Literature Review of Ecology of Ohiwa Harbour

Environment Bay of Plenty
Environmental Publication 2010 10

5 Quay Street
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Whakatane
NEW ZEALAND

ISSN: 1175 9372

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Environmental Publication 2010 10
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May 2010

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Acknowledgements

Thank you very much to Simon Stokes and especially Nancy Willems and Tim Senior for helpful feedback and suggestions along the way. Thank you also to Karen Day and Michelle Lee for assistance in tracking down reports.

Executive summary

This literature search has been carried out to address Action 12.3.3 (Assess Ecological Quality of Ohiwa Harbour) of the Ohiwa Harbour Strategy. In order to accurately assess the ecological quality of an area, its ecology must be well understood. Ecology is defined for the purposes of this report as the study of the distribution and abundance of organisms and their interaction with the environment. Past reports have provided an overview of studies on different aspects of the ecology of Ohiwa Harbour and its catchment (Bioresearches 1975, Park 1991), but there is a need for a more up-to-date assessment of available ecological information.

This literature search summarises and assesses the information available on the status of different aspects of the ecology of Ohiwa Harbour and its catchment (shown in Figure 1), and discusses gaps in our knowledge where there is a need for further study. The reports used and an analysis of the information they provide are listed in the annotated bibliography in Appendix 1. In order to address gaps in knowledge identified by this report, 11 recommendations are made.

The information in the reports summarised in this document needs to be collated if an overall document of the status of the ecology of Ohiwa Harbour and its catchment is to be produced. This would allow an improved understanding of the state of the ecology of the catchment and any significant issues it faces. A brief discussion of what would be involved in the collation of such a document concludes this report.

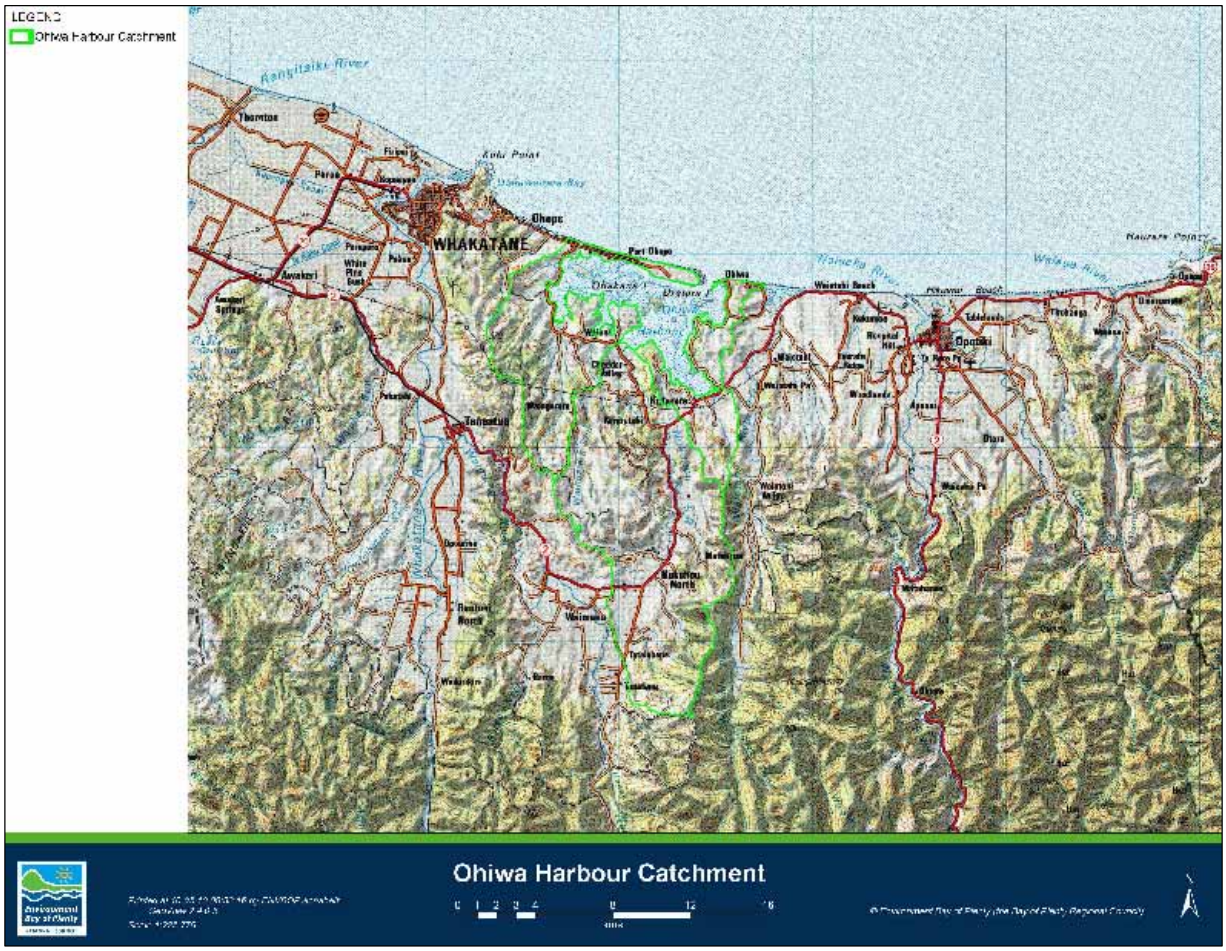

Figure 1 Map of Ohiwa Harbour Catchment location.

Contents

Part 1: Indigenous vegetation and habitats for indigenous fauna

Numerous reports have been produced with information on indigenous vegetation and habitats for indigenous fauna in the Ohiwa Harbour catchment. General outlines of the Harbour vegetation are provided in Shaw (1982), Owen (1991) and Owen (1995). Shaw (1982) also discusses features that make harbour ecology especially susceptible to disturbance. More detailed reports concerning specific sites, specific vegetation types and significant flora are summarised below.

1.1 Vegetation mapping and description

(i) Vegetation mapping and description of protected areas

The vegetation and flora, including features of special significance and threats to ecological values, of protected areas around Ohiwa Harbour are described in several reports. Beadel (1988) describes vegetation and flora, as well as areas and features of significance, at the Ohope and Port Ohope Recreation Reserves. Beadel and Shaw (1988) and Clarkson and Regnier (1988) map the vegetation of Motuotu Island Nature Reserve, Ohiwa and Oscar Reeve Scenic Reserves, Pataua Island Scientific Reserve and Matekerepu Historic Reserve, as well as describing main habitats and features and providing a species list for each site. The data these reports are based on are now rather outdated, but still used in more recent reports on identifying botanic conservation values (Beadel 1994/1997, Beadel 1995, Wildland Consultants 1999, Wildland Consultants 2006). Beadel (1999) describes the vegetation and flora of Whangakopikopiko Wildlife Management Reserve.

(ii) Vegetation mapping and description of recommended areas for protection

More recent fieldwork has been conducted in recommended areas for protection. Beadel (1993) identifies nineteen representative sites of indigenous vegetation in and around Ohiwa Harbour, and describes their vegetation types, significant taxa and threats to these ecological values. Beadel *et al*. (1999) describe vegetation and flora present, and threats to ecological values, at sites around the Harbour as part of a study of recommended areas for protection throughout the Taneatua Ecological District. A lot of information used in this report is based on Beadel (1993), but sites in the upper Nukuhou catchment are also surveyed and described. Specific sites in the Harbour have also been the focus of botanical surveys, with the botanical conservation values of Hiwarau C Block described by Beadel (1994), and the vegetation of Hiwarau Part C and Hiwarau A9 blocks described by Owen (1994b). Clarkson (1985) and Beadel (2001) describe vegetation at various sites around the harbour visited on Rotorua Botanical Society fieldtrips.

(iii) Identifying sites of botanical conservation value

This previously published information on both protected areas and recommended areas for protection is compiled to identify sites of botanical conservation value and significant natural ecosystem areas in the Ohiwa Harbour Catchment in the following reports: Beadel (1994/1997), Beadel (1995), Wildland Consultants (1999) and Wildland Consultants (2006). Limited field surveys are sometimes carried out as part of these studies, but most rely on previous work.

(iv) Vegetation values in terms of habitat provision

Vegetation values in terms of habitat provision are the focus of several reports. The fauna and flora associated with major habitat types in the Harbour zone is discussed in Bioresearches (1975). Rasch (1989a and 1989b) describes vegetation and common species for areas of wildlife habitat and ranks them according to their value to wildlife. The fieldwork for these reports was carried out over 20 years ago so some information is very outdated, but the Department of Conservation Bay of Plenty Conservancy office is in the process of updating the Bay of Plenty report (Christensen, 2009). Owen (1994a) describes sites that are important to marshbird populations and describes habitat quality rankings and existing threats and impacts. Dowding and Moore (2006) collate information on habitat used by endemic shorebirds, but most information provided in this report is nationally generalised and not overly informative in terms of assessing the ecology of Ohiwa Harbour.

As summarised in this section, areas of indigenous vegetation and habitats for indigenous fauna have been well mapped and described throughout Ohiwa Harbour and its catchment. Some sites have been the focus of very detailed field surveys, while other assessment of sites has relied on previously published reports, some of which are now very outdated. The only report (Beadel, 1993) focussing on the Harbour in its entirety has been relied on heavily despite the information now being fairly old and focussing only on the 19 sites described in the report.

The compilation of a register of sites, as discussed in the Ohiwa Harbour Strategy, would allow identification of sites for which no recent field survey has taken place. Monitoring of vegetation, largely of responses to threats, is carried out in specific areas of the Harbour (Shaw, 2000), but the creation of an ongoing monitoring programme of sites throughout the catchment would allow quicker detection of trends and a better understanding of indigenous flora in the Harbour catchment. The large amount of published material would also allow a comparison of trends.

1.2 Specific vegetation types

(i) Algae abundance and distribution

Concern over increased algae abundance, particularly of sea lettuce, has led to several studies into algae ecology. Algae distribution is described and mapped in Bioresearches (1975) and Richmond (1977). Algae are linked with nutrient enrichment in Bioresearches (1975) and Park (1996), and the effects of enhanced algal growth on harbour ecology are discussed in Bioresearches (1975) and Snow (1995). Intasuwan *et al*. (1993) compare genetic variations between red algae populations throughout New Zealand, and as sample red algae in Ōhiwa Harbour for genetic variation as part of this study. Sea lettuce (*Ulva* sp.) has been well studied in Ohiwa and particularly Tauranga Harbours. Monitoring is conducted by Environment Bay of Plenty every second month to gain data on sea lettuce biomass, nutrient status, environmental influences and sediment water interactions (Park 1992, Park 1996, Park 2005). Sea lettuce swarmer release, growth of individual plants and populations, and recruitment were studied by Snow (1995).

(ii) Changing mangrove and salt marsh distribution

Concern over changing mangrove and salt marsh distribution in response to sedimentation in the Harbour catchment has resulted in many reports focussing on different aspects of mangrove and salt marsh ecology. The distribution of mangroves and salt marshes is described in Richmond (1977) and Daniel (1984), and their changing distribution in response to sedimentation is discussed in Daniel (1984), Park (2000a) and Park (2005). Aspects of mangrove biology, community and disturbances at major mangrove sites are discussed by Daniel (1984). Mangrove demography is discussed in Burns and Ogden (1985). Woodroffe and Grindror (1991) looked at factors, particularly the importance of sea-level fluctuations, which influence mangrove biogeography. de Lange and de Lange (1994) investigate different factors controlling the distributional limits of mangroves, and found the relative importance of coastal processes affecting propagule dispersal means a southern extension of distributional limits is unlikely. The role of mangroves and salt marshes in harbour ecology is discussed in Acroyd and Kilner (1980), Daniel (1984) and Fergusson (1988).

(iii) Wetland extents

Wetland vegetation around Ohiwa Harbour and temporal changes in extent are mapped and described in Park (2000a). Freshwater wetland loss and the influence of this on sedimentation rates are described in Park (2005).

(iv) Terrestrial vegetation distribution and condition

Different aspects of terrestrial vegetation have been studied in the Ohiwa Harbour catchment. The distribution of dune vegetation and its effect on sedimentation are discussed in Richmond (1977), with a more recent study mapping sand dune vegetation and describing its condition described in MacKenzie (2010). Forest regeneration in coastal kanuka forest and the establishment of plots to record the present structure and composition are described in Smale (1990) and Smale (1993). Pohutukawa canopy condition around the Harbour has been monitored through a combination of aerial and ground surveys. The results, and changes between surveys, are summarised in Gosling and Shaw (1990), Shaw and Taylor (2003), Hall (2007a) and Willems (2009). Existing vegetation survey and monitoring of significant flora, as well as vegetation response to altered threats, carried out in the area by the Department of Conservation is described in Shaw (2000).

(v) Adventive species

Adventive species are discussed in several reports. Clarkson (1985) and Beadel (2001) both describe the area of *Spartina* invasion, while Shaw and Allen (2003) describe the ecological effects, management options and past distribution of sea couch. The use of haloxyfop to eliminate *Spartina* in the Harbour without damaging mangrove populations is discussed by Shaw and Gosling (1997). Adventive plant species present in areas of indigenous vegetation were mapped as part of fieldwork by Beadel and Shaw (1988), Clarkson and Regnier (1989), Beadel (1993) and Beadel *et al*. (1999).

As discussed in this section, detailed information is available on specific vegetation types in the Harbour catchment, allowing identification of trends in their ecological state. Environment Bay of Plenty's Natural Environment Regional Monitoring Network (NERMN) programme includes regular monitoring of algae and mangrove abundance and distribution. Other vegetation types, including sand dune and pohutukawa canopy condition also have regular monitoring conducted. These

vegetation types have been chosen for monitoring generally due to threats to ecological values so it is important this continues. The level of detail is good for the vegetation types studied, but there are some vegetation types, notably moss and liverworts, for which there is no available ecological information specific to the Ohiwa Harbour catchment, and it would be beneficial to consider a survey of these other vegetation types even if there are no known threats associated with them.

1.3 Significant flora

(i) Significant species

Various species of plants within the Ohiwa Harbour are considered noteworthy and under threat. *Stipa stipoides* reaches its southern distributional limit on the eastern side of the North Island, and *Avicennia marina* subsp. *australasica* reaches its southern distribution limit in New Zealand at Ohiwa Harbour (Beadel, 1993). Species with local distributions are also described in Beadel (1993). Six plant species present at Ohiwa Harbour are listed in the Bay of Plenty Conservancy Threatened Species List (Owen and Cashmore, 2006). Site visits to areas of significant flora are described in Clarkson (1985), Beadel (1992), Beadel (1993) and Beadel (2001).

(ii) Significant plant communities

Saltmarsh communities of Ohiwa Harbour are considered to be representative of the Whakatane Ecological Region and the Eastern Bay of Plenty (Owen, 1996). There are also areas that exemplify indigenous flora and the sequence from saltmarsh communities to indigenous vegetation (Owen, 1996). These areas are documented in the Bay of Plenty Regional Coastal Environment Plan 2003.

Ohiwa Harbour is ecologically significant for particular species of plants and plant communities described in the above reports. Ongoing monitoring, particularly monitoring of threatened plant species, is important in protecting these ecological values, as well as better understanding threats to them and trends in their distribution and abundance. Documented site visits to sites of known threatened plants have not taken place since 2001, so there is a need to do some survey work to quantify distribution and abundance and identify and update threats.

Part 2: Fauna distribution and abundance

Information available on fauna populations in the Ohiwa Harbour catchment varies greatly in level of detail. Some communities have been extensively documented and are regularly monitored, while others are poorly understood. This information and gaps in knowledge are summarised below.

2.1 Freshwater fish

(i) Fish surveys

Data on freshwater fish species present in the Ōhiwa Harbour catchment, as well as on their abundance and size, are stored in the National Institute of Water and Atmospheric Research's Freshwater Fish Database. A freshwater fish survey of streams throughout the catchment without Freshwater Fish Database records was carried out by Bloxham (2007). This report also discusses geomorphological and anthropogenic (fish passage barriers) controls on species distribution, and prioritises streams and fish passage barriers for remedial work. One localised freshwater fish survey was carried out in Wainui Stream to investigate the effects of a weir inhibiting fish passage (Rowe and Bowman, 1995).

(ii) Whitebait ecology

Fieldwork to investigate whitebait ecology has been carried out in several streams in the Ohiwa Harbour catchment. Mitchell (1990) describes whitebait spawning and eggs on the Tunanui and Waiotane Streams and the Nukuhou River, as well as vegetation and land use that may threaten survival of whitebait eggs. This work on the Waiotane Stream also found banded kokopu eggs (Mitchell, 1991). McDowall *et al*. (1994) looked at the age of migration from the sea and differences in life cycles between whitebait species at sites around New Zealand, including in Ohiwa Harbour. The importance of the Nukuhou River as a whitebait fishery, and the need for a more detailed survey, is discussed in Owen (1994b).

(iii) Threatened species

Two freshwater fish species found in the Ohiwa Harbour catchment are listed on the Bay of Plenty Conservancy Threatened Species List (Owen and Cashmore, 2006).

The information available on freshwater fish species in the Ohiwa Harbour catchment is fairly up-to-date and detailed. There are several streams and wetlands in the catchment listed in Bloxham (2007) that have still not been surveyed, and carrying out surveys in these areas would improve understanding of koaro and kokopu species distribution. The establishment of a regular freshwater fish monitoring programme will allow comparison of trends in ecological values using this study as a baseline. The need for a more detailed survey into inanga spawning habitat is described in Owen (1994b). Information on threats to ecological values is discussed in Mitchell (1990) and Bloxham (2007), with Bloxham (2007) prioritising remedial work to address identified threats.

2.2 Freshwater invertebrates

(i) Freshwater invertebrate ecology monitoring throughout the Bay of Plenty is carried out as part of Environment Bay of Plenty's Natural Environment Regional Monitoring Network (NERMN). The only site monitored in the Ohiwa Harbour catchment is the Nukuhou River, and the results from this site are presented in several reports (McIntosh and Park 1997, Wilding 2001).

Freshwater invertebrate communities present at the monitoring site have been well documented, but there has been no other work on freshwater invertebrates elsewhere in the Harbour catchment. Community assemblages in other freshwater ecosystems are likely to be very different as the Nukuhou has the second lowest water quality in the Bay of Plenty (Park, 2005). Limited information is available on threats to freshwater invertebrates, although some assumptions could be made based on the premise that most freshwater invertebrate monitoring is carried out as an indicator of environmental conditions. Studying other freshwater invertebrate communities in the catchment would allow better understanding of these threats.

2.3 Estuarine fish

(i) A species list of marine fish in the Harbour is provided as part of a beach seine survey of northern New Zealand harbours (Francis *et al.*, 2005). Several studies of Ohiwa Harbour note the presence of fish species encountered during fieldwork without carrying out detailed quantitative surveys (Paul 1966, Bioresearches 1975).

(ii) The importance of the Harbour as habitat and a food source for marine species is described in several reports (Bioresearches 1975, Daniel 1984).

Limited information on the status of marine fish in the Harbour can be gained from these studies. There have not been many quantitative studies of marine fish found within the Harbour, despite the popularity of the Harbour for recreational fishing and anecdotal evidence for decline in fisheries (Quinn, 2002). A better understanding of this aspect of harbour ecology would be gained by carrying out a baseline survey, which would also signal whether future monitoring needed to take place.

2.4 Estuarine invertebrates

(i) The distribution and abundance of edible shellfish in the Harbour have been well studied, with descriptions and distribution maps produced in Paul (1966), Bioresearches (1975), Richmond (1977) and McArdle and Blackwell (1989). Pressure on shellfish resources is discussed in several reports (e.g. Park, 2005), with anecdotal evidence for declining fisheries presented in Quinn (2002). Concern about over-exploitation led to several surveys on the distribution, size and abundance, as well as controls on these factors, of green-lipped mussels (Kilner and Akroyd 1982, Paul-Burke 2007). The control of environmental conditions on mussel morphological differences is discussed in Hichman (1979). The population dynamics of cockles in the Harbour were studied by Blackwell (1984), who found intraspecific competition was the main control on density. The spread of Pacific oysters from the oyster farm and the presence of Japanese oysters in the Harbour are documented in Dinamini (1971), Acroyd and Kilner (1980) and van der Wouden (1993), but not quantitatively surveyed. Monitoring of shellfish for contaminants has been carried out as part of the NERMN programme since 1992 and the results are discussed in several reports (McIntosh 1999, Park 2005).

(ii) Benthic communities have been annually monitored for abundance and habitat data since 1990 at several sites in the Harbour as part of the NERMN programme, providing information on water quality and ecosystem health over time. The results are presented and discussed in several reports (Park 1993, Park 1996, McIntosh and Park 1997, Park 2000b, Park 2005). Information on meiofauna distribution and abundance in relation to physico-chemical parameters is presented for several sites, including Ohiwa Harbour, by Hack *et al*. (2007). Hack *et al*. (2008) provide data on different aspects of the life-cycle of the marine copepod *Robertsonia propinqua* as part of a study to formulate a biomeasure of sediment-associated contamination effects.

(iii) Gastropod and crab distribution is described in Richmond (1977). Wiseman (2003) studied whether there was a correlation between the density of the common gastropod *Amphibola crenata* (mud snail) and proportions of sediment/silt content within fenced and unfenced areas. Jones and Simon (1983) looked at different aspects of the population structure and reproductive biology of burrowing mud crabs in the Harbour, as well as other sites, and compared these with latitude.

Detailed monitoring as part of the NERMN programme is being undertaken on estuarine invertebrates, resulting in a lot of detailed information on species distribution and abundance, threats to ecological values and trends in the ecological state of those values.

2.5 Birds

(i) Ohiwa Harbour is recognised as being of high value with regard to the number and rarity of birds it supports (Forbes and Bridgewater, 1990). Ohiwa Harbour has been ranked as an Outstanding Site of Special Wildlife Interest (Rasch 1989a and 1989b) and a wetland of international importance for wading birds (Owen, 1994a). This ranking reflects the importance of the Harbour as a breeding and wintering habitat for waterfowl, especially shorebirds including a number of national and international migratory shorebird species (Owen *et al.*, 2006). The values of the Harbour in providing habitat, food resources and roosting and nesting space is described in Bioresearches (1975) and Daniel (1984). Several reports discuss the significant fauna (uncommon species, species with limited distributions and migrating species) present in the Harbour (Daniel 1984, Owen 1994a, Dowding and Moore 2006, Owen and Cashmore 2006, Owen *et al.* 2006). Nineteen bird species are listed on Owen and Cashmore (2006)'s Bay of Plenty Conservancy Threatened Species List.

(ii) Several surveys on bird species have been carried out in the Harbour. Rasch (1989a and 1989b) details bird species present and threats to their habitat. A survey of marshbird populations and their habitats was carried out in November 1990 and the resulting report describes the distribution, biology and status of marshbird species within the Harbour (Owen, 1994a). Data is collected by the Ornithological Society of New Zealand twice a year in Ohiwa Harbour. The resulting data from high tide roosts on the distribution and abundance of shorebird species are presented in Owen *et al.* (2006). Southey (2009) uses OSNZ data to evaluate the status of waders throughout New Zealand, providing abundance data for waders in the Harbour. Pest birds in the Ohiwa Harbour catchment were surveyed in 1997 (Hall, 1997). Several studies in the Harbour note the presence of bird species encountered during fieldwork, without carrying out detailed quantitative studies (Bioresearches 1975, Daniel 1984, Quinn 2002). A species list for the Harbour is reproduced in Shaw (1982).

(iii) North Island brown kiwi have been reported from Wainui Stream in the catchment (Owen 1994b), but no detailed survey into their abundance in the Ōhiwa catchment has been undertaken. Ideally a survey should take place in autumn when calling increases so the birds are more conspicuous (Owen 1994b).

(iv) Site-specific information on bird species is provided in several reports. Owen (1994b) recorded 26 bird species in a survey at Hiwarau. Collins (2006) describes pest control on Whangakopikopiko and bird species on the island, as well as providing information on fledging rates for several species.

Shorebird populations in the Harbour are well monitored, with ongoing data collection by members of the Ornithological Society of New Zealand, allowing detailed analysis of trends in shorebird ecology. The importance of the Harbour has been well documented, with many reports detailing rare and migrating species found there. Threats to bird species are discussed in most of the reports described in this section. Marshbird species are well described in Owen (1994a), and bird species in general by Rasch (1989a and 1989b) but the data from these reports is now fairly outdated, and need to be updated. The previous reports provide a baseline that will allow analysis of temporal trends.

2.6 Mammals

(i) There are no records of bats or attempts at a bat survey in the Ohiwa Harbour catchment in any ecological reports. Records do exist for other areas in the Bay of Plenty but the nearest area with any sightings is Urewera National Park (Rasch 1989a and 1989b).

(ii) Pest animals in the Ohiwa Harbour catchment were surveyed in 1997 (Hall, 1997). The survey looked at rabbits, mustelids, rats, hares, possums, goats and feral cats and indicated the need for monitoring or action to be taken with respect to these pests.

The only mammals recorded in the Harbour catchment are introduced mammals. These mammals have a significant effect on catchment ecology, and ongoing control is important. Hall (1997) documents the location and details of control work carried out. No bat survey has ever been carried out in the Harbour catchment and could be considered, although it is fairly unlikely bats do occur.

2.7 Reptiles

(i) There have been no detailed surveys of reptiles in the Ohiwa Harbour catchment. Brief searches for lizards were undertaken during a field survey in Hiwarau, but none were found (Owen, 1994b). Little is known nationwide about the true distribution, conservation status or biology of reptiles due to their elusiveness (Rasch 1989a, Rasch 1989b).

Nothing is known about reptile ecology in the Ohiwa Harbour catchment. This is a priority area for study.

2.8 Terrestrial invertebrates

(i) There have only been limited studies of invertebrates in the Ohiwa Harbour catchment. A pest animal survey in 1997 surveyed wasp abundance (Hall, 1997) and a land snail survey looked at two reserves in the catchment (Mayhill, 1994). Frequently observed species encountered during fieldwork were recorded by Daniel (1984).

(ii) In general little is known about insect fauna throughout New Zealand due to the number of species indicating the difficulty of determining distribution, but as insects are generally closely related to plant communities, the best way of ensuring insect survival is by protecting representative examples of all types of indigenous vegetation (Rasch 1989a, 1989b).

Very little is known about terrestrial invertebrates (in contrast to freshwater and estuarine invertebrates) in the Ohiwa Harbour catchment. Limited information can be inferred based on the large amount of reports discussing indigenous vegetation, but this is another priority area for ecological study.

Part 3: Interactions between organisms and the environment

3.1 Hydrology and geomorphology

The hydrology and geomorphology of the Harbour, and the effect they have in providing habitat or controlling species distribution is described in Bioresearches (1975), Richmond (1977), Daniel (1984) and Richmond *et al*. (1984). Shaw (1982) describes the physiography of the Harbour and factors which perform functions to the biota in the estuary. The surrounding land use and threats associated with it are discussed in several reports (Bioresearches 1975, Daniel 1984, Cromarty and Scott 1995, Wiseman 2003, Park 2005).

3.2 Water quality

The quality of water has a big impact on species abundance and distribution in freshwater and estuarine ecosystems. The only freshwater water quality information is from monitoring on the Nukuhou River, and these results are discussed in Taylor and Park (1991). Estuarine water quality monitoring and sampling for bacterial numbers in shellfish carried out by Environment Bay of Plenty is summarised in Scholes (2005) and Park (2005), and earlier results are discussed in McIntosh and Park (1997). Water quality specific to the oyster farm has also been periodically studied (Roughan and Okell 1988, Rohleder 1990, Lawrie 1997). Water quality in terms of suitability for recreational use is described in Deely and McIntosh (1998) and Scholes and Wiseman (2004). Nutrient enrichment of the Harbour and its catchment is discussed as an issue impacting on harbour ecology in several reports (Bioresearches 1975, Daniel 1984, Park 2005).

3.3 Sedimentation

Sedimentation is discussed as a serious issue to harbour ecology in several reports (Bioresearches 1975, Acroyd and Kilner 1980, van der Wouden 1993, Hall 2007b), with sedimentary processes well described in Gibb (1977). Sedimentation increases area available as mangrove habitat, and the resulting mangrove expansion is an issue discussed in several reports (Bioresearches 1975, Gibb 1977, Park 2005). Biological effects on sedimentation are documented in Richmond (1977) and Richmond et al. (1984). Future changes linked with sedimentation events can now be monitored after the collection of sediment samples and establishment of survey cross sections in 2002-03 (Park, 2005), therefore this gap in knowledge is being addressed.

An important part of ecology is the study of organisms and their interaction with the environment. Discussing all the environmental factors that affect biological life in the Harbour is beyond the scope of this report but reports describing some of the most significant factors are summarised in this section. Richmond (1977) details the other side of the interaction, the effect biological life has on the environment. Most of the monitoring currently undertaken has an anthropogenic focus such as shellfish edibility and bathing water suitability.

Conclusion and recommendations

This report summarises and assesses the information available on the status of different aspects of the ecology of Ohiwa Harbour and its catchment, and identifies gaps in our knowledge where there is a need for future study. To address these gaps, and therefore better understand the ecology of the Ohiwa Harbour catchment, the following actions are recommended:

1 Compile a register of sites, including both protected and unprotected areas, based on previously published information. This would then allow identification of sites for which no recent field surveys had taken place, and survey work of these areas should then be undertaken. Re-surveying of areas of indigenous vegetation is recommended to be carried out every five years.

2 Continue current monitoring of specific vegetation types described in this report, as this has all been designed to allow more informed management of identified threats.

3 Gather information on vegetation types, notably moss and liverworts, for which no specific survey data has been collected.

4 Carry out survey work to identify and update knowledge on threats to known threatened plant populations. Visits to known sites have been conducted in the past (e.g.: Beadel, 1992), but there is no regular monitoring conducted.

5 Establish a freshwater fish monitoring programme using Bloxham (2007) as a baseline study, and carry out survey work for streams not sampled in that study.

6 Conduct a detailed survey into inanga spawning habitat.

7 Freshwater invertebrate sampling to be carried out for streams in the catchment, with the exception of the Nukuhou River which is currently monitored as part of the NERMN programme.

8 Carry out a baseline survey into marine fish abundance to establish whether there is a need for a monitoring programme to be established.

9 Update the fauna reports by Rasch (1989a and 1989b) and Owen (1994a) for a better understanding of bird populations in the catchment. The Department of Conservation are currently in the process of updating Rasch (1989a).

10 Detailed field surveys to be carried out to build an understanding of terrestrial invertebrates and reptiles in the Harbour catchment, for which only very limited information has been collected.

11 A survey to confirm the absence of bats in the catchment.

In order to produce an overall document on the status of the ecology of Ohiwa Harbour and its catchment, the information in the reports summarised in this document needs to be collated. The collation of such a document would allow a good understanding of the status of the catchment ecology, and therefore identification of large-scale issues affecting different aspects of the catchment ecosystem. This would be a big job, and only appropriate for a limited time period as ecosystems are constantly changing and our knowledge is continually improving, so information is soon out of date. The overview of harbour ecology documents produced by Bioresearches (1975) and Park (1991) would provide a base, but only describe the Harbour itself, not the entire catchment, and need to incorporate more recently published work. An accurate assessment of catchment ecology would also need to address the gaps identified by this study.

Appendices

Appendix 1 – Annotated bibliography

Beadel, S.M. 1988. *The Vegetation and Flora of the Ohope and Port Ohope Recreation Reserves, Eastern Bay of Plenty.* Report prepared for the Department of Conservation, Rotorua.

This report includes an inventory of the vegetation and flora of the Ohope and Port Ohope Recreation Reserves, and discusses areas and features of significance. The vegetation types are listed and described, and a detailed vegetation map is presented. The regional and national significance of the vegetation and flora is discussed. The information is very detailed, but the report is based on field inspections carried out in June 1988 so this data is of limited reliability.

Beadel, S.M. 1992. *Threatened and Local Plant Survey (1989-1992), Whakatane Field Centre, Department of Conservation.* Report prepared by Wildland Consultants Ltd. for the Department of Conservation, Rotorua.

This report summarises sites visited by Whakatane field centre staff inspecting known threatened and local plant sites in the Whakatane district, and details the 1992 report. Sites visited in the Ohiwa Harbour catchment are the population of Stipa stipoides at Port Ohope, and the Metrosideros carminea plant in the road reserve adjacent to Matekerepu Historic Reserve. The population of the pest plant Spartina near Kutarere is also described.

Beadel, S.M. 1993. *The Coastal Environment Regional Plan: Ohiwa Harbour Indigenous Vegetation.* Report prepared by Wildland Consultants Ltd, Rotorua for the Bay of Plenty Regional Council, Whakatane.

This report describes and maps wetland and terrestrial vegetation within and adjacent to Ohiwa Harbour, and also delineates areas for protection. Nineteen representative areas of present day vegetation are identified and classed according to relative botanical conservation value. Vegetation types, significant taxa and threats in these nineteen areas are also described. The report identifies plants in the harbour at their distribution limits, as well as threatened and local taxa.

Beadel, S.M. 1994. *Botanical Conservation Values of Hiwarau C Block.* Report prepared by Wildland Consultants Ltd. for Department of Conservation, Rotorua.

A field inspection was carried out in January 1994 to identify the part(s) of Hiwarau of highest nature conservation value. A map is produced of relative nature conservation value, including areas which could be developed. The freshwater wetlands present in this area are described as probably the best remaining examples in the Taneatua Ecological District.

Beadel, S. 1994/1997. *Significant Indigenous Vegetation of the Bay of Plenty Coastal Zone.* Report prepared by Wildland Consultants Ltd for the Bay of Plenty Regional Council, Whakatane.

This study was designed and carried out primarily as a desk exercise based on existing information with limited field checking of some sites. Sites of botanical conservation value were identified. Each site has been ranked based on its relative values, and the justification for its selection is outlined. The ecological units comprising each site are listed, and the sites are all mapped. The vegetation types at each site are described.

Beadel, S.M. 1995. *Vegetation and flora of lands administered by Bay of Plenty conservancy.* Wildland Consultants Ltd. Contract Report No. 130 prepared for Department of Conservation, Rotorua.

This report is an inventory of the vegetation and flora on all lands administered by the Department of Conservation in the Bay of Plenty conservancy. Information is presented for each site in the following fields: conservation unit number, area, ecological conservation district, bioclimatic zone, vegetation types and habitat, vegetation map, flora, botanical conservation rank and justification, significant features/notes, and references. Information for sites in the Ohiwa Harbour catchment is based on existing information, with the exception of the Nukuhou River. However, there are no features of botanical significance or indigenous vegetation recorded from this site.

Beadel, S. 1999. *Vegetation and flora of Whangakopikopiko Wildlife Management Reserve, Ohiwa Harbour.* Wildland Consultants Report No. 239 prepared for Department of Conservation, Whakatane.

This report surveys the vegetation and flora of the Whangakopikopiko reserve, and identifies related management requirements. The vegetation has been mapped and described, checklists compiled of indigenous and adventive plant species, and the botanical conservation significance has been evaluated.

Beadel, S.M. 2001. *Ohiwa Harbour and Waiotahi Spit field trip.* Rotorua Botanical Society Newsletter 36, May 2001

This report describes vegetation, ecologically significant areas and threats to vegetation at several estuarine and terrestrial sites around the Harbour. Additions are made to the original species list of the area in Clarkson and Regnier (1989).

Beadel, S.M., Shaw, W.B. 1988. *Taneatua Ecological District. Biological Survey of Reserves Series Report No. 12.* Department of Conservation, Wellington.

This report describes what is found in reserves in the Taneatua Ecological District, and gives a statement of their biological worth. Reserves described in the Ohiwa catchment are Tauwhare Pa Scenic Reserve, Uretara Island Scenic Reserve, Motuotu Nature Reserve, Ohiwa Scenic Reserve, Patawa Scenic Reserve, Matekerepu Historic Reserve and Kotare Scenic Reserve. Relevant data on the reserves included in Clarkson and Regnier (then unpublished) was incorporated into the report. For each of these sites, a vegetation map is produced, the geomorphology described, the main habitats described in detail, condition commented, a conservation ranking assigned and a section on conclusions and recommendations describes significant ecological features and pressures. There is also a section on threats and a species list is provided for each site. The information provided is very detailed, but the survey work was carried in the 1980s, so some of the information in the report would already have been out of date when it was published, and there is a large risk associated with relying on this data.

Beadel, S.M., Shaw, W.B., Gosling, D.S. 1999. *Taneatua Ecological District: Survey report for the Protected Natural Areas Programme.* Report prepared by Wildland Consultants Ltd. for Department of Conservation, Rotorua,

This report is part of a series which describe recommended areas for protection within ecological districts, and evaluates the representativeness of existing protected natural areas. Sites throughout the Harbour and its catchment not currently protected are described, based either on existing information or on field surveys. For each site a vegetation map is produced, the vegetation, flora, fauna and threat or modifications are described. The site is discussed in terms of its ecological importance and the botanical conservation ranking assigned to it is justified.

Bioresearches Limited. 1975. *Ecology of the Ohiwa Harbour.* Unpublished report to the Bay of Plenty Catchment Commission and Regional Water Board.

The ecology of Ohiwa Harbour is discussed in this report, with descriptions of major habitats, the distribution and abundance of edible shellfish, the ecological importance of the Harbour to bird and fish species, the distribution of algae and ecological changes occurring within the Harbour. Threats to the harbour ecosystem, particularly through increased sedimentation, are discussed, and recommendations for future management are made. The report covers most aspects of harbour ecology very well, but is very old so the data cannot be relied upon.

Blackwell, R.G. 1984. *Aspects of the population dynamics of Chione stutchburyi in Ōhiwa Harbour, Bay of Plenty, New Zealand.* Unpublished PhD thesis, University of Auckland.

The fine scale spatial and temporal variation of a Chione stutchburyi population within Ōhiwa Harbour is studied using descriptive and correlative techniques between May 1978 and December 1981 to identify factors influencing the demographic mechanisms of survival, recruitment and growth. Data show density appears to be maintained by intraspecific competition, overlaid by spatially and temporally variable recruitment.

Bloxham, M. 2007. *Freshwater Survey Report- Ohiwa Harbour Catchment.* Environmental Publication 2007/05. Environment Bay of Plenty, Whakatane.

A study of streams in the Ohiwa Harbour catchment was carried out to quantify the freshwater fish values of Ohiwa Harbour's tributaries and impediments to fish passage. The report also discussed factors such as geomorphology and fish passage barriers which restrict available habitat area. Quantitative records for the threatened species shortjaw kokopu, long fin eel and banded kokupu are given. The report uses information in NIWA's freshwater fish database, and surveyed previously un-surveyed stream. The report builds on knowledge from an earlier DOC survey on fish passage barriers by corroborating, using fish survey techniques, which streams presently provide fish access and, of those that do not, how effective the instream obstacles are at arresting fish passage. Eleven fish species were encountered. New populations of several species were also discovered.

Burns, B.R., Ogden, J. 1985. *The demography of the temperate mangrove [Avicennia marina (Forsk.) Vierh] at its southern limit in New Zealand.* Australian Journal of Ecology 10(2): 125-133.

This journal article presents results from demographic modelling of the mangrove population growing at its southern limit, which were verified with aerial photographs. The modelling indicates that survivorship of the young tree size class is the main determinant of the population growth rate while annual seed production is relatively unimportant as seedlings are retained in a seedling bank for several years.

Christensen, B.R. 2009. *Bay of Plenty Conservancy Science and Research Prospectus.* Technical Report Series 30. Department of Conservation, Rotorua.

This report lists and prioritises current and future scientific research carried out by the Department of Conservation in the Bay of Plenty Conservancy. It lists an update of Rasch (1989a) as a current project.

Clarkson, B.R., Regnier, C.E. 1989. *West Gisborne. Biological Survey of Reserves Report No. 16.* Department of Conservation, Wellington.

This report describes what is found in reserves and a statement of their biological worth. Survey work was carried out between 1983 and 1984 in Motuotu Island Nature Reserve, Ohiwa Scenic Reserve, Pataua Island Scientific Reserve and Oscar Reeve Scenic Reserve. For each of these sites, a vegetation map is produced, the geomorphology described, the main habitats described in detail, condition commented, a conservation ranking assigned and a section on conclusions and recommendations describes significant ecological features and pressures. There is also a section on threats and a species list is provided for each site. The report presents very detailed information, but is limited in spatial coverage and is based on very old data.

Clarkson, B. 1985. *Ohiwa Harbour field trip: 19 May 1985.* Rotorua Botanical Society Newsletter 5, August 1985.

This report describes vegetation, ecologically significant areas and threats to vegetation at several estuarine and terrestrial sites around the harbour.

Collins, M. 2006. *One Good Turn.* Forest & Bird 320: 30-31.

This article describes pest control on Tern Island (Whangakopikopiko) and bird species on the island, as well as providing information on fledging rates for several bird species.

Daniel, L.J. 1984. *Mangroves and Salt Marshes of Ohiwa Harbour.* Department of Lands and Survey, Gisborne.

The distribution of salt marshes and mangroves is described and mapped in this report. The taxonomy of mangroves, their physiology, their role in the food chain and their expansion with sedimentation are all discussed. A table is provided of major salt marsh and mangrove sites with a description of community and disturbance. The ecological values of the Harbour in providing food and habitat to bird and fish species, as well as threats to the Harbour ecosystem, are discussed. Species observed during the study are noted.

de Lange, W.P., de Lange, P.J. 1994. *An appraisal of factors controlling the latitudinal distribution of mangrove (Avicennia marina var. resinifera) in New Zealand.* Journal of Coastal Research 10(3): 539-546.

This article appraises different factors controlling mangrove limits, which are at their south-eastern distributional limit in Ohiwa Harbour. The study shows coastal processes affecting propagule dispersal are more important controls on distribution than climatic factors, so natural establishment south of present limits is unlikely.

Deely, J., McIntosh, J. 1998. *Bathing Suitability Survey Summer 1998.* Environmental Report 98/3. Environment Bay of Plenty, Whakatāne.

This report describes the results of the Bathing Suitability Survey of summer 1997/98, which indicates water quality conditions. One site in Ohiwa Harbour is surveyed as part of the study.

Dinamani, P. 1971. *Occurrence of the Japanese oyster, Crassostrea gigas (thunberg) in northland, New Zealand.* New Zealand Journal of Marine and Freshwater Research 5(2): 352-357.

This article documents occurrences of this oyster, including from the oyster farm in Ohiwa Harbour for the first time.

Francis, M.P., Morrison, M.A., Leathwick, J., Walsh, C., Middleton, C. 2005. *Predictive models of small fish presence and abundance in northern New Zealand harbours.* Estuarine, Coastal and Shelf Science 64: 419-435.

This article describes a survey of harbours and estuaries carried out to formulate a predictive model which is not specific to Ohiwa Harbour, but does provide a species list for fish in the eight beach seine tows carried out in the Harbour.

Dowding, J.E., Moore, S.J. 2006. *Habitat networks of indigenous shorebirds in New Zealand.* Science for Conservation 261. Department of Conservation, Wellington.

This report reviews current knowledge and collates information on region, habitats and sites used by seven endemic shorebird species in New Zealand. For Ohiwa Harbour information is provided on banded dotterels, New Zealand dotterels and variable oystercatchers.

Environment Bay of Plenty. 2003. *Regional Coastal Environment Plan.* Environment Bay of Plenty, Whakatane.

This report includes a summary of ecological features (based on previous reports) that make Ohiwa Harbour an Area of Significant Conservation Value, as well as providing management guidelines. Specific areas of the Harbour are identified as good representations of the Whakatane Ecological Region.

Environment Bay of Plenty. 2008. *Ohiwa Harbour Strategy.* Resource Policy Publication 2008/06. Environment Bay of Plenty, Whakatāne.

This Strategy sets out a vision for the Harbour, identifies issues, key community values and aspirations, and recommends actions to achieve those. It outlines the process for the assessment of ecological quality that this literature search is designed to do.

Forbes, S., Bridgewater, G. 1990. *Coastal Resource Inventory First Order Survey, Bay of Plenty Conservancy.* Department of Conservation, Wellington.

This survey provides the basis for a national overview of coastal conservation values. It is based on existing information compiled from regional and national databases, published and unpublished reports, limited field surveys and personal or anecdotal information from various experts. Each volume includes a brief description of the conservancies' coastal zone, a summary of the conservation values, a list of issues of concern and recommendations for further work. The information is described on site sheets and plotted on maps at a scale of 1:250 000 to give a broad, overall impression of the coastal conservation values within each conservancy. Ohiwa Harbour and Ohope Spit-Ohiwa Spits are listed as sites of national importance.

Gibb, J.G. 1977. *Late Quaternary sedimentary processes at Ohiwa Harbour, eastern Bay of Plenty with special reference to property loss on Ohiwa Spit.* Ministry of Works and Development, Wellington.

This report describes sedimentary processes in Ohiwa Harbour and likely changes to sedimentation rates in the future. The interaction of sedimentary processes and the Harbour ecosystem is discussed, particularly the expansion of mangroves in response to increased sedimentation.

Gosling, D., Shaw, W.B. 1990. *Pohutukawa survey in the eastern Bay of Plenty.* Rotorua Botanical Society Newsletter 21, December 1990.

An aerial survey of pohutukawa in the eastern Bay of Plenty was carried out to determine the condition of these stands following reports of severe possum browse on isolated pohutukawa trees around the Harbour margins. Significant damage was found on Uretara Island, thought to be the result of possum browsing.

Hack, L.A., Trembles, L.A., Wratten, S.D., Lister, A., Keesing, V. 2007. *Benthic meiofauna community composition at polluted and non-polluted sites in New Zealand intertidal environments.* Marine Pollution Bulletin 54(11): 1801-1812.

Over winter 2004 six sites in northern New Zealand were sampled for physico-chemical parameters, which were compared with meiofauna distribution and abundance. Information on meiofauna assemblages from Ōhiwa Harbour is presented as part of this study.

Hack, L.A., Trembles, L.A., Wratten, S.D., Lister, A., Keesing, V. 2008. *Toxicity of estuarine sediments using a full life-cycle bioassay with the marine copepod Robertsonia propinqua.* Ecotoxicology and Environmental Safety 70(3): 469-474.

This study looked at different aspects of the life-cycle of a marine copepod to formulate a more ecologically informative measure of sediment-associated contamination effects than chemical thresholds. As part of this article, data on the male and female survival rates, fecundity, clutch size, number of eggs in a reproductive cycle and juvenile survival are provided for several sites, including one in Ohiwa Harbour.

Hall, S. 1997. *Rabbit and Wasp Survey: Ohiwa Harbour Catchment, Bay of Plenty.* Operations Report 97/2. Environment Bay of Plenty, Whakatāne.

The purpose of this study was to produce accurate data on rabbit infestation levels and wasp abundance in the Ohiwa Harbour catchment. Results from the survey on the abundance of rabbits, wasps, mustelids, rats, hares, possums, magpies, peacocks and goats are presented in this report. Problem pest areas were documented and the need for further monitoring or action indicated.

Hall, S. 2007a. *Pohutukawa Monitoring- Field Inspections in the Eastern Bay of Plenty Region 2007.* Report prepared by Natural Environment Ltd for Environment Bay of Plenty, Whakatāne.

This report was prepared to provide information on the condition of pohutukawa at selected coastal Category One and Nationally Significant sites in the eastern Bay of Plenty. Canopy condition in 2003 and again in 2007 at Whitiwhiti, Hiwirau and Pataua Island is identified and any changes are described. Other vegetation present and threats to it are discussed.

Hall, T. 2007b. *Land Resources Works in the Ohiwa Harbour Catchment.* File Reference 2519 01. Environment Bay of Plenty, Whakatāne.

This report identifies sedimentation as the primary environmental issue for the Harbour, and work being done to manage this threat.

Hichman, R.W. 1979. *Allometry and growth of the green-lipped mussel Perna canaliculus in New Zealand.* Marine Biology 51(4): 311-327.

This study investigates variation with environmental conditions of the allometry of using green-lipped mussel length to predict mussel weight. Raft- and shore- grown mussels are shown to be morphologically distinct at several sites around New Zealand, including in Ohiwa Harbour.

Intasuwan, S., Gordon, M.E., Daugherty, C.H., Lindsay, G.C. 1993. *Assessment of allozyme variation among New Zealand populations of Gracilaria chilensis (Gracialiares, Rhodophyta) using starch-gel electrophoresis.* Hydrobiologia 260-261 (1): 159-165.

This article compares genetic variations between red algae populations throughout New Zealand. One of the sites sampled for genetic variation is in Ohiwa Harbour.

Jones, M.B., Simons, M.J. 1983. *Latitudinal variation in reproductive characteristics of a mud crab, Helice crassa (Grapsidae).* Bulletin of Marine Science 33(3): 656-670.

This study looked at the population structure and reproductive biology of burrowing mud crabs in relation to latitude. Data on different aspects of burrowing mud crab reproductive characteristics, such as population size structure, sex ratio, and number of eggs were collected for several sites, including in Ohiwa Harbour.

Kilner, A.R. and Akroyd, J.M. 1982. *Ohiwa Harbour Mussel Survey Summer 1978-79.* Fisheries Technical Report No. 158. Ministry of Agriculture and Fisheries, Wellington.

Scuba diving surveys of the distribution, abundance and size of the green lipped mussel Perna canaliculus were carried out in summer 1978/79 after concern the beds were being over-exploited. The results are presented in this report, which were limited because of the lack of information on growth rates, which is needed to fully evaluate the stability of the mussel beds.

Lawrie, A.L. 1997. *Compliance Report: Marine Aquaculture in the Bay of Plenty.* Environmental Report 95\5. Environment Bay of Plenty, Whakatāne.

The effects of the Ohiwa Harbour oyster farm on water quality, and the monitoring required of the consent holder, are described in this report.

McArdle, B.H., Blackwell, R.G. 1989. *Measurement of density variability in the bivalve Chione stutchburyi using spatial autocorrelation.* Marine Ecology Progress Series 52: 245-252.

As part of this survey, the density distribution of New Zealand cockle, Chione stutchburyi, was sampled. The study is principally concerned with sampling design and techniques for adequate detection of spatial and temporal distribution patterns, but does also discuss factors influencing cockle distribution and density in the Harbour on different spatial and temporal scales.

McDowall, R.M., Mitchell, C.P., Brothers, E.B. 1994. *Age at migration from the sea of juvenile Galaxias in New Zealand (Pisces: Galaxiidae).* Bulletin of Marine Science 54(2): 385-402.

This study looked at the age of migration from the sea and differences in life cycles between whitebait species from different sites around New Zealand, including one in Ohiwa Harbour.

McIntosh, J. 1999. *Shellfish Quality Assessment.* Environmental Report 1999/08. Environment Bay of Plenty, Whakatane.

Shellfish throughout the Bay of Plenty, including from several sites in Ohiwa Harbour, are sampled every three years for the presence of contaminants as part of the NERMN. This report presents the results of this monitoring programme, and discusses phenomena specific to Ohiwa, such as the influence of strong winds on shellfish contamination levels.

McIntosh, J., Park, S. 1997. *Environmental Quality of Ohiwa Harbour.* Environmental Report 97/17. Environment Bay of Plenty, Whakatane.

This report summarises the results of monitoring since the NERMN was established in 1990, and indicates some areas where monitoring could be extended to better investigate the environmental effects of land-use. The report analyses results on the water quality of the Nukuhou River and Ohiwa Harbour, as well as bacterial levels in shellfish. Monitoring of marginal vegetation is recommended to be carried out. Included in the report are results from the estuarine and rivers water quality monitoring programmes, estuarine and freshwater ecology programmes, bathing water and shellfish quality programmes. Land use changes since 1975 are discussed.

McIntyre, N., Pavlovich, K., Hayes, L. *Values of Ohiwa Bay: Resident and Non-resident Values of Ohiwa District, Bay of Plenty, New Zealand.* Department of Leisure Studies, University of Waikato.

This study identified five broad value themes associated with Ohiwa District, one of which was natural values. Issues surrounding pollution and concerns regarding shellfish pillage were frequently mentioned as important to people surveyed.

MacKenzie, H. 2010. *Sand Dune Vegetation Mapping and Condition Assessment for Otamarakau-Cape Runaway 2009.* Environmental Publication 2010/02. Environment Bay of Plenty, Whakatane.

Through a combination of walking sand dune extents, aerial photograph analysis and a series of belt transects, mapping of sand dune vegetation throughout the Bay of Plenty was completed in 2009. This report outlines the work and gives management priorities for transects, including several sites in the Ohiwa Harbour catchment. The data provides baseline information for sand dune condition and extent in the region.

Mayhill, P.C. 1994. *Report on land snails of Otanewainuku District.* Unpublished report held by Department of Conservation, Whakatane.

This survey of land snails in the Bay of Plenty included the Pataua Island Scientific Reserve and the Kotare Scenic Reserve in the Ohiwa Harbour catchment. Four species were found and described.

Mitchell, C.P. 1990. *Whitebait Spawning Grounds in the Bay of Plenty.* New Zealand Freshwater Fisheries Miscellaneous Report No. 40. MAF Fisheries, Rotorua.

This study was conducted to provide information to DOC managers to assist with the protection of the Bay of Plenty whitebait fishery by protecting the spawning grounds from unnecessary damage. The objectives of the study were to locate whitebait spawning grounds throughout the Bay of Plenty, record vegetation cover and land use at spawning sites that may affect spawning success and record land ownership so formal moves for protection can be initiated. Detailed information on whitebait spawning is provided for three sites in the Ohiwa Harbour catchment. The Tunanui and Waiotane Streams were studied closely during 1986/87 to investigate the ecology of spawning sites. Eggs were found at the mouth of a small stream on the Nukuhou River in 1987.

Mitchell, C.P. 1991. *Deposition of Galaxias fasciatus eggs with Glaxias maculatus eggs at a tidal site.* New Zealand Journal of Marine and Freshwater Research 25: 201-205.

Fieldwork was conducted on the Waiotane Stream to describe the spawning ecology of Galaxias maculatus (common whitebait). Eggs were found in the intertidal location of the transects of Galaxis fasciatus (banded kokupu), which are normally a forest-dwelling species not found as adults in the intertidal zone.

National Institute of Water and Atmospheric Research. *The New Zealand Freshwater Fish Database.* Available after registration at www.niwa.co.nz

The New Zealand Freshwater Fish Database records the occurrence of fish in the fresh waters of New Zealand, including from sites around Ohiwa Harbour. Information stored in the database is the site location, the species present, their abundance and size, as well as information such as the fishing method used and a physical description of the site, which includes vegetation present. NIWA maintain the database, but data are regularly contributed to it by a wide variety of organisations including the Department of Conservation, universities, regional councils, consultants and fish and game councils.

New Zealand Ornithological Society. www.osnz.org.nz

The Bay of Plenty branch of the New Zealand Ornithological Society carries out twice yearly counts of shorebirds on the Harbour. The results of these surveys between 1984 and 2003 are summarised in Owen et al. (2006). Recent results can be obtained by emailing OSNZEO@slingshot.co.nz.

Owen, K.L. 1991. *A Preliminary Directory of Bay of Plenty Wetlands of International Importance.* Department of Conservation, Rotorua.

This directory lists wetlands in the Bay of Plenty that meet the RAMSAR criteria for wetlands of international importance. A brief overview of each area is given, and important vegetation types, land use, disturbances and threats are described. The hydrological and biophysical values of the Harbour as well as its importance to bird species, and notable species, are discussed. Important flora and vegetation sequences are described, and reasons for RAMSAR inclusion for the Harbour are given.

Owen, K.L. 1994a. *Marshbird Habitat of Ohiwa Harbour.* Technical Report Series No. 22. Department of Conservation, Rotorua.

A survey of marshbird (Australasian bittern, banded rail, spotless crake, marsh crake and North Island fernbird) populations and their habitats was undertaken in the Harbour in November 1990. This report describes the distribution, biology and status of the five marshbird species, as well as Australasian harriers, pukekos and New Zealand kingfishers. Forty two sites are identified as important to marshbird populations. Descriptions are provided for each of these sites, along with information on their value to marshbird populations, habitat quality rankings, existing threats and impacts, and recommendations for protection and conservation management. Owen (1994a) has surveyed, documented, and identified the best examples of marshbird habitats on Ohiwa Harbour, and assessed their management requirements.

Owen, K.L. 1994b. *Wildlife and Wildlife Habitats of Hiwarau Part C Block and Hiwarau A9 Block, Nukuhou River Valley.* Department of Conservation, Rotorua.

An inspection of these blocks in the Ohiwa Harbour catchment was carried out to assess the wildlife and wildlife habitat of the blocks, to evaluate the natural and historic resources associated with the blocks for the trustees. The vegetation of the blocks is described, and a list of common vascular plant species is provided. The survey recorded the presence of 26 bird species recorded in forest and shrubland and wetland areas. Brief searches for native lizards took place without any luck. Threats to habitat areas are described. The importance of the Nukuhou River as a whitebait fishery is discussed. The importance of the blocks as an ecological corridor, and the need for their protection is described. Recommendations are given for future management. The need for fencing, a kiwi survey and whitebait spawning habitat survey are all mentioned.

Owen, K.L. Ohiwa Harbour. In: Cromarty, P., Scott, D.A. (eds.) 1995. *A Directory of Wetlands in New Zealand.* Department of Conservation, Wellington.

The section on Ohiwa Harbour in this directory describes the physical and ecological features of the area, land tenure, conservation measures taken and proposed, land use and possible changes in land use, disturbances and threats to the Harbour's health, and different values associated with the Harbour, as well as noteworthy fauna and flora.

Owen, K.L., Cashmore, P. 2006. *Bay of Plenty Conservancy Threatened Species List March 2006.* Unpublished report. Department of Conservation, Rotorua.

Threatened species in the Bay of Plenty are listed in this report. On the list there are six plant species, nineteen bird species and two fish species found in the Ohiwa Harbour catchment.

Owen, K.L., Wilson, T.D., Latham, P.D., Young, K.D. 2006. *Distribution and conservation of shorebirds in the Bay of Plenty, New Zealand, 1984-2003.* Technical Report Series No. 26. Department of Conservation, Bay of Plenty Conservancy, Rotorua.

This report identifies shorebird roosting sites throughout the Bay of Plenty, and presents data on the distribution of shorebird species and changes in abundance between seasons and over the duration of the study. Species for which Ohiwa Harbour holds at least one percent of the national population are listed. The two principal spring tide roosts- Ohope and Ohiwa Spits, and threats to them are described, and other important roosts within the Harbour are listed.

Park, S. 1991. *Bay of Plenty Regional Council Coastal Overview Report 1991.* Technical Publication Number 3. Bay of Plenty Regional Council, Whakatane.

This report summarises previous work on the geological evolution, hydrology and sediments of Ohiwa Harbour. Benthic habitats and associated fauna are described, as well as maritime marsh, algae and avifauna. The information provided is all based on previous reports. Water quality of the Harbour is discussed. Several areas where more information is needed are discussed, but many of these, notably quantitative assessments of algal abundance or water quality data, have since been addressed.

Park, S. 1992. *Bay of Plenty Regional Council Natural Environment Regional Monitoring Network Coastal and Estuarine Ecology Ulva lactuca Monitoring Programme 1991/92.* Technical Report Number 32. Bay of Plenty Regional Council, Whakatane.

This report introduces and details the methodology and results of the first year of surveys specific to sea lettuce investigations. The ecology of Ulva is extensively described, but most of the report is focussed on Tauranga Harbour. Results are presented for both harbours on mean biomass and tissue nutrient status, as well as sediment and water chemistry. Factors influencing growth that need to be researched and better understood are discussed.

Park, S. 1993. *Bay of Plenty Regional Council Regional Monitoring Network Coastal and Estuarine Ecology Monitoring Programme 1990/91.* Technical Report No. 13. Bay of Plenty Regional Council, Whakatane.

Environment Bay of Plenty undertakes an annual Coastal and Estuarine Ecology Regional Monitoring Network survey over summer each year. This report introduces and details the methodology and results of the first survey of sites are collected. There are six benthic macrobenthic animal monitoring sites in the Harbour. Species richness and diversity in the harbour and variance between sites are discussed. A species list for each site is produced, including the raw data on species abundance.

Park, S. 1996. *Sea lettuce monitoring in the Bay of Plenty: Changes in abundance, nutrients and environmental influences for the period July 1992-June 1996.* Environmental Report 96-23. Environment Bay of Plenty, Whakatane.

Monitoring of sea lettuce cover, biomass, tissue nutrients and recruitment is conducted every second month by Environment Bay of Plenty in Tauranga and Ohiwa Harbours. The resulting data, and information on environmental influences and sediment water interactions, are presented in this report. This baseline data can then be used to help analyse the role of natural climatic or anthropogenic influences in causing periodic nuisance blooms.

Park, S. 2000a. *Bay of Plenty Maritime Wetlands Database.* Environmental Report 2000/21. Environment Bay of Plenty, Whakatane.

Wetland vegetation surveys, digital mapping, data capture and estimation of historic wetland from aerial photography have been completed for most maritime wetland within the Bay of Plenty. This data allows assessment of ecosystem impacts and changes linked to management over time. Temporal changes in palustrine and estuarine wetland and seagrass meadow extent are discussed in the report. Threats to maritime wetland are discussed, particularly reclamation for agricultural use.

Park, S. 2000b. *Benthic Macrofauna Monitoring.* Environmental Report 2000/15. Environment Bay of Plenty, Whakatane.

Environment Bay of Plenty's Coastal and Estuarine Ecology benthic macrofauna monitoring programme includes over 50 sites throughout the harbours and coastal environment of the Bay of Plenty. This report summarises data on water quality and the health of ecosystems. Species richness and sediment parameters have shown a moderate degree of variability, but over the ten-year period of monitoring none of the sites has shown a consistent change.

Park, S. 2005. *Environmental Quality of Ohiwa Harbour - 2005.* Environmental Publication 2005/05. Environment Bay of Plenty, Whakatane.

This report summarises information on various indicators of the environmental quality of Ohiwa Harbour. Data are provided on water quality monitoring, changing seagrass and mangrove distributions, freshwater wetland loss, benthic community monitoring and land use change, much of which has been collected as part of the National Environmental Regional Monitoring programme.

Park, S.G., Taylor, J.R. 2001. *Natural Environment Regional Monitoring Network: Bay of Plenty Rivers' Water Quality (1989-2000).* Environmental Report 2001/12. Environment Bay of Plenty, Whakatane.

This report presents water quality data (both physicuo-chemical and baceteriological) between 1989 and 2000 for the Bay of Plenty rivers collected as part of the Natural Environment Regional Monitoring Programme. Data for each site has been summarised into a water quality score based on seven key parameters. The Nukuhou River has a low water quality score, but this appears relatively stable which may be a function of more effective dairy shed waste disposal properties. Natural influences such as humic colouration and catchment erodability would also have an effect.

Paul, L.J. 1966. *Observations on past and present distribution of mollusc beds in Ohiwa Harbour, Bay of Plenty.* New Zealand Journal of Science 9: 30-40.

A survey of the distribution and density of the mollusc beds in Ohiwa Harbour was carried out in 1963 after a proposal to introduce treated sewage effluent into the harbour. Extensive beds of cockles and pipis were found and mapped, while rock oysters and green-lipped mussels which were present in considerable numbers early in the century were virtually eliminated through over-exploitation and sedimentation. Improved farming practices have reduced erosion and the remaining beds were found to have stabilised. The position of mollusc beds in relation to bottom sediments and water currents, and historical changes in mollusc populations caused by these two environmental factors, are discussed. Invertebrates on or near the main shellfish beds, birds and fish observed during the study are all listed.

Paul-Burke, K. 2007. *Baseline Survey of Kuku, Perna canaliculus, Green Lipped Mussel Populations in the Western Side of Ohiwa Harbour for Environment Ngati Awa.*

A baseline survey was undertaken on the western side of Ohiwa Harbour to investigate the state of green-lipped mussels, and determine their distribution, sizing and population density. Decreases in the abundance of mussels were found in areas where there was a high silt component or where a significant presence of unidentified tubular sponge populations was observed. The report discusses the ongoing sedimentation issue, and other issues affecting mussel abundance, notably competition for space.

Quinn, P.J. 2002. *Ohiwa: The Food Basket of Many Hands.* New Zealand Geographic 57: 79-94.

This article mainly details with people's attachment to the Harbour, but also provides anecdotal evidence about declines in fisheries, the effects of erosion, bird species present and threats to different aspects of the Harbour's ecology.

Rasch, 1989a. *Wildlife and Wildlife Habitat in the Bay of Plenty Region.* Regional Report Series No. 11. Department of Conservation, Rotorua.

Survey work done between 1982 and 1984 in the Bay of Plenty region is summarised in this report. Data was collected for areas of wildlife habitat on the degree of modification, area, land tenure, vegetation types, fauna species present, threat to habitat and extent of public use. Each site was given a conservation ranking based on its value to wildlife, and the entire Harbour is ranked as an outstanding site of special wildlife interest. The report states little is known about the true distribution, conservation status and biology of reptiles or insect fauna. Ohiwa Harbour is ranked as an outstanding Site of Significant Wildlife Interest and a description of the Harbour morphology, fauna species and modification is provided.

Rasch, 1989b. *Wildlife and Wildlife Habitat in the East Cape Region.* Regional Report Series No. 12. Department of Conservation, Rotorua.

Survey work done between 1982 and 1984 in the East Cape region is summarised in this report. Data was collected for areas of wildlife habitat on the degree of modification, area, land tenure, vegetation types, fauna species present, threat to habitat and extent of public use. Each site was given a conservation ranking based on its value to wildlife, and the entire Harbour is ranked as an outstanding site of special wildlife interest. The report states little is known about the true distribution, conservation status and biology of reptiles or insect fauna. Ohiwa Harbour is ranked as an outstanding Site of Significant Wildlife Interest and a description of the Harbour morphology, fauna species and modification is provided.

Richmond, B. 1977. *Geomorphology and Modern Sediments of Ohiwa Harbour.* Unpublished thesis, University of Waikato.

This thesis principally describes the geomorphology and hydrology of Ohiwa Harbour, but also discusses biological effects on sedimentation and produces a general biofacies (areas dominated by a particular macro-organism after which it is named) map for the Harbour. The distribution of vegetation types, aquatic invertebrates and algae, and their effects on sedimentation, are also discussed.

Richmond, B.M., Nelson, C.S., Healy, T.P. 1984. *Sedimentology and evolution of Ohiwa Harbour, a barrier-impounded estuarine lagoon in Bay of Plenty.* New Zealand Journal of Marine and Freshwater Research 18: 461-478.

This article mainly describes the geomorphology of the Harbour, but also discusses the biological communities in the Harbour and the effects on sedimentation they have. A table summarises the major characteristics of the dominant biofacies: the dominant and associated species, their preferred environment, preferred substrate, and major effects on sedimentation.

Rohleder, M. 1990. *Preliminary survey on the water and shellfish quality of the eastern zone of Ohiwa Harbour.* Bay of Plenty Area Health Board, Health Development Unit.

Data are presented in this report from a survey of the water and shellfish quality in the eastern Harbour.

Roughan, B.M., Okell, R.S. 1988. *Sanitary Survey Ohiwa Harbour Shellfish Leases 25, 43 and 52 and the Baker Lease.* Department of Health, Rotorua.

Water quality analysis was carried out in shellfish growing area of the Harbour and the data are presented in this report. The report states the growing lease areas are affected by non-point pollution which causes the water quality to fluctuate of a sufficient frequency that the area should not be conditionally approved. The report also details harvesting restrictions and harvest practices related to different species.

Rowe, D.K., Bowman, E. 1995. *Fish passage past the Wainui Stream Weir.* NIWA Consultancy Report TFL004 prepared for Tasman Forestry Ltd. Information should not be used without prior consent of client

The results of a fish survey above and below the Wainui Stream weir are presented in this report, and the implications of the weir on the stream ecosystem are discussed.

Scholes, P. 2005. *NERMN Estuarine Water Quality 2005.* Environmental Publication 2005/19. Environment Bay of Plenty, Whakatane.

Water quality in Ohiwa Harbour is monitored as part of Environment Bay of Plenty's Natural Environment Regional Monitoring Programme. Dissolved oxygen (near the surface), temperature and salinity are measured in the field and samples are collected for analysis of turbidity, suspended solids, conductivity, salinity (laboratory), pH, chlorophyll a, nitrate-nitrogen, ammonium-nitrogen, dissolved reactive phosphorus, total phosphorus, and indicator bacteria. Results from Ohiwa Harbour show the importance of the wind in stirring up sediments. Water quality trends over time are also discussed.

Scholes, P., Wiseman, J. 2004. *Bathing Beach Grading Report.* Environmental Publication 2004/13. Environment Bay of Plenty, Whakatane.

This report evaluates the water quality for the Bay of Plenty's most popular and higher risk recreational waters. Evaluating the risks runoff and discharges pose to recreational waters is now determined by a system based on indicator bacteria results, as well as a catchment survey of potential microbiological hazards. One site in Ōhiwa Harbour is surveyed as part of this report.

Shaw, D.J. 1982. *Coastal Resource Management in New Zealand. A Case Study: The Whakatane District Coastal Resource, Its Management, Control, Planning & Implications For Its Future Use.* Unpublished thesis. Lincoln College, University of Canterbury.

This report describes the vegetation communities and physiography of the Harbour and factors which it make it particularly susceptible to harmful environmental impacts. Physical functions performed by the estuary for its biota are discussed. The report also identifies five major types of birdlife and gives a species list.

Shaw, W.B. 2000. *Vegetation survey and monitoring in Whakatane Field Centre. Conservation Advisory Science Notes No. 273.* Department of Conservation, Wellington.

Existing vegetation survey and monitoring undertaken by the Department of Conservation's Whakatane Field Centre is summarised and justified in this report, including areas in the Ohiwa Harbour catchment.

Shaw, W.B., Allen, R.B. 2003. *Ecological impacts of sea couch and saltwater paspalum in Bay of Plenty estuaries.* DOC Science Internal Series 113. Department of Conservation, Wellington.

This report describes the ecological effects, management options and past recorded distributions of sea couch. The potential for saltwater paspalum distribution limits to expand with projected climate change is also mentioned.

Shaw, W.B., Gosling, D.S. 1997. *Spartina ecology, control and eradication- recent New Zealand experience.* Proceedings of the Second International Spartina Conference: 32-38.

Use of haloxyfop to eliminate the estuarine grass Spartina alterniflora without damage to mangroves is discussed in this article as a successful example of selective control.

Shaw, W.B., Taylor, J. 2003. *Aerial monitoring of coastal indigenous forest in the Bay of Plenty Region 2003.* Wildland Consultants Ltd Contract Report No. 687 prepared for Environment Bay of Plenty, Whakatane.

An aerial survey of indigenous forest was undertaken in March 2003 to assess canopy condition and the results are summarised in this report. Pohutukawa around the Harbour was found to be in generally good condition.

Smale, M.C. 1990. *Ecology, Succession and Conservation of Coastal Kanuka Communities in Eastern Bay of Plenty.* Forest Research Institute Contract Report FEW 90/28 prepared for Department of Conservation, Wellington.

Coastal kanuka communities in the eastern Bay of Plenty were studied in 1989-90 to review the occurrence of coastal kanuka communities on sand dunes, to assess the structure and composition of remnant coastal kanuka communities and to describe the natural dynamics of these communities, identifying threats and formulating management prescriptions. Uretara Island is the only site described in the Ohiwa Harbour catchment.

Smale, M.C. 1993. *Forest regeneration on Uretara Island, Ohiwa Harbour, Bay of Plenty.* Tane 34: 145-153.

A study was made of secondary kanuka forest, the predominant plant community, on the main hill of Uretara Island. The history of the island, and vegetation clearance is described. Adventive fauna on the island are described. In the study, temporary plots were recorded to study the present structure and composition of the forest. Information on the density and size of different species is provided.

Snow, J.A. 1995. *The population ecology of intertidal Ulva in the Bay of Plenty.* Unpublished thesis, University of Auckland.

This thesis investigated three aspects of the life history of Ulva: swarmer release, growth of individual plants and populations, and recruitment in Tauranga and Ohiwa Harbours. The study compares results between the harbours and discusses the effects of enhanced algal growth. It also looks at seasonal variations and factors increasing algal abundance.

Southey, I. 2009. *Number of waders in New Zealand 1994-2003.* DOC Research and Development Series 308. Department of Conservation, Wellington.

This report evaluates OSNZ count data to examine the status of wading birds throughout New Zealand. Data is provided for Ohiwa Harbour.

Tai Perspectives. 1993. *Bay of Plenty Coastal and Estuarine Ecology Monitoring Programme Identification of Amphipod (Crustacea) Species.* Report prepared for the Bay of Plenty Regional Council.

This report mainly describes features for identifying amphipod species, but does mention one species (Cephalophoxys regium) recorded inter-tidally in the Ohiwa Harbour, as well as at other places in the Bay of Plenty.

Taylor, J.R., Park, S.G. 2001. *Natural Environment Regional Monitoring Network: Bay of Plenty Rivers' Water Quality (1989-2000).* Environmental Report 2001/12. Environment Bay of Plenty, Whakatane.

This report presents physico-chemical and bacteriological water quality data of the rivers collected between 1989 and 2000 as part of Environment Bay of Plenty's NERMN programme. Water quality parameters of the Nukuhou River are discussed in the report.

van der Wouden, A. 1993. *Ohiwa: A Short History and Guide.* Whakatane and District Historical Society, Monograph 23.

This booklet is principally concerned with the history of human settlement around Ohiwa Harbour, but some descriptions, such as changes to Te Puna Mango (the Shark Pool), where sharks used to give birth before shallowing took place, give indications of past ecological conditions.

Wilding, T.K. 2001. *River Invertebrate Monitoring 1991-2000.* Environmental Report 2001/13. Environment Bay of Plenty, Whakatane.

This report examines the state and trends of invertebrate communities in Bay of Plenty rivers based on data collected as part of the Natural Environment Regional Monitoring Programme. Data from the Nukuhou exceeded expectations given more than half the catchment is in pasture and it has one of the greatest proportions of dairying. In contrast the water quality data does reflect land use, including elevated ammonia and sediment levels, supporting the need for both water quality and ecological monitoring.

Wildland Consultants Ltd. 1999. *Natural Heritage of Ōpotiki District.* Wildland Consultants Ltd Contract Report No. 185 prepared for Opotiki District Council, Opotiki and Environment Bay of Plenty, Whakatane.

This project mapped and documented natural heritage sites in the Opotiki District. Sites around Ohiwa Harbour that are important for their natural heritage value are identified, and the indigenous vegetation and habitats for indigenous fauna were described and evaluated. For each site vegetation, flora, fauna and threats are all discussed, and a botanical conservation rank is given and justified. For all the sites in the Ohiwa catchment, the information in this report is based entirely on data from previous reports.

Wildland Consultants Ltd. 2006. *Significant Indigenous Vegetation and Significant Habitats of Indigenous Fauna in the Coastal Environment of the Bay of Plenty Region.* Wildland Consultants Ltd. Contract Report No. 1345 prepared for Environment Bay of Plenty, Whakatane.

This study was undertaken to review the location, extent and site-specific information on significant indigenous vegetation and significant habitats of indigenous fauna within the Bay of Plenty coastal environment. The results are based on existing information and a field survey where there were gaps in the information. Sites both in the harbour and its catchment are mapped, the vegetation and habitat types described, indigenous flora and fauna, as well as threats and modifications are discussed. The sites are evaluated for ecological significance based on the Regional Policy Statement Heritage Criteria, and given a relative significance which is then discussed and justified. Collates most existing information in concise manner.

Willems, N. 2009. *Coastal indigenous forest canopy condition in the Bay of Plenty region: Aerial Monitoring 2007.* Environmental Publication 2009/10. Environment Bay of Plenty, Whakatāne.

This report describes the results of coastal forest aerial and ground canopy monitoring in 2007, and any changes since a previous survey in 2003. Scores around Ohiwa Harbour were mostly the same, except for Ohakana Island and Hiwarau, where scores were slightly lower. The report also evaluates the methodology used as part of the two surveys.

Wiseman, J. 2003. *Ohiwa Harbour: Study of Ohiwa Harbour to indicate whether there is a correlation between the density of Amphibola crenata and a proportion of fine sediment silt content within fenced and unfenced sites.* Environment Bay of Plenty, Whakatane.

This study looked at whether the density of mud snails was correlated with silt content at sites around Ohiwa Harbour. The ecological functions performed by salt marsh and mangroves are discussed in the report, as well as threats to the Harbour ecosystem, particularly from cattle.

Woodroffe, C.D., Grindror, J. 1991. *Mangrove biogeography: the role of Quaternary environmental and sea-level change.* Journal of Biogeography 18: 479-492.

This study looked at factors controlling the distributional limits of mangroves, and particularly the importance of sea-level fluctuations in controlling their biogeography.