some small overhangs. Large *Ancorina* colonies, *Stelleta*, *Tethya*, *Cliona*, *Polymastia* with other encrusting forms. Brachiopod clumps down deeper at about 15 m depth.
- (37) Goat Island. Transect set on the exposed (eastern) side, along a southern facing gully. Sloping bedrock covered with tattered *Ecklonia* and some large sponges (*Ancorina*, *Stellata* and *Tethyas*). Along the gut, there are numerous clumps of *Steginoporella* and other bryozoan thickets, with several species of Didemnid ascidians.
- (38) Motuora Island. Survey dive on the northeast edge on a submarine reef extension. Water turbid with flocculents. Reef sampled on a steep outer edge adjacent to a sand plain w/ large megaripples and shell debris. Transect set at 13.3 m depth with some deeper sections. Substrate sediment-laden, but large *Ancorina* colonies with some orange *Raspalia*, *Callyspongia* and other pastel orange tubular sponge (possibly an *Esperiopsis*). Some isolated patches of brachiopods and few bryozoans.

**Appendix II. Species Accumulation Curves for Determining Species Richness of Sites**



**Appendix IIa.** Species accumulation functions for sites 1 to 19, showing the tendency to approach saturation, with the exception of some sites in the outer Gulf region (e.g. Tryphe 15). Site names and numbers refer to those in Figure 1 and Table 1.



**Appendix IIb.** Species accumulation functions for sites 20 to 38, showing the tendency to approach saturation, with the exception of some sites in the outer Gulf region (e.g. Pinnac 28). Site names and numbers refer to those in Figure 1 and Table 1.

**Appendix III. Tables for Fish and Macroinvertebrate Consumers Found in Surveys.**

To be accompanied by raw data files from the survey.

**Appendix IV. Results of the Multiregression (GAM) Models for Epifaunal Invertebrates, Cryptic Fishes and Mobile Invertebrates**

**Appendix V. Mapped Predictions from the GRASP (Generalised Regression and Spatial Prediction) Routine for Epifaunal Invertebrates, Cryptic Fishes and Mobile Invertebrates**

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