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EXECUTIVE SUMMARY

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This report forms part of the *Taking Stock* project which is seeking to understand the long-term effects of climate variations and human impacts on the structure and functioning of New Zealand's marine shelf ecosystems. It uses archaeological data to estimate the numbers and biomass of marine animals used as food by people in two New Zealand study areas during the period before European settlement. The study areas are Greater Hauraki, on the northeast coast of the North Island, and Otago-Catlins, on the southeast coast of the South Island. For each area estimates are made for three points in time; *ca.* 1400 AD, *ca.* 1550 AD, and *ca.* 1750 AD.

The method used to generate the estimates is novel, and involves three steps. First, archaeological data were analysed to determine the range of marine animal species harvested by Maori at each focal date in each study area, and the proportional contribution of each species to the total energy harvest from animals. Second, the scale of the total energy harvest from animals was approximated by estimating the size of human population, the energy required to sustain them, and the proportion of that derived from animal foods. Finally, the number of each marine animal species required to contribute the proportions derived in the first step to the total energy harvest from animals estimated in the second step was calculated using an estimate of the calorific value of the meat derived from an individual of the species concerned. Three estimates were made for each species; a minimum estimate which used the lowest probable values for each variable in the second step of analysis, a maximum estimate using the highest probable values, and a best estimate based on the most realistic or well-supported values. Cumulative calculation errors were applied to each set of estimates.

Estimates are presented for 101 taxa from the Greater Hauraki study area (46 shellfish, 28 fish, 22 birds and 5 mammals) and 96 from the Otago-Catlins study area (36 shellfish, 25 fish, 28 birds and 7 mammals). In a small number of cases estimates are available for only one or two of the focal dates, either because of changes in the availability of the species concerned or the pattern of harvesting by Maori.

For the majority of species the minimum, best and maximum estimates all indicate increased harvesting over time. For example, at *ca.* 1400 AD in Greater Hauraki the best estimate of harvested biomass of snapper (*Pagrus auratus*) is 72.1 ± 21.6 tonnes (minimum 12.1 ± 3.6 t; maximum 107.5 ± 32.3 t), which rose to 938.8 ± 281.7 t (min. 354.8 ± 106.4 t; max. 1354.7 ± 406.4 t) at *ca.* 1550 AD, and then 997.2 ± 299.2 (min. 560.1 ± 168.0 t; max. 1393.9 ± 418.2 t) at *ca.* 1750 AD. In contrast, marine mammals and some marine and coastal bird exhibit declining trends under all three sets of estimates. For example, the fur seal (*Arctocephalus forsteri*) which yielded a best estimate of 284.9 ± 85.5 t (min. 47.9 ± 14.4 t; max. 425.1 ± 127.5 t) at *ca.* 1400 AD in Greater Hauraki was no longer harvested at the two later focal dates. In Otago-Catlins harvests of the same species fall successively from best estimates of 237.0 ± 71.1 t (min. 55.2 ± 16.6 t; max. 383.5 ± 115.1 t) to 103.3 ± 31.0 t (min. 24.0 ± 7.2; max. 173.8 ± 52.1 t) then 77.0 ± 23.1 t (min. 57.4 ± 17.2; max. 99.7 ± 29.9 t) in *ca.* 1400, 1550 and 1750 AD, respectively.

In the Greater Hauraki region growth of the human population was one of two main reasons for the increased harvests of most marine animals. In addition, the demand placed on most fish, shellfish and some bird species increased over time because seals, moas and some of the marine and coastal birds that made important contributions to earlier Maori diets ceased to be available. This process of replacement of one food source by another was the single most important driver of change in Otago-Catlins, where the human population remained more or less stable throughout the study period.

As well as contributing to understanding of long-term changes in the structure and functioning of New Zealand's marine shelf ecosystems, the estimates provide baseline data against which modern customary and commercial harvests of marine animals can be measured.

1. INTRODUCTION

1.1 Overview

New Zealand was the last major land mass to be settled by humans, their arrival dated to around 1280 AD (Wilmshurst et al. 2011). Consequently, New Zealand has a short and reasonably complete archaeological, historical and contemporary record of human exploitation of marine resources compared to most other places where the earliest evidence of human impacts on marine ecosystems is difficult to discern because of climate fluctuations and changes in sea level (MacDiarmid 2011). The collaborative multi-disciplinary *Taking Stock* project, funded by the Ministry of Fisheries, has the overall objective of determining the effects of climate variation and human impact on the structure and functioning of New Zealand shelf ecosystems over the timescale of human occupation. To achieve this it set out to build a mass balance model of current coastal and marine shelf ecosystems in each of two study areas, and then to estimate how each of these operated at five earlier intervals: *ca.* 1950 AD (before modern industrial fishing), *ca.* 1750 AD (before European whaling and sealing), *ca.* 1550 AD (about the middle of the Maori period of occupation), *ca.* 1400 AD (soon after Maori arrival in New Zealand) and *ca.* 1000 AD (before human settlement). For each of the earlier intervals reconstruction depends in part on estimation of the taxonomic composition and biomass of removals from the marine environment through human activities. This report draws upon archaeological data for the exploitation of marine resources by Māori in the Hauraki Gulf and along the Otago-Catlins coast to estimate what they harvested from the sea at three intervals between earliest settlement and European arrival at the end of the 18th century AD (*ca.* 1400, 1550, 1750 AD).

1.2 Previous Research

There is a long history of using archaeological data to infer changes in past ecosystems. Numerous instances of animal extinctions and distributional changes have been detected, dated and examined through archaeological research (e.g. Grayson 2001, Rick & Erlandson 2008). In New Zealand, as elsewhere in the world, most of these examples concern terrestrial fauna, and in many cases predation by people and their commensals or human-induced habitat modification have been implicated (Anderson 1989, Anderson 1997, Holdaway 1999, McGlone 1989).

For the marine environment, evidence is much more equivocal. New Zealand seals provide one well-explored case of pre-industrial human impacts (Smith 1989, Smith 2005), and internationally there are others for terrestrial-breeding marine mammals (Bryden et al. 1999, Burton et al. 2001). Equally, there are cases of apparently stable, long-term exploitative relationships (Etnier 2007), and for marine-breeding animals there is little undisputed evidence of dramatic human impact before the emergence of commercial whaling in the 18th and 19th centuries (Reeves & Smith 2006) and more recent industrial-scale fisheries (Myers & Worm 2003, Pauly et al. 1998). Indeed, the New Zealand data for pre-European shell and fin fisheries show that it is difficult to separate potential effects of human predation and climate without intensive and closely targeted archaeological research (Leach 2006).

Direct estimation of animal population biomass from archaeological data is not generally possible. The archaeological window into past ecological systems is blurred by transformative processes that influence the creation of the archaeological record. These include harvesting and carcass processing, which are largely determined by cultural patterns, along with natural taphonomic processes of decay, and variations in the accuracy with which different items are amenable to archaeozoological analysis (Reitz

& Wing 2008). Furthermore archaeologists are primarily concerned with determining long-term patterns and regularities in human behaviour, rather than reconstructing past ecosystems, and their data acquisition and analytical methods are designed accordingly. In order to be useful in palaeoecological reconstruction, archaeozoological data must be interpreted with due regard to the cultural and natural formation processes that shaped them, and the archaeological filters through which they have passed.

In the case of pre-European New Zealand, one of the key cultural factors that must be accommodated is the mobile nature of human settlement, whereby members of a community are hypothesised (Anderson & Smith 1996, Walter et al. 2006) to have made regular intra-annual shifts of residence to facilitate the exploitation of dispersed, seasonally available resources, and communities made occasional territorial shifts over time. Thus no single site can be considered to provide a complete picture of the pattern of marine resource exploitation by a community, and some sites may represent multiple phases of exploitation with differing return intervals. In these circumstances it is essential to aggregate data at a regional level from a judiciously selected range of sites.

With these cautions in mind, some inferences about palaeoecology are possible. The *presence* of physical remains of an animal species in a regional set of archaeological sites can generally be used to infer that this species occurred in the catchment area of those sites at the time of their occupation, and thus provides a basis for reconstructing the distribution of that species in the past. Similarly, where age or sex can be determined from physical remains, the presence of animals of specific age or sex classes allows some inferences to be made about the age composition and breeding status of exploited populations. Potential confounding factors include long-distance transportation of preserved food remains, industrial usage of bones, teeth or shells from distant sources or older archaeological deposits, and disturbance of archaeological deposits introducing taxa from earlier or later time periods. Where recovery and analytical procedures are adequate, problems of this kind can usually be identified and ameliorated. In contrast, the *absence* of a species, age or sex class in the archaeological record is not so clear cut. Cultural factors such as dietary preference and harvesting technology, or analytical factors such as sample size, may have intervened. These must be accounted for before archaeological absences can be used to infer lacunae in past animal distributions.

Caution is required in making inferences about the abundance of various species in the past from archaeological data. The *relative abundance* of taxa in archaeozoological assemblages is primarily a record of the frequency with which they were harvested, modified over time by taphonomic decay. Nonetheless it is reasonable to infer that species which are regularly represented in high frequencies in a regional sample of sites were relatively commonly available. Furthermore, where there is a significant decline in the relative abundance of a species over time, without any evidence for changes in harvesting technology, a decline in their availability can be inferred. Relative abundances of archaeofauna can also be used to derive quantitative assessments of the relative importance of various animals in the diet of the people exploiting them by converting them into the weights of meat that they represent, from which can be derived estimates of the nutritional and energy yields derived from each exploited species (Smith 2004, Smith 2011).

Two broad approaches were taken to generate information useful to the *Taking Stock* project. First, an overview of marine resource utilisation was constructed for each study area based upon the presence/absence of marine taxa in archaeozoological assemblages and, where suitable data was available, their relative abundance. The second approach involved estimating the magnitude of marine biomass removals through human exploitation in each study area. This was undertaken using estimates of the size of human populations, their energy requirements and the relative contributions of marine foods to their diet.

1.3 Objectives

The purpose of this report is to assess and collate existing archaeological data on human removals from the marine environment in two New Zealand study areas in order to address the archaeological aspects of Objective 2 of the *Taking Stock* Project ZBD200505, which was "To assess and collate existing archaeological, historical and contemporary data (including catch records and stock assessments) on relevant components of the marine ecosystem to provide a detailed description of change in the shelf marine ecosystem in two areas of contrasting human occupation over last 1000 years". The specific objective for the archaeological component of this project was to provide detailed estimates of the magnitude of human removals from the marine shelf ecosystems of two study areas at three points in times between first human arrival in New Zealand and European settlement.

2. METHODS

2.1 Study Areas and Selection of Study sites

Two study areas were utilized for the *Taking Stock* project, *Greater Hauraki* on the east coast of the North Island and *Otago-Catlins* on the east coast of the South Island, in each case extending from mean high water out to a depth of 250 m (Figure 1). To derive archaeological information relevant to human exploitation of these areas data was drawn from archaeological sites on the adjacent coasts. More than 10 000 sites presumed to derive from the pre-European period have been recorded adjacent to the Greater Hauraki coast and some 800 in Otago-Catlins (CINZAS 2008), the difference reflecting the marked concentration of pre-European Maori population in the northern third of the country.

Only a small proportion of recorded sites in each area have been investigated by archaeological excavation, and information from these was assessed through a review of published literature, theses and dissertations in archaeology from University of Auckland and University of Otago, and excavation reports lodged in the NZ Historic Places Trust's Archaeological Report Digital Library. A sample for each study area was selected for detailed analysis on the basis of two criteria: the availability of data on faunal remains suitable for the methodology described below; and the availability of reliable chronological information enabling the sites, or specific assemblages from them to be placed securely in time.

The requirements for data on faunal remains were (a) that taxonomic identifications had been reported for all animal remains in the excavated sample, and (b) the number of animals assigned to each taxon was reported. In this context identifications include determinations to species level along with assignments to genus, family or higher-level designations as necessitated by the nature of archaeozoological material. Identification data were accepted as reported, except where assemblages or components of them had been re-examined (e.g. Leach & Boocock 1993, Millener 1981, Smith 1985, Worthy 1998) any revisions of identification were incorporated. Where necessary identifications were updated to accommodate revisions of nomenclature, based on the following sources: for shellfish, Spencer et al. (2009); finfish, Froese & Pauly (2010); birds, Checklist Committee (OSNZ) (2010); and mammals, King (1995) and Baker et al. (2010). Quantification of identified taxa was in terms of the *minimum number of individuals (MNI)*: the smallest number of individual animals necessary to account for all of the remains of a taxon in an archaeological assemblage (Reitz & Wing 2008). While NISP (number of identified specimens) is sometimes preferred for inter-assemblage comparisons (Lyman 2008), this measure was not reported for the majority of assemblages under consideration here. Initially assemblages were selected for analysis only if MNI were reported for all classes of fauna represented at the site. However this did not provide sufficiently large datasets for some time periods in each study area, and additional assemblages for which some taxa were noted as present but not quantified were also included. All the taxonomic identifications, MNI values and presence data utilised in this study, along with the data sources that they were drawn from, are reported in detail by Smith & James-Lee (2010).

With regard to chronology, the primary requirement was for radiocarbon determinations that closely dated formation of the occupation deposit from which the faunal sample under analysis derived. All dates reported in publications were treated according to protocols that are set out in detail elsewhere (Smith 2010). In brief these involved checking data accuracy; culling dates that did not meet sample suitability criteria (Anderson 1991, Petchey 1999, Schmidt 2000a); recalibration using the SH04 calibration curve (McCormac et al. 2004) for terrestrial samples, and for marine samples the Marine 04 calibration curve (Hughen et al. 2004) with delta R set at -7±45, as recommended by the Waikato Radiocarbon Dating Laboratory (Petchey pers. com.); and, where appropriate, combining multiple determinations from the same context into pooled mean ages (Ward & Wilson 1978). The 126 admissible dates and 29 pooled mean ages employed in this study are reported in Smith & James-Lee (2010).

Together the selection criteria admitted a total of 107 assemblages from 67 sites for analysis. For the Greater Hauraki area a total of 75 assemblages from 48 sites were included and 32 assemblages from 19 sites in the Otago-Catlins area (Figure 1). In order to provide data relevant to *Taking Stock's ca.* AD 1400, *ca.* AD 1550 and *ca.* AD 1750 time slices, and bearing in mind the uncertainties inherent in radiocarbon dating, assemblages were grouped according to three broad period designations: Early (*ca.* AD 1250–1450), Middle (AD 1450–1650), and Late (AD 1650–1800). Assemblages were allocated to time periods using Smith's (2010) protocol which uses both 1σ and 2σ calibrated age ranges to distinguish those that can be assigned with confidence to a discrete period from those that overlap the period boundaries. On this basis almost two thirds of the assemblages were assigned to one of the target periods, and the remainder to one of the two overlap zones (Table 1). Although the latter do not represent discrete time spans, they usefully group assemblages that cluster in age around the arbitrary period boundaries, and for assessment of general trends in faunal assemblage composition during the initial steps of the analysis described below (2.3.1, 2.3.2) they are used as if they were discrete periods. However estimation of the magnitude of Maori marine harvest was undertaken only for the three formal periods.

2.2 Analytical Method: Overview

Estimates of the magnitude of marine biomass removals by people in the prehistoric past are necessarily speculative, as they depend upon variables that cannot be known with precision. However it is possible to deduce reasonable bounds for these, and thereby constrain the limits of speculation. The approach used here builds upon that employed by Leach (2006: 277-279) to calculate the scale of the Maori snapper fishery in Northland. It has been adapted to incorporate the full range of marine taxa harvested by Maori in each study region. There were three major steps involved in this analysis (Figure 2).

1. The archaeological assemblage data discussed above were scrutinized to establish the range of animal species harvested by Maori in each study area during each study period, the relative frequencies with which this occurred, and proportional contributions of each species to the total energy harvest from animals.

2. The scale of the total energy harvest from animals during each period in each study area was approximated by estimating the size of the human population, the energy required to sustain them, and the proportion of this derived from animal foods.

3. The number of each marine animal species required to contribute the proportions derived in (1) to the total energy harvest from animals estimated in (2) was calculated using an estimate of the calorific value of meat derived from an individual of the species concerned.

Each of these steps is discussed further below.

2.3 Analysis of archaeological data

Although the final outputs of this project concern the harvesting of marine animals, preliminary analysis of archaeological data incorporated both marine and terrestrial fauna, as it is necessary to reconstruct the contributions of all sources of food in pre-European Maori diet in order to apply the model described above. Archaeological data from each time period in each study area were analysed in five steps.

2.3.1 Determining the range of species harvested.

The species of animals harvested was established by summarising the full suite of assemblages in each area/period data set. This enabled incorporation of taxa represented only in assemblages for which quantified data were incomplete. The proportion of assemblages in which each species was represented during each study period was calculated to provide the broadest level analysis of changes in harvest patterns over time. Analysis of these data disclosed taxa that are likely to be either under- or over-represented in quantified archaeofaunal samples, and also highlighted variations in species representation between sites of different functional types, both factors relevant to defining overall regional patterns. Further details and results of this analysis are presented elsewhere (Smith in press).

2.3.2 Determining the frequency with which species were harvested.

The frequency with which species were harvested was investigated through analysis of the data sets quantified via MNI. This is a derived measure, and presents some difficulties as variations in calculation methodology can influence data outputs, especially when, as here, information is drawn from a range of different researchers (Reitz & Wing 2008). However it was the only measure available for a wide range of assemblages, and the only one from which estimates of harvested biomass across all classes of fauna could be generated. The uncertainties that this introduces into calculations are considered further below (Section 2.3.5).

MNI for each assemblage were first subdivided into seven faunal classes (fish, shellfish, marine and coastal birds, marine mammals, moas, smaller terrestrial birds, and terrestrial mammals) and %MNI within each class calculated. This procedure provides a much finer-grained assessment of within-class frequency than is possible when assemblages are treated as a whole, due to wide variations in faunal class abundance between sites of different functional types, such as specialised shell fishing camps or generalised occupation sites (Smith in press).

Mean %MNI across all assemblages in each period/area data set were then calculated. For two data sets (Greater Hauraki, Middle/Late and Late period marine/coastal birds) comprising a small number of assemblages with low species MNI, %sum MNI was preferred as a better estimate of relative abundance. Where the taxa list for a period/area set included imprecisely identified taxa (e.g. *Phalacrocorax melanoleucos?; Trachurus ?sp.;* ‘elephant seal or leopard seal’; etc.) in addition to positively identified species of the same sort(s), frequencies for the former were redistributed to the latter. Where the latter included more than one positively identified species, their relative abundance was factored into the redistribution so as to maintain proportionality of positively identified taxa.

For several data sets adjustments were made to incorporate taxa known to be present from analysis in 2.3.1 above, but not present in the quantified samples. This was required for all classes of fauna for the Middle period in Otago-Catlins for which there were only two study assemblages, neither having quantified data. In these cases the average of mean %MNI in each of the adjacent overlap periods (Early/Middle, Middle/Late) was calculated for the species noted as present in the Middle period assemblages, and the resulting values were adjusted so that each faunal class summed to 100%. For the Middle period in Greater Hauraki none of the assemblages, quantified or otherwise, yielded marine or coastal birds, but as argued elsewhere (Smith in press) this is more likely to reflect sampling variation than lack of harvesting. For the present analysis, the range of species represented in the subsequent overlap period (Middle/Late) was utilised, with their frequency derived from the average of mean %MNI in the Early/Middle and Middle/Late overlap periods, adjusted to total 100%.

Finally, adjustments were made to the Late period frequencies for marine/coastal bird in both study areas where Diomedeidae appeared to be over-represented through bones from beach wrecks being collected as raw material for artefact manufacture (Smith in press). Comparison with earlier periods suggests remains of this family are about twice as common as expected, and on this basis %MNI for species in this family were reduced by half and all other taxon frequencies increased proportionately.

The adjusted %MNI values for each taxon are referred to as *taxon frequencies* when incorporated in subsequent steps of the analysis. Values for the Early, Middle and Late periods in each study area are listed in Appendix 1.

2.3.3 Determining the energy yield per species in study assemblages

The importance of each species as a source of energy in the human diet was evaluated for each assemblage using procedures set out in detail elsewhere (Smith 2011). In brief this involved converting the frequency of each species in an assemblage first to the weight of meat that they represented and then to the calorific value of energy that this would produce (Figure 3).

For smaller-sized classes of fauna it was presumed that all usable meat on each animal would have been available for consumption, and MNI were used as the starting point for calculation. Mean adult body weights, and a conservative estimate of the proportion likely to have been usable meat in the prehistoric New Zealand setting were used to generate meat yields, and data from proximate composition analysis for the species concerned or the nearest comparable taxon were used to derive calorific yields. Details of the values adopted for each species, the rationale for their selection, and the sources that they are drawn from are given elsewhere (Smith 2011).

For larger-sized animals, archaeological evidence frequently discloses only partial carcass representation, hence assuming that complete animals were present risks over-estimating their dietary importance. Except where skeletal element representation in an assemblage indicated that a complete or near complete individual was present, species frequency for the larger animal classes was measured in terms of the *minimum number of butchery units (MNBU)*: the smallest number of butchery units necessary to account for all of the remains of a taxon in an archaeological assemblage. Age and sex related size differences are also relevant to accurate estimation of dietary importance in large animals, and where adequate data were available for archaeological remains (in the present context, only for some seal species) these were incorporated into calculations (Smith 2011).

These procedures were applied to the subset of study assemblages with quantified data for all classes of fauna. In each case the proportion of total energy from animals (%Kcal) derived from each of the seven major classes of fauna was calculated, and incorporated into the following step.

2.3.4 Determining the relative energy yields of each faunal class per area/period

The relative contributions to the energy harvest from each faunal class during each formal period (i.e. Early, Middle, Late) in each study area was estimated from mean energy contributions (%Kcal) of each major faunal class in either the total area/period data set, or a subset thereof. A series of adjustments were then made to each set of calculated values to take account of probable under-representation of some classes of fauna. Both the rationale for the selection of most appropriate data suites and justification for subsequent adjustments are discussed in detail in a manuscript currently in preparation (Smith n.d.). Key elements of these are summarised below.

For the Early period in both study areas all the sample sites appear to have been villages at which a wide range of subsistence activities were represented, indicating that the best estimate of the relative importance of each faunal classes could be derived from its mean %Kcal in the total data set for each area. Sites from the Middle period in Greater Hauraki included a small number of generalised village sites along with a greater number of specialised shellfish gathering and/or fishing camps. Most of the latter represented comparatively small volumes of food energy, and if incorporated directly into an area/period average would over-estimate the importance of shellfish and fish. The best estimate for this period was drawn from the mean %Kcal of the five largest assemblages, which included two villages and three short-term camps. For the Middle period in Otago-Catlins, which had no quantified data sets, mean %Kcal for each of the two adjacent overlap periods were averaged to provide a best estimate. Quantified assemblages from the Late period in both study areas were relatively few in number, of greatly unequal sizes and did not well represent the expected range of site types. The addition of Middle/Late overlap period assemblages largely resolved these problems, hence the best estimate for the Late period in each study area was derived from mean %Kcal of all Middle/Late and Late assemblages.

Adjustments were made to the calculated values for each area/period so that they would better represent the overall makeup of human dietary patterns. These are summarised below.

1. Due to the coastal location of nearly all study sites, it is likely that terrestrial animals exploited by the Maori communities of each study area are under-represented. It is difficult to estimate the magnitude of this as there are as yet no comprehensive analyses of energy yields per taxa at inland sites. A semi-quantitative analysis of relative frequencies of the main faunal classes in Early period sites in the southern South Island (Anderson 1982: Table 5) shows that when inland sites are added to those on the coast, the weighted abundance of terrestrial taxa increases by about 7%. In view of the generally lower energy yields from terrestrial animals compared to those from the sea, a lower value was used here, and 5% was added to the total calculated value for terrestrial animals, distributed proportionately to each component (moas, terrestrial birds, terrestrial mammals), and 5% deducted from the total for marine animals, subtracted proportionately from each component (fish, shellfish, marine and coastal birds, marine mammals).

2. While marine mammals were totally absent from the study assemblages from the Middle and Late periods in Greater Hauraki, analysis in 2.3.1 showed that small numbers of dolphins had almost certainly been exploited. To accommodate this 0.05% of total Kcal was transferred from fish to marine mammals in those two data sets.

3. Both marine/coastal and terrestrial small birds appear to be under-represented in the archaeological record, especially after the Early period, with the most likely explanation relating to the manner in which bird carcasses were processed for preservation and transport (Smith in press). There is as yet no quantified measure of the magnitude of under-representation, and the values used here are estimates. The calculated values for marine/coastal and terrestrial small birds were increased by 1% in Early period assemblages and 1.5% in Middle and Late period

assemblages, with equivalent amounts subtracted from the marine and terrestrial components with the highest values. This adjustment was not applied to the Otago-Catlins Late period marine/coastal birds, which were already well represented in the calculated value.

4. Dogs appeared to be under-represented in the Early period data sets from both study areas, with relative frequencies lower than those reported for other sites of this age (Allo Bay-Petersen 1979; Clark 1995). On current data it is difficult to quantify the impact of this on relative energy yields and an arbitrary value of 1% is used here, with this proportion of total Kcal transferred from the moa component to terrestrial mammals.

5. Sharks and rays are almost certainly under-represented in the archaeological record due to poor survival of their predominantly cartilaginous skeletons, while ethnohistorical evidence indicates that they were likely to have been a significant component of Late period Greater Hauraki Maori fisheries (Smith in press). If at least one taxon from this class had been represented in each Late period assemblage, the energy yield for fish would have been at least 4% higher than the calculated values. On this basis, 4% of total Kcal was transferred from shellfish to fish.

6. Shellfish appear to have been under-represented in the Late period Otago-Catlins data set, with higher relative frequencies at sites not able to be included in the present study (Davies 1980). As with dogs, it is difficult to quantify the extent of under-representation, and an estimate was employed, with 2.5% of total Kcal was transferred from fish to shellfish.

Table 2 lists both the initial calculated values and final adjusted values for the Early, Middle and Late Periods in each study area. The final adjusted values are referred to as *faunal component energy proportions* when incorporated into subsequent steps of the analysis.

2.3.5 Calculating the contributions of each species to total energy harvested from animals

The contribution of each species to the total energy harvest from animal foods during each of the three formal periods in each study area was calculated as follows (also see Figure 2).

a. Taxon frequencies determined in 2.3.2 were multiplied by energy yield per animal using the procedures described in 2.3.3 to derive an energy output per species. Note that for fur seals, these calculations were undertaken by age-sex class, and that for Pilot whales, energy yield per animal assumed that only 10% of available meat weight was consumed, following protocols established elsewhere (Smith 1985, 2004).

b. The energy output for each species calculated in (a) was divided by the sum of energy outputs for all species represented within the major faunal component to which it belonged to determine the proportion which that species contributed to total energy derived from that faunal component.

c. The proportional contribution of each species calculated in (b) was multiplied by the relevant faunal component energy proportion determined in 2.3.4 to derive a final *proportional energy contribution per species.* The values calculated for each species are listed in Appendix 1.

Cumulative calculation errors involved in deriving the proportional energy contribution per species were determined from estimates of the size of error associated with the three key input variables in the calculation. The taxon frequencies were based upon MNI data, which have inherent uncertainty (section 2.3.2) and calculated as means across variable sized sample sets of assemblages suggesting an error of ± 5% is in order. Energy yields per individual animal were derived from a mean body weight, an estimate of the proportion typically eaten, and a value for the energy yield per kg of flesh. Each of these is likely to have varied due to a range of factors including the age, size and condition of the animal concerned along with day-to-day variations in the butchery and consumption practices of the communities harvesting the animals. Again, ± 5% is allowed for each component, giving a cumulative error of ± 15% for the estimate of energy yield per animal. The faunal component energy proportions were the most difficult to derive from the archaeological data because they involved judgement about composition of an appropriate regional data set, and incorporated several adjustments to calculated values to correct for perceived biases in the archaeological record. For these an error of ± 10% is proposed. With the final proportional energy contribution per species derived from the product of these three variables, an error of ± 30% should be applied to the calculated values.

2.4 Estimating the scale of the total energy harvest from animals

The scale of the total energy harvest from animals during the focal year of each period in each study area was calculated from estimates of (a) the size of human population, (b) average energy needs per person per day, and (c) the proportion of that energy derived from animal foods. There are considerable uncertainties about these variables, described below, and different values for these produce widely different totals for the estimate of total energy from animals. For these reasons an attempt has been made to give a good indication of upper and lower limits as well as what is considered a ‘best estimate’. Minimum estimates of total energy from animals use the lowest likely values for (a), (b) and (c); maximum estimates use the highest acceptable values; while best estimates are based on what are considered here to be the most well supported or realistic values. These values are summarised in Table 3 and the rationale for their selection given below in sections 2.4.1 to 2.4.3.

2.4.1 Estimating the size of human population

The size of the human population is most reliably determined for the Late period (*ca.* 1750 AD) based upon detailed analysis by Pool (1991) who gave a best estimate of *ca.* 100,000 for the total New Zealand population in 1769, with *ca.* 90% of that in the North Island. It is estimated here that the Greater Hauraki study area population was about 13.5% of the North Island total, based on Urlich’s (1969) estimate that 5% were in Thames-Coromandel and 7% in Auckland, to which has been added one tenth of the 15% she estimated for the whole of Northland. This yielded the best estimate value of 12 150. Minimum and maximum values were calculated using total North Island populations of 80 000 and 100 000 respectively, giving estimates for Greater Hauraki of 10 800 and 13 500. Anderson (1998: 196–7) has estimated that in the early 19th century the population of Ngai Tahu in the southern two thirds of the South Island was no more than 5000. Anderson’s analysis of the distribution of this population, along with the distribution of Late period archaeological sites suggests a population at *ca.* 1750 AD for Otago-Catlins of about 1800, with ± 200 allowed for minimum and maximum estimates.

Population estimates for the Early period (*ca.* 1400 AD) are based on the likelihood that the initial colonising population would have grown rapidly from a founding population of *ca.* 300-500 at 1280 AD increasing exponentially at rates in the order of 2% to 3.5% per annum. This would give nationwide totals of at least 4000, and possibly up to 20 000 by 1400 AD, with the best estimate towards the upper end of this range. Based on what is known of the nationwide distribution of Early period archaeological sites, it is estimated that this population was more or less evenly distributed between the North and South Islands, and about a quarter of the North Island total was in Greater Hauraki. This gives minimum, best and maximum estimates of 500, 2000 and 2500. Likewise, it is likely that about a quarter of the South Island population were in Otago-Catlins. The same minimum and maximum estimates used for Greater Hauraki have been adopted, but a slightly lower best estimate of 1800.

For the Middle period (*ca.* 1550 AD) in Greater Hauraki population size was estimated using the trend line for population growth in prehistoric New Zealand indicated by cumulative frequency of radiocarbon dates, adjusted for calibration stochastic distortion effect (McFadgen et al. 1994: Figure 3). This suggests that at *ca.* 1550 AD the population would have reached about 90% of its *ca.* 1750 AD level (Figure 4). This factor was applied to the North Island population estimates for the Late period given above, giving a minimum of 72 000, best estimate of 80 000, and a maximum of 90 000. The proportion of these within Greater Hauraki is difficult to assess, but a range of values were used here; 8.5% for the minimum estimate, 12.6% for the best estimate, and 13% for the maximum; giving population estimates of 6100, 10 200 and 11 700.

It is widely recognised that the population in southern New Zealand took a much lower trajectory, perhaps even declining after the Early period (Jacomb et al. 2010, McGlone et al. 1994). Examination of the median ages of radiocarbon dated study assemblages from Otago-Catlins used in this study supports this view (Figure 4), although it needs to be noted that both there are additional dated sites from both Middle and Late periods that were excluded from the present study because they lacked fully identified and/or quantified fauna. The best estimate used here (1800) assume that the population at *ca.* 1550 AD was no greater than at *ca.* 1400 AD, while the maximum estimate (2600) is slightly higher than that of the earlier period and the minimum estimate (500) maintains the same lower limit as at *ca.* 1400 AD.

2.4.2 Estimating average energy needs per person per day

The daily energy requirements of a person depend upon a wide range of factors including gender, body weight, activity levels and the energy demands of the environmental conditions in which they live. The estimates used here are drawn from data compiled and reviewed in detail elsewhere (Leach 2006, Leach et al. 1996) which focused explicitly on determining an appropriate range for prehistoric populations in the Pacific and New Zealand. For Greater Hauraki the minimum value (1800) is that accepted by Leach et al. (1996: 24) as the lowest viable for a 70 kg woman with low activity levels. The best estimate (2150) is the mean value suggested for pre-European Maori by Leach (2006: 277). The maximum (2172) is the midpoint between that mean and the value derived by stochastic modelling of pre-European diet in the Chatham Islands (Leach et al. 2003), where the environmental conditions are likely to have placed greater energy demands on individuals than was the case in Greater Hauraki.

Values adopted for Otago-Catlins are set slightly higher to accommodate the greater energy demands of a colder climate. The minimum value (2150) is Leach's mean for pre-European Maori; the best estimate (2172) is the value adopted above for the upper limit in Greater Hauraki; and the maximum value (2193) is that derived for the Chatham Islands.

2.4.3 Estimating the proportion of energy derived from animal foods

Estimates of the proportion of the total energy consumed by people that derived from animal foods are based upon analysis of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ isotopes from the small number of archaeologically-derived samples of human bone collagen thus-far analysed from the Pacific region (Leach et al. 2000, Leach et al. 2003). These exhibit wide variation: the lowest value (0.4) is from Watom Island in the tropical Pacific with a horticultural and fishing economy; a moderately high value (0.66) derives from Wairau Bar, South Island New Zealand, where horticulture was combined with hunting of large animals; and the highest value (0.9) is from the Chatham Islands where subsistence relied upon hunting, fishing and the gathering of wild plants.

In Greater Hauraki archaeological data for the Middle and Late periods indicate an economy based on horticulture, fisheries and a very modest level of hunting (Smith in press, Smith n.d.). On this basis the Watom and Wairau Bar values are adopted for minimum and maximum values respectively, and the mid-point between these is used for the best estimate. Archaeological data for the early period indicate a much greater reliance on hunting, hence the Wairau Bar value is adopted for the best estimate, with midpoints between that and each of the higher and lower measured values used for minimum and maximum estimates.

The Otago-Catlins region was beyond the growing limits for pre-European horticultural crops, with wild plant foods contributing to a diet that archaeological data indicates relied heavily on both hunting and fishing throughout the prehistoric sequence (Smith in press, Smith n.d.). On this basis a single set of values is used for all periods with the Wairau Bar and Chatham Islands values adopted for the minimum and maximum estimates respectively, and the midpoint between these used as the best estimate.

2.4.4 Calculating total energy harvest from animals

Estimates for the total energy harvest (Kcal) from animals in each study area during each of the target years (1400 AD, 1550AD, 1750) were calculated as follows. The estimate of human population size was multiplied by the estimated energy needs per person per day, which was multiplied by 365 to determine the total energy needs for the year, and this was then multiplied by the estimated proportion of energy derived from animal foods. In doing this minimum input values were combined to produce minimum estimates, and likewise for best and maximum values. Calculated values, referred to as *energy from animals*, are shown in Table 4.

2.5 Estimating the number and biomass of marine animals harvested

The final step of analysis involved using the variables and values calculated or estimated in the preceding sections to estimate the number and biomass of animals harvested during the focal year in each study area. This was undertaken in three steps.

a. The proportional energy contribution per species (2.3.5) was multiplied by the energy from animals (2.4.4) to derive the total energy harvested from that species.

b. Total energy harvested from species was divided by the energy yield per individual of that species (2.3.3) to determine the number of animals harvested.

c. The number of animals harvested was multiplied by the mean body weight per individuals of that species (2.3.3) to determine the biomass harvested.

The estimated cumulative error (± 30%) in calculating proportional energy per species was applied to the number and biomass estimates (b and c), with uncertainties about the scale of the energy harvest from animals expressed in the minimum, best and maximum estimates. Results of this are presented below.

3. RESULTS

Analysis of the archaeological study assemblages demonstrated that at least 210 marine or coastal species had been harvested by Maori in Greater Hauraki (147 shellfish, 35 fish, 22 birds, 6 mammals), and at least 159 in Otago-Catlins (90 shellfish, 32 fish, 30 birds, 7 mammals). Estimates made of the number and biomass harvested from each of these are presented in Tables 5 – 28. Within each of these tables taxa are arranged by systematic order after the following authorities: for fish, Froese & Pauly (2010); shellfish, Spencer *et al.* (2009); birds, Checklist Committee (OSNZ) (2010); and mammals, Baker *et al.* (2010). This enables placement of taxa identified only to genus or higher levels, and those less securely identified, alongside the positively identified species to which they are most closely related. Common names for taxa in these tables are listed in Appendix 1. For shellfish the tables list individually only the 22 species with highest harvested biomass in each area/period with the remainder grouped as 'all others'. In the following presentation of results, only the best estimate values are used in text; minimum and maximum can be found in the Tables. The latter exhibit parallel trends to those identified using the best estimate values.

3.1 Fish

3.1.1 Greater Hauraki

A total of 35 fish taxa are recorded archaeologically as harvested by Maori in Greater Hauraki. These included some genus, family or higher level groupings necessitated by the nature of archaeological data: it is virtually impossible to identify the various species of Labridae on the basis of skeletal morphology, so they are treated as a single family group; *Anguilla* species are also indistinguishable, so are treated as a genus group; Carangidae are often difficult to distinguish, and only sometimes identified to species level; and the poor survival of elasmobranch remains frequently precludes specific identification.

At *ca.* 1400 AD 22 of these taxa were included in a total fish harvest best estimated at 128.5 ± 44.3 tonnes (Table 5). The taxonomic range narrowed to 16 at *ca.* 1550 AD in a total harvest of 2328.2 ± 698.5 t (Table 6). By *ca.* 1750 AD, the total fish take of 2607.1 ± 782.1 t was drawn from 15 taxa (Table 7).

Snapper (*Pagrus auratus)* were the largest single contributor to the fish harvest at each time period, rising from 72.0 ± 21.6 t to 938.8 ± 281.6 t and then 997.2 ± 299.2 t, although as a proportion of total harvested fish biomass this represents a falling trend from 56% to 40% then 38%. At *ca.* 1400 AD only three other taxa other than snapper made up significant proportions of harvested biomass; kahawai (*Arripis trutta*) 19.2 ± 5.8 t (15%), wrasses (Labridae) 13.5 ± 4.0 t (10.5%), and leatherjacket (*Meuschenia scaber*) 11.3 ± 3.4 t (8.8%). At *ca.* 1550 AD there were four main contributors to harvested biomass in addition to snapper; sharks (Carcharhiniformes) not positively identified to species, 511.4 ± 153.4 t (22%); horse mackerel (*Trachurus novaezelandiae*), 323.1 ± 96.9 t (13.9%); kahawai, 227.9 ± 68.4 t (9.8%); and barracouta (*Thyrsites atun*) 169.3 ± 50.8 t (7.3%). The harvest of wrasses (23.1 ± 6.9 t) was now only 6.9% of the total, while leatherjackets were not represented in any of the study sites from this era. At *ca.* 1750 AD the harvested biomass of sharks not positively identified to species (959 ± 287.8 t, 36.8%) was almost equal to that of snapper, and would just outstrip it if combined with the 39.9 ± 12 t identified as from northern dogfish (*Squalus blainvillei*). The eagle ray (*Myliobatis tenuicaudatus*) was the only other significant component of the fishery at *ca.* 1750 AD, contributing 319.3 ± 95.8 t (12.2%).

1.1.2 Otago-Catlins

A total of 32 taxa were identified in study sites from the Otago-Catlins region, including the genus and higher-level groupings noted for Greater Hauraki, along with Nototheniidae, as it is difficult to distinguish various species of black cods on skeletal morphology.

In total 22 of these taxa were included in a total fish harvest best estimated at 78.3 ± 23.5 t at *ca.* 1400 AD (Table 8). The taxonomic range narrowed to 14 at *ca.* 1550 AD in a total harvest of 797.5 ± 239.3 t (Table 9). By *ca.* 1750 AD, the total fish take of 725.1 ± 217.5 t was drawn from 9 taxa (Table 10).

Barracouta (*Thyrsites atun*) formed the largest part of harvested fish biomass at each time period, contributing 43.2 ± 13.0 t (55.2%) at *ca.* 1400 AD, 361.4 ± 108.4 t (45.3%) at *ca.* 1550 AD, and 363.3 ± 109.0 t (50.1%) at *ca.* 1750 AD. Three further species made important contributions to harvested biomass at *ca.* 1400 AD; ling (*Genypterus blacodes*) 7.8 ± 2.3 t (9.9%), hapuku (*Polyprion oxygenios*) 7.7 ± 2.3 t (9.8%), and red cod (*Pseudophycis bachus*) 6.8 ± 2.0 t (8.7%). The same three species were the major components in addition to barracouta at *ca.* 1550 AD, although in differing order; hapuku 141.0 ± 42.3 t (17.7%), red cod 128.3 ± 38.5 t (16.1%), and ling 68.2 ± 20.5 t (8.5%). This order was maintained at *ca.* 1750 AD; hapuku 230.9 ± 69.3 t (31.8%), red cod 68.4 ± 20.5 (9.4%), and ling 56.8 ± 17 t (7.8%).

3.2 Shellfish

3.2.1 Greater Hauraki

The archaeological study sites provided records of 147 shellfish taxa harvested by Maori in the Greater Hauraki region, with 31 of these being identifications only to genus or family level leaving the possibility that the total number of species may have been slightly more than this. Of these taxa, 88 were represented in the estimated harvest of 6.6 ± 2.0 t at *ca.* 1400 AD (Table 11), 66 in the estimate of 1736.3 ± 520.9 t at *ca.* 1550 AD (Table 12), and 38 in the estimate of 2294.7 ± 688.4 t at *ca.* 1750 AD (Table 13).

Three species dominate the shellfish biomass harvested at *ca.* 1400 AD, making up two thirds of the total; paua (*Haliotis iris*) 2.2 ± 0.7 t (34%), cats eye (*Lunella smaragdus*) 1.2 ± 0.4 t (18.2%), and green-lipped mussel (*Perna canaliculus*) 0.9 ± 0.3 t (14.3%). At *ca.* 1550 AD two species made up more than 84% of the total biomass harvested: cockle (*Austrovenus stutchburyi*) 1103.2 ± 331.0 t (63.5%), and pipi (*Paphies australis*) 358.2 ± 107.5 t (20.6%). Of the three formerly dominant species (paua, cats eye and green lipped mussel), only cats eyes at 5% made a notable contribution with the others providing less than 0.1% of harvested biomass. The same two species, cockle and pipi continued to dominate the shellfish harvest at *ca.* 1750 AD as they did at *ca.* 1550; cockle providing 1358.0 ± 407.4 t (59.2%), and pipi 594.5 ± 178.4 t (25.9%). Tuatua (*Paphies subtriangulata*) with 250.5 ± 75.2 t (10.9%) was the only additional species at *ca.* 1750 to provide more than 1 % total biomass harvested.

3.2.2 Otago-Catlins

The shellfish identified from study sites in Otago-Catlins include 90 taxa, including 25 identifications to only to genus or family level. At *ca.* 1400 AD 55 taxa were represented in the total shellfish harvest estimated at 9.1 ± 2.7 t (Table 14), with just 12 taxa in the estimated 43.0 ± 12.9 t harvested at *ca.* 1550 AD (Table 15), but 29 were included in the estimated harvest of 51.4 ± 15.4 t at *ca.* 1750 AD (Table 16). The reduced taxonomic range at *ca.* 1550 is almost certainly due to the restricted sample of study sites available for that time period; ten study assemblages were available for *ca.* 1400 AD and nine for *ca.* 1750 AD , but only two for *ca.* 1550 AD.

At *ca.* 1400 AD four species made up 82.4% of the total harvested biomass; cockle (*Austrovenus stutchburyi*) 2.4 ± 0.7 t (26.9%), paua (*Haliotis iris*) 2.3 ± 0.7 t (24.8%), blue mussel (*Mytilus galloprovincialis*) 1.5 ± 0.5 t (16.6%), and pipi (*Paphies australis*) 1.3 ± 0.3 t (14.1%). Two of these four species also dominate harvested shellfish biomass at *ca.* 1550 AD; blue mussels providing 16.1 ±

4.8 t (37.4%), and paua 14.2 ± 4.3 t (33%). Mudsnails (*Amphibola crenata*) added another 4.2 ± 1.3 t (9.8%), cockles 2.3 ± 0.2 t (5.4%), and pipi 1.7 ± 0.5 t (4%) to the total harvested biomass in *ca.* 1550 AD. At *ca.* 1750 AD the rank order of the two leading shellfish species reverses; paua yielding 35.1 ± 10.5 t (68.4%), and blue mussels 8.2 ± 2.5 t (15.9%). None of the other previously important species contributed more than 2.5% of total harvested biomass at *ca.* 1750 AD.

3.3 Marine and Coastal Birds

3.3.1 Greater Hauraki

A total of 22 marine and coastal bird species were positively identified in the study sites from Greater Hauraki, along with identifications to five higher-level taxonomic groupings. Twenty two taxa were represented in the estimated harvest of 19.2 ± 5.8 t in *ca.* 1400 AD (Table 17). Only seven taxa were among the harvest of 28.3 ± t at *ca.* 1550 AD (Table 18), while at *ca.* 1750 AD there were ten in the 56.2 ± 16.9 t harvested (Table 19).

At *ca.* 1400 AD four taxa together made up 70.1% of the biomass harvested from marine and coastal birds; little penguin (*Eudyptula minor*) 4.7 ± 1.4 t (24.4%), spotted shag (*Stictocarbo punctatus*) 4.0 ± 1.2 t (20.7%), albatrosses (Diomedeidae) 2.5 ± 0.8 t (13.2%), and pied shag (*Phalacrocorax varius*) 2.3 ± 0.7 t (11.9%). Three of these taxa together yielded 90.2% of the harvested biomass in *ca.* 1550 AD; albatrosses 17.6 ± 5.3 t (62.2%), little penguin 5.1 ± 1.5 t (185), and spotted shag 2.8 ± 0.8 t (10%). At *ca.* 1750 AD the same three taxa provided 71.6% of the harvested biomass; albatrosses 17.6 ± 5.3 t (31.3%), spotted shag 14.1 ± 4.2 t (25%), and little penguin 8.6 ± 2.6 t (15.3%).

3.3.2 Otago-Catlins

Thirty taxa of marine and coastal birds species were identified in the study sites from Otago Catlins. These include penguins listed as *Megadyptes* sp. as virtually all were identified prior to recent separation of the smaller extinct Waitaha penguin (*M. waitaha*) from the larger extant yellow-eyed penguin (*M. antipodes*) (Bossenkool et al. 2009). The date at which the former replaced the latter in the study area is not yet clearly known. At *ca.* 1400 25 marine and coastal bird taxa formed part of a total estimated harvest of 32.1 ± 9.6 t (Table 20). Only sixteen were among the harvest of 46.9 ± 14.1 t in *ca.* 1550 AD (Table 21), while 18 contributed to the 80.3 ± 24.1 t harvested in *ca.* 1750 AD (Table 22).

At *ca.* 1400 AD four species made up 76% of the total biomass harvested from marine and coastal birds; *Megadyptes*, at this time almost certainly the waitaha penguin, 8.8 ± 2.6 t (27.2%), Fiordland crested penguin (*Eudyptes pachyrhynchus*) 8.5 ± 2.5 t (26.4%), white-capped albatross (*Thalassarche cauta*) 4.7 ± 1.4 t (14.5%), and little penguin (*Eudyptula minor*) 2.5 ± 0.8 t (7.8%). Five taxa, including the four above, made up 74% of the biomass harvested at *ca.* 1550 AD; spotted shag (*Stictocarbo punctatus*) 9.9 ± 3.0 t (21%), white-capped albatross 6.9 ± 2.1 t (14.6%), *Megadyptes* sp. penguin 6.8 ± 2.1 t (14.6%), Fiordland crested penguin 5.8 ± 1.8 t (12.5%), and little penguin 5.3 ± 1.6 t (11.3%). At *ca.* 1750 AD the leading four taxa contributed 67.9% of the total biomass harvested; white capped albatross 20.6 ± 6.2 t (25.6%), Stewart Island shag (*Leucocarbo chalconotus*) 15.1 ± 4.5 t (18.8%), spotted shag 9.9 ± 3.0 t (12.3%), and *Megadyptes*, by this time probably yellow-eyed penguin, 9.0 ± 2.7 t (11.2%).

3.4 Marine Mammals

3.4.1 Greater Hauraki

At least five marine mammal taxa are recorded as part of the Maori marine harvest in Greater Hauraki. These include the fur seal (*Arctocephalus forsteri*), sea lion (*Phocarctus hookeri*) and elephant seal (*Mirounga leonina*), along with at least one species of pilot whale (*Globicephala*) and dolphins that have not been identified to species level.

All these taxa were represented in the total harvest estimated at 414.5 ± 124.3 t in *ca.* 1400AD (Table 23). Fur seals made up the largest part of this, 284.9 ± 85.5 t (68.7%), followed by sea lions, 63.4 ± 19.0 t (15.3%), and pilot whales, 57.5 ±17.3 t (13.9%). By *ca.* 1550 AD the total harvest had fallen to 1.79 ± 0.54 t, derived entirely from dolphins (Table 24). Dolphins were also the sole contributor to the marine mammals harvest of 2.13 ± 0.64 t in *ca.* 1750 AD (Table 25).

3.4.1 Otago-Catlins

The archaeological record shows that at least eight marine mammal taxa were harvested in Otago-Catlins, including the fur seal (*Arctocephalus forsteri*), sea lion (*Phocarctus hookeri*), elephant seal (*Mirounga leonina*), leopard seal (*Hydrurga leptonyx*), at least one species of pilot whale (*Globicephala*) and dolphins that include the common dolphin (*Delphinus delphis*) and Hectors dolphin (*Cephalorhynchus hectori*). The latter are treated here as a single group as the majority of dolphin remains have not been identified to species level.

At *ca.* 1400 AD five taxa were included in the total harvest of 371.3 ± 111.4 t (Table 26). This was dominated by two species; fur seals providing 237.0 ± 71.1 t (63.8%), and sea lions 126.2 ± 37.8 t (34%). Four of the same taxa, plus another, made up the considerably smaller harvest of 144.5 ± 43.4 t at *ca.* 1550 AD (Table 27). Fur seals, at 103.3 ± 31 t (71.5%), and sea lions, at 47.2 ± 11.2 t (25.8%), were again dominant at *ca.* 1550 AD. At *ca.* 1750 AD the total harvest had fallen further to 121.6 ± 36.5 t derived from just three taxa (Table 28). The main contributors to the total harvested biomass at *ca.* 1750 AD were fur seals, at 77.0 ± 23.1 t (63.4%), and pilot whales at 44.0 ± 13.2 t (36.2 %).

4. DISCUSSION

There has been only one previous attempt to calculate the numbers and biomass of marine animals harvested by Maori, and this was concerned solely with the numbers of snapper harvested at *ca.* 1769 in the Northland region (Leach 2006). This utilised an analytical method broadly similar to that employed here, but with some differences in input values. Leach's estimate of 1919 ± 1612 t of snapper harvested for the whole of Northland is almost exactly double that given by the best estimate here for the Greater Hauraki region. The latter has a coastline approximately half the length of the Northland region, suggesting that the methods produce broadly comparable results.

One of the major difference between the two approaches is the use here of minimum, best and maximum estimates to provide a narrower band of greatest likelihood within the necessarily wide error margins that must apply to calculations this sort. The differences between the minimum, best and maximum estimates of harvested biomass are illustrated for snapper in the Greater Hauraki region (Figure 5), which shows that at *ca.* 1750 AD the upper end of the error limit for the maximum estimate is 4.6 times greater than the lower error limit for the minimum value. As noted in section 2.4 the extent of these differences is driven largely by the choice of values selected for human population size, daily energy requirements and proportion derived from animals. While values considered most likely to reflect the situation in each study area at each focal date were employed for calculation of the best estimates, these still need to be considered with some caution and are best viewed as indicators of the order of magnitude of Maori harvests, rather than precise descriptors.

In both study areas the total biomass harvested for three of the four major classes of fauna increased over time, with only marine mammals exhibiting a declining trend (Figure 6). In Greater Hauraki this can be attributed partly to growth of the human population, for which the best estimate at *ca.* 1750 AD is 6.1 times greater than that at *ca.* 1400 AD. However both the fish and shellfish harvests expanded at considerably greater rates than this (20.3 and 347.7 times respectively). The primary driver of this was the need for Maori to compensate for the loss of two major sources of food following the extinction of moa and extirpation of fur seals and sea lions from northern New Zealand between 1400 and 1550 AD (Schmidt 2000b, Smith 2005). Fish and shellfish have significantly lower energy yields per kilogram than the animals they were replacing, further increasing demand upon these fisheries. The harvest of marine and coastal birds expanded at less than half the rate of human population growth, indicating an overall diminution of their part in the human diet, which is likely to reflect reduced availability through both hunting pressure and the impact of introduced mammalian predators (Holdaway 1999, Smith in press).

Otago-Catlins provides an even clearer demonstration of the replacement process, as the best estimates of human population postulate no growth between *ca.* 1400 and *ca.* 1750 AD. Over the same period fish and shellfish harvests expanded by 9.9 and 5.6 times respectively, while the marine mammal harvest fell to a third of its initial level. In this case the modest growth in the harvest of marine and coastal birds indicates that they played an increasingly important part in human diet over time. This divergence from the pattern observed in Greater Hauraki may reflect the important role that growth of the human population played in depleting marine and coastal bird resources in the latter area.

There is a strong trend through time in all four major classes of fauna from both study areas towards exploitation of a narrower taxonomic range. The number of taxa within each class harvested at *ca.* 1750 AD ranges between 20% and 72% of those exploited at *ca.* 1400 AD (Table 29). Detailed analysis elsewhere (Smith in press) shows that for fish and shellfish, at least, this cannot be attributed to the size of archaeological samples under analysis; there are insufficient datasets to conduct similar tests for birds and mammals. Only a small part of this trend is attributable to reduction of available taxonomic breadth. Of marine taxa represented in the study assemblages only one has become extinct, and the Waitaha penguin appears to have been rapidly replaced by the yellow-eyed penguin (Bossenkool et al. 2009). Localised depletions were somewhat more common. As already noted, fur seals and sea lions were extirpated from northern New Zealand, and at least some petrels, prions and shearwaters ceased breeding on one or both of the main islands (Holdaway 1999) restricting opportunities for anything other than opportunistic harvesting of these taxa to distant offshore islands.

Neither extinction nor serious depletion of populations has been documented for any of the fish or shellfish taxa. For these classes of fauna, explanations for the narrowing of the range of species harvested can be found in the cultural sphere. In the case of shellfish it can been attributed largely to shifts in human settlement patterns which, in Greater Hauraki focussed increasingly on land suitable for horticulture in the vicinity of estuaries, which typically support a high abundance but restricted range of edible species (Smith in press). Otago-Catlins settlements of the later period appear to be more strongly clustered than those of earlier periods, especially in the vicinity of rocky headlands, although the driving forces in this case are less clearly understood. Declining diversity of fish catches may have been influenced by these changes in settlement pattern, but there are also indications that Maori fishing practice became more specialised with the dominant species in each region, snapper in Greater Hauraki and barracouta in Otago-Catlins, forming an increasingly large proportion of the total number of fish caught. It may be that the reliability with which these species could be located and harvested in large numbers became a critical factor when the demise of seals and moas placed increasing demand on fishing as a source of dietary energy.

Although there are broad similarities in some trends over time, the patterns of species exploitation and timing of changes in these varies considerably between the two study areas. This is not unexpected as regional differences in pre-European Maori subsistence patterns are widely recognised (Leach 2006, Smith 2004). It does indicate, however, that the harvest estimates generated here should not be applied to other areas or more generally across the country. There are also some indications of subregional variations within the datasets used here. For example the relative importance of leatherjackets at *ca.* 1400 AD in Greater Hauraki can be correlated with the concentration of Early period sites in the region on the east coast of the Coromandel, while the rise to prominence of mackerel fisheries at *ca.* 1550 AD coincides with a greater number of sites around the shores of the Hauraki Gulf (Smith in press).

One further feature of the species-by-species estimates is worthy of further comment. In several cases there is a considerable difference between the relative abundance of taxa and their relative contributions to harvested biomass, due to differences in body size. For example sharks make up only 6.2 % of the number of fish harvested in Greater Hauraki at *ca.* 1750 AD, but contributed 36.8% of harvested biomass, almost equal to that from snapper which made up 59% of the total number of fish. With only a small number of exceptions, previous analyses of the archaeological evidence for Maori fishing have relied solely on estimates of abundance, and for this reason they have been unable to detect the late prehistoric rise in the importance of shark fishing in northern New Zealand.

Finally, this study has relied entirely upon pre-existing data of variable and sometimes unknown quality. There are several ways in which future research could enhance the accuracy with which estimates could be made regarding marine harvests in the past. Most importantly, existing archaeological data is least adequate for the Middle and Late periods of New Zealand’s prehistory, largely because so much research effort has been focussed on the study of the initial colonisation phase. Furthermore, much of what is available for later periods has derived from small-scale development-driven rescue excavations, rather than properly resourced research investigations. Targeted research on the nature and consequences of later phases of occupation has the potential to provide greater clarity regarding the breadth, magnitude and consequences of Maori exploitation of the marine environment.

5. MANAGEMENT IMPLICATIONS

The data presented in this report makes available for the first time a suite of numerical estimates for the levels of customary harvest of a wide range of New Zealand's marine resources covering a substantial portion of the period prior to European settlement in New Zealand. These provide baseline data against which modern customary and commercial harvests can be assessed, and will have value in future stock assessments. Once integrated with other suites of data from the *Taking Stock* project, they will contribute to greater understanding of the long-term structure and functioning of New Zealand's marine shelf ecosystems.

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Table 1: **Number of study assemblages per area and period.**

Period	Greater Hauraki	Otago-Catlins	Total
Early	8	10	18
Early/Middle	11	9	20
Middle	25	2	27
Middle/Late	18	2	20
Late	13	9	22
Total	75	32	107

Table 2: **Faunal component energy proportions (% total Kcal from animals): initial calculated values and final adjusted values.**

Area/period	Value	Shellfish	Fish	Marine/coastal bird	Marine mammal	Moa	Terrestrial bird	Terrestrial mammal
Greater Hauraki								
Early	initial	0.66	11.50	3.39	59.77	21.10	1.46	2.11
Early	final	0.62	10.74	4.16	54.80	23.38	2.76	3.54
Middle	initial	43.13	51.72	0	0	0	0	5.15
Middle	final	40.11	48.19	1.50	0.05	0	1.50	8.65
Late	initial	51.95	43.16	1.05	0	0	0.51	3.33
Late	final	44.50	44.12	2.50	0.05	0	2.67	6.17
Otago-Catlins								
Early	initial	0.61	5.81	5.92	57.21	27.05	0.77	2.63
Early	final	0.57	5.39	6.49	52.10	29.49	1.90	4.06
Middle	initial	3.38	59.07	8.42	21.10	3.15	1.95	2.93
Middle	final	3.20	54.36	9.46	19.95	4.36	4.66	4.00
Late	initial	1.89	57.36	17.73	12.00	0	2.25	8.77
Late	final	4.28	52.49	16.22	10.98	0	4.77	11.25

Table 3: **Maximum, minimum and best estimate values for variables used in estimating total energy from animals.**

	Human population size (n)			Energy/person/day (kcal)			Proportion from animals		
Area/year	Min	Best	Max	Min	Best	Max	Min	Best	Max
Greater Hauraki									
ca. 1400	500	2 000	2 500	1 800	2 150	2 172	0.53	0.66	0.78
ca. 1550	6 100	10 200	11 700	1 800	2 150	2 172	0.40	0.53	0.66
ca. 1750	10 800	12 150	13 500	1 800	2 150	2 172	0.40	0.53	0.66
Otago-Catlins									
ca. 1400	500	1 800	2 500	2 150	2 172	2 193	0.66	0.78	0.90
ca. 1550	500	1 800	2 600	2 150	2 172	2 193	0.66	0.78	0.90
ca. 1750	1 600	1 800	2 000	2 150	2 172	2 193	0.66	0.78	0.90

Table 4: Estimated total energy (Kcal x 10^6) harvested from animals during focal years in each study area.

Area/year	Minimum estimate	Best estimate	Maximum estimate
Greater Hauraki			
ca. 1400	174.11	1 035.87	1 545.92
ca. 1550	1 603.08	4 242.36	6 121.85
ca. 1750	2 838.24	5 053.40	7 063.67
Otago-Catlins			
ca. 1400	258.97	1 113.06	1 801.00
ca. 1550	388.45	1 236.74	1 873.04
ca. 1750	828.70	1 113.06	1 440.80

Table 5: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Greater Hauraki at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Carcharhiniforme ?sp	24	0.485	0.146	144	2.886	0.866	215	4.307	1.292
Myliobatis tenuicaudatus	3	0.051	0.015	15	0.304	0.091	23	0.453	0.136
Elasmobranchii ?sp	27	0.268	0.080	159	1.595	0.478	238	2.380	0.714
Callorhinchus milii	3	0.011	0.003	15	0.064	0.019	23	0.095	0.029
Anguilla spp.	27	0.024	0.007	159	0.144	0.043	238	0.214	0.064
Pseudophycis bachus	27	0.040	0.012	159	0.239	0.072	238	0.357	0.107
Zeus faber	52	0.073	0.022	311	0.436	0.131	465	0.651	0.195
Chelidonichthys kumu	92	0.064	0.019	547	0.383	0.115	816	0.571	0.171
Pseudocaranx dentex	6	0.010	0.003	38	0.061	0.018	57	0.091	0.027
Trachurus declivis	3	0.003	0.001	15	0.020	0.006	23	0.029	0.009
Trachurus novaezelandiae	3	0.003	0.001	15	0.015	0.005	23	0.023	0.007
Arripis trutta	1 795	3.231	0.969	10 679	19.221	5.766	15 937	28.686	8.606
Pagrus auratus	5 504	12.110	3.633	32 750	72.049	21.615	48 875	107.525	32.258
Nemadactylus macropterus	448	0.358	0.108	2 666	2.133	0.640	3 978	3.183	0.955
Latridopsis ciliaris	79	0.214	0.064	471	1.271	0.381	703	1.897	0.569
Mugil cephalus	3	0.003	0.001	15	0.015	0.005	23	0.023	0.007
Aldrichetta forsteri	544	0.109	0.033	3 235	0.647	0.194	4 829	0.966	0.290
Labridae	1 508	2.261	0.678	8 970	13.455	4.036	13 386	20.079	6.024
Parapercis colias	119	0.083	0.025	706	0.494	0.148	1 054	0.738	0.221
Thyrsites atun	111	0.255	0.077	661	1.520	0.456	986	2.268	0.680
Serollela brama	24	0.056	0.017	144	0.332	0.100	215	0.495	0.149
Meuschenia scaber	2 365	1.892	0.568	14 074	11.259	3.378	21 003	16.803	5.041
TOTAL	12 765	21.605	7.448	75 950	128.542	44.316	113 347	191.835	66.137

Table 6: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Greater Hauraki at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Carcharhiniforme ?sp	9 663	193.267	57.980	25 572	511.436	153.431	36 901	738.017	221.405
Anguilla spp.	5 815	5.234	1.570	15 389	13.850	4.155	22 207	19.987	5.996
Chelidonichthys kumu	1 355	0.949	0.285	3 587	2.511	0.753	5 176	3.623	1.087
Pseudocaranx dentex	12 724	20.359	6.108	33 671	53.874	16.162	48 589	77.742	23.323
Trachurus declivis	219	0.284	0.085	579	0.752	0.226	835	1.085	0.326
Trachurus novaezelandiae	122 082	122.082	36.625	323 061	323.061	96.918	466 186	466.186	139.856
Arripis trutta	47 836	86.104	25.831	126 586	227.855	68.357	182 667	328.801	98.640
Pagrus auratus	161 260	354.772	106.432	426 736	938.820	281.646	615 793	1354.745	406.423
Mugil cephalus	5 815	5.815	1.745	15 389	15.389	4.617	22 207	22.207	6.662
Aldrichetta forsteri	9 663	1.933	0.580	25 572	5.114	1.534	36 901	7.380	2.214
Labridae	5 815	8.723	2.617	15 389	23.084	6.925	22 207	33.311	9.993
Genyagnus monopterygius	44	0.022	0.007	116	0.058	0.017	167	0.083	0.025
Parapercis colias	44	0.031	0.009	116	0.081	0.024	167	0.117	0.035
Thyrsites atun	27 809	63.962	19.189	73 591	169.260	50.778	106 194	244.247	73.274
Scomber australasicus	11 631	11.631	3.489	30 779	30.779	9.234	44 415	44.415	13.324
Rhombosolea ?sp	15 479	4.644	1.393	40 961	12.288	3.687	59 108	17.732	5.320
TOTAL	437 256	879.811	263.943	1 159 561	2 328.213	698.464	1 669 721	3 359.679	1 007.904

Table 7: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Greater Hauraki at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Squalus blainvillei	8 966	22.415	6.725	15 964	39.910	11.973	22 314	55.786	16.736
Carcharhiniforme ?sp	26 941	538.829	161.649	47 968	959.369	287.811	67 051	1 341.011	402.303
Myliobatis tenuicaudatus	8 966	179.322	53.797	15 964	319.278	95.783	22 314	446.289	133.887
Anguilla spp.	20 950	18.855	5.656	37 300	33.570	10.071	52 139	46.925	14.077
Chelidonichthys kumu	8 966	6.276	1.883	15 964	11.175	3.352	22 314	15.620	4.686
Pseudocaranx dentex	20 950	33.519	10.056	37 300	59.680	17.904	52 139	83.422	25.026
Trachurus declivis	8 966	11.656	3.497	15 964	20.753	6.226	22 314	29.009	8.703
Carangidae ?sp	8 966	9.863	2.959	15 964	17.560	5.268	22 314	24.546	7.364
Arripis trutta	17 975	32.356	9.707	32 005	57.608	17.282	44 736	80.525	24.158
Pagrus auratus	254 586	560.089	168.027	453 283	997.222	299.166	633 601	1 393.922	418.177
Mugil cephalus	8 966	1.793	0.538	15 964	3.193	0.958	22 314	4.463	1.339
Labridae	8 966	13.449	4.035	15 964	23.946	7.184	22 314	33.472	10.041
Odax pullus	8 966	8.070	2.421	15 964	14.368	4.310	22 314	20.083	6.025
Thyrsites atun	8 966	20.622	6.187	15 964	36.717	11.015	22 314	51.323	15.397
Meuschenia scaber	8 966	7.173	2.152	15 964	12.771	3.831	22 314	17.852	5.355
TOTAL	431 063	1 464.288	439.286	767 495	2 607.119	782.136	1 072 809	3 644.247	1 093.274

Table 8: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Otago-Catlins at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Elasmobranchii ?sp	1	0.008	0.002	3	0.034	0.010	6	0.055	0.017
Anguilla spp.	1	0.016	0.005	3	0.068	0.020	6	0.110	0.033
Pseudophycis bachus	1 058	1.587	0.476	4 546	6.819	2.046	7 356	11.033	3.310
Lotella rhacinus	1	0.001	0.000	3	0.003	0.001	6	0.006	0.002
Genypterus blacodes	362	1.810	0.543	1 556	7.779	2.334	2 517	12.587	3.776
Helicolenus barathris	3	0.001	0.000	14	0.005	0.002	22	0.009	0.003
Scorpaena cardinalis	32	0.032	0.010	139	0.139	0.042	225	0.225	0.067
Chelidonichthys kumu	0	0.000	0.000	2	0.001	0.000	3	0.002	0.001
Polyprion oxygenios	89	1.789	0.537	385	7.691	2.307	622	12.444	3.733
Trachurus declivis	1	0.001	0.000	2	0.002	0.001	3	0.004	0.001
Trachurus novaezelandiae	16	0.016	0.005	69	0.069	0.021	112	0.112	0.034
Pagrus auratus	238	0.525	0.157	1 025	2.255	0.676	1 658	3.649	1.095
Nemadactylus macropterus	34	0.027	0.008	146	0.117	0.035	236	0.189	0.057
Latridopsis ciliaris	28	0.074	0.022	118	0.320	0.096	192	0.517	0.155
Latris lineata	191	0.572	0.172	820	2.459	0.738	1 326	3.979	1.194
Aldrichetta forsteri	1	0.000	0.000	3	0.001	0.000	6	0.001	0.000
Labridae	212	0.318	0.095	911	1.366	0.410	1 474	2.211	0.663
Parapercis colias	750	0.525	0.157	3 222	2.256	0.677	5 214	3.650	1.095
Nototheniidae	524	0.838	0.252	2 252	3.603	1.081	3 644	5.830	1.749
Thyrsites atun	4 373	10.058	3.018	18 796	43.232	12.970	30 414	69.952	20.985
Rexea solandri	2	0.007	0.002	10	0.031	0.009	17	0.050	0.015
Hyperoglyphe antarctica	1	0.003	0.001	3	0.014	0.004	6	0.022	0.007
TOTAL	7 917	18.209	5.463	34 029	78.264	23.479	55 061	126.636	37.991

Table 9: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Otago-Catlins at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Elasmobranchii ?sp	238	2.375	0.713	1 021	10.209	3.063	1 718	17.180	5.154
Pseudophycis bachus	19 906	29.859	8.958	85 559	128.338	38.501	143 977	215.965	64.789
Genypterus blacodes	3 172	15.861	4.758	13 634	68.170	20.451	22 943	114.716	34.415
Helicolenus barathris	31	0.012	0.004	132	0.053	0.016	222	0.089	0.027
Scorpaena papillosus	31	0.031	0.009	132	0.132	0.040	222	0.222	0.067
Scorpaena cardinalis	460	0.460	0.138	1 976	1.976	0.593	3 325	3.325	0.998
Neophrynichthys latus	31	0.058	0.017	132	0.250	0.075	222	0.421	0.126
Polyprion oxygenios	1 640	32.794	9.838	7 048	140.951	42.285	11 860	237.190	71.157
Nemadactylus macropterus	46	0.037	0.011	198	0.158	0.047	333	0.266	0.080
Latris lineata	590	1.770	0.531	2 536	7.607	2.282	4 267	12.802	3.840
Labridae	4 682	7.022	2.107	20 122	30.183	9.055	33 861	50.791	15.237
Parapercis colias	3 984	2.789	0.837	17 125	11.987	3.996	28 817	20.172	6.052
Nototheniidae	5 256	8.410	2.523	22 592	36.147	10.844	38 017	60.827	18.248
Thyrsites atun	36 556	84.079	25.224	157 121	361.379	108.414	264 401	608.121	182.436
TOTAL	76 622	185.557	55.667	329 325	797.541	239.262	554 183	1 342.086	402.626

Table 10: **Estimated numbers (N) and biomass (tonnes) of fish harvested in Otago-Catlins at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Elasmobranchii ?sp	170	1.702	0.511	229	2.286	0.686	296	2.960	0.888
Callorhinchus milii	170	0.715	0.214	229	0.960	0.288	296	1.243	0.373
Pseudophycis bachus	3 3928	50.891	15.267	45 570	68.355	20.506	58 988	88.481	26.544
Genypterus blacodes	8461	42.303	12.691	11 364	56.819	17.046	14 710	73.550	22.065
Polyprion oxygenios	8597	171.936	51.581	11 547	230.935	69.281	14 947	298.934	89.680
Latridopsis ciliaris	51	0.138	0.041	69	0.185	0.056	89	0.240	0.072
Labridae	1021	1.532	0.460	1 372	2.058	0.617	1 776	2.664	0.799
Parapercis colias	221	0.155	0.046	297	0.208	0.062	385	0.269	0.081
Thyrsites atun	11 7614	270.513	81.154	157 974	363.339	109.002	204 488	470.323	141.097
TOTAL	17 0233	539.885	161.965	228 649	725.146	217.544	295 974	938.663	281.599

Table 11: **Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Greater Hauraki at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Mytilus galloprovincialis	1.77	0.0053	0.0016	10.52	0.0316	0.0095	15.71	0.0471	0.0141
Perna canaliculus	39.35	0.1574	0.0472	234.14	0.9366	0.2810	349.43	1.3977	0.4193
oyster ?sp.	20.22	0.0404	0.0121	120.27	0.2405	0.0722	179.50	0.3590	0.1077
Paphies australis	6.81	0.0068	0.0020	40.50	0.0405	0.0121	60.44	0.0604	0.0181
Paphies subtriangulata	22.68	0.0454	0.0136	134.94	0.2699	0.0810	201.39	0.4028	0.1208
Austrovenus stutchburyi	6.44	0.0129	0.0039	38.32	0.0766	0.0230	57.19	0.1144	0.0343
Dosinia ?sp.	2.71	0.0054	0.0016	16.11	0.0322	0.0097	24.05	0.0481	0.0144
Cellana denticulata	30.02	0.0600	0.0180	178.59	0.3572	0.1072	266.52	0.5330	0.1599
Cellana radians	17.55	0.0351	0.0105	104.40	0.2088	0.0626	155.81	0.3116	0.0935
Haliotis iris	2.50	0.3748	0.1124	14.86	2.2297	0.6689	22.18	3.3275	0.9983
Diloma aethiops	2.90	0.0058	0.0017	17.24	0.0345	0.0103	25.72	0.0514	0.0154
Diloma ?sp	1.21	0.0181	0.0054	7.17	0.1076	0.0323	10.71	0.1606	0.0482
Lunella smaragdus	50.20	0.2008	0.0602	298.68	1.1947	0.3584	445.75	1.7830	0.5349
Nerita atramentosa	6.59	0.0066	0.0020	39.20	0.0392	0.0118	58.50	0.0585	0.0175
Maoricolpus roseus	1.84	0.0018	0.0006	10.94	0.0109	0.0033	16.32	0.0163	0.0049
Maoricrypta costata	3.79	0.0076	0.0023	22.52	0.0450	0.0135	33.61	0.0672	0.0202
Maoricrypta monoxyla	1.44	0.0014	0.0004	8.58	0.0086	0.0026	12.81	0.0128	0.0038
Cominella maculosa	2.07	0.0041	0.0012	12.31	0.0246	0.0074	18.37	0.0367	0.0110
Haustrum haustorium	3.46	0.0519	0.0156	20.57	0.3085	0.0926	30.70	0.4605	0.1381
Dicathais orbita	2.54	0.0381	0.0114	15.13	0.2270	0.0681	22.58	0.3387	0.1016
Amalda australis	1.43	0.0014	0.0004	8.52	0.0085	0.0026	12.71	0.0127	0.0038
Amphibola crenata	9.54	0.0095	0.0029	56.77	0.0568	0.0170	84.72	0.0847	0.0254
all others	9.46	0.0107	0.0032	56.31	0.0639	0.0192	84.04	0.0954	0.0286
TOTAL	246.50	1.1015	0.3304	1 466.61	6.5535	1.9660	2 188.75	9.7803	2.9341

Table 12: Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Greater Hauraki at *ca.* 1550 AD.

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Perna canaliculus	114.8	0.459	0.138	303.9	1.216	0.365	438.5	1.754	0.526
Saccostrea cucullata glomerata	336.8	0.337	0.101	891.4	0.891	0.267	1 286.2	1.286	0.386
Ostrea chilensis	108.5	0.217	0.065	287.1	0.574	0.172	414.3	0.829	0.249
Pecten novaezelandiae	334.3	0.334	0.100	884.7	0.885	0.265	1 276.7	1.277	0.383
Pecten ?sp.	365.6	0.366	0.110	967.6	0.968	0.290	1 396.3	1.396	0.419
Cardita aoteana	271.5	0.272	0.081	718.6	0.719	0.216	1 037.0	1.037	0.311
Purpurocardia ?sp.	417.9	0.418	0.125	1 105.8	1.106	0.332	1 595.7	1.596	0.479
Paphies australis	135 349.3	135.349	40.605	358 185.7	358.186	107.456	516 872.4	516.872	155.062
Paphies subtriangulata	20 255.1	40.510	12.153	53 602.6	107.205	32.162	77 350.1	154.700	46.410
Austrovenus stutchburyi	208 439.5	416.879	125.064	551 610.0	1 103.220	330.966	795 989.3	1591.979	477.594
Cellana radians	488.8	0.978	0.293	1 293.5	2.587	0.776	1 866.5	3.733	1.120
Diloma aethiops	5 818.3	11.637	3.491	15 397.4	30.795	9.238	22 218.9	44.438	13.331
Lunella smaragdus	8 228.0	32.912	9.874	21 774.3	87.097	26.129	31 420.9	125.684	37.705
Zeacumantus ?sp.	246.1	0.246	0.074	651.3	0.651	0.195	939.9	0.940	0.282
Struthiolaria papulosa	1 078.5	2.157	0.647	2 854.2	5.708	1.713	4 118.7	8.237	2.471
Maoricrypta ?sp.	320.2	0.320	0.096	847.5	0.847	0.254	1 223.0	1.223	0.367
Argobuccinum pustulosum tumidum	201.5	0.403	0.121	533.2	1.066	0.320	769.4	1.539	0.462
Janthina janthina	1 100.7	1.101	0.330	2 913.0	2.913	0.874	4 203.5	4.204	1.261
Cominella adspersa	630.4	1.261	0.378	1 668.3	3.337	1.001	2 407.3	4.815	1.444
Cominella ?sp.	930.5	0.931	0.279	2 462.6	2.463	0.739	3 553.6	3.554	1.066
Alcithoe arabica	162.7	0.488	0.146	430.6	1.292	0.388	621.4	1.864	0.559
Amphibola crenata	6 171.6	6.172	1.851	16 332.5	16.332	4.900	23 568.2	23.568	7.070
all others	739.7	2.373	0.712	1957.6	6.279	1.884	2824.8	9.061	2.119
TOTAL	393 626.5	656.118	196.835	1 041 685.3	1 736.337	520.901	1 503 182.3	2505.585	751.675

Table 13: **Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Greater Hauraki at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Perna canaliculus	723.6	2.895	0.868	1 288.4	5.154	1.546	1 800.9	7.204	2.161
Purpurocardia ?sp.	11 131.7	11.132	3.340	19 819.6	19.820	5.946	27 704.0	27.704	8.311
Paphies australis	333 923.2	333.923	100.177	594 539.9	594.540	178.362	831 051.4	831.051	249.315
Paphies subtriangulata	70 348.8	140.698	42.209	125 253.8	250.508	75.152	175 080.5	350.161	105.048
Austrovenus stutchburyi	381 349.4	762.699	228.810	678 980.7	1 357.961	407.388	949 083.4	1 898.167	569.450
Mactra discors	4 783.9	14.352	4.305	8 517.5	25.553	7.666	11 905.8	35.718	10.715
Dosinia anus	92.0	0.184	0.055	163.8	0.328	0.098	229.0	0.458	0.137
Dosinia ?sp.	261.8	0.524	0.157	466.1	0.932	0.280	651.5	1.303	0.391
Myadora striata	261.8	0.262	0.079	466.1	0.466	0.140	651.5	0.652	0.195
Haliotis iris	8.2	1.231	0.369	14.6	2.192	0.658	20.4	3.064	0.919
Zethalia zelandica	2 879.7	2.880	0.864	5 127.2	5.127	1.538	7 166.8	7.167	2.150
Cookia sulcata	8.2	0.123	0.037	14.6	0.219	0.066	20.4	0.306	0.092
Lunella smaragdus	386.5	1.546	0.464	688.2	2.753	0.826	962.0	3.848	1.154
Zeacumantus lutulentus	1 914.7	1.915	0.574	3 409.0	3.409	1.023	4 765.2	4.765	1.430
Struthiolaria papulosa	772.6	1.545	0.464	1 375.6	2.751	0.825	1 922.8	3.846	1.154
Aethocola glans	115.0	0.230	0.069	204.7	0.409	0.123	286.1	0.572	0.172
Cominella adspersa	679.0	1.358	0.407	1 209.0	2.418	0.725	1 690.0	3.380	1.014
Cominella glandiformis	460.0	0.460	0.138	819.0	0.819	0.246	1 144.8	1.145	0.343
Cominella virgata	574.8	0.575	0.172	1 023.4	1.023	0.307	1 430.5	1.431	0.429
Xymene ambiguous	1 580.2	1.580	0.474	2 813.4	2.813	0.844	3 932.6	3.933	1.180
Dicathais orbita	8.2	0.123	0.037	14.6	0.219	0.066	20.4	0.306	0.092
Amphibola crenata	834.4	0.834	0.250	1 485.7	1.486	0.446	2 076.7	2.077	0.623
all others	7 363.0	7.726	2.318	13 109.5	13.755	4.127	18 324.5	19.227	5.768
TOTAL	820 708.4	1 288.793	386.638	1 461 245.6	2 294.655	688.397	2 042 537.9	3 207.483	962.245

Table 14: **Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Otago-Catlins at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Mytilus galloprovincialis	116.9	0.351	0.105	502.3	1.507	0.452	812.8	2.438	0.732
Perna canaliculus	11.5	0.046	0.014	49.3	0.197	0.059	79.8	0.319	0.096
Aulacomya maoriana	0.4	0.001	0.000	1.7	0.003	0.001	2.8	0.006	0.002
Mactra discors	1.0	0.003	0.001	4.4	0.013	0.004	7.1	0.021	0.006
Paphies australis	298.0	0.298	0.089	1 280.7	1.281	0.384	2 072.2	2.072	0.622
Austrovenus stutchburyi	284.8	0.570	0.171	1 224.2	2.448	0.734	1 980.8	3.962	1.188
Protothaca crassicostata	1.2	0.001	0.000	5.2	0.005	0.002	8.3	0.008	0.003
Dosinia ?sp.	2.0	0.004	0.001	8.8	0.018	0.005	14.2	0.028	0.009
Cellana ornata	0.4	0.001	0.000	1.7	0.003	0.001	2.7	0.005	0.002
Cellana strigilis	7.6	0.015	0.005	32.5	0.065	0.019	52.5	0.105	0.032
Patelloida corticata	1.7	0.002	0.001	7.2	0.007	0.002	11.7	0.012	0.003
Haliotis iris	3.5	0.525	0.157	15.0	2.255	0.676	24.3	3.648	1.094
Haliotis australis	0.7	0.069	0.021	3.0	0.296	0.089	4.8	0.479	0.144
Diloma aethiops	24.3	0.049	0.015	104.5	0.209	0.063	169.1	0.338	0.101
Diloma ?sp	1.0	0.015	0.005	4.4	0.066	0.020	7.1	0.107	0.032
Cookia sulcata	4.2	0.062	0.019	17.8	0.268	0.080	28.9	0.433	0.130
Lunella smaragdus	4.1	0.017	0.005	17.8	0.071	0.021	28.8	0.115	0.035
Maoricrypta ?sp	2.6	0.003	0.001	11.4	0.011	0.003	18.4	0.018	0.006
Argobuccinum pustulosum tumidum	1.0	0.002	0.001	4.4	0.009	0.003	7.1	0.014	0.004
Paratrophon patens	0.4	0.000	0.000	1.7	0.002	0.001	2.7	0.003	0.001
Amphibola crenata	78.6	0.079	0.024	337.7	0.338	0.101	546.5	0.546	0.164
Siphonaria ?sp	1.0	0.001	0.000	4.2	0.004	0.001	6.9	0.007	0.002
all others	4.0	0.004	0.001	17.3	0.017	0.005	28.0	0.028	0.008
TOTAL	850.9	2.116	0.635	3 657.1	9.094	2.728	5 917.5	14.714	4.414

Table 15: **Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Otago-Catlins at *ca.* 1550 AD**

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Mytilus galloprovincialis	1 246.0	3.738	1.121	5 355.5	16.066	4.820	9 012.1	27.036	8.111
Perna canaliculus	25.1	0.100	0.030	107.9	0.432	0.130	181.6	0.727	0.218
Aulacomya maoriana	3.8	0.008	0.002	16.2	0.032	0.010	27.2	0.054	0.016
Ostrea chilensis	2.6	0.005	0.002	11.1	0.022	0.007	18.7	0.037	0.011
Purpurocardia ?sp	36.4	0.036	0.011	156.4	0.156	0.047	263.2	0.263	0.079
Paphies australis	402.1	0.402	0.121	1 728.1	1.728	0.518	2 908.0	2.908	0.872
Paphies subtriangulata	14.8	0.030	0.009	63.6	0.127	0.038	107.0	0.214	0.064
Austrovenus stutchburyi	269.5	0.539	0.162	1 158.5	2.317	0.695	1 949.6	3.899	1.170
Cellana strigilis	13.0	0.026	0.008	55.7	0.111	0.033	93.8	0.188	0.056
Notoacmea elongata	3.6	0.004	0.001	15.3	0.015	0.005	25.8	0.026	0.008
Patelloida corticata	11.5	0.011	0.003	49.3	0.049	0.015	83.0	0.083	0.025
Haliotis iris	22.0	3.298	0.990	94.5	14.177	4.253	159.0	23.857	7.157
Haliotis australis	1.0	0.099	0.030	4.2	0.425	0.127	7.1	0.715	0.214
Cantharidus ?sp	14.9	0.015	0.004	64.0	0.064	0.019	107.6	0.108	0.032
Diloma aethiops	43.6	0.087	0.026	187.2	0.374	0.112	315.1	0.630	0.189
Diloma subrostrata	3.5	0.004	0.001	15.2	0.015	0.005	25.6	0.026	0.008
Diloma ?sp	12.7	0.190	0.057	54.5	0.818	0.245	91.7	1.376	0.413
Cookia sulcata	13.9	0.208	0.063	59.7	0.896	0.269	100.5	1.507	0.452
Lunella smaragdus	35.3	0.141	0.042	151.9	0.608	0.182	255.6	1.023	0.307
Maoricrypta ?sp	3.2	0.003	0.001	13.6	0.014	0.004	22.8	0.023	0.007
Amphibola crenata	977.3	0.977	0.293	4 200.5	4.201	1.260	7 068.5	7.069	2.121
Siphonaria ?sp	4.0	0.004	0.001	17.0	0.017	0.005	28.6	0.029	0.009
all others	27.3	0.080	0.024	117.5	0.344	0.103	197.8	0.579	0.174
TOTAL	3 186.9	10.007	3.002	13 697.6	43.009	12.903	23 050.1	72.375	21.713

Table 16: **Estimated numbers (N x 10^3) and biomass (tonnes) of shellfish harvested in Otago-Catlins at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%	N x10^3	Biomass	± 30%
Mytilus galloprovincialis	2 032.6	6.098	1.829	2 730.0	8.190	2.457	3 533.9	10.602	3.180
Perna canaliculus	69.1	0.276	0.083	92.8	0.371	0.111	120.1	0.480	0.144
Aulacomya maoriana	13.0	0.026	0.008	17.5	0.035	0.011	22.7	0.045	0.014
Mytilidae ?sp.	99.0	0.099	0.030	132.9	0.133	0.040	172.1	0.172	0.052
Ostrea chilensis	5.5	0.011	0.003	7.3	0.015	0.004	9.5	0.019	0.006
Paphies australis	34.6	0.035	0.010	46.4	0.046	0.014	60.1	0.060	0.018
Paphies subtriangulata	33.7	0.067	0.020	45.3	0.091	0.027	58.6	0.117	0.035
Paphies ventricosa	5.0	0.020	0.006	6.7	0.027	0.008	8.6	0.034	0.010
Austrovenus stutchburyi	109.1	0.218	0.065	146.6	0.293	0.088	189.7	0.379	0.114
Cellana radians	427.1	0.854	0.256	573.7	1.147	0.344	742.6	1.485	0.446
Cellana ?sp.	467.6	0.468	0.140	628.0	0.628	0.188	812.9	0.813	0.244
Haliotis iris	174.4	26.164	7.849	234.3	35.142	10.543	303.3	45.490	13.647
Scutus breviculus	144.4	2.166	0.650	194.0	2.910	0.873	251.1	3.766	1.130
Zethalia zelandica	2.5	0.003	0.001	3.4	0.003	0.001	4.4	0.004	0.001
Cookia sulcata	16.7	0.250	0.075	22.4	0.336	0.101	29.0	0.435	0.131
Lunella smaragdus	244.3	0.977	0.293	328.1	1.312	0.394	424.7	1.699	0.510
Haustrum lacunosum	4.7	0.009	0.003	6.4	0.013	0.004	8.2	0.016	0.005
Amphibola crenata	511.7	0.512	0.154	687.3	0.687	0.206	889.6	0.890	0.267
all others	4.0	0.004	0.001	5.4	0.005	0.002	7.0	0.007	0.002
TOTAL	4 398.9	38.257	11.477	5 908.4	51.385	15.416	7 648.2	66.515	19.955

Table 17: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Greater Hauraki at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptula minor	714	0.785	0.236	4 248	4.673	1.402	6 340	6.974	2.092
Diomedeidae ?sp	94	0.425	0.128	562	2.530	0.759	839	3.775	1.133
Macronectes halli	30	0.134	0.040	177	0.798	0.239	264	1.190	0.357
Pterodroma macroptera	115	0.057	0.017	682	0.341	0.102	1 018	0.509	0.153
Pachyptila vitata	51	0.010	0.003	306	0.061	0.018	457	0.091	0.027
Puffinus griseus	177	0.142	0.043	1 054	0.844	0.253	1 574	1.259	0.378
Puffinus gavia	327	0.098	0.029	1 944	0.583	0.175	2 901	0.870	0.261
Puffinus assimilis	144	0.029	0.009	854	0.171	0.051	1 274	0.255	0.076
Pelecanoides urinatrix	181	0.024	0.007	1 076	0.140	0.042	1 606	0.209	0.063
Morus serrator	8	0.017	0.005	45	0.103	0.031	67	0.154	0.046
Phalacrocorax melanoleucos	48	0.034	0.010	288	0.202	0.061	430	0.301	0.090
Phalacrocorax carbo	102	0.225	0.068	609	1.339	0.402	908	1.998	0.600
Phalacrocorax varius	191	0.383	0.115	1 139	2.277	0.683	1 699	3.398	1.019
Stictocarbo punctatus	555	0.667	0.200	3 305	3.966	1.190	4 932	5.918	1.775
Calidras canutus rogersi	4	0.000	0.000	23	0.002	0.001	35	0.003	0.001
Charadrius obscurus	4	0.001	0.000	23	0.003	0.001	35	0.005	0.002
Anarhyncus frontalis	4	0.000	0.000	23	0.001	0.000	35	0.002	0.001
Larus dominicanus	202	0.171	0.051	1 199	1.019	0.306	1 790	1.521	0.456
Larus novaehollandiae	4	0.001	0.000	23	0.006	0.002	35	0.009	0.003
Hydroprogne caspia	25	0.017	0.005	149	0.104	0.031	222	0.155	0.047
Childonias albostriata	25	0.002	0.001	149	0.012	0.004	222	0.018	0.005
Sterna striata	4	0.001	0.000	23	0.004	0.001	35	0.006	0.002
TOTAL	3 009	3.223	0.967	17 902	19.178	5.753	26 716	28.620	8.586

Table 18: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Greater Hauraki at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptula minor	1 753	1.928	0.578	4 639	5.103	1.531	6 694	7.364	2.209
Diomedeidae ?sp	1 480	6.659	1.998	3 916	17.622	5.287	5 651	25.430	7.629
Pterodroma macroptera	823	0.411	0.123	2 177	1.088	0.327	3 141	1.571	0.471
Phalacrocorax melanoleucos	370	0.259	0.078	979	0.686	0.206	1 413	0.989	0.297
Stictocarbo punctatus	892	1.070	0.321	2 360	2.832	0.849	3 405	4.086	1.226
Larus dominicanus	370	0.315	0.094	979	0.833	0.250	1 413	1.201	0.360
Sterna striata	370	0.059	0.018	979	0.157	0.047	1 413	0.226	0.068
TOTAL	6 057	10.701	3.210	16 030	28.320	8.496	23 132	40.867	12.260

Table 19: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Greater Hauraki at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptula minor	4 392	4.831	1.449	7 819	8.601	2.580	10 929	12.022	3.607
Diomedeidae ?sp	2 196	9.881	2.964	3 909	17.593	5.278	5 465	24.591	7.377
Pterodroma macroptera	4 392	2.196	0.659	7 819	3.909	1.173	10 929	5.465	1.639
Puffinus gavia	6 587	1.976	0.593	11 728	3.519	1.056	16 394	4.918	1.475
Pelecanoides urinatrix	2 196	0.285	0.086	3 909	0.508	0.152	5 465	0.710	0.213
Procellariidae ?sp	2 196	0.751	0.225	3 909	1.337	0.401	5 465	1.869	0.561
Phalacrocorax melanoleucos	2 196	1.537	0.461	3 909	2.737	0.821	5 465	3.825	1.148
Stictocarbo punctatus	6 587	7.905	2.371	11 728	14.074	4.222	16 394	19.673	5.902
Larus dominicanus	2 196	1.866	0.560	3 909	3.323	0.997	5 465	4.645	1.393
Sterna striata	2 196	0.351	0.105	3 909	0.626	0.188	5 465	0.874	0.262
TOTAL	35 132	31.579	9.474	62 552	56.226	16.868	87 435	78.593	23.578

Table 20: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Otago-Catlins at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptes pachyrhynchus	493	1.974	0.592	2 121	8.484	2.545	3 432	13.727	4.118
Megadyptes ?sp	388	2.036	0.611	1 667	8.752	2.626	2 697	14.161	4.248
Eudyptula minor	533	0.586	0.176	2 291	2.520	0.756	3 707	4.077	1.223
Diomedea exulans	19	0.149	0.045	80	0.640	0.192	130	1.036	0.311
Thalassarche bulleri	16	0.003	0.001	69	0.014	0.004	112	0.022	0.007
Thalassarche cauta	242	1.087	0.326	1 039	4.674	1.402	1 681	7.562	2.269
Pterodroma inexpecta	58	0.019	0.006	248	0.081	0.024	401	0.130	0.039
Pterodroma cookii	55	0.011	0.003	237	0.047	0.014	384	0.077	0.023
Pachyptila vitata	42	0.008	0.003	183	0.037	0.011	295	0.059	0.018
Pachyptila turtur	186	0.023	0.007	800	0.100	0.030	1 295	0.162	0.049
Puffinus griseus	314	0.251	0.075	1 351	1.081	0.324	2 186	1.748	0.525
Puffinus tenuirostris	42	0.025	0.008	180	0.108	0.032	291	0.175	0.052
Puffinus gavia	69	0.021	0.006	295	0.089	0.027	478	0.143	0.043
Pelagodroma marina	22	0.001	0.000	95	0.004	0.001	153	0.007	0.002
Pelecanoides urinatrix	225	0.029	0.009	967	0.126	0.038	1 565	0.204	0.061
Pelecanoides georgicus	98	0.012	0.004	420	0.050	0.015	680	0.082	0.024
Phalacrocorax melanoleucos	28	0.020	0.006	122	0.085	0.026	197	0.138	0.041
Phalacrocorax carbo	29	0.064	0.019	124	0.273	0.082	201	0.442	0.133
Phalacrocorax varius	132	0.265	0.079	569	1.138	0.341	921	1.842	0.553
Leucocarbo chalconotus	170	0.425	0.127	731	1.827	0.548	1 182	2.956	0.887
Stictocarbo punctatus	338	0.406	0.122	1 454	1.745	0.524	2 353	2.824	0.847
Larus dominicanus	59	0.050	0.015	255	0.217	0.065	413	0.351	0.105
Larus novaehollandiae	21	0.005	0.002	90	0.023	0.007	146	0.036	0.011
Childonias albostriata	11	0.001	0.000	48	0.004	0.001	78	0.006	0.002
Sterna striata	45	0.007	0.002	195	0.031	0.009	315	0.050	0.015
TOTAL	3 637	7.480	2.244	15 632	32.149	9.645	25 294	52.018	15.605

Table 21: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Otago-Catlins at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptes pachyrhynchus	340	1.358	0.408	1 460	5.838	1.751	2 456	9.825	2.947
Megadyptes ?sp	303	1.591	0.477	1 303	6.839	2.052	2 192	11.509	3.453
Eudyptula minor	1 118	1.230	0.369	4 804	5.285	1.585	8 085	8.893	2.668
Thalassarche cauta	354	1.595	0.479	1 524	6.856	2.057	2 564	11.537	3.461
Pachyptila turtur	238	0.030	0.009	1 333	0.128	0.038	1 724	0.215	0.065
Puffinus griseus	249	0.200	0.060	584	0.858	0.257	1 804	1.444	0.433
Puffinus gavia	349	0.105	0.031	2 685	0.450	0.135	2 526	0.758	0.227
Puffinus assimilis	190	0.133	0.040	1 167	0.571	0.171	1 373	0.961	0.288
Pelagodroma marina	175	0.008	0.002	584	0.034	0.010	1 266	0.057	0.017
Pelecanoides urinatrix	971	0.126	0.038	2 666	0.543	0.163	7 024	0.913	0.274
Phalacrocorax melanoleucos	214	0.150	0.045	8 497	0.643	0.193	1 546	1.082	0.325
Phalacrocorax carbo	260	0.572	0.172	1 117	2.458	0.737	1 880	4.136	1.241
Phalacrocorax varius	234	0.468	0.140	1 997	2.010	0.603	1 691	3.383	1.015
Leucocarbo chalconotus	354	0.886	0.266	1 524	3.809	1.143	2 564	6.410	1.923
Stictocarbo punctatus	1 912	2.294	0.688	8 216	9.860	2.958	13 826	16.592	4.978
Larus dominicanus	185	0.158	0.047	1 566	0.677	0.203	1 341	1.140	0.342
TOTAL	7 447	10.902	3.271	47 447	46.859	14.058	53 862	78.854	23.656

Table 22: **Estimated numbers (N) and biomass (tonnes) of marine and coastal birds harvested in Otago-Catlins at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Eudyptes pachyrhynchus	318	1.272	0.382	427	1.709	0.513	553	2.212	0.664
Megadyptes ?sp	1 272	6.680	2.004	1 709	8.972	2.692	2 212	11.614	3.484
Diomedea exulans	590	4.723	1.417	793	6.344	1.903	1 026	8.212	2.463
Diomedea epomorpha	405	3.239	0.972	544	4.350	1.305	704	5.631	1.689
Thalassarche chrysostoma	648	2.917	0.875	871	3.918	1.175	1 127	5.072	1.521
Thalassarche bulleri	70	0.014	0.004	94	0.019	0.006	121	0.024	0.007
Thalassarche cauta	3 403	15.311	4.593	4 570	20.565	6.170	5 916	26.621	7.986
Pterodroma cookii	824	0.107	0.032	1 107	0.144	0.043	1 433	0.186	0.056
Pachyptila vitata	1 031	0.206	0.062	1 385	0.277	0.083	1 793	0.359	0.108
Puffinus gavia	318	0.095	0.029	427	0.128	0.038	553	0.166	0.050
Pelagodroma marina	181	0.008	0.002	243	0.011	0.003	314	0.014	0.004
Pelecanoides urinatrix	496	0.065	0.019	667	0.087	0.026	863	0.112	0.034
Phalacrocorax carbo	916	2.015	0.604	1 230	2.706	0.812	1 592	3.503	1.051
Phalacrocorax varius	359	0.718	0.215	482	0.965	0.289	624	1.249	0.375
Leucocarbo chalconotus	4 506	11.265	3.380	6 052	15.131	4.539	7 835	19.586	5.876
Stictocarbo punctatus	6 118	7.342	2.203	8 218	9.861	2.958	10 637	12.765	3.829
Larus dominicanus	1 627	3.578	1.074	2 185	4.806	1.442	2 828	6.222	1.866
Larus novaehollandiae	1 014	0.264	0.079	1 363	0.354	0.106	1 764	0.459	0.138
TOTAL	**24 097**	59.819	17.946	**32 366**	80.346	24.104	**41 896**	104.004	31.201

Table 23: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Greater Hauraki at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Arctocephalus forsteri									
- pup	74	0.639	0.192	442	3.799	1.140	659	5.670	1.701
- juvenile	233	5.837	1.751	1 389	34.729	10.419	2 073	51.830	15.549
- sub adult male	202	20.166	6.050	1 200	119.979	35.994	1 791	179.055	53.716
- adult female	42	2.125	0.637	253	12.642	3.793	377	18.866	5.660
- adult male	127	19.111	5.733	758	113.705	34.111	1 131	169.692	50.907
- total	679	47.877	14.363	4 042	284.853	85.456	6 032	425.112	127.534
Phocarctus hookeri	95	10.663	3.199	564	63.443	19.033	842	94.682	28.405
Mirounga leonina	1	0.790	0.237	5	4.700	1.410	7	7.013	2.104
Globicephala ?sp	7	9.668	2.900	42	57.522	17.257	63	85.845	25.754
Dolphin ?sp	8	0.667	0.200	47	3.971	1.191	70	5.926	1.778
Total	790	69.666	20.900	4 700	414.489	124.347	7 013	618.579	185.574

Table 24: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Greater Hauraki at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Dolphin ?sp	8	0.667	0.200	21	1.791	0.537	31	2.584	0.775

Table 25: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Greater Hauraki at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Dolphin ?sp	14	1.198	0.359	25	2.133	0.640	35	2.981	0.894

Table 26: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Otago-Catlins at *ca.* 1400 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Arctocephalus forsteri									
- pup	64	0.549	0.165	274	2.355	0.706	443	3.810	1.143
- juvenile	492	12.303	3.691	2 112	52.795	15.839	3 417	85.426	25.628
- sub adult male	191	19.140	5.742	821	82.135	24.640	1 329	132.899	39.870
- adult female	82	4.104	1.231	352	17.612	5.283	570	28.497	8.549
- adult male	128	19.140	5.742	548	82.135	24.640	886	132.899	39.870
- total	957	55.235	16.571	4 107	237.030	71.109	6 645	383.529	115.059
Phocarctus hookeri	260	29.262	8.779	1 121	126.163	37.849	1 815	204.140	61.242
Mirounga leonina	1	1.227	0.368	5	5.265	1.580	9	8.519	2.556
Hydrurga leptonyx	1	0.153	0.046	5	0.658	0.197	9	1.065	0.319
Dolphin ?sp	6	0.518	0.156	26	2.224	0.667	43	3.599	1.080
Total	1 226	86.396	25.919	5 265	371.341	111.402	8 519	600.852	180.256

Table 27: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Otago-Catlins at *ca.* 1550 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Arctocephalus forsteri									
- pup	22	0.192	0.058	96	0.826	0.248	162	1.390	0.417
- juvenile	215	5.374	1.612	924	23.098	6.929	1 555	38.869	11.661
- sub adult male	84	8.416	2.525	362	36.171	10.851	609	60.867	18.260
- adult female	30	1.509	0.453	130	6.484	1.945	218	10.911	3.273
- adult male	57	8.538	2.561	245	36.696	11.009	412	61.751	18.525
- total	409	24.028	7.208	1 756	103.274	30.982	2 955	173.788	52.136
Phocarctus hookeri	77	8.664	2.599	331	37.240	11.172	557	62.666	18.800
Hydrurga leptonyx	0.5	0.061	0.018	2	0.263	0.079	4	0.442	0.133
Globicephala ?sp	0.5	0.665	0.200	2	2.858	0.858	4	4.810	1.443
Dolphin ?sp	2	0.207	0.062	11	0.888	0.266	18	1.494	0.448
Total	489	33.625	10.088	2 102	144.523	43.357	3 537	243.201	72.960

Table 28: **Estimated numbers (N) and biomass (tonnes) of marine mammals harvested in Otago-Catlins at *ca.* 1750 AD.**

	Minimum estimate			Best estimate			Maximum estimate		
	N	Biomass	± 30%	N	Biomass	± 30%	N	Biomass	± 30%
Arctocephalus forsteri									
- juvenile	555	13.880	4.164	745	18.613	5.584	964	24.093	7.228
- sub adult male	218	21.802	6.541	292	29.235	8.771	378	37.843	11.353
- adult male	145	21.756	6.527	194	29.173	8.752	252	37.763	11.329
- total	918	57.437	17.231	1 231	77.021	23.106	1 594	99.700	29.910
Globicephala ?sp	24	32.772	9.832	32	44.018	13.205	42	56.979	17.094
Dolphin ?sp	5	0.390	0.117	6	0.523	0.157	8	0.677	0.203
Total	947	90.600	27.180	1 270	121.562	36.469	1 644	157.356	47.207

Table 29: Taxa harvested at *ca.* 1750 AD as a proportion of taxa harvested at *ca.* 1400 AD.

	Greater Hauraki	Otago-Catlins
Fish	0.68	0.41
Shellfish	0.43	0.53
Marine and coastal bird	0.45	0.72
Marine mammal	0.20	0.60

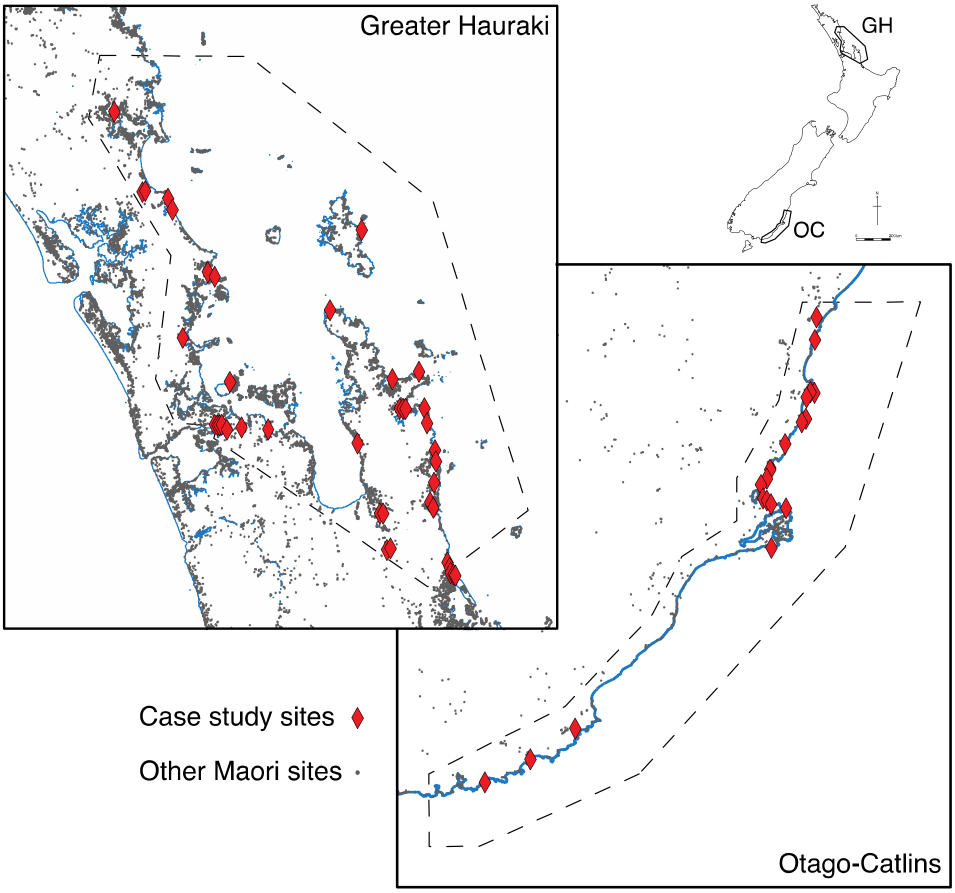

Figure 1: Greater Hauraki and Otago-Catlins, showing location of study sites and other pre-European Maori sites.

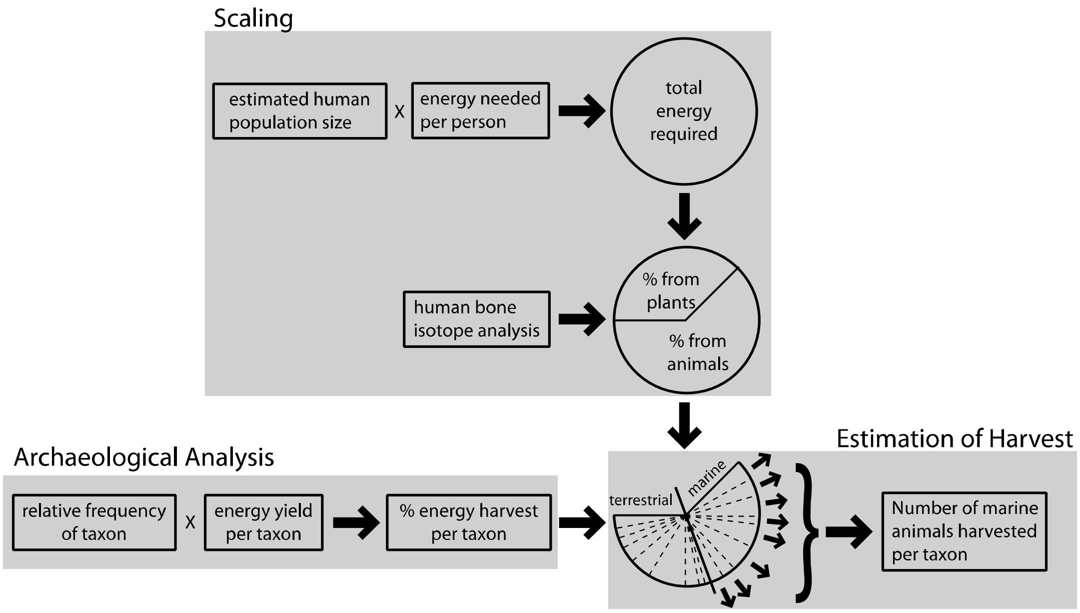

Figure 2: Simplified model of analytical procedure.

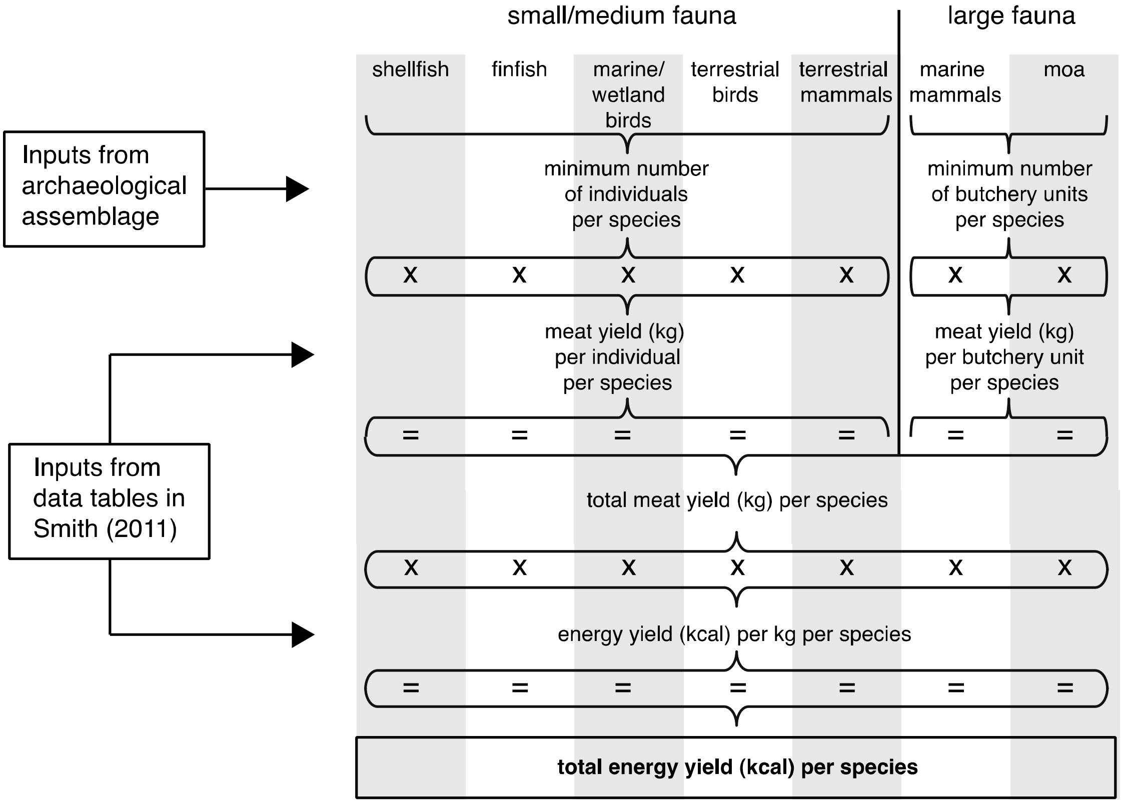

Figure 3: Procedures used in determining energy yield per species in study assemblages.

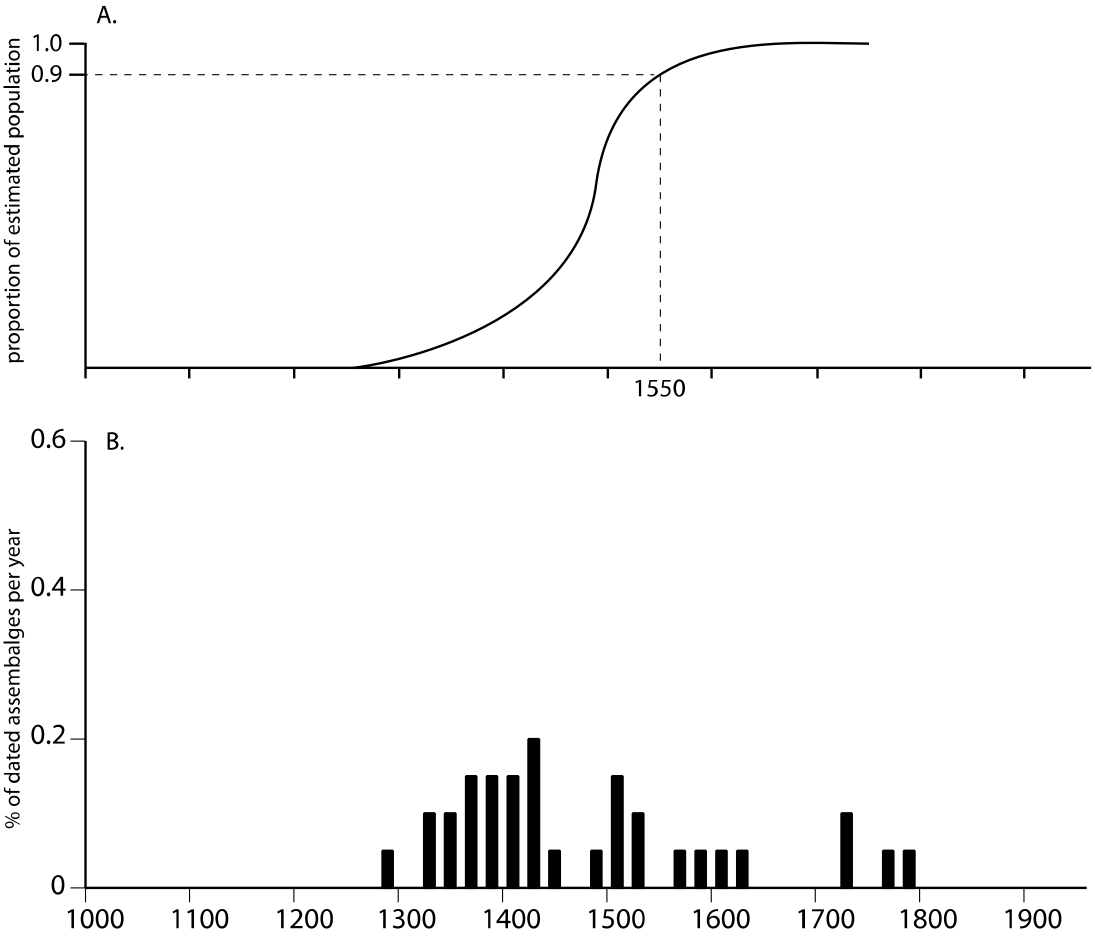

Figure 4: (A) Estimated growth rate for total New Zealand population based on cumulative frequency of radiocarbon dates (after McFadgen *et al.* 1994: Figure 4) showing proportion of population at *ca.* 1550 AD. (B) Frequency of radiocarbon dated assemblages in Otago-Catlins study dataset.

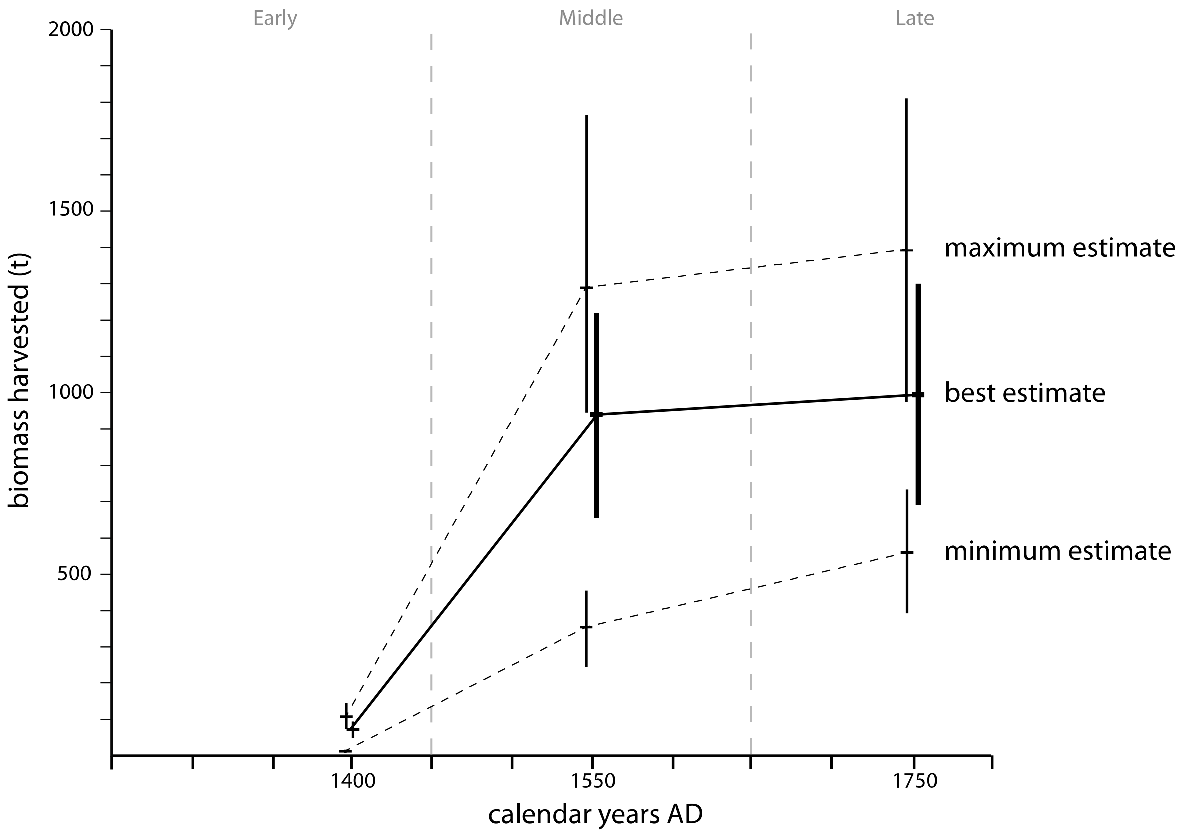

Figure 5: Minimum, best and maximum estimates for biomass of snapper harvested in Greater Hauraki.

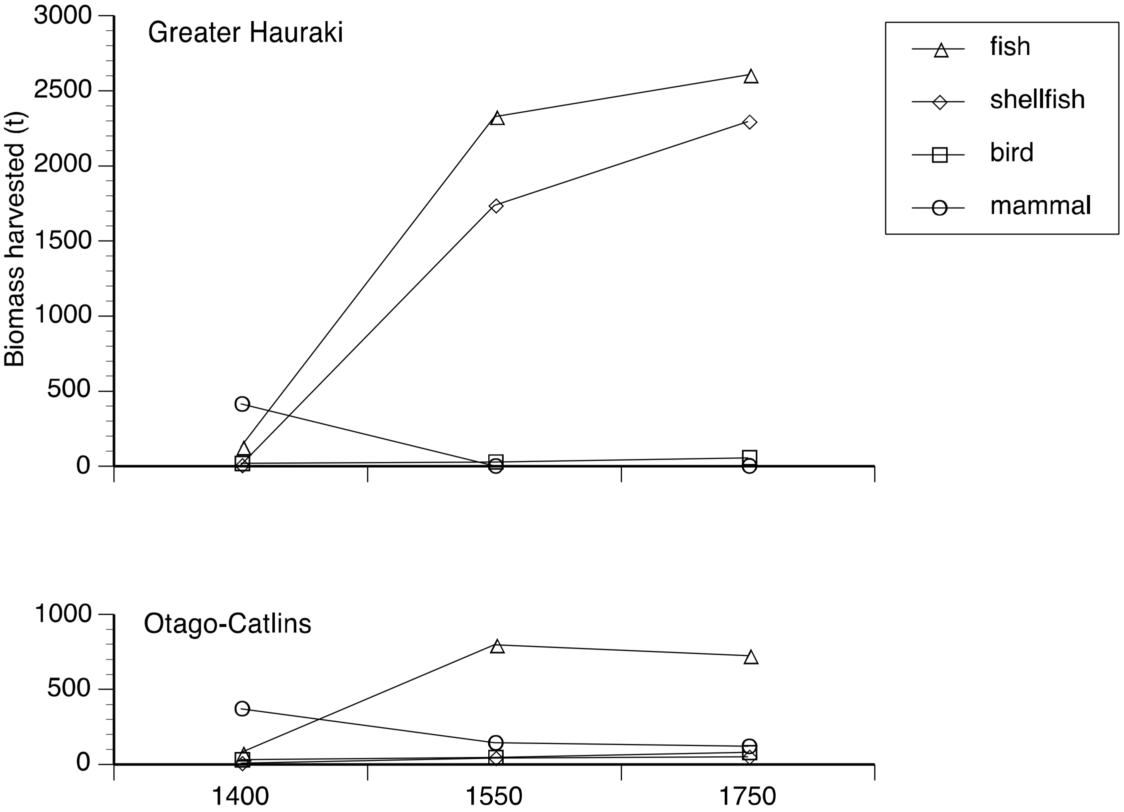

Figure 6: Best estimates for biomass harvested from four classes of marine fauna in each study area

APPENDIX 1 DATA INPUTS FOR MARINE ANIMAL SPECIES

The following tables list for each taxon at each of three focal dates in each study area (1) its frequency as a proportion of all animals in the faunal classes to which it belongs (*taxon frequency*, as defined in section 2.3.2), and (2) its proportional contribution to total energy derived from all animal foods (*proportional energy contribution* as defined in section 2.3.5).

Appendix 1.1 Fish – Greater Hauraki

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
Taxon		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Squalus blainvillei	northern dogfish					2.08	0.8475
Carcharhiniforme ?sp	shark ?sp	0.19	0.2231	2.21	9.6544	6.25	15.2029
Myliobatis tenuicaudatus	eagle ray	0.02	0.0315			2.08	6.7799
Elasmobranchii ?sp	Elasmobranch ?sp	0.21	0.1443				
Callorhinchus milii	ghost shark	0.02	0.0066				
Anguilla spp	eel spp.	0.21	0.0104	1.33	0.2461	4.86	0.5008
Pseudophycis bachus	red cod	0.21	0.0131				
Zeus faber	john dory	0.41	0.0300				
Chelidonichthys kumu	red gurnard	0.72	0.0262	0.31	0.0420	2.08	0.1568
Pseudocaranx dentex	trevally	0.05	0.0049	2.91	1.0570	4.86	0.9829
Trachurus declivis	jack mackerel	0.02	0.0017	0.05	0.0159	2.08	0.3688
Trachurus novaezelandiae	horse mackerel	0.02	0.0013	27.92	6.8394		
Carangidae ?sp	carangidae					2.08	0.2882
Arripis trutta	kahawai	14.06	2.3744	10.94	6.8730	4.17	1.4587
Pagrus auratus	snapper	43.12	5.7160	36.88	18.1870	59.06	16.2171
Nemadactylus macropterus	terakihi	3.51	0.2502				

Appendix 1.1 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Latridopsis ciliaris	blue moki	0.62	0.1114				
Mugil cephalus	grey mullet	0.02	0.0018	1.33	0.4446		
Aldrichetta forsteri	yellow-eyed mullet	4.26	0.0503	2.21	0.0971	2.08	0.0509
Labridae	wrasses	11.81	0.9092	1.33	0.3809	2.08	0.3317
Odax pullus	butterfish					2.08	0.1990
Genyagnus monopterygius	spotted stargazer			0.01	0.0009		
Parapercis colias	blue cod	0.93	0.0301	0.01	0.0012		
Thyrsites atun	barracouta	0.87	0.1180	6.36	3.2091	2.08	0.5844
Scomber australasicus	blue mackerel			2.66	0.9502		
Serollela brama	common warehou	0.19	0.0395				
Meuschenia scaber	leatherjacket	18.53	0.6459			2.08	0.1502
Rhombosolea ?sp	flounder ?sp			3.54	0.1932		
Total		100	10.74	100	48.19	100	44.12

Appendix 1.2 Fish – Otago-Catlins

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Elasmobranchii ?sp	elasmobranch ?sp	0.010	0.0029	0.31	0.8597	0.10	0.1925
Callorhinchus milii	ghost shark					0.10	0.0926
Anguilla spp	eel spp	0.010	0.0066				
Pseudophycis bachus	red cod	13.359	0.3474	25.98	6.5376	19.93	3.4820
Lotella rhacinus	rock cod	0.010	0.0002				
Genypterus blacodes	ling	4.572	0.4320	4.14	3.7856	4.97	3.1553
Helicolenus barathris	sea perch	0.040	0.0002	0.04	0.0023		
Scorpaena papillosus	red rock cod			0.04	0.0058		
Scorpaena cardinalis	red scorpion fish	0.408	0.0061	0.60	0.0864		
Neophrynichthys latus	dark toadfish			0.04	0.0170		
Chelidonichthys kumu	red gurnard	0.005	0.0001				
Polyprion oxygenios	hapuku	1.130	0.6379	2.14	11.6921	5.05	19.1564
Trachurus declivis	jack mackerel	0.005	0.0002				
Trachurus novaezelandiae	horse mackerel	0.204	0.0056				
Pagrus auratus	snapper	3.012	0.1665				
Nemadactylus macropterus	terakihi	0.428	0.0127	0.06	0.0173		
Latridopsis ciliaris	blue moki	0.348	0.0261			0.03	0.0151
Latris lineata	trumpeter	2.409	0.2006	0.77	0.6205		
Aldrichetta forsteri	yellow-eyed mullet	0.010	0.0000				
Labridae	wrasses	2.677	0.0859	6.11	1.8982	0.60	0.1294
Nototheniidae	black cods	6.618	0.2039	6.86	2.0459		
Parapercis colias	blue cod	9.469	0.1277	5.20	0.6785	0.13	0.0118

Appendix 1.2 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Thyrsites atun	barracouta	55.236	3.1239	47.71	26.1132	69.09	26.2549
Rexia solandri	gemfish	0.030	0.0025				
Hyperoglyphe antarctica	bluenose warehou	0.010	0.0010				
Total		100.000	5.39	100.000	54.36	100.000	52.49

Appendix 1.3 Shellfish – Greater Hauraki

		ca 1400		ca 1550		ca 1750	
Taxon		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Linucula hartvigiana	nut shell	0.008	0.000010				
Mytilus galloprovincialis	blue mussel	0.718	0.002722	0.001	0.000642		
Perna canaliculus	green-lipped mussel	15.965	0.080051	0.029	0.043792	0.088	0.153952
Limnoperna pulex	little black mussel	0.004	0.000006				
Barbatia novaezealandiae	ark shell	0.002	0.000002				
Glycermis modesta	small dog cockle	0.001	0.000001				
Tucetona laticostata	large dog cockle	0.015	0.000019				
Ostrea chilensis	mud oyster/bluff oyster			0.028	0.026970	0.001	0.001138
Saccostrea cuccullata glomerata	rock oyster	0.080	0.000101	0.086	0.032395		
oyster ?sp.		8.201	0.020743	0.030	0.022491		

Appendix 1.3 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Anomia trigonopsis	golden oyster	0.043	0.000054				
Pecten novaezelandiae	queen scallop	0.055	0.000073	0.085	0.033485	0.011	0.005141
Pecten ?sp.		0.022	0.000028	0.093	0.036623		
Talochlamys zelandiae	fan scallop	0.002	0.000002				
Divalucina cumingi	lace cockle	0.062	0.000079				
Cardita aoteana	dog foot cockle			0.069	0.026117		
Purpurocardia purpurata	purple cockle	0.025	0.000032				
Purpurocardia ?sp.				0.106	0.040190	1.356	0.597315
Myllita stowei		0.002	0.000002				
Cyclomactra ovata	oval trough shell			0.006	0.004210		
Mactra discors	large trough shell			0.003	0.003548	0.583	0.770092
Mactra ?sp.				0.007	0.004937		
Paphies australis	pipi	2.761	0.001796	34.385	6.696830	40.687	9.217530
Paphies subtriangulata	tuatua	9.201	0.032120	5.146	5.377563	8.572	10.419895
Paphies ventricosa	toheroa			0.018	0.027131		
Diplodonta striatula		0.001	0.000001				
Felaniella zelandica		0.004	0.000006				
Austrovenus stutchburyi	cockle	2.613	0.003566	52.954	21.632550	46.474	22.084135
Protothaca crassicostata	ribbed venus	0.406	0.000513			0.001	0.000440
Tawera spissa	morning star	0.096	0.000121				
Tawera ?sp.		0.031	0.000039	0.028	0.010587		
Dosinia anus	ringed venus shell	0.261	0.000660	0.016	0.011878	0.011	0.009873
Dosinia subrosea	fine dosinia			0.014	0.010593		
Dosinia ?sp.		1.099	0.002779	0.001	0.000513	0.032	0.028095
Irus reflexus	irregular cockle	0.025	0.000031				
Myadora striata	battleaxe					0.032	0.014047

Appendix 1.3 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Cellana denticulata	denticulate limpet	12.177	0.030800				
Cellana ornata	ornate limpet	0.028	0.000035				
Cellana radians	radiate limpet	7.119	0.018006	0.124	0.094021		
Asteracmea suteri		0.001	0.000001				
Patelloida corticata	encrusted limpet	0.315	0.000398				
Haliotis iris	paua	1.014	0.238822	0.000	0.031834	0.001	0.082054
Haliotis australis	silver paua	0.013	0.002075				
Haliotis ?sp.		0.140	0.000178				
Scutus breviculus	shield limpet	0.013	0.000251	0.004	0.021550		
Tugali elegans	grooved limpet	0.043	0.000054				
Coelotrochus viridius	green top shell	0.016	0.000020				
Cantharidus ?sp.		0.003	0.000003				
Diloma aethiops	spotted top shell	1.175	0.002972	1.478	1.119211	0.001	0.000881
Diloma bicanaliculata	knobbed topshell	0.001	0.000001				
Diloma subrostrata	mudflat top shell	0.317	0.000400				
Diloma ?sp		0.489	0.009279				
Antisolarium egenum		0.194	0.000245				
Zethalia zelandica	wheel shell			0.010	0.003876	0.351	0.154521
Trochidae ?sp.				0.003	0.000969		
Calliostoma pellucidum		0.002	0.000002				
Calliostoma punctulatum	spotted tiger shell			0.004	0.001437		
Cookia sulcata	cooks turban	0.140	0.002664			0.001	0.006606
Lunella smaragdus	cats eye	20.366	0.103023	2.090	3.165479	0.047	0.082961
Herpetopoma bella		0.002	0.000002				
Nerita atramentosa	black nerita	2.673	0.003380				
Zeacumantus lutulentus	horn shell	0.006	0.000008	0.031	0.011752	0.233	0.102740

Appendix 1.3 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Zeacumantus subcarinatus	brown horn shell			0.005	0.002078		
Zeacumantus ?sp.				0.063	0.023673		
Maoricolpus roseus	turret shell	0.746	0.000943	0.040	0.015299		
Maoricrypta ?sp.				0.081	0.030801		
Rissoina ?sp.		0.003	0.000003				
Struthiolaria papulosa	ostrich foot			0.274	0.207	0.094	0.082912
Maoricrypta costata	ribbed slipper shell	1.536	0.003884				
Maoricrypta monoxyla	white slipper shell	0.585	0.000740				
Sigapatella novaezelandiae	circular slipper shell	0.108	0.000272				
Sigapatella tenuis	small circular slipper shell	0.131	0.000166				
Lamellaria ophione		0.003	0.000003				
Argobuccinum pustulosum	swollen trumpet shell			0.051	0.038758		
Cabestana spengleri	spenglers trumpet shell			0.005	0.005814		
Janthina janthina	violet snail			0.280	0.105870		
Aethocola glans	knobbed whelk	0.258	0.000653	0.004	0.002924	0.014	0.012337
Buccinulum pallidum powelli	lined whelk	0.001	0.000002				
Buccinulum vittatum vittatum		0.002	0.000002				
Buccinulum ?sp.				0.029	0.010833		
Cominella adspersa	speckled whelk	0.008	0.000020	0.160	0.121263	0.083	0.072874
Cominella glandiformis	purple-mouthed whelk	0.086	0.000108	0.013	0.004937	0.056	0.024682
Cominella maculosa	spotted whelk	0.839	0.002122	0.023	0.017365		
Cominella quoyana quoyana	quoy's whelk	0.008	0.000010				
Cominella virgata	red mouthed whelk	0.018	0.000022	0.042	0.015803	0.070	0.030844
Cominella ?sp.		0.124	0.000157	0.236	0.089501		
Penion sulcatus	siphon whelk	0.001	0.000003	0.008	0.008580		
Zemitrella ?sp.		0.001	0.000001				

Appendix 1.3 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Taron ?sp.		0.005	0.000007	0.002	0.000676	0.013	0.005750
Haustrum haustorium	dark rock shell	1.402	0.026605	0.018	0.100685	0.001	0.006606
Haustrum scobina	oyster borer	0.226	0.000286				
Murexsul mariae		0.002	0.000002				
Murexsul octogonus	octagonal murex	0.002	0.000004				
Xymene ambiguous	large trophon	0.064	0.000081	0.000	0.000169	0.193	0.084790
Xymene plebeius		0.055	0.000070				
Xymene traversi		0.070	0.000088				
Dicathais orbita	white rock shell	1.032	0.019570	0.018	0.100710	0.001	0.006606
Austromitra rubiginosa		0.043	0.000054				
Alcithoe arabica	arabic volute			0.041	0.046954	0.001	0.001321
Amalda australis	southern olive shell	0.581	0.000735				
Phenatoma rosea	pink tower shell	0.003	0.000003				
Turbonilla zealandica		0.065	0.000082				
Acteonidae ?sp		0.129	0.000163				
Amphibola crenata	mudsnail	3.871	0.004895	1.568	0.593590	0.102	0.044774
Amuarochiton glaucus		0.022	0.000027				
Antalis nana	tusk shell	0.028	0.000036				
gastropod ?sp.	gastropod ?sp			0.193	0.073	0.897	0.395088
Total		100	0.62	100	40.11	100	44.50

Appendix 1.4 Shellfish – Otago-Catlins

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Mytilus galloprovincialis	blue mussel	13.736	0.107401	39.098	1.154553	46.206	0.586416
Perna canaliculus	green-lipped mussel	1.348	0.013925	0.788	0.030769	1.570	0.026332
Aulacomya maoriana	ribbed mussel	0.047	0.000244	0.118	0.002324	0.297	0.002509
Limnoperna pulex	little black mussel			0.006	0.000062		
Modiolus areolatus	bearded mussel			0.003	0.000093		
Mytilidae sp.						2.250	0.009519
Barbatia novaezealandiae	ark shell	0.000	0.000000				
Glycermis modesta	small dog cockle	0.001	0.000004	0.003	0.000028		
Ostrea chilensis	mud oyster	0.000	0.000001	0.081	0.002050	0.124	0.001357
Purpurocardia ?sp.	false cockle ?sp			1.142	0.011240		
Lasaea hinemoana				0.004	0.000038		
Mactra discors	large trough shell	0.120	0.000940	0.003	0.000084		
Zenatia acinaces	scimitar mactra			0.000	0.000004		
Paphies australis	pipi	35.018	0.046950	12.616	0.063885	0.786	0.001711
Paphies subtriangulata	tuatua			0.464	0.012617	0.767	0.008951
Paphies ventricosa	toheroa					0.113	0.001906
Macomona liliana	large wedge shell	0.007	0.000036				
Serratina charlottae	wedge shell	0.003	0.000014				
Austrovenus stutchburyi	cockle	33.473	0.094134	8.458	0.089839	2.481	0.011325
Protothaca crassicostata	ribbed venus	0.141	0.000367				
Tawera spissa	morning star			0.012	0.000114		
Tawera ?sp.				0.004	0.000038		
Dosinia ?sp.		0.240	0.001253				

Appendix 1.4 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Ruditapes largillierti	oblong venus	0.025	0.000064	0.028	0.000278		
Myadora striata	battleaxe			0.000	0.000004		
Cellana ornata	ornate limpet	0.046	0.000121	0.031	0.000305		
Cellana radians	radiate limpet	0.035	0.000182	0.023	0.000457	9.710	0.082152
Cellana strigilis	striated limpet	0.888	0.004627	0.407	0.008012	0.017	0.000140
Cellana ?sp.		0.020	0.000052	0.007	0.000064	10.629	0.044966
Notoacmea elongata		0.012	0.000030	0.112	0.001105		
Notoacmea pileopsis	black edged limpet			0.019	0.000190		
Notoacmea scopulina		0.012	0.000030	0.004	0.000038		
Patelloida corticata	encrusted limpet	0.197	0.000515	0.360	0.003543		
Radiacmea inconspicua		0.004	0.000011	0.009	0.000084		
Haliotis iris	paua	0.411	0.199726	0.690	1.266069	3.965	3.125533
Haliotis virginea	virgin paua	0.012	0.001880	0.004	0.002366		
Haliotis australis	silver paua	0.081	0.026326	0.031	0.037352		
Haliotis ?sp.	paua sp.	0.032	0.000083	0.014	0.000140		
Emarginula ?sp				0.000	0.000002		
Scutus breviculus	shield limpet	0.012	0.000454	0.010	0.001441	3.283	0.208336
Coelotrochus viridius	green top shell	0.012	0.000030	0.011	0.000107	0.008	0.000035
Cantharidius sanguineus	oval top shell			0.035	0.000343		
Cantharidus ?sp.				0.432	0.004257	0.008	0.000035
Diloma aethiops	spotted top shell	2.858	0.014896	1.367	0.026917	0.017	0.000140
Diloma arida				0.031	0.000305		
Diloma bicanaliculata	knobbed topshell			0.004	0.000038		
Diloma nigerrima	bluish top shell	0.012	0.000030	0.063	0.000622		
Diloma subrostrata	mudflat top shell	0.001	0.000004	0.111	0.001096		
Diloma zelandica		0.025	0.000064	0.025	0.000243		

Appendix 1.4 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Diloma ?sp		0.120	0.004695	0.398	0.058709		
Zethalia zelandica	wheel shell	0.001	0.000004	0.084	0.000823	0.058	0.000245
Cookia sulcata	cooks turban	0.488	0.019082	0.436	0.064340	0.379	0.024064
Lunella smaragdus	cats eye	0.486	0.005066	1.109	0.043645	5.553	0.093963
Modelia granosa	southern cats eye	0.031	0.000243	0.004	0.000114		
Maoricolpus roseus	turret shell	0.001	0.000004	0.005	0.000045		
Maoricrypta ?sp.		0.311	0.000810	0.099	0.000972		
Zeaculpus symmetricus	Stewart Island turret shell			0.023	0.000229		
Risellopsis varia				0.004	0.000038		
Littorinidae ?sp				0.017	0.000165		
Struthiolaria ?sp		0.001	0.000007	0.000	0.000004		
Sigapatella novaezelandiae	circular slipper shell			0.006	0.000116		
Argobuccinum pustulosum	swollen trumpet shell	0.120	0.000627				
Aethocola glans	knobbed whelk					0.008	0.000070
Buccinulum linea	many-lined whelk			0.012	0.000229		
Buccinulum vittatum littorinoides				0.019	0.000190		
Buccinulum ?sp.		0.000	0.000001	0.015	0.000299		
Cominella glandiformis	purple-mouthed whelk	0.003	0.000007	0.012	0.000118		
Cominella ?sp.		0.003	0.000007	0.003	0.000028		
Haustrum lacunosum	white whelk	0.005	0.000026	0.039	0.000770	0.108	0.000910
Haustrum scobina	oyster borer			0.009	0.000089		
Xymene ambiguous	large trophon			0.001	0.000009		
Xymene huttoni				0.003	0.000028		
Xymene ?sp.		0.012	0.000030	0.012	0.000114		
Paratrophon patens	rock trophon	0.046	0.000121	0.031	0.000305		
Muricidae ?sp				0.009	0.000087		

Appendix 1.4 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Amphibola crenata	mudsnail	9.235	0.024070	30.666	0.301855	11.632	0.049210
Benhamina obliquata		0.001	0.000004	0.004	0.000080	0.008	0.000070
Siphonaria australis	siphon limpet			0.000	0.000002		
Siphonaria propria		0.002	0.000006				
Siphonaria ?sp		0.116	0.000303	0.124	0.001219		
Trimusculus conicus	false limpet			0.004	0.000040		
Antalis ?sp	tusk shell	0.001	0.000004			0.008	0.000035
gastropod ?sp.		0.032	0.000084				
Patellacea ?sp				0.047	0.000466	0.008	0.000035
Polyplacophora ?sp.		0.035	0.000091	0.178	0.001752	0.008	0.000035
Total		100	0.57	100	3.20	100	4.28

Appendix 1.5 Marine and Coastal Birds – Greater Hauraki

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Eudyptula minor	Little penguin	23.73	1.014	28.94	0.270	12.50	0.382
Diomedeidae ?sp	Albatross ?sp	3.14	0.549	24.43	0.933	6.25	0.782
Macronectes halli	Northern giant petrel	0.99	0.173				
Pterodroma macroptera	Grey-faced petrel	3.81	0.074	13.58	0.058	12.50	0.174
Pachyptila vitata	Broad-billed prion	1.71	0.013				

Appendix 1.5 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Puffinus griseus	Sooty shearwater	5.89	0.183				
Puffinus gavia	Fluttering shearwater	10.86	0.127			18.75	0.156
Puffinus assimilis	Norfolk little shearwater	4.77	0.037				
Pelecanoides urinatrix	Common diving petrel	6.01	0.030			6.25	0.023
Procellariidae ?sp	petrel ?sp					6.25	0.059
Morrus serrator	Australasian gannet	0.25	0.022				
Phalacrocorax melanoleucos	Little shag	1.61	0.044	6.11	0.036	6.25	0.122
Phalacrocorax carbo	Black shag	3.40	0.290				
Phalacrocorax varius	Pied shag	6.36	0.494				
Stictocarbo punctatus	Spotted shag	18.46	0.860	14.72	0.150	18.75	0.626
Calidras canutus	Lesser knot	0.13	0.000				
Charadrius obscurus	NZ dotterel	0.13	0.001				
Anarhynchus frontalis	Wrybill	0.13	0.000				
Larus dominicanus	Southern black-backed gull	6.70	0.221	6.11	0.044	6.25	0.148
Larus novaehollandiae	Red-billed gull	0.13	0.001				
Hydroprogne caspia	Caspian tern	0.83	0.023				
Childonias albostriata	Black-fronted tern	0.83	0.003				
Sterna striata	White-fronted tern	0.13	0.001	6.11	0.008	6.25	0.028
Total		**100**	**4.16**	**100**	**1.50**	**100**	**2.50**

Appendix 1.6 Marine and Coastal Birds – Otago-Catlins

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Eudyptes pachyrhynchus	NZ crested penguin	13.568	1.713	4.56	1.179	1.32	0.345
Megadyptes ?sp	Waitaha/Yellow-eyed peng.	10.664	1.767	4.07	1.381	5.28	1.811
Eudyptula minor	Little penguin	14.654	0.509	15.01	1.067		
Diomedea exulans	Wandering albatross	0.512	0.129			2.45	1.281
Diomedea epomorpha	Southern Royal albatross					1.68	0.878
Thalassarche chrysostoma	Grey-headed albatross					2.69	0.791
Thalassarche bulleri	Buller's albatross	0.443	0.003			0.29	0.004
Thalassarche cauta	White-capped albatross	6.644	0.943	4.76	1.384	14.12	4.152
Pterodroma inexpecta	Mottled petrel	1.587	0.016				
Pterodroma cookii	Cooks petrel	1.518	0.010			3.42	0.029
Pachyptila vittata	Broad-billed prion	1.168	0.007			4.28	0.056
Pachyptila turtur	Fairy prion	5.120	0.020	3.20	0.026		
Puffinus griseus	Sooty shearwater	8.641	0.218	3.35	0.173		
Puffinus tenuirostris	Short-tailed shearwater	1.152	0.022				
Puffinus gavia	Fluttering shearwater	1.888	0.018	4.69	0.091	1.32	0.026
Puffinus assimilis	Little shearwater			2.55	0.115		
Pelagodroma marina	White-faced storm petrel	0.606	0.001	2.35	0.007	0.75	0.002
Pelecanoides urinatrix	Common diving petrel	6.189	0.025	13.04	0.110	2.06	0.017
Pelecanoides georgicus	South Georgian diving petrel	2.688	0.010				
Phalacrocorax melanoleucos	Little shag	0.780	0.017	2.87	0.130		
Phalacrocorax carbo	Pied shag	3.641	0.230	3.14	0.406	1.49	0.195
Phalacrocorax varius	Black shag	0.794	0.055	3.49	0.496	3.80	0.546
Leucocarbo chalconotus	Stewart Island Shag	4.674	0.369	4.76	0.769	18.70	3.055

Appendix 1.6 continued

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Stictocarbo punctatus	Spotted shag	9.304	0.352	25.67	1.990	25.39	1.991
Larus dominicanus	Southern black-backed gull	1.632	0.044	2.49	0.137	6.75	0.970
Larus novaehollandiae	Red-billed gull					4.21	0.072
Larus bulleri	Black-billed gull	0.577	0.005				
Childonias albostriata	Black-fronted tern	0.309	0.001				
Sterna striata	White-fronted tern	1.247	0.006				
Total		100.00	**6.49**	100.00	**9.46**	100.00	**16.22**

Appendix 1.7 Marine Mammals – Greater Hauraki

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Arctocephalus forsteri	fur seal - pup	9.40	0.5385				
Arctocephalus forsteri	fur seal - juvenile	29.56	5.0526				
Arctocephalus forsteri	fur seal – sub adult male	25.53	17.9041				
Arctocephalus forsteri	fur seal - adult female	5.38	1.9185				
Arctocephalus forsteri	fur seal - adult male	16.13	18.1182				
Arctocephalus forsteri	fur seal - total	86.00					
Phocarctus hookeri	sea lion	12.00	9.4682				
Mirounga leonina	elephant seal	0.10	0.6887				
Globicephala ?sp	pilot whale	0.90	0.6571				
Dolphin ?sp	dolphin ?sp	1.00	0.4542	100.00	0.05	100.00	**0.05**
Total		100	54.80	100	0.05	100	0.05

Appendix 1.8 Marine Mammals – Otago-Catlins

		ca 1400 AD		ca 1550 AD		ca 1750 AD	
		Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution	Taxon frequency	Proportional energy contribution
Arctocephalus forsteri	fur seal - pup	5.20	0.3111	4.57	0.1090		
Arctocephalus forsteri	fur seal - juvenile	40.11	7.1595	43.96	3.1273	60.10	2.5242
Arctocephalus forsteri	fur seal – sub adult male	15.60	11.4247	17.21	5.0233	23.60	4.0668
Arctocephalus forsteri	fur seal – adult female	6.69	2.4912	6.17	0.9157		
Arctocephalus forsteri	fur seal – adult male	10.40	12.1993	11.64	5.4418	15.70	4.3333
Arctocephalus forsteri	fur seal - total	78.00		83.55		99.40	
Phocarctus hookeri	sea lion	21.20	17.4680	15.75	5.1722		
Mirounga leonina	elephant seal	0.10	0.7192				
Hydrurga leptonyx	leopard seal	0.10	0.0899	0.10	0.0358		
Globicephala ?sp	pilot whale ?sp	0.10	0.0762	0.10	0.0304	0.10	0.4680
Dolphin ?sp	dolphin ?sp	0.50	0.2371	0.50	0.0945	0.50	0.0558
Total		100.00	**52.10**	100.00	**19.95**	100.00	**10.98**