

# AN INVENTORY OF THE STATUS AND ORIGIN OF NEW ZEALAND ESTUARINE SYSTEMS

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**SUMMARY:** Estuaries are vulnerable, unstable areas sensitive to the impact of man, because they are at the interface of two contrasting environments in which the results of environmental changes induced by man are focused. This study presents data on the extent, character, status and on the number of surveys of New Zealand estuaries. The widest possible interpretation of the term *estuary* has been used so as to produce the most comprehensive list.

Detailed study of topographic maps and information from questionnaires indicate that there are 301 estuaries widely distributed around the coast with an average of 1 per 32 km of coastline. Some data on the status of 54% of these is available. These estuaries range in size from a few ha to over 15 000 ha but over ninety percent are less than 1700 ha, and 68% are less than 500 ha in area. Most estuaries are associated with human population concentrations of less than 500 persons. Overall there is approximately 0.03 ha of estuarine area per person. Bar-built and lagoonal estuaries predominate in both the North and South Islands.

Questionnaire results suggest that the water of most estuaries is well-mixed and clean or slightly polluted. Significantly more North Island estuaries are seriously polluted. The status of more than two-thirds of the estuaries has remained unchanged over the last 10 years. The balance among those which have changed is towards an overall deterioration and this has been more pronounced in the South Island. Research and surveys of estuaries are not very well developed and only 19% have been the subject of one or more reports. Very few have received satisfactory, detailed, simultaneous study of both their physical and biological characteristics over any length of time. In view of the many uses to which they are put, the frequent proximity of urban population concentrations, and the channelling of the effects of many different, widely dispersed human activities through them, estuaries should be the subject of a great deal more research. The use of systems modelling techniques as an aid to research and management is advocated.

## INTRODUCTION

Estuaries are the link between the freshwater and marine environments and largely because of this they are the scene of rapid environmental fluctuations ranging from those produced by regular, periodic inundation by the sea to those produced by river floods. Changes in the timing and coupling of the marine and freshwater environments, as well as the impact of meteorological conditions, produce a region of mixing where the environmental parameters at any one place are liable to be highly variable. Estuarine areas are rich in plant and animal life and are known to be among the most productive of any habitat. Rivers deliver abundant supplies of nutrients (all too often supplemented by the activities of man) which are the chief reason for the high biological productivity. Included within the term estuary are a wide variety of environments that are characterised by salinity fluctuations. These may range from river-

mouths occasionally inundated by the sea and where the freshwater influence is dominant, to mudflats dominated by the tide where the influence of fresh and seawater are more nearly balanced, to long narrow arms of the sea partially diluted by fresh water and which may be stratified to some extent. All of these qualities of instability, plant and animal richness, high productivity and great variety of form and function, make estuaries not only an interesting area for ecological research, but also make them exceedingly vulnerable to the impact of man. An estuary is the focal point of a whole watershed and as a result the widespread and small incremental changes by man are concentrated to a very high level.

The decision to hold an Estuarine Symposium at the 1975 annual conference, served to precipitate some action on a resolution made by the Council of the New Zealand Ecological Society in November

1973. It was then apparent that information relating to estuarine systems was becoming increasingly sought after and that an urgent prerequisite was to identify the systems and collate the available information on them so as to guide future research and prevent needless repetition of projects. As far as is known this has never been attempted before in New Zealand, although Bayly (1975) has recently produced a very thorough and useful review of Australian estuaries. Dr I. Estcourt, of the New Zealand Oceanographic Institute, is also preparing a bibliography of published work on all aspects of New Zealand estuaries. The present paper (1) is, however, only a first step towards the aim of reviewing the extent of knowledge about our estuarine resources and it is hoped that at some future date another, more authoritative and comprehensive treatment will be attempted.

The data upon which this paper is based, were accumulated from topographic maps, population census data and a questionnaire that was sent to all authorities and individuals with personal knowledge of individual estuaries and their response and comments have been invaluable. The compilers would like to acknowledge their indebtedness to the many contributors, without whose co-operation this survey would have been impossible. In particular many members of the Royal Forest and Bird Protection Society, and Professor P. S. Corbet and Dr R. M. Kirk of Canterbury University have been most helpful. Dr M. B. Jones and Professor G. A. Knox provided valuable comments on the final draft of the manuscript.

(1) This paper is based on a larger document compiled by C. McLay, F. Rose, C. Hay and S. Davis, and distributed at the 1975 New Zealand Ecological Society Conference.

## RESULTS

### Classification

The complexities of shoreline processes create a wide variety of coastal conditions (Pritchard, 1952) that almost defy definition of what constitutes an estuary. This survey of the New Zealand coastline presented extreme difficulty in defining an estuarine system as might be expected. The major criteria that must be used (topographic, river flow and tidal activity) combine to produce a wide variety of environments. For the purpose of this paper the term *estuary* has been taken to comprise both *estuarine* and *lagoonal* environments. The following definitions are based on one given by Cameron and Pritchard (1963).

An *estuarine environment* is a semi-enclosed

coastal body of water having a free connection with the open sea and where there is a discernible effect of one or more rivers, resulting in salinity variations over the average tidal cycle.

A *lagoonal environment* is a semi-enclosed body of water having a free connection with the open sea and where, due to a large volume of fresh water, from one or more rivers, the addition of sea water is intermittent and normally restricted to periods of storm wave activity or high tidal elevations.

The classification that we have used is intentionally very broad so as to include the full range as it was considered that a first inventory of New Zealand estuaries should attempt to be as comprehensive of possible. It is appreciated that professions will define estuaries in differing and perhaps more precise terms and that the list, may as a result, be reduced in number. The inclusion of some estuaries was subject to much dispute which further emphasised the difficulties in identifying what we mean by this term. Frequently

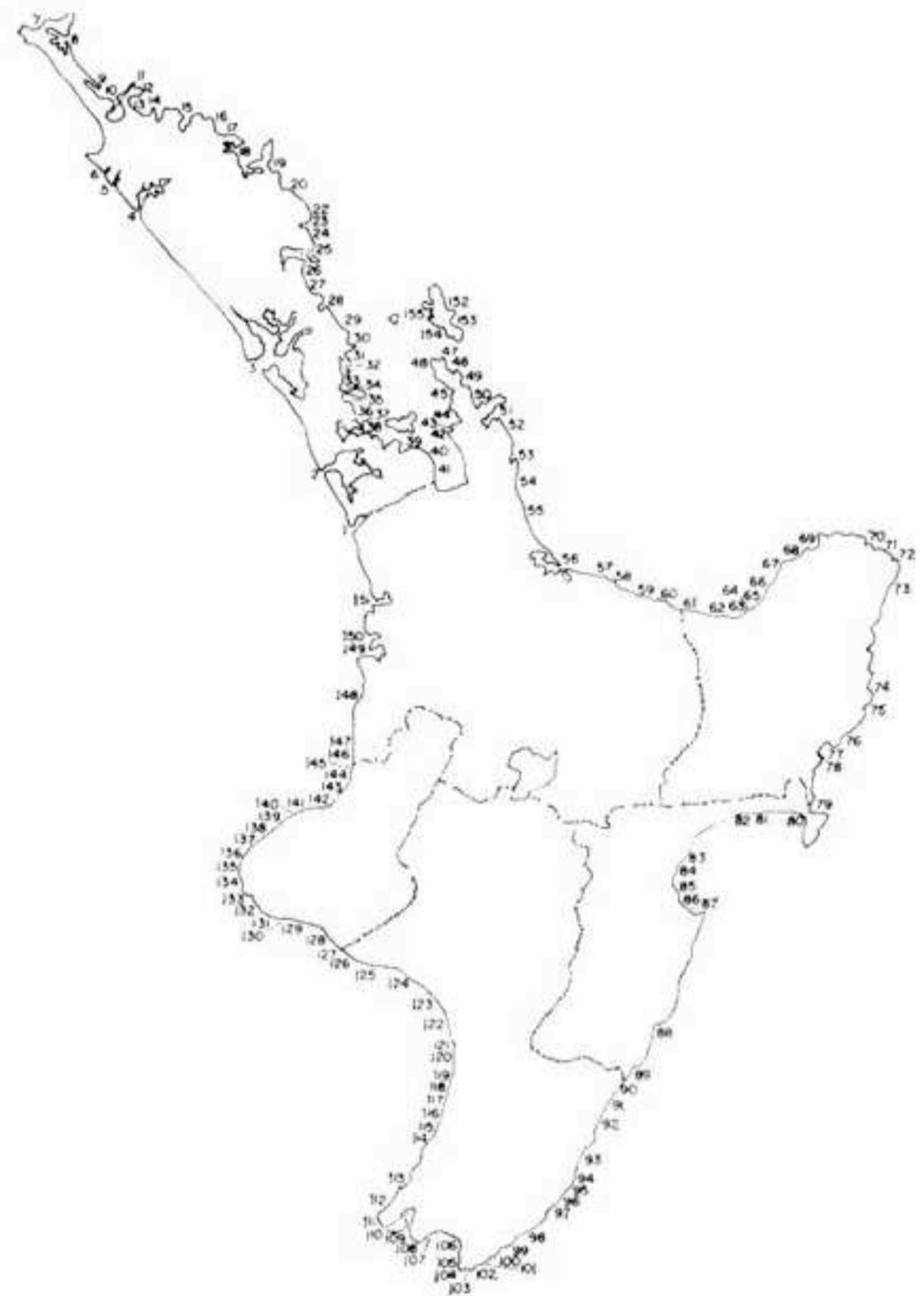


FIGURE 1A. A map of the North Island of New Zealand showing the location of estuarine areas, the names of which can be found in Appendix Table 1.

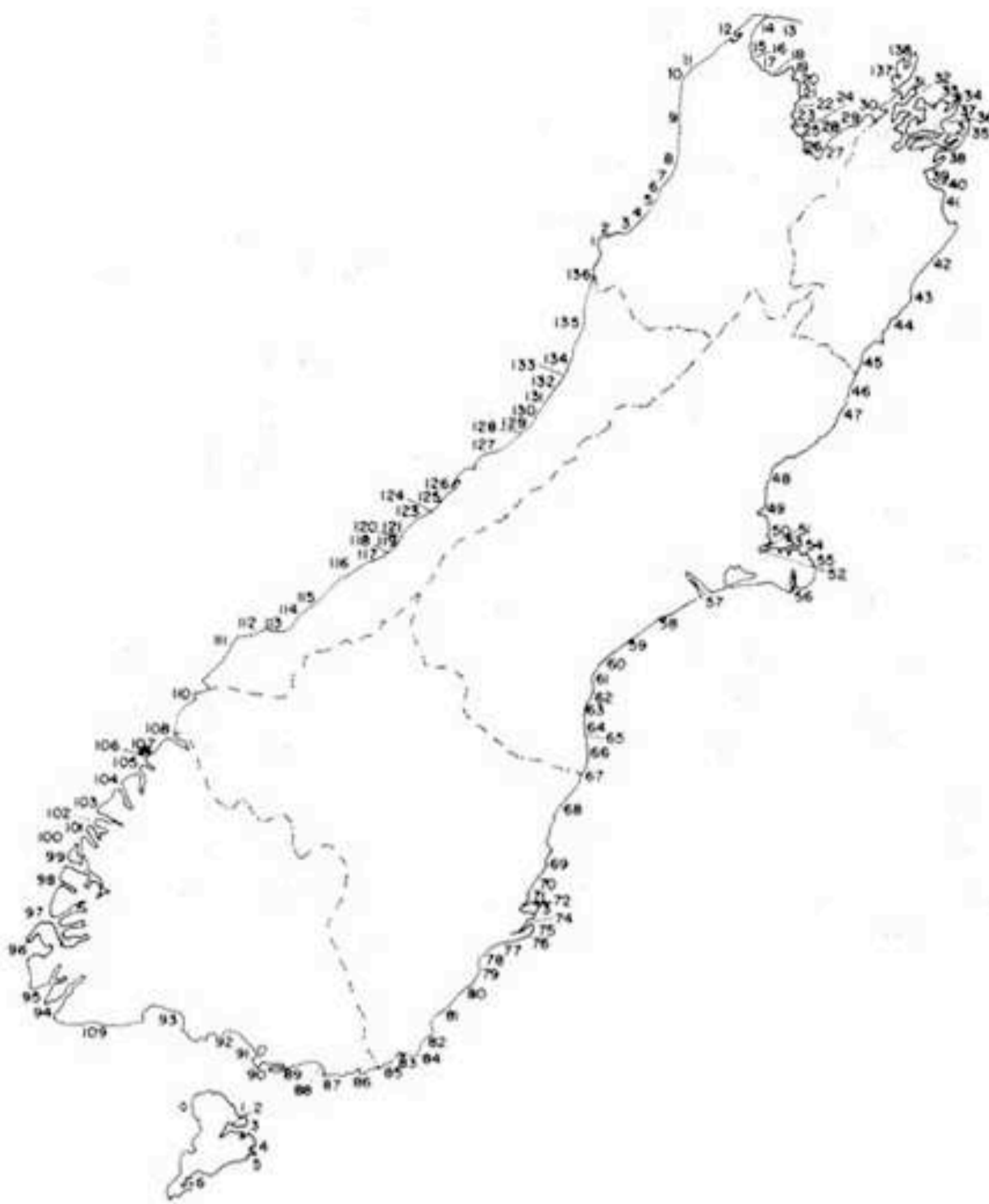


FIGURE 1B. A map of the South Island of New Zealand and Stewart Island showing the location of estuarine areas, the names of which can be found in Appendix, Table 1.

deletions were made on account of the lack of a permanent free connection with the sea. In some cases (e.g. in the Marlborough and Fiordland areas) we have used names that encompass several separate estuarine areas that have the same connection to the sea. The distribution of estuaries around New Zealand is shown in Fig. 1. The names are listed and numbered along with all relevant information in

Appendix, Table 1. A convention of numbering clockwise around the coast, starting in the northernmost province of each island, has been used. The total number of estuaries is 301. Provincial areas with the largest numbers are Northland (40), Wellington (37), Nelson (32), Westland (26), Waikato (26), and Southland (24). (Appendix, Tables 1, 2).

#### Classification by Area

Table 1 summarises the information on the area of estuarine habitats according to location on the major islands and some off-shore islands. To merit inclusion an estuary had to be of a "significant" size as it appeared on a topographic map. Attempts to measure areas from maps, without personal knowledge of the extent was not always possible and has yielded very approximate results for some of them. Even where personal knowledge was available from questionnaire contributors, the local estimates often varied quite considerably. Where there was difficulty in determining the extent of a system, and personal knowledge was not forthcoming, an area was not entered in Appendix Table 1, but the estuary was assigned to the category of "Other". Most of the cases in this category included small estuaries. The problems encountered underline the need for interpretation of each estuarine area from aerial photos, and the establishment of a firm criterion based on minimum area.

The total estimated area of estuaries is around 100 000 ha and Table 1 shows that there are a wide range of sizes from less than 100 ha to over 15 000 ha; but the majority (68%) are less than 500 ha in area. Cumulative percentage plotted against the natural logarithm of the area gives a very good negative linear relationship for most of the range (Fig. 2). About 90% are less than 1700 ha in area and the median size is approximately 200 ha. The distribution of sizes among the North and South Islands

TABLE 1. The number and area of Estuarine Systems on each of the major islands of the New Zealand area.

|                 | No. of Estuarine systems | Estuarine system area |         |          |           |       | Others* (NE) |
|-----------------|--------------------------|-----------------------|---------|----------|-----------|-------|--------------|
|                 |                          | <100                  | 101-500 | 501-1000 | 1001-2000 | >2000 |              |
| North Island    | 155                      | 27                    | 24      | 9        | 7         | 5     | 83           |
| South Island    | 138                      | 26                    | 26      | 12       | 7         | 4     | 63           |
| Stewart Island  | 6                        | 1                     | 3       | —        | —         | —     | 2            |
| Chatham Island  | 1                        | —                     | —       | —        | —         | —     | 1            |
| Campbell Island | 1                        | —                     | —       | —        | —         | —     | 1            |
| TOTAL           | 301                      | 54                    | 53      | 21       | 14        | 9     | 150          |

Total estimated area 102 224 ha.

\* — Area not estimated.

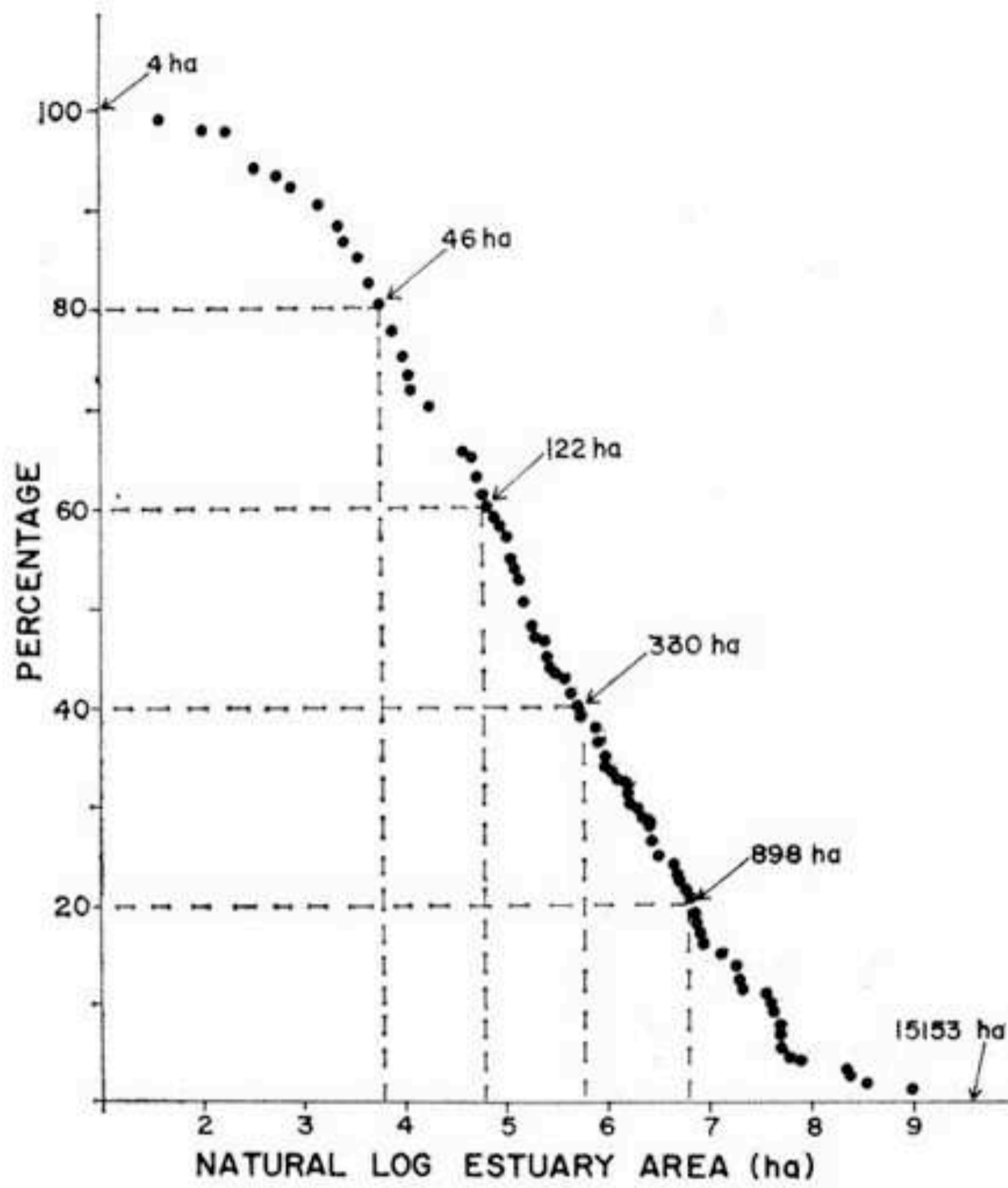


FIGURE 2. Size distribution of some New Zealand estuaries with percentage of the total plotted against the natural log of the area (ha).

are very similar. In the South Island, large estuarine areas are found almost exclusively in Fiordland and the Marlborough Sounds area, whereas regional groupings are much less clearly defined in the North Island. The number with areas not specified is considerable: 54% in the North Island, 46% in the South Island or 50% of the total. The estimate of 100 000 ha must be regarded as very approximate and probably tending to underestimate the total true area. It may be compared with the total area of New Zealand which is  $26.9 \times 10^6$  ha, and the total length of coastline which is 9654 km. (Anon, 1974). The average distance between estuaries is approximately 32 km.

*Classification by Population*

A gross picture of the relationship between estuaries and human population may be obtained by dividing the estimated area by the population size which gives .03 ha per person. But the impact of population on estuaries is very much more localised and analysis on a finer scale is required.

Using the New Zealand census of Population and Dwellings, 1971, the size of population centres adjacent to each estuary was determined (Table 2). These estimates include only the population that was centered around the area and did not include transient summer populations of holiday resorts or population centres upstream. In this respect, the use of these data tends to underestimate the human pressures likely to be exerted on the system. The exclusion of populations further upstream, which may increase demands made on the system was inevitable in a national survey, which can only hope to establish indicators. In other cases we may have overestimated the effects of people because estuaries other than those in the immediate vicinity are used for the purposes of sewage disposal or recreation. But more precise information will only become apparent in surveys on a regional scale. However, the resulting picture is, I believe, not too distorted because not very many estuaries are involved, compared to the total.

The majority of estuaries in New Zealand are associated with population levels of less than 500 people and only 12% are the immediate environment of populations of 5000 or more people. Not surprisingly, a greater proportion (8.3%) of North Island estuaries are associated with populations of more than 20 000 people. In the South Island, the corresponding figure is 2.8%. This does not mean that estuarine resources are not unduly threatened by human disruption. Every single estuary is important and none should be abused, however small it may be. Most may be fairly secure because of their location in remote, coastal areas but this does not mean that we can do what we like with the remainder.

TABLE 2. Number of estuaries associated with population categories.

|                 | Population Classes |                  |                       |                          |                    |
|-----------------|--------------------|------------------|-----------------------|--------------------------|--------------------|
|                 | <500<br>(A)        | 500-4 999<br>(B) | 5 000-19 999<br>(C+D) | 20 000-79 999<br>(E+F+G) | >80 000<br>(H+I+J) |
| North Island    | 107                | 27               | 8                     | 9                        | 4                  |
| South Island    | 100                | 23               | 11                    | 2                        | 2                  |
| Stewart Island  | 6                  | —                | —                     | —                        | —                  |
| Chatham Island  | 1                  | —                | —                     | —                        | —                  |
| Campbell Island | 1                  | —                | —                     | —                        | —                  |
| TOTAL           | 215                | 50               | 19                    | 11                       | 6                  |

*Classification by Topography*

Pritchard (1952, 1967) has suggested a topographical classification of estuaries which divides them into three groups: drowned river valleys (or coastal plain estuaries) (DR), fiords (FD) and bar-built estuaries (BB). Drowned river valleys have resulted from eustatic changes in sea level and consequently they are seldom deeper than 30m (Dyer, 1973) and are frequently filled with varying thicknesses of recent sediment. The input of fresh water is usually small compared to the volume of the tidal compartment (i.e., the volume between high and low water levels). Examples of drowned river valleys are Queen Charlotte Sound and Otago Harbour. Fiords are formed by glacial action re-shaping coastal river valleys. They are frequently deep, long and narrow and are restricted to the south-western part of the South Island and Campbell Island (Perversance Harbour). Bar-built estuaries are typically shallow and closely related to drowned river valleys. However they have a characteristic bar across the mouth and the outlet may shift from time to time. The Avon-Heathcote estuary and the New River estuary, Invercargill are good examples of this type. Chiefly to accommodate river-mouth areas we have included a fourth category called lagoons (L). From the point of view of estuarine biology these are probably the least interesting but it is a common and widely distributed type of coastal habitat.

the north and east coasts of the North Island and the east coast of the South Island. The off-shore islands are characterised by drowned river valleys as are the Marlborough Sounds and Banks Peninsula area of the South Island, and the Taranaki area of the North Island. Fiords are found only in the south-western corner of the South Island and on Campbell Island (Appendix, Table 2).

## QUESTIONNAIRE RESULTS

To try and gain useful, up to date information on the present status of estuaries a short questionnaire was sent out to more than 100 authorities and persons whose responsibilities and interests included estuarine areas. [The questionnaire was based on one used in a similar survey of the United Kingdom (Gameson, 1973)]. It included six questions covering water stratification, present (1975) condition, condition compared with 10 years earlier, the existence of any surveys or reports on the estuary in question and relevant information about people or organisations with responsibility for enforcing legislation dealing with tidal waters. About 30% of the authorities and persons canvassed were able to respond and many were able to complete the questionnaire fully. Our chief objective was to collect mainly qualitative information about each estuary. The questions about present and past condition are some-

TABLE 3. *Topographic classification of estuarine systems.*

|                 | Type of Estuary |               |        |       | Total |
|-----------------|-----------------|---------------|--------|-------|-------|
|                 | Bar-built       | Drowned River | Lagoon | Fiord |       |
| North Island    | 102             | 22            | 31     | —     | 155   |
| South Island    | 61              | 28            | 34     | 15    | 138   |
| Stewart Island  | —               | 6             | —      | —     | 6     |
| Chatham Island  | 1               | —             | —      | —     | 1     |
| Campbell Island | —               | —             | —      | 1     | 1     |
| TOTAL           | 164             | 56            | 65     | 16    | 301   |

Using topographic maps it was often difficult to classify the estuaries into the four groups, partially because of insufficient evidence on the maps and partially because the groups are not altogether distinct and tend to merge into one another. This is especially true for bar-built estuaries and lagoons. Table 3 summarises the analysis and indicates a marked preponderance throughout New Zealand of estuaries and lagoons that are characteristic of depositional coastlines, i.e. L and BB. Of the total, 78% are either bar-built or lagoonal environments (86% of the total in the North Island and 70% in the South Island). They are particularly evident on

what subjective and answers can only be a matter of opinion without the use of good quantitative data. However local people, closely involved with the coastal environment, are better able than anyone to give judgements about present and past status and at this stage such information is better than none at all. Some questionnaire data is available for 163/301 (i.e. 54%) of the estuaries. There is a notable absence of information about the Gisborne and Wellington areas in the North Island and Nelson-Marlborough, Southland and Westland areas of the South Island. These gaps in our information should be kept in mind when the results are examined.

### 1 Stratification

Respondents were asked to indicate whether the estuary was well mixed, slightly stratified, highly stratified, salt wedge, or not known. In general the response to this question was poor (34%), probably because few people understood what the question was referring to. The results (Table 4) suggest that well-

the coverage was much better from the North Island (57%) than from the South Island (24%). More than two-thirds of the estuaries in both North and South Islands are apparently in a similar condition to what they were 10 years ago (Table 6). When estuaries whose status is considered to have changed are balanced against each other we see that there has been

TABLE 4. Degree of stratification of New Zealand estuarine systems.

|                      | North Is. | South Is. | Stewart Is. | Campbell Is. | Chatham Is. | Total<br>in N.Z. |
|----------------------|-----------|-----------|-------------|--------------|-------------|------------------|
| Well mixed           | 43        | 16        | —           | —            | —           | 59               |
| Slightly stratified  | 16        | 4         | —           | 1            | —           | 21               |
| Highly stratified    | 3         | 4         | —           | —            | —           | 7                |
| Salt wedge           | 9         | 6         | —           | —            | —           | 15               |
| Total No. classified | 71        | 30        | —           | 1            | —           | 102              |

mixed estuaries dominate both the North and South Islands and those showing anything more than slight stratification are rare.

### 2 General Condition (1975)

The question on water quality was, without exception, answered on every returned questionnaire. The alternative states which respondents were asked to select from were, clean, slightly polluted, moderately polluted and grossly polluted. Table 5 shows that most estuaries are either clean or considered to be only slightly polluted; however the data shows pollu-

an overall deterioration that is much more pronounced in the South Island (15% loss) than in the North Island (1% loss). It would appear that the impact of man has been much more pronounced in the South Island. Table 7 shows that most of the positive changes have come about as a result of improvement in grossly and moderately polluted estuaries, while the negative changes have resulted from deterioration of clean areas and further deterioration of previously only slightly polluted estuaries.

TABLE 5. Pollution status of New Zealand estuarine systems.

|                               | North Is. | South Is. | Stewart Is. | Campbell Is. | Chatham Is. | Total<br>in N.Z. |
|-------------------------------|-----------|-----------|-------------|--------------|-------------|------------------|
| Clean                         | 37        | 21        | 2           | 1            | 1           | 62               |
| Slightly polluted             | 51        | 16        | —           | —            | —           | 67               |
| Moderately polluted           | 20        | 6         | —           | —            | —           | 26               |
| Grossly polluted              | 6         | 1         | —           | —            | —           | 7                |
| Total No. polluted<br>systems | 77        | 23        | —           | —            | —           | 100              |
| Total No. systems             | 114       | 44        | 2           | 1            | 1           | 162              |

tion to be more significant in the North Island where only 40% are classed as clean whereas 50% in the South Island are clean. This difference may be grossly underestimated because most of the unknown estuaries are in remote areas and therefore likely to be clean and very many more South Island estuaries are in the unknown category. All the off-shore island estuaries are classed as clean.

### 3 Changes in Condition

Responses to the request for information on changes of condition over the period 1965-75 covered a reasonable number of estuaries (40%), although

### 4 Surveys

The number of surveys that have been carried out or are in the process of being carried out is very small. Replies were received for 157 estuaries out of 301 and only 19% of our estuaries have been the subject of one or more surveys. North Island estuaries have been much more intensively studied than those in the South Island. Reports were usually of a specialised nature and very seldom published. A list of these is available on request from the author. Surveys mainly covered biology, water quality, hydraulic aspects, sedimentation and development

proposals (see Table 8). The quality of the surveys was very variable and rarely were all aspects of estuarine research co-ordinated and carried out simultaneously for any length of time. Many reports

Estuary (Knox and Kilner, 1973), Otago Harbour, New River Estuary. To these we will soon be able to add Porirua Harbour which includes the Pauatahanui Inlet environmental programme.

TABLE 6. *Changes in the pollution status of New Zealand estuarine systems between 1965 and 1975.*

|         | North Is. | South Is. | Stewart Is. | Campbell Is. | Chatham Is. | Total<br>in N.Z. |
|---------|-----------|-----------|-------------|--------------|-------------|------------------|
| Better  | 14        | 2         | —           | —            | —           | 16               |
| Similar | 59        | 24        | —           | 1            | —           | 84               |
| Worse   | 15        | 7         | —           | —            | —           | 22               |
| Total   | 88        | 33        | —           | 1            | —           | 122              |

TABLE 7. *Transition matrix of the changing status of New Zealand Estuaries. (The letters refer to: C — clean, SP — slightly polluted, MP — moderately polluted, GP — grossly polluted).*

|    | C    | SP   | MP   | GP   |
|----|------|------|------|------|
| C  | .355 | .074 |      |      |
| SP | .008 | .264 | .083 | .017 |
| MP |      | .066 | .058 | .017 |
| GP |      |      | .058 |      |

TABLE 8. *Classification of surveys of New Zealand estuarine systems.*

|   | North Is. | South Is. | Total |
|---|-----------|-----------|-------|
| No. of systems subject of $\geq 1$ survey | 40        | 17        | 57    |
| Total No. of surveys                      | 67        | 44        | 111   |
| No. of ecological/biological surveys      | 25        | 13        | 38    |
| No. of water quality surveys              | 18        | 17        | 35    |
| No. of hydraulic/marine surveys           | —         | 3         | 3     |
| No. of sedimentation surveys              | 2         | 2         | 4     |
| No. of development surveys                | 5         | 2         | 7     |
| No. of Internal Affairs surveys           | 14        | —         | 14    |
| No. of miscellaneous surveys              | 3         | 7         | 10    |

were the results of very short inspections and based on very little quantitative, reliable information. Water quality assessments tended to be conducted by statutory authorities, whereas biological, hydrological and ecological surveys tended to be university oriented. A noticeable trend in recent years has been the increasing number of surveys being carried out by private or business consultants, advising on aspects of the development of coastal areas. One cannot help noticing the very poor quality of the ecological side of their reports. Although more North Island estuaries have been looked at, the average number of surveys/system is greater in the South Island. But in both islands only a few estuaries seem to have been studied in any depth and these are Manukau Harbour, Waitemata Harbour, Wellington Harbour (see Pedersen, 1974), Waimea Inlet, Avon-Heathcote

## DISCUSSION

In reporting the results of this survey I wish to emphasise its preliminary nature and hope that provided this is kept in mind the results will not be misused. Information has been drawn chiefly from topographic maps and questionnaires, and from a small number of personal observations. It has become very apparent just how many different disciplines and aspects must be consulted when looking at estuaries as whole systems, and that no one group of persons has anywhere near an adequate grasp of the necessary techniques and concepts involved. These include experts in physical and biological aspects of marine studies, geologists, sedimentologists, hydrographers, geographers and environmental scientists whose interests lie in the multiple use of coastal

resources. In a proper study of estuaries all these persons should be involved. A recent attempt at interdisciplinary assessment by Ketchum (1972) indicates the kinds of problems involved.

A great many environmental and social factors influence the condition of an estuary making it a heterogeneous and complex environment whose management is liable to be particularly difficult. The integration of all influences and recognition of the constraints within which the status of an estuary lies, presents a challenge to those who advocate multiple-use. To implement multiple-use objectives it seems essential that the methods and concepts of system analysis should be employed. Ketchum (1972) has outlined in a formal way this kind of approach to estuarine management by which rational decisions could be reached using all existing information integrated into a realistic model of the system. The essential steps in the modelling process are first of all to set down the objectives of the model. Experience in simulation modelling has taught us that there is nothing more useless than a model which was built without a particular question or problem in mind. We speak of "realistic models" as though they represent the *whole* system but this is never the case and it seems both unlikely and also unnecessary that this would ever be the case. The second step is to specify the state variables which characterise the system, e.g. plant and animal biomass, nutrient levels, salinity, sedimentation rates, and the driving variables which make the system function etc., e.g. solar energy input, detrital energy input, freshwater flux etc. The third step is to determine the coupling relationships between these state variables. The next step is to estimate the magnitude of the parameters from experimental or field data and then to carry out computation on a digital computer with the object of producing a state-history of the system. Finally and most importantly the model predictions must be verified by comparison of expected and observed values. All this is not necessarily a one-way path but always involves several "passes" through this kind of procedure before satisfactory results are obtained. As noted by Ketchum, the greatest uncertainty in developing system models of this kind is the prediction of what man himself will do. However he still sees a great deal of value in the use of systems methods to evaluate the potential effects of any one of a number of alternate courses of action. Another value lies in the feedback that we receive from a model in the form of "requests" for certain, specific kinds of information that are thereby drawn into the decision-making process. Attempts at model-building are always instructive in guiding research.

The coastal zone of New Zealand must be viewed as a unique national resource which is of greater importance to the majority of the population than many of those people realise. This was very clearly brought out by a comment made during the Nelson Estuarine Symposium by a speaker who pointed out that we often speak of "reclaiming" estuaries as though we are simply taking back what is rightfully ours. In other words we consider that we are entitled to any land that estuaries may occupy and we fail to recognise them as natural resources to be used and protected in the same way that some other natural area would be treated.

Compared to other developed countries, New Zealand has quite a small population in relation to its size and the length of its coastline. Dividing the length of the coastline by the number of people gives a figure of 3.2 m/person, which is similar to Australia, 2.99 m, but very much larger than the United Kingdom 8 cm, or U.S.A. 9 cm, or Russia 25 cm or Italy 19 cm (which has a comparable land mass to New Zealand). But despite the large amount of coastline, critical problem areas are beginning to appear in some parts of New Zealand, especially in the north, as our population continues to grow and move, and more people desire to live by the sea. Many aspects of these problems have recently been discussed in several valuable publications (Glikson, 1971, New Zealand Institute of Surveyors, 1969, Peel-Brahtz, 1972, and Town and Country Planning Division, 1972). Our coastline and estuaries in particular are finite and man must make the best sustainable use of these that he possibly can. Using them as rubbish tips and convenient dumping places for human sewage are not consistent with this objective. The exponential growth of human activities and the absence of proper planning and long term considerations make it essential that we guard the coastal resources that we have, very carefully.

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## APPENDIX

TABLE 1. Questionnaire data and reference numbers of New Zealand estuarine systems.

The following abbreviations have been used in presenting the data.

## Population Category—

|   |                 |
|---|-----------------|
| A | <500            |
| B | 500-4 990       |
| C | 5 000-9 999     |
| D | 10 000-19 999   |
| E | 20 000-39 999   |
| F | 40 000-59 999   |
| G | 60 000-79 999   |
| H | 80 000-99 999   |
| I | 100 000-199 999 |
| J | >200 000        |

## Area—

NE: area not estimated

## Topographic classification—

|     |               |
|-----|---------------|
| BB: | bar-built     |
| DR: | drowned river |
| FD: | fiord         |
| L:  | lagoonal      |

## Stratification—

|     |                     |
|-----|---------------------|
| WM: | well mixed          |
| SS: | slightly stratified |
| HS: | highly stratified   |
| SW: | salt wedge          |
| —:  | not known           |

## Condition—

|     |                     |
|-----|---------------------|
| C:  | clean               |
| SP: | slightly polluted   |
| MP: | moderately polluted |
| GP: | grossly polluted    |
| —:  | not known           |

## Change in condition—

|    |           |
|----|-----------|
| B: | better    |
| S: | similar   |
| W: | worse     |
| —: | not known |

## Surveyed—

|    |                     |
|----|---------------------|
| y: | one or more surveys |
| x: | none                |
| —: | not known           |

TABLE 1 (cont.)

| Ref. No.         | Estuarine system  | Census Data         | Map Data  |                            | Questionnaire Data       |           |                                 |          |
|------------------|---|---------------------|-----------|----------------------------|--------------------------|-----------|---------------------------------|----------|
|                  |   | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition | Changes in condition since 1965 | Surveyed |
| <i>Northland</i> |   |                     |           |                            |                          |           |                                 |          |
| 1.               | Waikato R. mouth (Port Waikato)   | B                   | 510       | BB                         | HS                       | MP        | W                               | Y        |
| 2.               | Manukau Harbour   | I                   | 8,052     | BB                         | SS                       | GP        | W                               | Y        |
| 3.               | Kaipara Harbour (Waionui Inlet, Tauhoa R., Oruawharo R., Arapaoa R., Otamatea R. mouths etc.) | D                   | 15,153    | BB                         | —                        | GP        | —                               | Y        |
| 4.               | Hokianga Harbour  | B                   | 2,689     | BB                         | WM                       | C         | —                               | X        |
| 5.               | Whangape Harbour (Awaroa R. and Rotokakahi R. mouths)   | A                   | 267       | BB                         | —                        | C         | —                               | —        |
| 6.               | Herekino Harbour  | A                   | 133       | BB                         | —                        | C         | —                               | —        |
| 7.               | Waitahora Stm. mouth  | A                   | NE        | BB                         | —                        | —         | —                               | —        |
| 8.               | Parengarenga Harbour  | A                   | 1,448     | BB                         | —                        | C         | —                               | —        |
| 9.               | Houhora Harbour, head   | A                   | 295       | BB                         | —                        | C         | —                               | —        |
| 10.              | Rangaunu Harbour  | B                   | 2,180     | BB                         | —                        | SP        | —                               | —        |
| 11.              | Awapoko R. mouth  | A                   | NE        | BB                         | —                        | SP        | —                               | —        |
| 12.              | Taipa R. mouth  | A                   | NE        | BB                         | —                        | SP        | —                               | —        |
| 13.              | Mangonui Harbour  | A                   | 144       | BB                         | —                        | SP        | —                               | —        |
| 14.              | Whangaroa Harbour   | B                   | 561       | BB                         | SW                       | SP        | —                               | X        |
| 15.              | Takou R. mouth  | A                   | NE        | BB                         | —                        | GP        | —                               | —        |
| 16.              | Tapuaetahi Ck. mouth  | A                   | NE        | BB                         | —                        | C         | —                               | —        |
| 17.              | Bay of Islands (Mangonui Inlet, Kerikeri Inlet, Waikare Inlet)                                | C                   | 5,780     | BB                         | —                        | SP        | —                               | —        |
| 18.              | Whangaruru Harbour  | A                   | 896       | DR                         | —                        | C         | —                               | —        |
| 19.              | Whanaki Inlet   | A                   | 63        | BB                         | —                        | SP        | —                               | —        |
| 20.              | Matapouri Bay   | A                   | NE        | BB                         | —                        | SP        | —                               | —        |
| 21.              | Tutukaka Harbour  | A                   | 19        | BB                         | —                        | SP        | —                               | —        |
| 22.              | Ngunguru R. mouth   | A                   | 150       | BB                         | —                        | SP        | —                               | —        |
| 23.              | Horahora R. mouth   | A                   | NE        | BB                         | —                        | SP        | —                               | —        |
| 24.              | Pataua R. and Taiharura R. mouths   | A                   | 192       | BB                         | —                        | SP        | —                               | —        |
| 25.              | Whangarei Harbour   | E                   | 2,199     | BB                         | —                        | MP        | B                               | —        |
| 26.              | Ruakaka R. mouth  | A                   | NE        | BB                         | —                        | SP        | W                               | —        |
| 27.              | Waipu R. mouth  | B                   | NE        | BB                         | —                        | SP        | —                               | —        |
| 28.              | Mangawhai Estuary   | A                   | 159       | BB                         | SS                       | SP        | S                               | X        |
| 29.              | Pakiri R. mouth   | A                   | NE        | BB                         | SW                       | SP        | S                               | X        |
| 30.              | Whangateau Harbour  | A                   | 172       | BB                         | SS                       | SP        | S                               | Y        |
| 31.              | Mellins Bay and Matakana R. mouth   | A                   | 131       | BB                         | SS                       | SP        | S                               | X        |
| 32.              | Mahurangi Harbour   | B                   | 596       | BB                         | WM                       | MP        | W                               | Y        |
| 33.              | Puhoi R. and Waiwera R. mouths  | A                   | NE        | BB                         | SS                       | SP        | S                               | Y        |
| 34.              | Orewa R. mouth  | B                   | 150       | BB                         | WM                       | SP        | W                               | Y        |
| 35.              | Karepiro Bay (Weiti R. and Okura R. mouths)   | B                   | 125       | BB                         | —                        | —         | —                               | —        |

TABLE 1 (cont.)

| Ref. No.                    | Estuarine system   | Census Data         | Map Data  |                            |                          | Questionnaire Data |                                 |          |
|-----------------------------|--|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                             |  | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| 36.                         | Waitemata Harbour (Hobsons Bay, Shoal Bay, Whau R., Henderson Ck. etc.)  | J                   | 1,919     | BB                         | WM                       | MP                 | W                               | Y        |
| 37.                         | Tamaki R. estuary  | G                   | 392       | BB                         | WM                       | MP                 | S                               | Y        |
| 38.                         | Maugamaungaroa R., Turanga Ck., Waikopua Ck. mouths (Cockle Bay)         | D                   | 396       | BB                         | —                        | —                  | —                               | —        |
| 39.                         | Wairoa R. mouth  | I                   | 63        | L                          | —                        | —                  | —                               | —        |
| 40.                         | Kawakawa Bay   | A                   | 25        | DR                         | —                        | —                  | —                               | —        |
| <i>Waikato</i>              |  |                     |           |                            |                          |                    |                                 |          |
| 41.                         | Firth of Thames, tidal flats and Waihou, Waitakaruru and Piaka R. mouths | D                   | 1,476     | DR                         | WM                       | SP                 | S                               | Y        |
| 42.                         | Manaia Harbour   | A                   | 125       | BB                         | WM                       | C                  | S                               | —        |
| 43.                         | Te Kouma Harbour   | A                   | 50        | BB                         | WM                       | C                  | S                               | X        |
| 44.                         | Coromandel Harbour   | B                   | 450       | BB                         | WM                       | MP                 | S                               | Y        |
| 45.                         | Colville Bay   | A                   | 75        | DR                         | WM                       | C                  | S                               | —        |
| 46.                         | Port Jackson—Pahi and Muriwai Stm. mouths                                | A                   | NE        | DR                         | WM                       | C                  | S                               | —        |
| 47.                         | Port Charles   | A                   | 19        | DR                         | WM                       | C                  | S                               | —        |
| 48.                         | Waikawau R. mouth  | A                   | NE        | L                          | WM                       | C                  | S                               | —        |
| 49.                         | Kennedy's Bay  | A                   | 38        | BB                         | WM                       | C                  | S                               | —        |
| 50.                         | Whangapoua Harbour   | A                   | 280       | BB                         | WM                       | SP                 | S                               | Y        |
| 51.                         | Whitianga Harbour  | B                   | 1,485     | BB                         | WM                       | SP                 | S                               | Y        |
| 52.                         | Purangi R. mouth (Mercury Bay)   | A                   | 45        | BB                         | WM                       | C                  | S                               | —        |
| 53.                         | Tairau Harbour   | B                   | 106       | BB                         | WM                       | C                  | S                               | —        |
| 54.                         | Wharekawa Harbour  | A                   | 31        | BB                         | WM                       | C                  | S                               | —        |
| 55.                         | Whangamata Harbour and Otah R. mouth                                     | B                   | 106       | BB                         | WM                       | SP                 | S                               | Y        |
| 56.                         | Tauranga Harbour   | E                   | 4,432     | BB                         | SS                       | SP                 | W                               | Y        |
| 57.                         | Maketu Estuary   | A                   | 38        | BB                         | WM                       | C                  | S                               | Y        |
| 58.                         | Waihi Estuary  | A                   | 50        | BB                         | WM                       | C                  | S                               | Y        |
| 59.                         | Tarawera R. mouth  | A                   | NE        | BB                         | WM                       | GP                 | S                               | Y        |
| 60.                         | Rangitaiki R. mouth  | A                   | NE        | BB                         | WM                       | C                  | S                               | Y        |
| 146.                        | Mokau R. mouth   | A                   | NE        | BB                         | WM                       | C                  | S                               | —        |
| 147.                        | Awakino R. mouth   | A                   | NE        | BB                         | WM                       | C                  | S                               | —        |
| 148.                        | Marokopa R. mouth  | A                   | NE        | BB                         | WM                       | C                  | S                               | —        |
| 149.                        | Kawhai Harbour   | B                   | 1,532     | BB                         | WM                       | SP                 | S                               | Y        |
| 150.                        | Aotea Harbour  | A                   | 768       | BB                         | WM                       | SP                 | S                               | Y        |
| 151.                        | Raglan (Whaingaroa) Harbour  | B                   | 806       | BB                         | WM                       | SP                 | S                               | Y        |
| <i>Great Barrier Island</i> |  |                     |           |                            |                          |                    |                                 |          |
| 152.                        | Whangapoua Ck. mouth   | A                   | 50        | BB                         | —                        | SP                 | S                               | Y        |
| 153.                        | Awana Stm. mouth   | A                   | NE        | DR                         | —                        | C                  | —                               | X        |

TABLE 1 (cont.)

| Ref. No.          | Estuarine system                                     | Census Data         | Map Data  |                            | Questionnaire Data       |           |                                 |          |
|-------------------|--|---------------------|-----------|----------------------------|--------------------------|-----------|---------------------------------|----------|
|                   |  | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition | Changes in condition since 1965 | Surveyed |
| 154.              | Whangaparupara Harbour                               | A                   | 31        | DR                         | WM                       | C         | —                               | Y        |
| 155.              | Port Fitzroy   | A                   | 227       | DR                         | WM                       | C         | —                               | X        |
| <i>Gisborne</i>   |  |                     |           |                            |                          |           |                                 |          |
| 61.               | Whakatane R. mouth                                   | C                   | NE        | BB                         | SW                       | SP        | —                               | Y        |
| 62.               | Ohiwa Harbour  | A                   | 639       | BB                         | —                        | SP        | S                               | Y        |
| 63.               | Waiotahi R. mouth                                    | A                   | 224       | BB                         | —                        | —         | —                               | —        |
| 64.               | Opotiki Harbour (Waioeka R. and Otara R. mouths)     | B                   | NE        | BB                         | —                        | —         | —                               | —        |
| 65.               | Motu R. mouth  | A                   | 800       | L                          | —                        | —         | —                               | —        |
| 66.               | Haparapara R. (Waikakariki R.)                       | A                   | 8         | L                          | —                        | —         | —                               | —        |
| 67.               | Kerepu R. mouth                                      | A                   | NE        | L                          | —                        | —         | —                               | —        |
| 68.               | Raukokore R. mouth                                   | A                   | NE        | L                          | —                        | —         | —                               | —        |
| 69.               | Whangaparaoa R. mouth                                | B                   | NE        | L                          | —                        | —         | —                               | —        |
| 70.               | Hicks Bay (Wharekahiki R. and Mangatutu Stm. mouths) | A                   | NE        | BB                         | —                        | —         | —                               | —        |
| 71.               | Karakatuwhero R. mouth                               | A                   | NE        | L                          | —                        | —         | —                               | —        |
| 72.               | Awatere R. mouth                                     | A                   | NE        | L                          | —                        | —         | —                               | —        |
| 73.               | Waipu R. mouth                                       | B                   | 159       | L                          | —                        | —         | —                               | —        |
| 74.               | Tolaga Bay (Uawa R. mouth)                           | B                   | 2,178     | BB                         | —                        | —         | —                               | —        |
| 75.               | Pakarae R. mouth                                     | A                   | NE        | BB                         | —                        | —         | —                               | —        |
| 76.               | Turanganui R. mouth                                  | E                   | NE        | DR                         | —                        | —         | —                               | —        |
| 77.               | Waipaoa R. mouth                                     | A                   | NE        | L                          | —                        | —         | —                               | —        |
| 78.               | Wherowhero Lagoon                                    | A                   | 118       | BB                         | —                        | SP        | S                               | Y        |
| <i>Hawkes Bay</i> |  |                     |           |                            |                          |           |                                 |          |
| 79.               | Maungawhio and Kopuawhara Lagoon                     | A                   | 30        | BB                         | SW                       | SP        | S                               | X        |
| 80.               | Nuhaka R. mouth                                      | A                   | 10        | L                          | SW                       | SP        | S                               | X        |
| 81.               | Wairoa R. mouth and Ngamotu Lagoon                   | C                   | 50        | BB                         | SW                       | MP        | W                               | Y        |
| 82.               | Waihua R. mouth                                      | A                   | 5         | BB                         | —                        | C         | S                               | X        |
| 83.               | Aropoanui R. mouth                                   | A                   | 4         | BB                         | SS                       | C         | S                               | X        |
| 84.               | Esk R. mouth   | A                   | NE        | BB                         | WM                       | C         | S                               | X        |
| 85.               | Ahuriri Estuary (Napier)                             | F                   | 50        | L                          | SW                       | MP        | W                               | Y        |
| 86.               | Ngaruroro R. and Tutaekuri R. mouths                 | E                   | 15        | L                          | WM                       | MP        | W                               | X        |
| 87.               | Tukituki R. mouth                                    | B                   | 10        | L                          | WM                       | MP        | W                               | X        |
| 88.               | Porangahau R. mouth                                  | A                   | 106       | BB                         | SW                       | SP        | S                               | X        |
| 89.               | Wainui R. mouth                                      | A                   | NE        | BB                         | —                        | —         | —                               | —        |

TABLE 1 (cont.)

| Ref. No.          | Estuarine system  | Census Data         |           | Map Data                   |                          | Questionnaire Data |                                 |          |
|-------------------|---|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                   |   | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| <i>Wellington</i> |   |                     |           |                            |                          |                    |                                 |          |
| 90.               | Akitio R. mouth   | A                   | NE        | BB                         | —                        | SP                 | S                               | X        |
| 91.               | Owahanga R. mouth                                       | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 92.               | Mataikona R. mouth                                      | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 93.               | Wharema R. mouth  | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 94.               | Kaiwhata R. mouth                                       | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 95.               | Arawhata Stm. mouth                                     | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 96.               | Huatokitoki Stm. mouth                                  | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 97.               | Whatipu Stm. mouth                                      | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 98.               | Pahaoa R. mouth   | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 99.               | Oterei R. mouth   | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 100.              | Awahea R. mouth   | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 101.              | Opouawe R. mouth  | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 102.              | Whawanui R. mouth                                       | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 103.              | Mangatoetoe Stm. mouth                                  | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 104.              | Otakaha Stm. mouth                                      | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 105.              | Paraki Stm. mouth                                       | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 106.              | L. Onoke (Palliser Bay)                                 | A                   | 119       | BB                         | SS                       | MP                 | S                               | Y        |
| 107.              | Wharepapa R., Wharekauhau Stm. and Mukamuka Stm. mouths | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 108.              | Orongorongo R. mouth                                    | A                   | NE        | L                          | SS                       | C                  | S                               | X        |
| 109.              | L. Kohangatera and L. Kohangapiripiri (Pencarrow Hd.)   | A                   | 10        | BB                         | SS                       | SP                 | W                               | X        |
| 110.              | Hutt R. mouth   | H                   | NE        | BB                         | —                        | GP                 | W                               | Y        |
| 111.              | Oteranga Stm. mouth                                     | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 112.              | Makara Stm. mouth                                       | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 113.              | Porirua Harbour (incl. Pauatahanui Inlet)               | E                   | 163       | BB                         | WM                       | MP                 | W                               | Y        |
| 114.              | Waikanae R. mouth                                       | D                   | NE        | BB                         | —                        | —                  | —                               | Y        |
| 115.              | Otaki R. mouth  | B                   | NE        | L                          | —                        | C                  | S                               | Y        |
| 116.              | Waitohu Stm. mouth                                      | A                   | NE        | BB                         | —                        | SP                 | S                               | X        |
| 117.              | Waikawa Stm. and Manakau Stm. mouths                    | A                   | NE        | BB                         | —                        | MP                 | S                               | Y        |
| 118.              | Ohau R. mouth   | A                   | NE        | BB                         | —                        | SP                 | S                               | X        |
| 119.              | Hokio Stm. mouth  | A                   | NE        | BB                         | —                        | SP                 | S                               | X        |
| 120.              | Manawatu R. mouth                                       | B                   | 45        | BB                         | —                        | MP                 | B                               | Y        |
| 121.              | Rangitikei R. mouth                                     | B                   | NE        | L                          | WM                       | C                  | S                               | Y        |
| 122.              | Turakina R. mouth                                       | A                   | NE        | BB                         | WM                       | C                  | S                               | X        |
| 123.              | Whangaehu R. mouth                                      | A                   | NE        | BB                         | SS                       | MP                 | S                               | X        |
| 124.              | Wanganui R. mouth                                       | E                   | 60        | BB                         | SW                       | GP                 | W                               | Y        |
| 125.              | Waitotara R. mouth                                      | A                   | NE        | BB                         | —                        | SP                 | S                               | X        |
| 126.              | Whenuakura R. mouth                                     | A                   | NE        | DR                         | —                        | SP                 | S                               | X        |

TABLE 1 (cont.)

| Ref. No.            | Estuarine system                    | Census Data         |           | Map Data                   |                          | Questionnaire Data |                                 |          |
|---------------------|-------------------------------------|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                     |                                     | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| <i>Taranaki</i>     |                                     |                     |           |                            |                          |                    |                                 |          |
| 127.                | Patea R. mouth                      | B                   | NE        | L                          | —                        | MP                 | B                               | X        |
| 128.                | Manawapou R. and Tangahoe R. mouths | C                   | NE        | DR                         | SS                       | MP                 | B                               | X        |
| 129.                | Waingongoro R. mouth                | A                   | NE        | DR                         | SS                       | MP                 | B                               | X        |
| 130.                | Inaha Stm. mouth                    | A                   | NE        | DR                         | WM                       | MP                 | B                               | X        |
| 131.                | Kaupokonui Stm. mouth               | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 132.                | Waiauua Stm. mouth                  | B                   | NE        | DR                         | —                        | C                  | S                               | X        |
| 133.                | Oaonui Stm. mouth                   | B                   | NE        | DR                         | —                        | C                  | B                               | X        |
| 134.                | Pungaereere Stm. mouth              | B                   | NE        | BB                         | —                        | SP                 | B                               | X        |
| 135.                | Kapoaiiau Stm. mouth                | A                   | NE        | DR                         | —                        | SP                 | B                               | X        |
| 136.                | Waiweranui R. mouth                 | A                   | NE        | DR                         | WM                       | C                  | S                               | Y        |
| 137.                | Stony R. mouth                      | B                   | NE        | DR                         | WM                       | SP                 | B                               | X        |
| 138.                | Oakura R. mouth                     | E                   | NE        | L                          | WM                       | SP                 | B                               | X        |
| 139.                | Waiwhakaiho R. mouth                | A                   | NE        | BB                         | HS                       | SP                 | B                               | X        |
| 140.                | Waiongana R. mouth                  | A                   | NE        | L                          | WM                       | MP                 | B                               | X        |
| 141.                | Waitara R. mouth                    | A                   | NE        | BB                         | HS                       | SP                 | S                               | X        |
| 142.                | Urenui R. mouth                     | A                   | NE        | BB                         | SS                       | SP                 | S                               | X        |
| 143.                | Mimi R. mouth                       | A                   | NE        | L                          | SS                       | SP                 | S                               | X        |
| 144.                | Tongaporutu R. mouth                | A                   | NE        | BB                         | SS                       | C                  | S                               | X        |
| 145.                | Mohakatino R. mouth                 | A                   | NE        | BB                         | SS                       | C                  | S                               | X        |
| <i>SOUTH ISLAND</i> |                                     |                     |           |                            |                          |                    |                                 |          |
| <i>Nelson</i>       |                                     |                     |           |                            |                          |                    |                                 |          |
| 1.                  | Okari R. mouth                      | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 2.                  | Buller R. mouth                     | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 3.                  | Orowaiti R. mouth                   | C                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 4.                  | Waimangaroa R. mouth                | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 5.                  | Mokihinui R. mouth                  | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 6.                  | Little Wanganui R. mouth            | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 7.                  | Karamea R. mouth                    | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 8.                  | Oparara R. mouth                    | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 9.                  | Heaphy R. mouth                     | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 10.                 | Big R. mouth                        | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 11.                 | Anaweka R. mouth                    | A                   | NE        | BB                         | —                        | —                  | —                               | —        |

TABLE 1 (cont.)

| Ref. No.           | Estuarine system                                | Census Data         |           | Map Data                   |                          | Questionnaire Data |                                 |          |
|--------------------|---|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                    |   | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| 12.                | Whanganui (West Haven) Inlet                    | A                   | 639       | BB                         | —                        | —                  | —                               | —        |
| 13.                | Farewell Spit tidal flats                       | A                   | 2,000     | BB                         | —                        | —                  | —                               | —        |
| 14.                | Pakawau Inlet                                   | A                   | 13        | BB                         | —                        | —                  | —                               | —        |
| 15.                | Ruataniwha Inlet                                | A                   | 172       | BB                         | —                        | —                  | —                               | —        |
| 16.                | Parapara Inlet                                  | A                   | 31        | BB                         | —                        | —                  | —                               | —        |
| 17.                | Takaka R. mouth                                 | B                   | 230       | DR                         | —                        | —                  | —                               | —        |
| 18.                | Wainui Estuary (Golden Bay)                     | A                   | 56        | BB                         | —                        | C                  | S                               | X        |
| 19.                | Totaranui Estuary                               | A                   | NE        | BB                         | —                        | C                  | —                               | Y        |
| 20.                | Awaroa Estuary                                  | A                   | 56        | BB                         | —                        | C                  | —                               | X        |
| 21.                | Torrent Bay                                     | A                   | NE        | BB                         | —                        | SP                 | —                               | —        |
| 22.                | Marahua Estuary                                 | A                   | NE        | DR                         | —                        | C                  | —                               | —        |
| 23.                | Otuwhero Inlet (Sandy Bay)                      | A                   | 102       | DR                         | —                        | —                  | —                               | —        |
| 24.                | Motueka R. mouth                                | B                   | 190       | L                          | —                        | —                  | —                               | —        |
| 25.                | Port Motueka (Moutere Inlet)                    | A                   | 596       | BB                         | WM                       | C                  | S                               | X        |
| 26.                | Waimea Inlet                                    | C                   | 2,061     | BB                         | HS                       | SP                 | W                               | Y        |
| 27.                | Nelson Haven                                    | E                   | 1,251     | BB                         | HS                       | SP                 | B                               | Y        |
| 28.                | Wakapuaka R. mouth                              | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 29.                | Whangamoia R. mouth                             | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 30.                | Croixelles Harbour                              | A                   | 960       | DR                         | —                        | —                  | —                               | —        |
| 137.               | Two Bay Lagoon, Greville Harbour, D'Urville Is. | A                   | 75        | DR                         | —                        | —                  | —                               | —        |
| 138.               | Port Hardy, D'Urville Is.                       | A                   | 347       | DR                         | —                        | —                  | —                               | —        |
| <i>Marlborough</i> |   |                     |           |                            |                          |                    |                                 |          |
| 31.                | Admiralty Bay                                   | A                   | 596       | DR                         | —                        | —                  | —                               | —        |
| 32.                | Fitzroy Bay and Hallam Cove                     | A                   | 225       | DR                         | —                        | —                  | —                               | —        |
| 33.                | Tennyson Inlet                                  | A                   | 527       | DR                         | —                        | —                  | —                               | —        |
| 34.                | Pelorus Sound (Havelock)                        | B                   | 784       | DR                         | SS                       | C                  | —                               | Y        |
| 35.                | Kenepuru Sound                                  | A                   | 1,009     | DR                         | —                        | —                  | —                               | —        |
| 36.                | Endeavour Inlet                                 | A                   | 386       | DR                         | —                        | —                  | —                               | —        |
| 37.                | Queen Charlotte Sound (Picton)                  | B                   | 1,450     | DR                         | —                        | —                  | —                               | —        |
| 38.                | Port Underwood, head                            | A                   | 488       | DR                         | —                        | —                  | —                               | —        |
| 39.                | Wairau R. mouth                                 | D                   | NE        | L                          | —                        | —                  | —                               | —        |
| 40.                | Big Lagoon                                      | A                   | 292       | L                          | —                        | —                  | —                               | —        |
| 41.                | Awatere R. mouth                                | B                   | NE        | L                          | —                        | —                  | —                               | —        |
| 42.                | Waima (Ure) R. mouth                            | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 43.                | Clarence R. mouth                               | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 44.                | Hapuku R. mouth                                 | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 45.                | Conway R. mouth                                 | A                   | NE        | L                          | —                        | —                  | —                               | —        |

TABLE 1 (cont.)

| Ref. No.          | Estuarine system   | Census Data         | Map Data  |                            |                          | Questionnaire Data |                                 |          |
|-------------------|--|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                   |  | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| <i>Canterbury</i> |  |                     |           |                            |                          |                    |                                 |          |
| 46.               | Waiau R. mouth   | B                   | NE        | L                          | —                        | C                  | S                               | Y        |
| 47.               | Hurunui R. mouth   | A                   | NE        | L                          | WM                       | C                  | S                               | Y        |
| 48.               | Saltwater Creek and Ashley R. mouth                              | C                   | 40        | BB                         | SW                       | SP                 | S                               | Y        |
| 49.               | Brooklands Lagoon and Waimakariri R. mouth                       | C                   | 50        | BB                         | SW                       | GP                 | S                               | Y        |
| 50.               | Avon-Heathcote Estuary (Christchurch)                            | I                   | 178       | BB                         | SW                       | SP                 | S                               | Y        |
| 51.               | Lyttelton Harbour, head  | B                   | 956       | DR                         | WM                       | SP                 | S                               | Y        |
| 52.               | Port Levy, head  | A                   | 182       | DR                         | —                        | —                  | —                               | —        |
| 53.               | Pigeon Bay, head   | A                   | 188       | DR                         | —                        | —                  | —                               | —        |
| 54.               | Okains Bay, head   | A                   | 75        | DR                         | —                        | —                  | —                               | —        |
| 55.               | Le Bons Bay, head  | A                   | 44        | DR                         | —                        | —                  | —                               | —        |
| 56.               | Akaroa Harbour, head   | B                   | 896       | DR                         | WM                       | SP                 | S                               | Y        |
| 57.               | Rakaia R. mouth  | B                   | 140       | L                          | —                        | —                  | —                               | —        |
| 58.               | Ashburton R. mouth   | D                   | NE        | L                          | —                        | C                  | S                               | X        |
| 59.               | Rangitata R. mouth   | A                   | 150       | L                          | —                        | C                  | S                               | X        |
| 60.               | Opihi R. mouth and lagoon  | B                   | NE        | L                          | —                        | C                  | S                               | X        |
| 61.               | Washdyke Lagoon  | A                   | 10        | BB                         | —                        | C                  | S                               | X        |
| 62.               | Pareora R. mouth   | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 63.               | Otaio R. mouth   | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 64.               | Makikihi R. mouth  | A                   | NE        | L                          | —                        | C                  | S                               | X        |
| 65.               | Wainono Lagoon (Hook R. mouth)                                   | A                   | 75        | BB                         | —                        | C                  | S                               | X        |
| 66.               | Waihao R. mouth  | A                   | NE        | BB                         | —                        | C                  | S                               | X        |
| <i>Otago</i>      |  |                     |           |                            |                          |                    |                                 |          |
| 67.               | Waitaki R. mouth   | B                   | 75        | L                          | —                        | C                  | S                               | X        |
| 68.               | Kakanui R. mouth   | B                   | NE        | L                          | WM                       | SP                 | —                               | X        |
| 69.               | Shag R. mouth  | B                   | NE        | L                          | WM                       | SP                 | S                               | X        |
| 70.               | Pleasant R. mouth  | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 71.               | Waikouaiti Estuary   | B                   | 30        | BB                         | WM                       | SP                 | S                               | Y        |
| 72.               | Blueskin Bay Estuary   | B                   | 113       | BB                         | SW                       | SP                 | W                               | X        |
| 73.               | Purakanui Bay Estuary  | A                   | 25        | BB                         | WM                       | SP                 | —                               | —        |
| 74.               | Otago Harbour (tidal flats, including area behind Aramoana Spit) | H                   | 984       | DR                         | SS                       | MP                 | S                               | Y        |
| 75.               | Papanui Inlet  | A                   | 63        | BB                         | —                        | —                  | —                               | —        |
| 76.               | Hoopers Inlet  | A                   | 75        | BB                         | WM                       | SP                 | —                               | X        |
| 77.               | Kaikorai Stm. mouth  | B                   | NE        | BB                         | WM                       | MP                 | —                               | X        |
| 78.               | Taieri R. mouth  | C                   | NE        | L                          | WM                       | MP                 | W                               | X        |
| 79.               | Akatore Ck.  | A                   | NE        | DR                         | —                        | —                  | —                               | —        |



TABLE 1 (cont.)

| Ref. No.         | Estuarine system   | Census Data         |           | Map Data                   |                          | Questionnaire Data |                                 |   | Surveyed |
|------------------|--|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|---|----------|
|                  |  | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 |   |          |
| 80.              | Tokomairiro R. mouth   | B                   | NE        | DR                         | SW                       | MP                 | B                               | X |          |
| 81.              | Clutha R. mouth  | C                   | 45        | L                          | SW                       | SP                 | W                               | Y |          |
| 82.              | Catlins R. Estuary   | A                   | 171       | BB                         | WM                       | SP                 | —                               | X |          |
| 83.              | Tahakpoa R. mouth  | A                   | NE        | BB                         | —                        | —                  | —                               | Y |          |
| 84.              | Tautuku R. mouth   | A                   | NE        | BB                         | —                        | —                  | —                               | — |          |
| 85.              | Waipati Estuary (Chasland R.)  | A                   | 13        | BB                         | —                        | —                  | —                               | — |          |
| 110.             | Hollyford R. mouth   | A                   | NE        | BB                         | —                        | —                  | —                               | — |          |
| <i>Southland</i> |  |                     |           |                            |                          |                    |                                 |   |          |
| 86.              | Waikawa Harbour  | A                   | 208       | BB                         | —                        | —                  | —                               | — |          |
| 87.              | Haldane Estuary  | A                   | 38        | BB                         | —                        | —                  | —                               | — |          |
| 88.              | Toetoes Harbour (Mataura R.)   | C                   | 63        | BB                         | —                        | —                  | —                               | — |          |
| 89.              | Waituna Lagoon (Waituna R.)  | A                   | 281       | BB                         | —                        | —                  | —                               | — |          |
| 90.              | Bluff Harbour and Awarua Bay   | B                   | 1,094     | BB                         | —                        | —                  | —                               | — |          |
| 91.              | New River Estuary (Invercargill) and Mokokoko Inlet  | F                   | 781       | BB                         | SS                       | MP                 | W                               | Y |          |
| 92.              | Jacobs R. Estuary (Riverton)   | B                   | 125       | BB                         | —                        | —                  | —                               | — |          |
| 93.              | Waiau R. mouth   | B                   | NE        | BB                         | —                        | —                  | —                               | — |          |
| 94.              | Preservation Inlet, head (Isthmus Sd, Long Sd, Useless Bay, Kisbee Bay, Welcome Bay, etc.) | A                   | 1,997     | FD                         | —                        | —                  | —                               | — |          |
| 95.              | Chalky Inlet, head (Landing Bay, South Port, Cunaris Sd, Edwardson Sd)                     | A                   | 2,368     | FD                         | —                        | —                  | —                               | — |          |
| 96.              | Dusky Sound, head (Fanny Bay, Cascade Cove, Duck Cove, Supper Cove, Shark Cove)            | A                   | 4,243     | FD                         | HS                       | C                  | —                               | Y |          |
| 97.              | Breaksea Sound, head (Wet Jacket Arm, Vancouver Arm, Broughton Arm)                        | A                   | 2,191     | FD                         | —                        | —                  | —                               | — |          |
| 98.              | Dagg Sound, head   | A                   | 390       | FD                         | —                        | —                  | —                               | — |          |
| 99.              | Doubtful Sound, head (First Arm, Crooked Arm, Shelter Cove, Deep Cove, Hall Arm)           | A                   | 1,903     | FD                         | HS                       | SP                 | W                               | X |          |
| 100.             | Thomson Sound, head (Bradshaw Sound, Precipice Cove, Gaer Arm)                             | A                   | 955       | FD                         | —                        | —                  | —                               | — |          |
| 101.             | Nancy Sound  | A                   | 316       | FD                         | —                        | —                  | —                               | — |          |
| 102.             | Charles Sound (Emelius Arm)  | A                   | 318       | FD                         | —                        | —                  | —                               | — |          |
| 103.             | Caswell Sound  | A                   | 365       | FD                         | —                        | —                  | —                               | — |          |
| 104.             | George Sound (SW Arm)  | A                   | 653       | FD                         | —                        | —                  | —                               | — |          |
| 105.             | Bligh Sound  | A                   | 437       | FD                         | —                        | —                  | —                               | — |          |
| 106.             | Sutherland Sound   | A                   | 253       | FD                         | —                        | —                  | —                               | — |          |
| 107.             | Poison Bay   | A                   | 192       | FD                         | —                        | —                  | —                               | — |          |
| 108.             | Milford Sound  | A                   | NE        | FD                         | SS                       | SP                 | W                               | X |          |
| 109.             | Big R. mouth   | A                   | NE        | L                          | —                        | —                  | —                               | — |          |

TABLE 1 (cont.)

| Ref. No.               | Estuarine system                              | Census Data         |           | Map Data                   |                          | Questionnaire Data |                                 |          |
|------------------------|---|---------------------|-----------|----------------------------|--------------------------|--------------------|---------------------------------|----------|
|                        |   | Population category | Area (ha) | Topographic classification | Degree of stratification | Condition          | Changes in condition since 1965 | Surveyed |
| <i>Westland</i>        |   |                     |           |                            |                          |                    |                                 |          |
| 111.                   | Cascade R. mouth                              | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 112.                   | Arawata R. mouth                              | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 113.                   | Waiatoto R. mouth                             | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 114.                   | Okuru R. mouth                                | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 115.                   | Haast R. mouth                                | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 116.                   | Paringa R. mouth                              | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 117.                   | Ohinemaka R. mouth                            | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 118.                   | Mahitahi R. mouth                             | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 119.                   | Makawhio (Jacobs) R. mouth                    | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 120.                   | Manakiaua R. mouth                            | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 121.                   | Karangarua R. mouth                           | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 122.                   | Cook R. mouth                                 | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 123.                   | Waikukupa R. mouth                            | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| 124.                   | Waiho R. mouth                                | A                   | NE        | L                          | —                        | —                  | —                               | —        |
| 125.                   | Three Mile Lagoon                             | A                   | 10        | BB                         | —                        | —                  | —                               | —        |
| 126.                   | Okarito Lagoon                                | A                   | 584       | BB                         | —                        | —                  | —                               | —        |
| 127.                   | Poerua R. and Wanganui R. mouths              | B                   | NE        | L                          | WM                       | C                  | S                               | X        |
| 128.                   | Waitaha R. mouth                              | A                   | NE        | L                          | —                        | C                  | S                               | X        |
| 129.                   | Mikonui R. mouth                              | A                   | NE        | L                          | WM                       | C                  | S                               | X        |
| 130.                   | Totara Lagoon                                 | B                   | 10        | BB                         | —                        | —                  | —                               | —        |
| 131.                   | Hokitika R. mouth                             | B                   | NE        | L                          | —                        | —                  | —                               | —        |
| 132.                   | Arahura R. mouth and Lagoon                   | A                   | NE        | L                          | WM                       | C                  | S                               | X        |
| 133.                   | Taramakau R. mouth                            | A                   | 25        | L                          | WM                       | C                  | S                               | X        |
| 134.                   | Grey R. mouth and Lagoon                      | C                   | 25        | L                          | —                        | —                  | —                               | —        |
| 135.                   | Canoe Ck. mouth                               | A                   | NE        | BB                         | —                        | —                  | —                               | —        |
| 136.                   | Porarari R. and Bullock Ck. mouths            | A                   | NE        | DR                         | —                        | —                  | —                               | —        |
| <i>Stewart Island</i>  |   |                     |           |                            |                          |                    |                                 |          |
| 1.                     | Port William                                  | A                   | 38        | DR                         | —                        | —                  | —                               | —        |
| 2.                     | Paterson Inlet, head, and along Freshwater R. | A                   | 508       | DR                         | —                        | —                  | —                               | —        |
| 3.                     | Big Glory Bay, tidal flats                    | A                   | 255       | DR                         | —                        | —                  | —                               | —        |
| 4.                     | Heron R. mouth                                | A                   | NE        | DR                         | —                        | C                  | —                               | —        |
| 5.                     | Lords R. mouth                                | A                   | NE        | DR                         | —                        | C                  | —                               | —        |
| 6.                     | Port Pegasus tidal flats                      | A                   | 602       | DR                         | —                        | —                  | —                               | —        |
| <i>Chatham Islands</i> |   |                     |           |                            |                          |                    |                                 |          |
|                        | Te Whanga Lagoon                              | A                   | NE        | BB                         | —                        | C                  | —                               | X        |
| <i>Campbell Island</i> |   |                     |           |                            |                          |                    |                                 |          |
|                        | Perserverance Harbour                         | A                   | NE        | FD                         | SS                       | C                  | S                               | X        |

MCLAY: NEW ZEALAND ESTUARIES

## APPENDIX

TABLE 2. Summary of topographic classification and area of estuaries according to provincial area of New Zealand

| <i>Provincial Area</i> | <i>BB</i> | <i>DR</i> | <i>FD</i> | <i>L</i> | <i>Total</i> | <i>Total Area (ha)<br/>estimated</i> | <i>No. not estimated<br/>(proportion)</i> |
|------------------------|-----------|-----------|-----------|----------|--------------|--------------------------------------|---|
| Northland              | 37        | 2         | —         | 1        | 40           | 44,859                               | 11 (.28)                                  |
| Waikato                | 21        | 4         | —         | 1        | 26           | 11,912                               | 7 (.27)                                   |
| Great Barrier Island   | 1         | 3         | —         | —        | 4            | 308                                  | 1 (.25)                                   |
| Gisborne               | 8         | 1         | —         | 9        | 18           | 4,126                                | 11 (.61)                                  |
| Hawkes Bay             | 7         | —         | —         | 4        | 11           | 280                                  | 2 (.18)                                   |
| Wellington             | 23        | 2         | —         | 12       | 37           | 397                                  | 32 (.86)                                  |
| Taranaki               | 5         | 10        | —         | 4        | 19           | —                                    | 19 (1.0)                                  |
| Nelson                 | 24        | 7         | —         | 1        | 32           | 8,779                                | 16 (.50)                                  |
| Marlborough            | —         | 8         | —         | 7        | 15           | 5,757                                | 6 (.40)                                   |
| Canterbury             | 6         | 6         | —         | 9        | 21           | 2,984                                | 8 (.38)                                   |
| Otago                  | 12        | 3         | —         | 5        | 20           | 1,594                                | 10 (.50)                                  |
| Southland              | 8         | —         | 15        | 1        | 24           | 19,171                               | 3 (.13)                                   |
| Westland               | 11        | 4         | —         | 11       | 26           | 654                                  | 21 (.81)                                  |
| Stewart Island         | —         | 6         | —         | —        | 6            | 1,403                                | 2 (.33)                                   |
| Chatham Islands        | 1         | —         | —         | —        | 1            | —                                    | 1 (1.0)                                   |
| Campbell Island        | —         | —         | 1         | —        | 1            | —                                    | 1 (1.0)                                   |
| Totals                 | 164       | 56        | 16        | 65       | 301          | 102,224                              | 151 (.50)                                 |