Department of Primary Industries

Jellyfish Fishery Development and Assessment

Dr Noel Coleman

State Government Victoria Department of Primary Industries

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NON-TECHNICAL SUMMARY

1999/138 Jellyfish fishery development and assessment

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OBJECTIVES:

1. Develop a sampling unit for efficient survey of jellyfish distribution and abundance.
2. Estimate spatial and temporal variations in abundance of *Catostylus mo*saicus in Port Phillip Bay, Western Port and Corner Inlet during 2000, 2001 and 2002.
3. Determine relationships between total weight, bell weight, discard (oral arms) weight and diameter of *Catostylus mosaicus* for several localities and the seasonality of these relationships.
4. Test whether the bells of *Catostylus mosaicus* meet national health standards for cadmium, mercury, zinc, lead and arsenic and test for the effects of bell size and locality on concentrations of these heavy metals in *C. mosaicus*.
5. Test whether the bells of *Catostylus mosaicus* meet national health standards for organochlorines, hydrocarbons and tributyl tin in Port Phillip Bay.
6. Provide annual fishery assessment reports which update commercial catch and effort.

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OUTCOMES ACHIEVED

The project has provided estimates of the abundance of the edible jellyfish *Catostylus mosaicus* (Quoy and Gaimard, 1824) in Port Phillip, Western Port and Corner Inlet, Victoria, during 2000, 2001 and 2002. Correlations between size and weight were established and were used to convert estimates of abundance to estimates of the total biomass of jellyfish and the biomass of jellyfish of commercial size (those with a bell diameter of 23 cm or more). The incidence of deterioration in jellyfish bells, which may affect the quality and value of the processed product, has been investigated. Problems associated with making accurate estimates of abundance and biomass have been identified and possible solutions suggested. Chemical analyses of jellyfish bells for heavy metals, total hydrocarbons, polycyclic aromatic hydrocarbons, organochlorine insecticides and tributyl tin showed concentrations of these contaminants to be below the maximum permitted levels, where these are specified, in the Food Standards for Australia and New Zealand. Fisheries managers and the permit holder under the Developmental Fishery Management Plan for the jellyfish fishery were kept informed of the survey results. The permit holder was supplied with jellyfish which were used in instructing local fishers in methods of jellyfish processing. No commercial fishing occurred during the course of the study and so data obtained from the study was not directly applied to the management of the fishery during this period.

Jellyfish have been eaten by the Chinese for over a thousand years. More recently, a rapid expansion of the fishery has occurred since the 1970s, particularly with the increasing consumption of jellyfish in Japan. The major fisheries are in China and south-east Asia (particularly Indonesia, Malaysia, Philippines, and Thailand), but increasing demand for the product has led to the establishment of small-scale fisheries in other areas, including Australia.

The species of commercial interest in Australia is *Catostylus mosaicus* (Quoy and Gaimard, 1824) which is found along the entire eastern coast and in bays and inlets in Victoria. In Victoria feasibility studies directed towards establishing a fishery were carried out between 1997 and 1999. In 1998 one company was issued with a developmental fishery permit which was valid for three years and then extended for an additional year. During this period (1998 – 2002) small quantities of jellyfish were taken and were used in market trials and to instruct local fishers in processing methods. Fisheries Victoria have recommended that the period of the developmental permit be extended for a further three years to determine whether the fishery can be developed on a fully commercial basis.

The purpose of the present study was to extend the scope of earlier feasibility studies in Victoria by carrying out further stock assessments, particularly in Western Port and Corner Inlet (to which little effort was directed in the earlier work). Monthly visits were made to each area between January and June in 2000, 2001 and 2002 and assessments were made of the abundance and biomass of *Catostylus mosaicus* (objective 2).

The abundance of *Catostylus mosaicus* was estimated by stratified random sampling within the survey areas. Each survey area was divided into strata based on information from the previous studies of jellyfish distribution. Within each stratum jellyfish visible in the top few metres of the water column were counted along randomly selected transects of known length and width. From these counts the mean number of jellyfish per transect and the total number of jellyfish per stratum, plus upper and lower 95% confidence intervals were estimated. Area-wide estimates of the mean number of jellyfish per transect and the total number of jellyfish were also made (objective 2).

Samples of *Catostylus mosaicus* were taken by dip net and used to provide size-frequency data. Relationships between bell diameter and total weight and between bell diameter and bell weight were determined (objective 3). From the estimates of abundance, the size-frequency data and the size-weight relationships, estimates of total biomass and of the biomass of commercial size jellyfish, plus upper and lower 95% confidence intervals, were made. Commercial size jellyfish are those with a bell diameter of 23 cm or more.

The occurrence of *Catostylus mosaicus* in Victoria is seasonal. *C. mosaicus* is generally found between January and June although a few individuals may be found outside this period and some do survive over the winter. During the 3 years of the study there were very large annual and geographical variations in abundance and biomass.

In 2000 there were so few *C. mosaicus* in any of the areas surveyed that no estimates of abundance and biomass were made.

In 2001 *C. mosaicus* were abundant in Port Phillip and Corner Inlet, but less so in Western Port. For Port Phillip the highest estimates of biomass were made in May. The total wet weight of jellyfish was estimated as 4,754 tonnes (lower and upper 95% confidence intervals 1,178 and 14,898 tonnes respectively) and the wet weight of commercial size jellyfish was estimated as 3,013 tonnes (lower and upper 95% confidence intervals 746 and 9,440 tonnes respectively). For Corner Inlet the highest estimates of biomass were made in April. Total biomass was estimated as 1,540 tonnes (lower and upper 95% confidence intervals 712 and 2,990 tonnes respectively) and the biomass of commercial size jellyfish was estimated as 339 tonnes (lower and upper 95% confidence intervals 147 and 660 tonnes respectively). For Western Port the highest estimate was made in February and was 8 tonnes tonnes total wet weight (lower and upper 95% confidence intervals 0.2 and 63 tonnes respectively). No jellyfish of commercial size were found.

In 2002 jellyfish were found in all three survey areas but were much less abundant than in 2001. For Port Phillip the highest estimates of biomass were made in February and were 374 tonnes total wet weight (lower and upper 95% confidence intervals 13 and 418 tonnes respectively) and 62 tonnes (lower and upper 95% confidence intervals 8 and 247 tonnes respectively) for commercial size jellyfish. For Corner Inlet the highest estimates of biomass were made in May and were 50 tonnes total wet weight (lower and upper confidence intervals 0.8 and 390 tonnes respectively) and 18 tonnes (lower and upper 95% confidence intervals 0.2 and 142 tonnes respectively) for commercial size jellyfish. So few *C. mosaicus* were found in Western Port that no estimates of abundance or biomass were made.

The estimates of abundance (and the biomass estimates derived from them) were not very precise (ie had wide confidence intervals associated with them). Lack of precision has been reported in other studies of the abundance of *Catostylus mosaicus* and arises because of the highly aggregated distribution which may be shown by this species. Strategies for improving precision (eg increased sampling effort, redefinition of stratum boundaries, sampling aggregations of jellyfish rather than sampling randomly) are discussed, as are the implications of using imprecise biomass assessment to set catch limits. The implications of the research findings for other aspects of the management of the fishery (eg stock boundaries, size limits, temporal and spatial closures) are also discussed.

Jellyfish bells may show imperfections, such as holes or cracks, which affect the grading and value of the processed product. While the incidence of such imperfections was variable, there was a tendency for them to be more prevalent towards the end of the season.

Jellyfish bells were analysed for a range of heavy metals, total hydrocarbons, polycyclic aromatic hydrocarbons, organochlorine insecticides and tributyl tin (objectives 4 and 5). In all cases concentrations were below maximum permitted levels, where these are specified, in the Food Standards for Australia and New Zealand.

No commercial scale fishing for jellyfish was carried out between 2000 and 2002 and so it was not possible to update commercial catch and effort statistics (objective 6) or to compare biomass taken by the fishery with fishery-independent assessments of biomass. However, fisheries managers and the holder of the developmental fishery permit were kept informed of the results of the survey work and the permit holder was provided with jellyfish to use in instructing local fishers in processing methods.

Objective 1 of the study was to develop a net capable of sampling jellyfish at different depths in the water column in order to refine abundance estimates made simply by counting jellyfish visible at the water's surface. A suitable net was designed and constructed at the Australian Maritime College in Tasmania. The net was deployed in Port Phillip in 2000 but caught no jellyfish. Because no biomass estimates had been made in the previous year, as jellyfish were scarce, the emphasis in 2001 was on obtaining estimates of jellyfish abundance by visual observations from a small boat. Further trials of the net, and an investigation of the effect of using the net on biomass estimates, were scheduled for April and May 2002, but the unexpected disappearance of *C. mosaicus* from Port Phillip after March 2002 meant that these trials did not take place. There are some potential problems associated with the use of the net, as opposed to visual counts, to assess abundance and these are discussed.

KEYWORDS: *Catostylus mosaicus*, jellyfish fishery, jellyfish abundance, jellyfish biomass

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Acknowledgments

My thanks are due to Neville Clarke and Bill Watts for help in counting and sampling jellyfish in Corner Inlet, and to Greg Duncan for help in counting and sampling jellyfish in Western Port. Gus Fabris (Marine and Freshwater Resources Institute) helped in the interpretation of chemical analyses. Dr Gary Poore, Museum Victoria, provided the identification for the crustacean, *Cymodoce gaimardii*, commonly found in association with *Catostylus mosaicus*. Di Brand, Melbourne Aquarium, provided information regarding the pathogen associated with deterioration of the bell in *Catostylus mosaicus*. Technical support was provided by the staff listed in Appendix 2. Sandy Morison of the Marine and Freshwater Resources Institute provided useful criticism of the original manuscript.

FINAL REPORT

1999/138 Jellyfish fishery development and assessment

Background

Jellyfish fisheries

Jellyfish have been eaten by the Chinese for over a thousand years. More recently a rapid expansion of the fishery has occurred since the 1970s, particularly with the increasing consumption of jellyfish in Japan (Omori and Nakano 2001). The major fisheries are in China and south-east Asia (particularly Indonesia, Malaysia, Philippines, and Thailand), but increasing demand for the product has led to the establishment of small-scale fisheries in other areas including Australia, India, Mexico, Turkey and the USA.

Jellyfish are coelenterates and belong to the phylum Cnidaria, which also includes sea anemones and corals. The species that are commercially fished belong to the order Rhizostomeae in the class Scyphozoa. The members of this order are characterised by large, tough bodies with a thick bell (umbrella). They possess oral arms but lack tentacles around the edge of the bell. At least 11 species are known to be fished, but the taxonomy of the group is poorly known and the actual number of species fished is probably higher (Omori and Nakano 2001). There are reports that *Aurelia aurita*, a widespread and common species belonging to the order Semaeostomeae, is fished in Turkey although a trial fishery for this species in Canada was unsuccessful, largely because of the low quality of the product (Sloan and Gunn 1985; Kingsford *et al.* 2000).

Establishing the size of the world-wide jellyfish catch accurately is difficult because of inconsistencies in reporting (Kingsford *et al.* 2001; Omori and Nakano 2001), but over the last five or six years estimated catches have ranged from over 300,000 tonnes (wet weight) to over 500,000 tonnes. Between 1988 and 1999 the value of jellyfish imported into Japan averaged US$48 million (Aus$89 million) a year (Omori and Nakano 2001).

Fishing methods include trawling, drift netting, seine netting and dipnetting (Kingsford *et al.* 2001; Omori and Nakano 2001). For some species the entire jellyfish may be retained for processing while in others the oral arms are removed and only the bell is retained. Fishing seasons are generally short, mostly being of 2 to 4 months duration, and fisheries are characterised by considerable fluctuations in the catch (Omori and Nakano 2001).

The life cycle of the jellyfish includes two stages, the free-swimming medusoid phase, which is relatively large, reproduces sexually and is the phase that is commercially fished, and an inconspicuous, bottom-dwelling polypoid phase which reproduces asexually, liberating larvae, known as ephyrae, which develop into medusae. Factors affecting survival and reproduction by the polypoid phase may be vital in determining the population size of the medusoid phase (Omori and Nakano 2001) but are virtually unknown.

Freshly caught jellyfish deteriorate rapidly if the temperature is warm and so need to be processed soon after capture. Both the bell and the oral arms may be processed. Where the arms are processed these are removed from the bell and processed separately. Processing involves the progressive reduction of water content using mixtures of salt and alum. There are various methods of processing, which may vary in detail (Sloan and Gunn 1985; Huang 1988), but traditionally these involve treating the catch with a salt mixture containing about 10% alum. The jellyfish are left in this brine for 3 – 4 days after which they are transferred to fresh brine solutions containing smaller amounts of alum. After it has been salted the product is air-dried. The process takes approximately 20 – 40 days and the finished product contains about 60 - 70 % moisture (as opposed to 94 – 98% in unprocessed jellyfish) and 16 – 25% salt (compared with 2 – 3% salt when fresh). The alum reduces pH, and acts as a disinfectant and hardening agent and the salt as a dehydrating agent. Either used separately is not sufficient for adequate processing (Hsieh and Rudloe 1994; Hsieh *et al*. 2001).

Processed jellyfish need to be rehydrated and desalted by being soaked in water for several hours. Ready-to-eat jellyfish, which has already been rehydrated and desalted, is available. In addition to its culinary use, jellyfish is also said to have medicinal properties (being effective against hypertension, back pain, arthritis and ulcers, reducing swelling, improving digestion and improving recovery from fatigue) although, apart from some evidence that jellyfish consumption may be effective against arthritis, these claims are largely unsupported by scientific research. Jellyfish have also been promoted as a diet food and as an aid to beautiful skin (Hsieh and Rudloe 1994; Hsieh *et al*. 2001).

Jellyfish fisheries in Australia

The species of commercial interest in Australia is the rhizostome jellyfish *Catostylus mosaicus* (Quoy and Gaimard, 1824). The potential value of this species has been recognised since at least the early 1980s, when taste tests on processed *Catostylus* collected from New South Wales showed that they compared favourably with processed jellyfish imported from Malaysia (Wootton *et al.* 1982), but attempts to establish commercial fisheries are more recent and are still only in a developmental stage.

An experimental fishery for *Catostylus mosaicus* was established in New South Wales in 1995. Catches between 1995 and 1998 were small, ranging from 10 to 33 tonnes wet weight. The small catches were largely due to a lack of processing plants rather than to lack of medusae (Kingsford *et al*. 2000). Feasibility studies directed towards establishing a fishery in Victoria were carried out between 1997 and 1999 (Hudson *et al*. 1997, 1998, 1999). Small amounts of jellyfish (to about 200 kg whole wet weight) were caught, processed and used in export trials (Hudson 1997; Fisheries Division 2002). Processed jellyfish exported to Japan was given a B grading by the importer (Fisheries Division 2002). A developmental permit was issued to The David Glory Group Pty Ltd in April 1998 for three years and was extended for 1 year to November 2002 but jellyfish were not taken in commercial quantities over that period. A small number of jellyfish were taken in 2002 and were used to instruct local fishers in jellyfish processing. To provide more time in which to see if a fully commercial fishery can be developed, a further developmental fishery plan for Victoria, covering the period 2002 to 2005, has been developed (Fisheries Division 2002). There is interest in establishing fisheries in Queensland and also in the Northern Territory where there has previously been some capture and processing of jellyfish (Field 1999; Queensland Fisheries Service 2001; Fisheries Division 2002). Omori and Nakano (2001) report that in 1997 0.2 tonnes of jellyfish were imported into Japan from Australia.

The biology of *Catostylus mosaicus*

Catostylus mosaicus is found along the entire eastern coast of Australia, from the Torres Strait in the north to Port Phillip in the south (Southcott 1982). It is also reported from Tasmania, South Australia and Western Australia (Coleman 1987). *C. mosaicus* is an inshore species, sometimes occurring in bays and estuaries in very large numbers (Southcott 1982), and tolerates a wide range of temperature (10^{o}C – 28^{o}C) and salinity (12 – 39) (Kingsford and Pitt 1998). Surveys along the coast of New South Wales have shown that medusae are most abundant close to rivers and lakes and that peaks of recruitment occur after heavy rain. The positive influence that freshwater apparently has on the abundance of *Catostylus* is perhaps because the polyp stage settles in or near rivers and is prompted to produce ephyrae larvae by lowered salinity (Kingsford and Pitt 1998). In Victoria *C. mosaicus* is reported from various bays and estuaries along the coast (Hudson *et al.* 1997; Hudson and Walker 1998, 1999). Surveys in both New South Wales and Victoria have found that *C. mosaicus* shows large scale temporal and spatial variations in population density.

As in other rhizostome jellyfish, the life cycle of *Catostylus mosaicus* includes a sexually reproducing, pelagic medusoid phase and an asexually reproducing, benthic polypoid stage. Studies in New South Wales have shown that the sexes are separate and that the proportions of male and female medusae are equal (Pitt and Kingsford 2000). The size at which maturity is reached varies with locality but is from about 12 cm to 15 cm in bell diameter. All medusae are likely to have reached maturity by the time they have reached a bell diameter of 16 cm. In New South Wales gametogenesis occurs for most of the year although may be reduced during winter. In Victoria reproductive activity is compressed into a shorter period because the occurrence of medusae is seasonal.

The development of the polyp stage has been observed in the laboratory (Pitt 2000). The fertilised egg turns into a planula larva and there is evidence that the planula larvae are brooded by adults. The larvae settle to the sea floor and are capable of attaching to a variety of substrata including wood, sandstone and shell fragments. The settled planula develops into a scyphistoma which has a mouth and up to 20 tentacles and a height of about 0.5 mm. After further growth strobilation occurs and the scyphistoma (now known as a strobila) buds off ephyrae larvae which become free-swimming and develop into the sexually reproducing medusoid phase. The body length of the strobila is about 2 mm. Strobila generally produce one ephyra larva but may produce up to five. The scyphistoma may also reproduce asexually, by budding, fission or the formation of podocysts which metamorphose back into scyphistomae, thus ultimately increasing the number of ephyrae formed (Fig. 1).

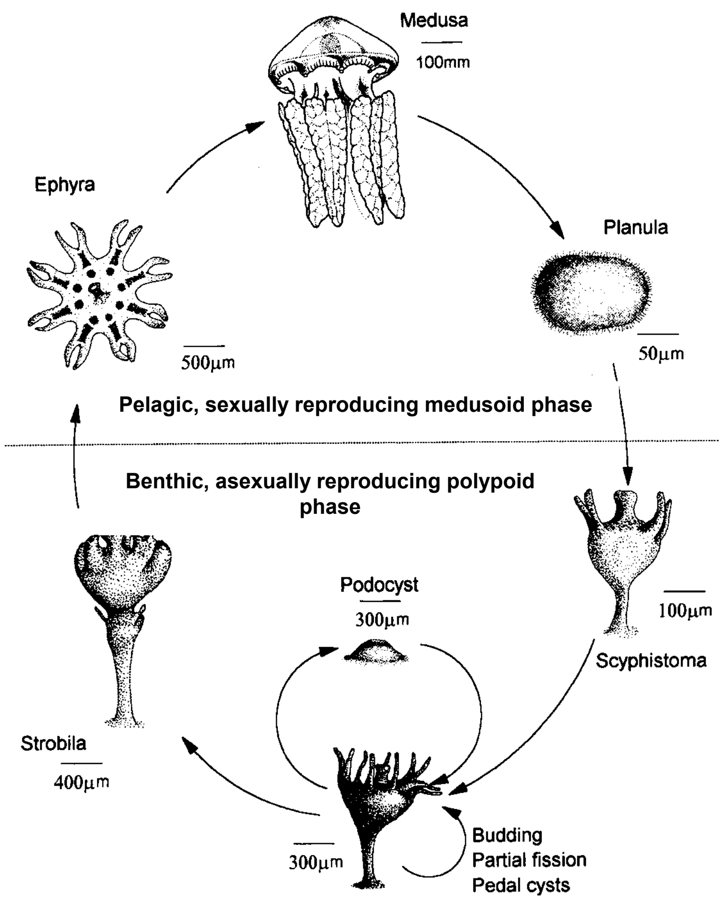


Figure 1. Life cycle of *Catostylus mosaicus***.**

(slightly modified from Pitt 2000).

The growth rate of *Catostylus* medusae is rapid. In Victoria the occurrence of medusae is seasonal, usually between January and June (although some medusae may survive over winter). Within this period medusae may reach a diameter of 30 to 40 cm (Hudson *et al.* 1997; Hudson and Walker 1998, 1999). In New South Wales *C. mosaicus* are found throughout the year (Kingsford and Gillanders 1995). Although growth rate may vary, estimates indicate that the time taken for newly released ephyrae larvae to reach a diameter of 2 cm is about 1 month; that over the first 100 days growth rate is in the range 27 – 63 mm bell diameter per month, that growth then slows to about 13 – 23 mm bell diameter per month; and that growth slows or ceases in the winter (Kingsford and Pitt 1998).

Catostylus mosaicus does not have a single mouth but, as in all rhizostomes, the 'mouth' is formed by a large number of grooves along the oral arms. Medusae feed on copepods, fish eggs and other planktonic organisms (Dakin 1987) with a body length not exceeding 3 mm (Queensland Fisheries Service 2001). The bells of *C. mosaicus* may be coloured, often being slightly pink or brown. It has been suggested that the colouration is due to the presence of symbiotic algae, from which the medusae may derive some nourishment (Kingsford and Gillanders 1995), although some doubt has been raised as to whether or not medusae do contain algae (Pitt 2000). While the medusae are generally considered to have only limited powers of locomotion, their movements are not simply passive and dictated by water currents. They can make vertical migrations through the water column, tending to be at the surface of the water in calm sunny conditions and to sink to the bottom in rougher, windy conditions (Hudson *et al.* 1997: Kingsford *et al*. 2000). They may also orientate themselves to swim against horizontal currents generated by wind and waves (Kingsford and Gillanders 1995).

Previous population surveys of the jellyfish *Catostylus mosaicus* in Victoria

Studies of the population abundance of *Catostylus mosaicus* in Port Phillip, Western Port and Corner Inlet, Victoria, were carried out between 1997 and 1999 (Hudson *et al.* 1997; Hudson and Walker 1998, 1999). The methods used in these surveys were essentially the same as used in the present study and the stratification used in the present study was based on the results of this earlier work.

During the 3 years that the earlier surveys were carried out in Port Phillip, abundance and biomass were highest in 1997. During this year sampling was carried out between February and June. The largest jellyfish measured was 42 cm in diameter and size-frequency histograms for March, April and May indicate a high proportion of individuals over 30 cm in diameter (although numbers of jellyfish measured are small, <70 in each month). Although small jellyfish were found early in the year, virtually no jellyfish less than 15 cm in diameter were collected after April. The largest estimates of biomass made were 17,782 tonnes for the northern part of the Geelong Arm (this area is referred to as the Outer Harbour in Hudson *et al.* 1997 and Hudson and Walker 1998, 1999 and corresponds to stratum 2 in the present work) and 14,805 tonnes for the western shore of Port Phillip (this area is referred to as the Geelong Arm in Hudson *et al.* 1997 and Hudson and Walker 1998, 1999 and corresponds to stratum 3 in the present work). Maximum estimates for the northern part of the bay and for the area around Mordialloc in the east (corresponding to strata 5 and 7 in the present work) were 806 tonnes and 1,296 tonnes respectively. The authors note that 'great uncertainty' is associated with the biomass estimates because of the great variation in the numbers of jellyfish per transect, which formed the basis of the biomass calculation. General conclusions drawn from the survey were that jellyfish aggregate inshore, predominantly in the west and north of the bay; that their occurrence is highly seasonal, from January to June; and that growth rate is rapid but that immigration from elsewhere might account for the occurrence of large individuals early in the season.

During 1998 sampling was limited to April and May. No jellyfish were observed in the east, around Mordialloc, but they were found in Corio Bay, along the western shore and in the north of the bay. The largest individual measured was 41.3 cm in diameter and jellyfish 30 cm or more in diameter were common. Abundance and biomass estimates were considerably less than in 1997. The highest estimate of biomass was 370 tonnes for the western shore followed by an estimate of 245 tonnes for Corio Bay. Estimates of biomass by region were 0.5% to 9% of those made in 1997.

In 1999 the earliest reports of jellyfish from Port Phillip were in the first week of February and sampling was carried out during March, April and May. Jellyfish were absent from the eastern shore but present along the western shore and in the Geelong Arm and Corio Bay. Biomass estimates were higher than in 1998 but lower than in 1997, being 750 tonnes for the western shore and 517 tonnes for Corio Bay. Bell size was smaller than in previous years with few individuals exceeding 25 cm in diameter and none reaching 30 cm.

Surveys of Western Port carried out in 1998 revealed only small numbers of small jellyfish in poor condition and no quantitative sampling was undertaken (Hudson and Walker 1998). A survey undertaken in the North Arm in April 1999 found jellyfish on 23 of 27 transects sampled, including small numbers of commercial size jellyfish. Biomass was estimated at 236 tonnes, much lower than the estimate of biomass in Port Phillip made for the same period (Hudson and Walker 1999). Small numbers of jellyfish were also found in the East Arm but were not quantitatively surveyed for the purpose of making biomass estimates.

Surveys of jellyfish abundance in Corner Inlet were carried out from March to May 1999 (Hudson and Walker 1999). Jellyfish were found in and around the mouth of the Franklin River (stratum 2a in the present survey), the Stockyard and doughboy channels (strata 2b and 2c in the present study), the Albert River and midge channels (stratum 5 in the present survey) the Toora Channel (stratum 1b in the present study) and the Tara River (not surveyed in the present study). The largest jellyfish measured was 27.2 cm in diameter. Highest biomass estimates were 36 tonnes for the Stockyard Channel and 34 tonnes for the Toora Channel. There was a clear association between jellyfish abundance and freshwater input to the Inlet, with small jellyfish being found at least 12 km upstream of the mouth of the Albert River. The association with freshwater was taken as an indication that the polyp stage occurred in the rivers or around the mouths of the rivers.

Population surveys of the jellyfish *Catostylus mosaicus* in Victoria, 2000 - 2002

Surveys undertaken between 1997 and 1999 were mainly carried out in Port Phillip, with less extensive work in Western Port and Corner Inlet, and showed considerable temporal and spatial variation in the abundance and biomass of *Catostylus mosaicus*. The current study extends the surveys carried out previously, particularly in Western Port and Corner Inlet. In this report the results of the more recent surveys are summarised and their implications for the management of the fishery are discussed. The results of chemical analyses of jellyfish bells are also presented. More detailed cruise reports (by area, by month and by year), tables of chemical analyses, and the results of some additional sampling in Port Phillip after field work for this project had finished are given in a series of appendices.

Need

Following the initial interest in harvesting jellyfish from Victorian waters, liaison with fishers during the preliminary studies carried out in 1997, 1998 and 1999 indicated high inter-annual variability in the abundance of jellyfish in Victoria. Stocks were found to be clumped and densities throughout Port Phillip, Western Port and Corner Inlet were highly variable. This inter-annual and regional variability in abundance highlights the need for flexibility in harvesting jellyfish from the different regions, depending on the size abundance and distribution of jellyfish throughout the various areas of the fishery.

For each (potential) region of the fishery, Port Phillip, Western Port and Corner Inlet, the current management plan contains a total allowable catch (TAC), expressed both as total weight and as bell weight. Stock assessments are needed for the various regions of the fishery in to determine whether current TACs are realistic and to increase our knowledge of the extent to which variations in biomass occur and whether or not there are consistent regional or annual trends. There is a need to assess the extent to which a TAC set in one year may be valid in subsequent years and the extent to which the TAC set as bell weight is consistent with the TAC set as total weight.

In previous surveys, estimates of abundance and biomass have been based only on mean numbers of jellyfish per sample. Although great variability in abundance and biomass has been noted, no quantitative estimate of this variability has been made. There is, therefore, a need to make estimates of abundance and biomass which also include some estimate of variability. An indication of variability is important in applying adaptive management strategies to the fishery. For example, if a TAC based on the mean biomass estimate for an area is rapidly achieved, knowing the variability associated with the mean will provide a basis on which the TAC could be increased but still be at a level which reflects estimated biomass. Determining size-weight relationships is also required so that estimated total biomass can be used to estimate bell biomass.

There is a need to establish whether or not jellyfish harvested from Victorian waters meet Australian national health standards for a range of heavy metals, organochlorines, hydrocarbons and tributyl tin.

Objectives

1 Develop a sampling unit for efficient survey of jellyfish distribution and abundance.

2. Estimate spatial and temporal variations in abundance of *Catostylus mosaicus* in Port Phillip Bay, Western Port and Corner Inlet during 2000, 2001 and 2002.

3. Determine relationships between total weight, bell weight, discard (oral arms) weight and diameter of *Catostylus mosaicus* for several localities and the seasonality of these relationships.

4. Test whether the bells of *Catostylus mosaicus* meet national health standards for cadmium, mercury, zinc, lead and arsenic and test for the effects of bell size and locality on concentrations of these heavy metals in C. mosaicus.

5. Test whether the bells of *Catostylus mosaicus* meet national health standards for organochlorines, hydrocarbons and tributyl tin in Port Phillip Bay.

6. Provide annual fishery assessment reports which update commercial catch and effort.

Methods

Construction of the sampling net.

The jellyfish sampling net (Fig. 2) was designed and constructed at the Australian Maritime College in Tasmania. The net has a mesh size of 3.5 cm and the circular opening has a diameter of 1.5 m. In front of the cod end of the net is a framework containing an exclusion grid which can be opened and closed (via a two-way cam cleat) by pulling on the grid activation rope. When the grid is closed, it prevents jellyfish being caught in the cod end of the net. The net is lowered through the water column with the grid closed. When the net is at the required depth one pull on the grid activation rope opens the grid and jellyfish can enter the cod end. Just before the net is retrieved another pull on the activation rope closes the grid. Any jellyfish that may be caught in the net as it is retrieved are therefore in front of the exclusion grid. When the net was used a small depth gauge was placed in the body of the net and recorded the depth at which it was set.

The net contained no escape opening in front of the grid and the assumption was made (but not tested) that jellyfish were not likely to be caught and pass into the back of the net as as it was being deployed and the grid opened. The possibility was considered that after the grid had been closed and the net was being hauled, small jellyfish could be caught in the net and squeezed through the grid. Consideration was given to covering the grid with a small mesh, to prevent jellyfish passing through, but because of the general lack of success in using the net (see p 53) this was not done.

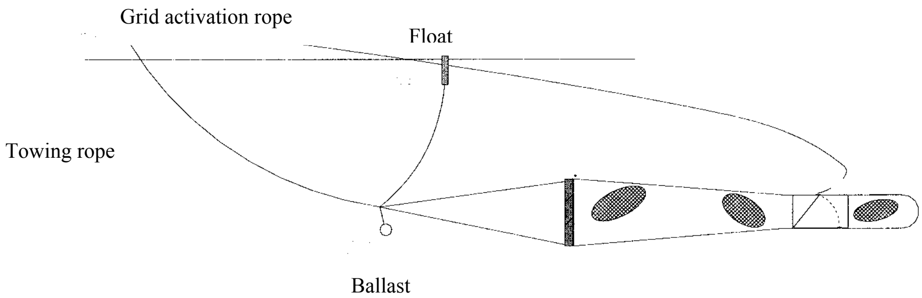


Figure 2. The jellyfish sampling net.

Top, General view of the net; middle, view through the mouth of the net showing the exclusion grid; bottom, diagram of the net being towed.

Study areas

Surveys for jellyfish abundance have been carried out in three major embayments along the central coast of Victoria: Port Phillip, Western Port and Corner Inlet (figs. 3 and 4). Each area was divided into strata. The strata used in Port Phillip were based on those used in previous studies of jellyfish distribution in the bay (Hudson and Walker, 1998, 1999). The boundaries of strata used in Western Port and Corner Inlet were based partly on the few observations of jellyfish distribution made during earlier studies of jellyfish abundance (Hudson and Walker 1999) and partly on geographical location or obvious physical features such as the presence of permanent channels (figs. 3 and 4).

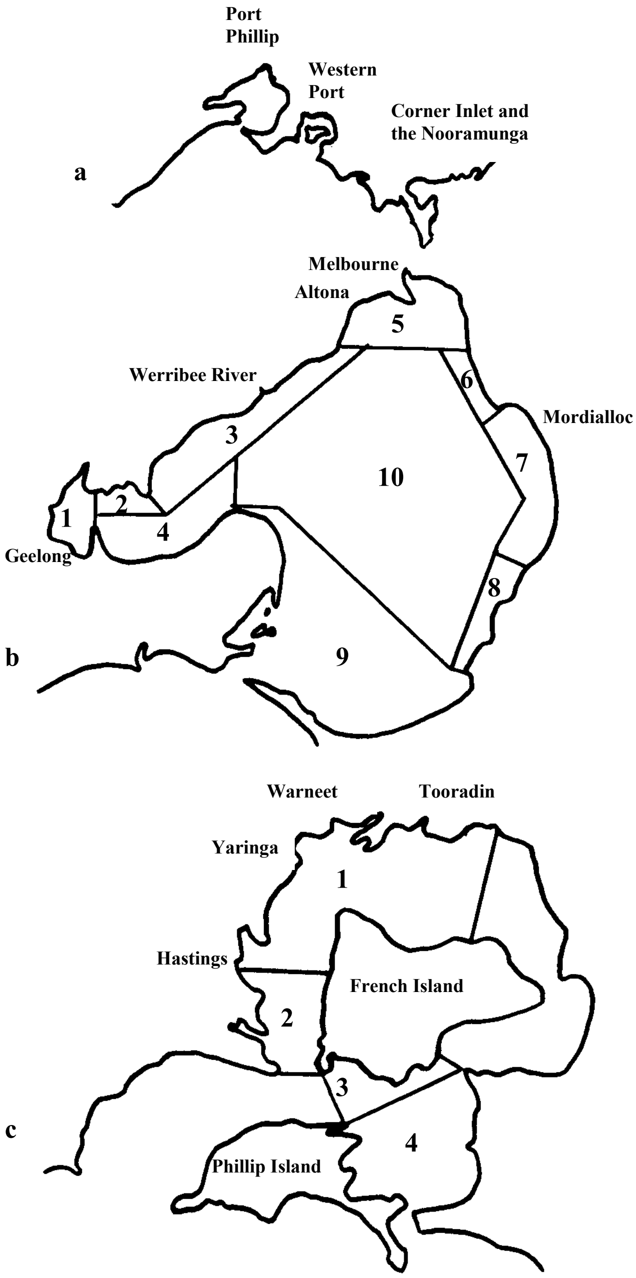


Figure 3. Location of sample areas and strata sampled in Port Phillip and Western Port.

a. Central coast of Victoria showing the locations of Port Phillip, Western Port and Corner Inlet and the Nooramunga; b. Port Phillip showing the stratum boundaries, Corio Bay is stratum 1 and Hobsons Bay is the northern part of stratum 5; c. Western Port showing the stratum boundaries.

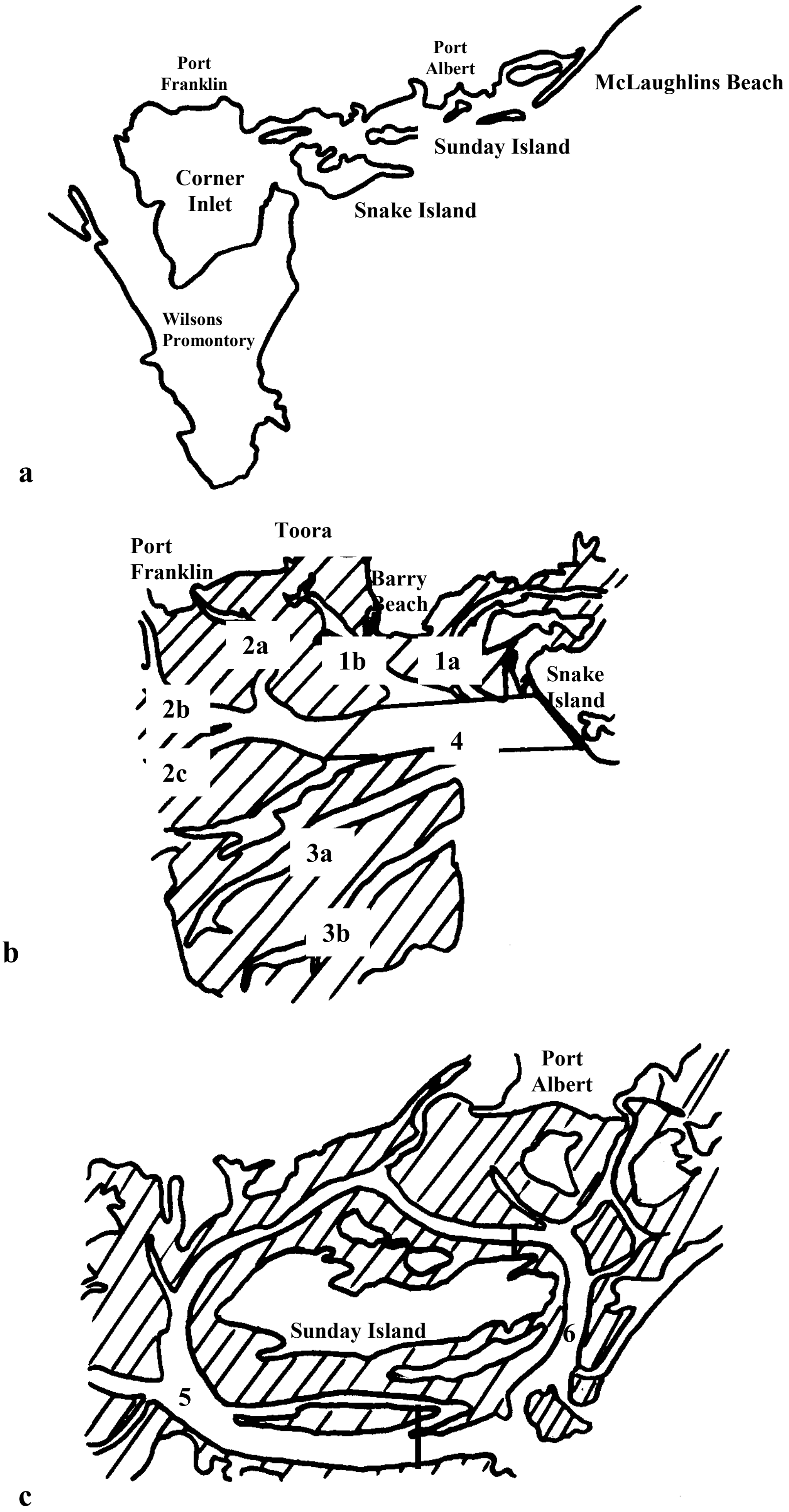


Figure 4. Strata sampled in Corner Inlet and the Nooramunga

a. General map of Corner Inlet and the Nooramunga (area between Corner Inlet and McLaughlins Beach); b. distribution of strata 1 – 4 allocated to channels in Corner Inlet; c. distribution of strata 5 – 6 allocated to channels around Sunday Island. Hatched areas are intertidal or very shallow sublittoral. The location of the area on the central coast of Victoria is shown in figure 3a

Selection of sample sites

The survey design used was that of stratified random sampling with proportional allocation of samples to strata. Proportional allocation was on the basis of stratum size. The definition of strata was primarily based on the results of the surveys carried out between 1997 and 1999 but also incorporated obvious physical features, especially in Corner Inlet which consists of intertidal areas divided by permanent channels.

Port Phillip was divided into 8 coastal and 2 central strata (Fig. 3). In total 100 stations were allocated to Port Phillip and all were allocated to the coastal strata. Sampling was concentrated around the edge of the bay as earlier studies had shown that *Catostylus mosaicus* were mostly found inshore and also because conditions in the centre of the bay were mostly unsuitable for working. On a few occasions samples were taken in stratum 9 and these were additional to the samples allocated to the coastal strata. No samples were taken stratum 10 (although casual observations were made when transiting the area, but no jellyfish were seen). Western Port was divided into 4 strata (Fig. 3) and was allocated 48 sample stations. Corner Inlet was divided into 6 strata and was allocated 72 sample sites (Fig. 4). Much of Corner Inlet consists of tidal flats surrounding permanent channels. Where a stratum contained two or three channels separated by tidal flats it was subdivided with each subdivision corresponding to a permanent channel.

The strata were marked on charts of the survey areas and the total area of each stratum was determined using a planimeter. Each stratum was subdivided into squares equivalent in area to 1 x 1 nautical mile in Port Phillip, 0.5 x 0.5 nautical mile in Western Port, and 0.5 x 0.5 nautical mile in some areas of Corner Inlet, and 0.3 x 0.3 nautical mile in the remainder. The size of the squares was dependent on the surface area and configuration of areas being sampled. Western Port and Corner Inlet are divided into channels and were subdivided into smaller units than was Port Phillip, which is a large open bay.

Each square was numbered. Before each sampling trip random numbers were used to select the squares representing the areas to be sampled.

Estimating jellyfish abundance

In the field sample sites were located by Global Positioning System. The sample sites chosen by randomly selecting grid numbers were areas rather than specific points. The point from which sampling started was dependent on the configuration of the sampling area (eg was some portion of the sample area too shallow for the sampling vessel to enter and so could not be included in the survey transect) and the prevailing conditions of wind and tide (which influenced the direction in which the sample was taken). While the sampling scheme was adhered to as closely as possible, weather conditions meant that it was not always possible to sample all the selected stations.

As in previous surveys (Hudson *et al.* 1997; Hudson and Walker 1998, 1999) the primary means of estimating abundance was by counting the numbers of jellyfish visible in the top few metres of the water column. For each sample the sampling vessel was driven slowly in a constant direction for 0.25 nautical miles (463 m). An observer stood on the bow of the sampling vessel and counted the jellyfish within an estimated 3 m of each side of the bow. Where it was not possible to steam for 0.25 nm in a constant direction (eg in the Franklin River) the distance was estimated from GPS marks, steaming time and visual clues. Where jellyfish were particularly dense the transect width was reduced to one or two metres.

On some occasions dense patches of jellyfish were encountered outside of the chosen sample sites. The numbers of jellyfish in these patches were estimated independently of the stratified random samples. The sampling vessel sailed around the edge of the patch, to plot its approximate size, and then counts were made along transects through the patch (adjusting the length or width of the transects as circumstances required).

During the first year of sampling the jellyfish net was extensively deployed throughout Port Phillip. The net was lowered with the codend closed by the exclusion grid. When the net was at the desired depth the mouth of the net was opened. At the end of the transect the mouth of the net was closed again and the net was retrieved. A small depth gauge was placed in the net and recorded the depth at which the net was set. It was possible to correlate the depth shown on the gauge with the number of turns of the winch used in setting the net and so, by varying the number of turns of the winch, the net could be deployed at any required depth.

Collection and treatment of samples

On each cruise jellyfish samples were collected using a dipnet. Samples were only taken where population density was relatively high and samples of around 100+ jellyfish could be collected rapidly (generally over a period of 40 to 90 minutes). Every effort was made to get a representative sample and to ensure that the proportion of each size in the sample was representative of the proportion of that size in the actual population. The jellyfish were kept in fishboxes on board the sampling vessel until they were processed onshore.

Onshore each jellyfish was weighed. The oral arms and viscera were removed and the bell was weighed. The diameter of each bell was measured to the nearest 0.5 cm. For this the bell was placed on a measuring board and the lappet (fringe around the edge) splayed out and included in the measurement. The presence of holes or deterioration of the bell and oral arms was noted

Generally a period of about 3 – 4 hours lapsed between the jellyfish being captured and being weighed and measured and by this time a lot of fluid and mucus had accumulated in the fishboxes. For some samples the weight of accumulated fluid was noted.

Analysis of data

The mean number of jellyfish per transect was determined. Because the total area of a transect and the total area of each stratum is known, it is possible to estimate the total number of jellyfish per stratum (which is the mean number of jellyfish per transect multiplied by the area of the stratum divided by the area of one transect).

Many statistical techniques, including those used in the present study, require that the data to which they are applied are normally distributed. Because the data (jellyfish per transect) were not normally distributed they were double-square root transformed (to induce a closer approach to normality) and calculations of total abundance and upper and lower 95% confidence intervals per stratum were performed on the transformed data. The data were then back-transformed to give real numbers for estimated abundance and confidence intervals. As an indication of total abundance and confidence limits for all strata sampled, the values per stratum were summed. Using square root transformed data reduces the spread between the lowest and highest values obtained (for jellyfish per transect) and produces lower estimates than does using untransformed data.

Relationships between bell diameter (in centimetres) and jellyfish weight (in grams) and between bell weight and total weight were established. The estimated total number of jellyfish was divided into size classes (measured as bell diameter) based on the proportion of each size class taken in size-frequency samples. Using the relationship between bell diameter and jellyfish weight, the total weight of all jellyfish was estimated. The total weight of commercial size jellyfish (those with a bell diameter of 23 cm or more) was estimated and, based on the relationship between total weight and bell weight, the total weight of all commercial size bells was estimated.

The biomass estimates for each month were based on the size-frequency samples and the size-weight relationships established for that month's samples. At the end of each season the slopes and elevations of regression lines relating size and weight were compared by analysis of variance. Some significant differences in size/weight relationships were found between areas and between months within areas. For this reason biomass estimates were not recalculated using pooled data. In using individual cruise results to estimate monthly biomass, the analysis follows the recommendation of Kingsford and Pitt (1998). These authors found statistically significant differences in size/weight relationships for samples from different locations and therefore recommended that these relationships should be calculated anew each time a biomass estimate is made.

Chemical analysis

Analyses for metals, total petroleum hydrocarbons, polycyclic aromatic hydrocarbons and organochlorine insecticides were carried out at the Marine and Freshwater Resources Institute. Analyses for tributyl tin were carried out at The Centre for

Advanced Analytical Chemistry (CSIRO).

Metal analyses were carried out using NATA accredited methods. Digestion and analytical procedures were based on UNEP/FAO/IAEA (1982) and NOAA (1993) methods. Jellyfish bells were freeze dried and then digested with hot concentrated nitric acid. Cadmium, copper, iron, nickel, and zinc in the diluted digests were determined by air-acetylene flame atomisation atomic absorption spectrometry (AAS) using matrix matched standards. Chromium was determined by nitrous oxide-acetylene flame atomisation AAS using matrix matched standards. Lead was determined by graphite furnace atomisation AAS with standards additions calibration. The mercury concentration in the acid digests was determined by cold vapour atomic absorption spectrometry AAS (Louie 1985). Arsenic was determined by hydride generation AAS. Reagent blanks and samples of fish standard reference material (National Research Council of Canada SRM DORM-2, dogfish muscle) were analysed with each batch of samples as a means of quality control.

Analysis of total petroleum hydrocarbons was carried out using NATA accredited methods. Jellyfish bells were homogenised and a subsample of about 50 grams was used for soxhlet extraction of the tissues, silica alumina clean-up of the extract followed by gas chromatography using mass spectrometry detection and quantitation by mixed standards calibration (UNEP/IOC/IAEA 1992). For quality control, known amounts of n-phenyldecane and n-phenylnonadecane were added to the sample and the amounts of these chemicals recovered by the extraction were noted.

For the analyses of polycyclic aromatic hydrocarbons and organochlorine insecticides jellyfish bells were homogenised. A subsample of about 50 grams was used for soxhlet extraction of the tissues, silica alumina clean-up of the extract followed by gas chromatography using mass spectrometry detection and quantitation by mixed standards calibration (UNEP/IOC/IAEA 1992). Although no specific quality control was carried out, two samples yielded unexpectedly high readings of polycyclic aromatic hydrocarbons. Replicates of these samples were analysed and provided the same results.

Sample preparation for the analysis of tributyltin was based on the procedure described by Gallina *et al.* (2000). Two composite samples were used, one consisting of 10 jellyfish bells from Corio Bay and one consisting of 10 jellyfish bells from Hobsons Bay. Each set of 10 bells was homogenised and then a subsample was digested with KOH at 60°C for 2 hours. Method blanks and spike recoveries were included in the sample preparation step.

Aliquots of sample buffered (pH 4.5) digest were captured onto Tenax. The ethylated butyltin species were thermally desorbed from the Tenax and analysed by GC-AAS (Bowles *et al*. 2002). The method was calibrated using matrix-matched standards and blanks.

Results of chemical analyses are reported as concentrations on a wet weight basis to allow comparison with maximum permitted concentrations (for metals) and maximum permitted residue limits (for pesticides) listed in the Australia New Zealand Food

Standards. (ANZFA 2001).

Results/Discussion

Some basic relationships between size and weight

Two basic relationships were used in estimating the biomass of *Catostylus mosaicus* from estimates of abundance. The relationship between $\log_{10}$ bell diameter and $\log_{10}$ total weight (Fig. 5) was used to calculate total biomass, and that between bell weight and total weight (Fig. 6) was used to estimate the total bell weight of all commercial size jellyfish (those with a bell diameter of 23 cm or more). The relationship between bell diameter and bell weight as a percentage of total weight (Fig. 7) was also investigated.

Regressions in which the r^2 value is less than 0.65 have little predictive power (Prarie 1996). The regressions relating bell diameter and total weight and relating total weight and bell weight are highly significant and have r^2 values in excess of 0.9. In contrast, while bell weight as a percent of total weight is significantly related to bell diameter r^2 values for regressions relating the two variables are low (<0.5).

Sampling cruises

A brief overview of the results of sampling (both visual counts along randomly selected transects and the collection of size-frequency samples) is presented in this section. Detailed results of sampling are given in Appendix 3 and results of chemical analyses are given in Appendix 4.

Sampling in Port Phillip in 2000

During January field trips were devoted to trialing the jellyfish sampling net and to making some minor modifications to improve efficiency and ease of handling. Extensive cruises were made throughout Port Phillip from February to May, and the net was deployed on all cruises. Almost no *Catostylus mosaicus* were seen throughout this period although in May the rhizostome jellyfish *Pseudorhiza haeckeli*, which is more typical of offshore waters, was abundant along the eastern coast. Because of the lack of *Catostylus* no size-frequency samples were taken and no abundance or biomass estimates were made.

The absence of *Catostylus* was not an artefact of using the net as the major means of sampling. Visual observations were made on all transects on which the net was used and also when travelling between sample stations. These observations revealed an almost total lack of jellyfish. There was also a lack of *Catostylus* in Western Port and in Corner Inlet in 2000, which indicates the the lack of *Catostylus* in Port Phillip was a reflection of a more widespread phenomenon.

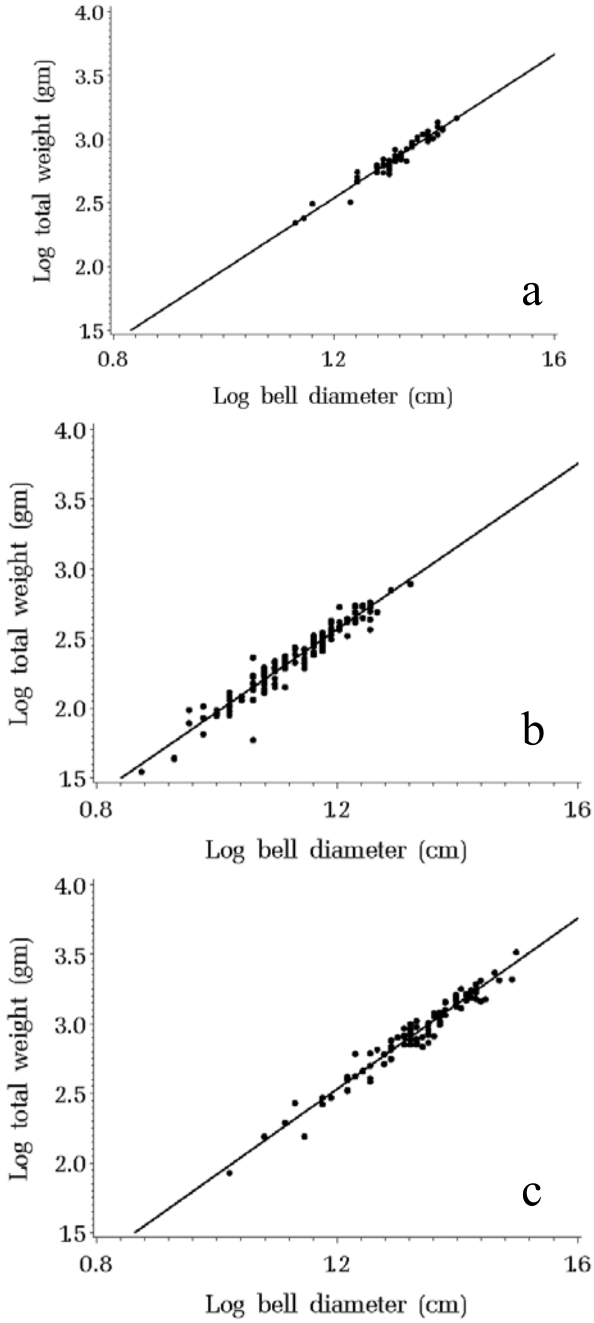


Figure 5. Examples of the relationship between $\log_{10}$ total weight in grams and $\log_{10}$ bell diameter in centimetres for *Catostylus mosaicus*.

a) collected from Port Franklin, Corner Inlet, in May 2002.
Log_{10} total weight = 2.813 x log10 bell diameter – 0.840 ($r^2 = 0.94$, $p < 0.0001$).
b) collected from Hastings, Western Port, in March 2001.
Log_{10} total weight = 2.983 x log10 bell diameter – 1.014 ($r^2 = 0.92$, $p < 0.0001$).
c) Collected from Corio Bay, Port Phillip, in April 2001.
Log_{10} total weight = 3.066 x log_{10} bell diameter – 1.150 ($r^2 = 0.95$, $p < 0.0001$).

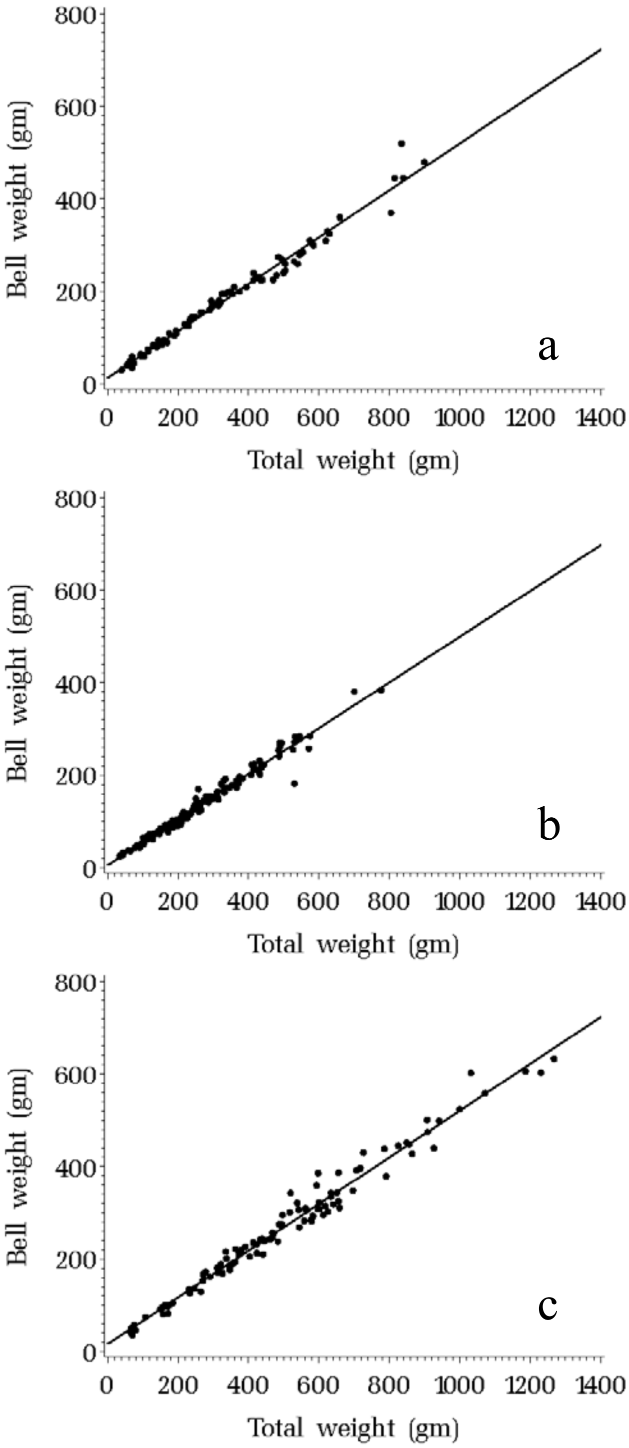


Figure 6. Examples of the relationship between bell weight in grams and total weight in grams for *Catostylus mosaicus*.

a) collected from Port Franklin, Corner Inlet, in April 2002.
Bell weight = 0.507 x total weight + 13.165 (r^2 = 0.98, p< 0.0001).
b) Collected from Hastings, Western Port, in March 2001.
Bell weight = 0.495 x total weight + 5.436 (r^2 = 0.97, p< 0.0001).
c) collected from Mordialloc, Port Phillip, March 2001.
Bell weight = 0.505 x total weight + 16.731 (r^2 = 0.95, p<0.0001).

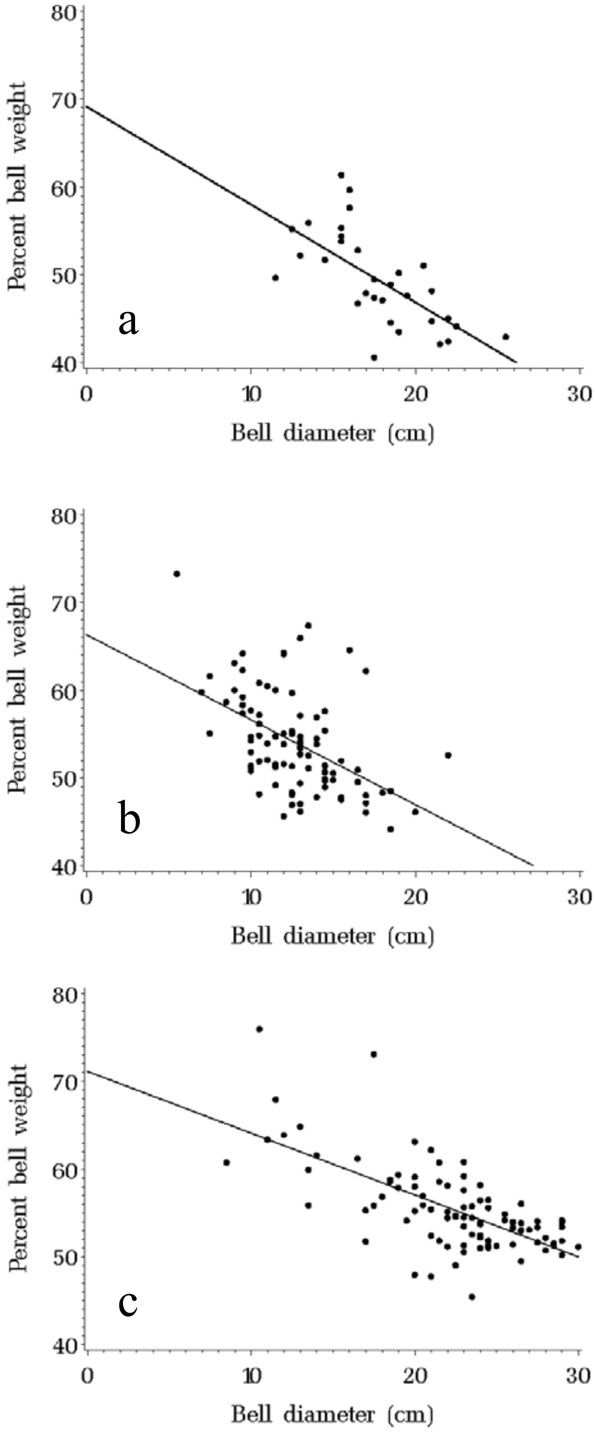


Figure 7. Examples of the relationship between bell weight as a percentage of total weight in grams and bell diameter in centimetres for *Catostylus mosaicus*.

a) collected from Port Albert, Corner Inlet, March 2002.
Percent bell weight = 69.159 – 1.114 x bell diameter in cm (r^2 = 0.44, p< 0.0001).
b) collected from Hastings, Western Port, in February 2001.
Percent bell weight = 66.341 – 0.969 x bell diameter in cm (r^2 = 0.25, p< 0.0001).
c) Collected from Corio Bay, Port Phillip, in June 2001.
Percent bell weight = 71.090 - 0.702 x bell diameter in cm (r^2 = 0.44, p< 0.0001).

Sampling in Port Phillip in 2001

During 2001 sampling relied entirely on visual counts made from a small boat. The use of a small boat, as compared to a trawler, meant that field trips could be completed more rapidly because of the faster speed of the smaller vessel and because no time was spent in deploying and retrieving the net. The use of a small vessel also reduced costs both because field trips were completed more rapidly and because the cost of operating the smaller vessel was less than that of chartering a trawler.

Because so few *Catostylus* had been seen during 2000, no random transect counts were carried out during the first cruise in January 2001. Instead strata 1, 2 and 4 were systematically searched for jellyfish.

From February to June stratified random sampling was carried out throughout Port Phillip although, because of weather conditions, it was not always possible to sample each stratum in each month. *Catostylus* were abundant during this period, particularly in Corio Bay and along the western and northern shores of the bay. Size-frequency samples were taken each month and biomass estimates were made.

The most consistent samples were taken from strata 1, 2, 3 and 4. They were taken from stratum 1 in all months from February to June and in strata 2 to 4 from February to May. Strata 5 to 8 were sampled less frequently because weather conditions prevented sampling in some months.

Numbers of jellyfish varied considerably between months but the highest numbers were clearly found in Corio Bay (stratum 1), the northern part of the Geelong Arm (stratum 2), the southern part of the Geelong Arm (stratum 4) and up the western shore of the bay (stratum 3) (Table 1). Numbers in the north (stratum 5) and east (strata 6 – 9) of the bay were considerably lower than those found in the west.

Table 1 Mean number of *Catostylus mosaicus* per transect in Port Phillip by stratum during 2001**.**

A dash indicates that no samples were taken.

Month	Stratum								
	1	2	3	4	5	6	7	8	9
February	109	5	14	43	2	0	1	0	-
March	49	75	42	8	26	10	14	0	0
April	110	33	2	3	-	-	-	-	0
May	208	295	5	138	6	3	11	0	-
June	150	-	-	-	-	-	-	-	-

The highest total biomass estimate was for May (Fig. 8). For strata 1 – 4 the total estimated weight was 4,549 tonnes. Strata 5 – 8 were also sampled in this month, and when the estimates for these strata are included the total weight was 4,754 tonnes, of which 3,013 tonnes was attributable to commercial size jellyfish. Lower and upper 95% confidence intervals were respectively 1,178 and 14,898 tonnes for all jellyfish and 746 and 9,440 tonnes for commercial size jellyfish.

In some months the proportion of commercial size jellyfish in the population (based on size-frequency samples) varied between different localities within the bay, but on average increased from 6% in February to 59% in June.

Typically, small medusae of *Catostylus* appear in Port Phillip in late spring or early summer, grow to sexual maturity over the following months and die out during late autumn and early winter. Sampling finished in June but fishers reported large jellyfish as present in Corio Bay throughout the winter. In November a brief survey of Corio Bay was undertaken. Small numbers of large *Catostylus* were seen. A few were sampled and ranged in size from 15 to 30 cm in bell diameter and in weight from 600 to 2,500 grams.

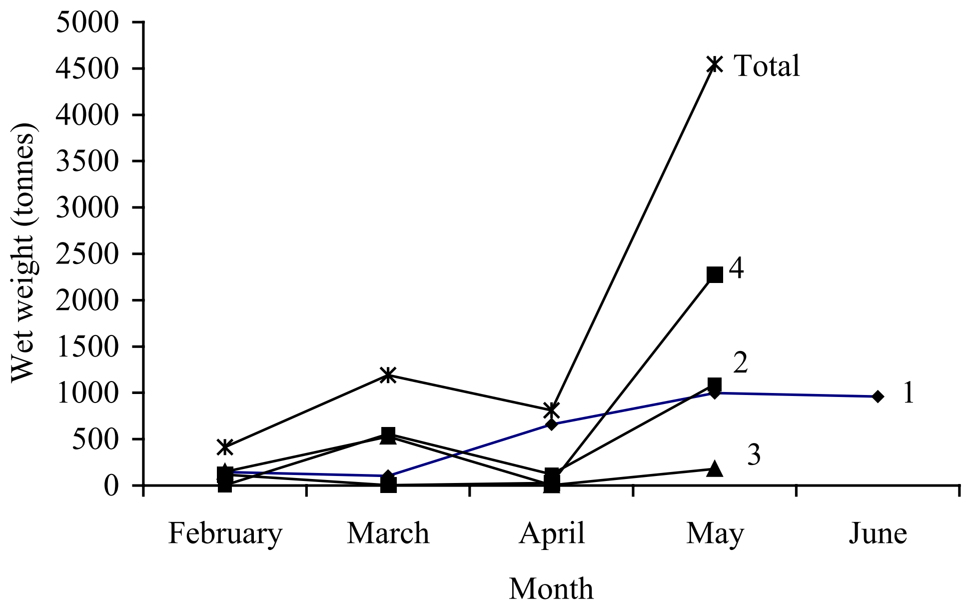


Figure 8. Estimated biomass of *Catostylus mosaicus* in Port Phillip, February to June 2001.

Estimates are for the total wet weight (tonnes) of jellyfish in strata 1 – 4 individually (lines 1 – 4) and in total (Total line) and are calculated from the mean number of jellyfish per transect.

Sampling in Port Phillip in 2002

Sampling was by stratified random sampling using visual counts made from a small boat. More days and sampling time were lost through bad weather than in the previous two seasons. *Catostylus* were present during the first three months of the year, though not as abundantly as in 2001, and samples in all months were dominated by large individuals. A trawler was chartered for April and May in order to re-trial the jellyfish net as a means of investigating the vertical distribution of jellyfish in the water column and of refining abundance estimates. However, by the end of April jellyfish had disappeared from Port Phillip and so no work with the net was possible. Size-frequency samples were obtained in January, February and March and biomass estimates were made for these months. The highest estimates of biomass were made in February and were 374 tonnes total wet weight (lower and upper 95% confidence intervals 13 and 418 tonnes respectively) and 62 tonnes (lower and upper 95% confidence intervals 8 and 247 tonnes respectively) for commercial size jellyfish.

Sampling in Western Port in 2000

There was no suitable boat that could be chartered in Western Port for using the jellyfish sampling net. Rather than pay the additional charter costs which would be involved in bringing a boat from Port Phillip, survey work in all years consisted entirely of visual observations made from a small boat.

Stratified random sampling was carried out between February and May. Few *Catostylus* were seen. Sufficient *Catostylus* for size-frequency sampling were found in the Hastings Channel in March and the Tooradin Channel in April, but their occurrence was very localised, all were much smaller than commercial size and no abundance or biomass estimates were made.

Sampling in Western Port in 2001

During January rough weather restricted sampling in the open waters of North Arm and East Arm to 2 transects in stratum 1 and 8 transects in stratum 2. No *Catostylus* were seen in stratum 1 and only 2 were seen in stratum 2. Additional searching was carried out in the sheltered areas of Tooradin Channel around Warneet, the Yaringa Boat Haven and Hastings Marina. Jellyfish, predominantly small and none of commercial size, were found in all of these locations.

During February and March stratified random sampling was carried out throughout Western Port. Size-frequency samples were taken and biomass estimates were made. No commercial size jellyfish were taken in the size-frequency samples. In February the estimate of biomass was 8 tonnes (lower and upper 95% confidence intervals 0.2 and 63 tonnes respectively) and in March it was 4 tonnes (with lower and upper confidence intervals of 0.1 and 22 tonnes).

During April only limited sampling could be undertaken in the open waters of North and East Arm because of bad weather. Only very small numbers of jellyfish were seen and no size-frequency samples were taken. Jellyfish were still relatively abundant in the sheltered waters of the Yaringa Boat Haven and a size frequency sample was taken here. The jellyfish were all small (4 – 14 cm bell diameter) and in poor condition.

During May a substantial area of the open waters of Western Port was surveyed. No jellyfish were seen.

Because of the low numbers of jellyfish seen in open waters in April and the failure to find any jellyfish in May, no sampling was undertaken in June.

Sampling in Western Port in 2002

Sampling was undertaken throughout the open waters of Western Port in January, February, April and May. Only very small numbers of jellyfish (<10 per cruise) were seen. A small, patch of jellyfish was found in the Tooradin Channel in May. Although the population density was high (845 individuals counted on one transect) all individuals were small (<10 cm bell diameter) and no commercial size individuals were seen. Because so few jellyfish had been seen in the open waters of North Arm and East Arm in previous months, no sampling was undertaken in June.

Sampling in Corner Inlet in 2000

Stratified random sampling was carried out throughout Corner Inlet in February, March and April. Few jellyfish were seen, although a small size-frequency sample (37 individuals) was collected in February. All were below commercial size. In May, because of the low numbers of jellyfish seen in previous months, random sampling was abandoned and active searching for jellyfish was carried out. No jellyfish were found. Several commercial fishers were contacted and all reported that they had seen no jellyfish. Because of the low numbers of jellyfish found throughout the season no abundance or biomass estimates were made.

Sampling in Corner Inlet in 2001

Random sampling was undertaken from January to June. Jellyfish were abundant and size-frequency samples were obtained from January to May. In June counts were made, and abundance was estimated, for jellyfish in strata 5 and 6. However, the abundance of jellyfish was low, no size frequency sample was taken and so no biomass estimate was made.

Although numbers varied considerably from month to month, jellyfish were found most consistently and abundantly in strata 1b, 2a, 2b, 5 and 6 (Table 2).

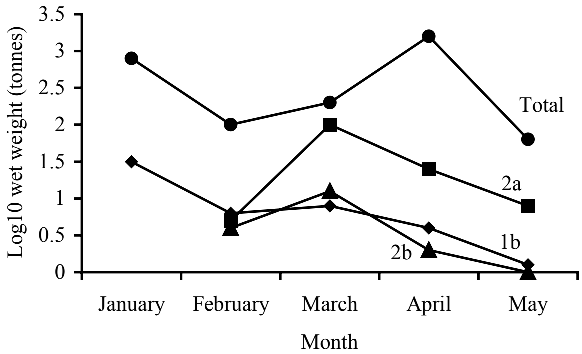
The months in which highest biomass estimates were made for these strata individually varied (Fig. 9) but for these strata combined the highest biomass estimate was made in April, mainly because of the very high estimate (1,459 tonnes) obtained for stratum 5. The highest biomass estimate for all strata sampled was also for April.

Table 2. Mean number of *Catostylus mosaicus* per transect in Corner Inlet by stratum during 2001.

A dash indicates that no samples were taken.

Month	Stratum								
	1a	1b	2a	2b	2c	3a	3b	4	5	6
Jan	-	-	80	-	-	-	-	-	255	-
Feb	0	37	35	21	0	-	-	7	96	16
Mar	2	231	358	15	6	4	1	3	67	19
Apr	1	10	53	3	2	1	1	1	405	32
May	0	2	19	3	1	0	6	1	27	13
Jun	-	-	-	-	-	-	-	-	1	1

Total biomass for April, claculated over all strata, was estimated as 1,540 tonnes (lower and upper 95% confidence intervals 712 and 2,990 tonnes respectively).



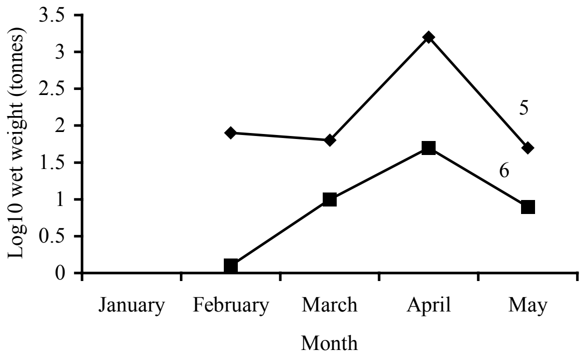


Figure 9. Estimated biomass of *Catostylus mosaicus* in Corner Inlet, January to May 2001.

Estimates are for the total wet weight (tonnes) of jellyfish in selected strata, as labelled, and for these strata in total and are calculated from the mean number of jellyfish per transect. Because of the wide range in biomass estimates, values are shown on a logarithmic scale.

The biomass of commercial size jellyfish was estimated as 339 tonnes (lower and upper 95% confidence intervals 147 and 660 tonnes respectively). The proportion of commercial size jellyfish was 13% in April, slightly lower than the highest proportion found, which was 14% in March.

In February, bay-wide random sampling produced an estimate of 6.7 tonnes of jellyfish for stratum 1b and an estimate of 106 tonnes over all strata sampled (Table 3).

By searching beyond the randomly selected transects, a small, dense patch of jellyfish was found at the mouth of the Toora Channel in stratum 1b. The area of the patch was estimated as 0.27 km^2. Counts were made on transects through the patch and the abundance and biomass of jellyfish in the patch were estimated (Table 4)

Table 3. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, February 2001.

Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	4	0	0	0	0	0	0
1b	6	134	13,165	105,480	0.1	6.7	54
2a	3	0	8,816	161,331	0	4.5	83
2b	4	7	7,688	170,828	<0.1	4	88
2c	4	0	0	0	0	0	0
4	4	7	8,221	183,382	<0.1	4.2	94
5	9	10,816	166,818	834,175	5.6	86	429
6	10	0	1,870	23,708	0	1	12
TOTAL	44	10,964	206,578	1,478,904	5.7	106.1	760
			Commercial size jellyfish			Commercial size jellyfish	
1a	4	0	0	0	0	0	0
1b	6	18	1,900	14,345	<0.1	2.2	17.4
					(<0.1)	(1.1)	(9.5)
2a	3	0	1,199	21,941	0	1.5	26
						(0.8)	(14)
2b	4	1	1,046	23,233	<0.1	1.3	28
					(<0.1)	(0.6)	(15)
2c	4	0	0	0	0	0	0
4	4	1	1,118	24,940	<0.1	1.3	30
					(<0.1)	(0.6)	(16)
5	9	1,471	22,687	113,448	1.8	27	137
					(1)	(15)	(75)
6	10	0	254	3,224	0	0.3	3.9
						(0.2)	(2.2)
TOTAL	44	1,491	28,094	201,131	1.9	33.6	242.3
					(1)	(18.3)	(131.7)

The patch of jellyfish contained an estimated 208 tonnes, thirty-one times as much as the estimate for the whole stratum and almost twice as much as estimated for all strata based on random counts. The confidence intervals for estimates made on the dense patch were also narrower than those made from the random transects because the counts made on transects through the patch were less variable than those from the random transects. Similarly, In April 2001 a dense patch of jellyfish was found in stratum 5 in Corner Inlet. The estimate of biomass in the patch was higher than that derived from random sampling for the stratum as a whole and the confidence intervals were lower (details in cruise report for April 2001 in Appendix 3)

Table 4. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in the aggregation found at the mouth of the Toora Channel, Corner Inlet, February 2001.

Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1b	4	165,602	267,618	410,782	128	208	319
			Commercial size jellyfish			Commercial size jellyfish	
	4	48,025	77,609	119,127	58	94	145
					(31)	(51)	(79)

Sampling in Corner Inlet in 2002

Stratified random sampling was carried out between January and May. No jellyfish were seen in January. From February to May sufficient jellyfish were encountered for obtaining size-frequency samples and biomass estimates were also made. Numbers of jellyfish were lower than in the previous year. Because of low numbers seen in the previous month, June's field trip took the form of active searching, rather than random sampling, for jellyfish. A small size-frequency sample was taken but because so few jellyfish were seen no abundance or biomass estimates were made. The highest biomass estimate was for May and was 50 tonnes total wet weight (lower and upper confidence intervals 0.8 and 390 tonnes respectively) and 18 tonnes (lower and upper 95% confidence intervals 0.2 and 142 tonnes respectively) for commercial size jellyfish.

Growth rates and size distribution of *Catostylus mosaicus*.

Kingsford and Pitt (1998) used modal analysis of size-frequency histograms to estimate growth rates of *Catostylus mosaicus* in New South Wales. Rates of growth varied but appeared to be linear and rapid over the first 50 – 100 days, within the range of 27 to 63 mm (bell diameter) per month, and slower, within the range 13 to 23 mm, after 100 days. There was little growth over the winter.

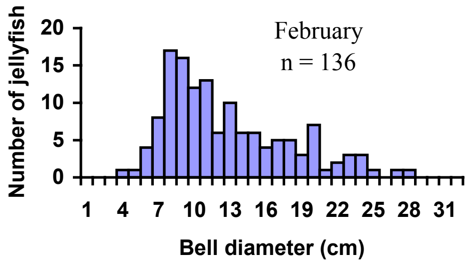
There were two major difficulties in using modal analysis in the present study. It was not always possible to obtain size-frequency samples from the same localities in consecutive months; and comparing histograms from different localities in successive months was not a valid approach since size-frequency distributions varied by locality even within the same water body in the same month. There were some localities from which size-frequency distributions were obtained in consecutive months, but there was no clear modal progression which could be used to estimate growth rate.

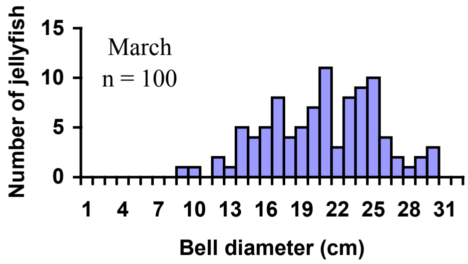
The size-frequency histogram obtained from Corio Bay in February 2001 (Fig. 10) covered a wide range of size classes and contained a high proportion of small medusae (diameter <10 cm). Through successive months to May 2001 the size range of jellyfish and the proportion of small individuals both decreased. This pattern continued into June but a group of small medusae, perhaps the result of a late release of ephyrae, was also collected in this month. The proportion of commercial size individuals increased from 7% in February to 61% in May and was 59% in June.

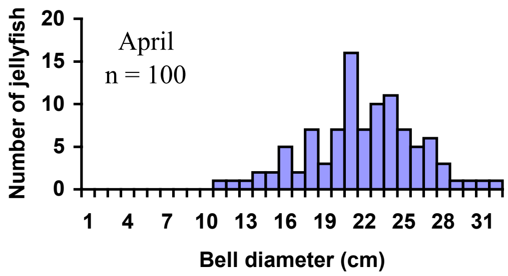
The pattern revealed by the histograms is therefore consistent with a spring release of ephyrae larvae which are recruited as small medusae in early summer and grow through to autumn.

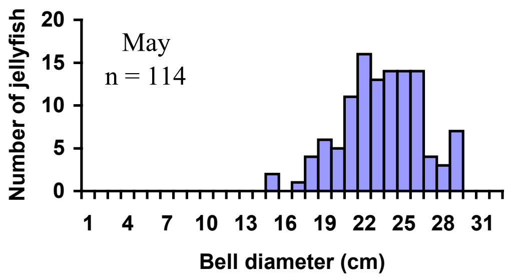
Histograms were not clearly unimodal, particularly those for February to April and so could not be readily used to estimate growth rates. The lack of a single, progressing mode might indicate a successive release of ephyrae and recruitment of medusae to the population, or could indicate that the population is composed of a mixture of medusae from areas where growth rate has differed slightly. There were successive peaks at 21mm, 22mm and 24mm in April May and June, and if these represent a true progression of modes would suggest growth rates within the range of those indicated by Kingsford and Pitt (1998).

The situation for Corio Bay in 2002 was quite different. Because of the smaller numbers of jellyfish than in 2001 only two size-frequency plots were obtained and these were for January and March (Fig. 11). Although the size range was larger in January than in March, in neither month were any small (<10 cm diameter) jellyfish found. The jellyfish sampled in March were generally smaller than those found in January and the mean diameter of the jellyfish sampled decreased from 24cm in January to 20 cm in March. The proportion of commercial size individuals decreased from 70% in January to 27% in March.


February
n = 136
Number of jellyfish
Bell diameter (cm)


March
n = 100
Number of jellyfish
Bell diameter (cm)


April
n = 100
Number of jellyfish
Bell diameter (cm)


May
n = 114
Number of jellyfish
Bell diameter (cm)

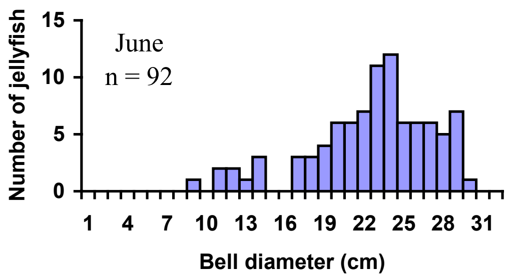
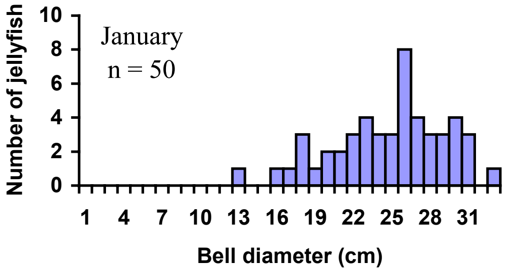

June
n = 92
Number of jellyfish
Bell diameter (cm)

Figure 10. Size-frequencies of *Catostylus mosaicus* in Corio Bay, February to June 2001.



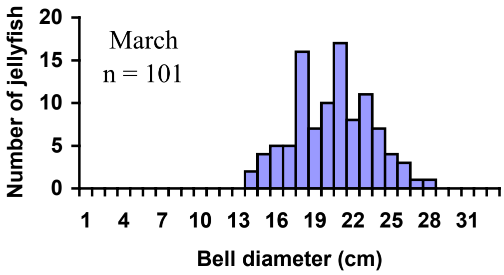


Figure 11. Size frequencies of *Catostylus mosaicus* in Corio Bay, January and March 2002.

Samples taken around the Franklin River in Corner Inlet showed similar patterns to those seen in Corio Bay. During 2001 there was no clear progression of modes from which growth rate could be inferred (Fig. 12). The smallest individuals were found in January and the proportion of commercial size jellyfish increased from 1% in January to 10% in April.

In 2002 the biggest size range and the largest individuals were found in early February (Fig. 13), although no very small individuals were found in any month. The highest proportion of commercial size individuals, 31%, was found in February. No commercial size individuals were found in April although in May 25% of individuals were commercial size. The tallest modes in late February, April, May and June were at 16, 17, 20 and 22 cm. respectively. If these indicate growth rates, the rates would be similar to those reported by Kingsford and Pitt (1998). The lack of small individuals, especially at the start of the season, suggests a failure in the production or recruitment of medusae.

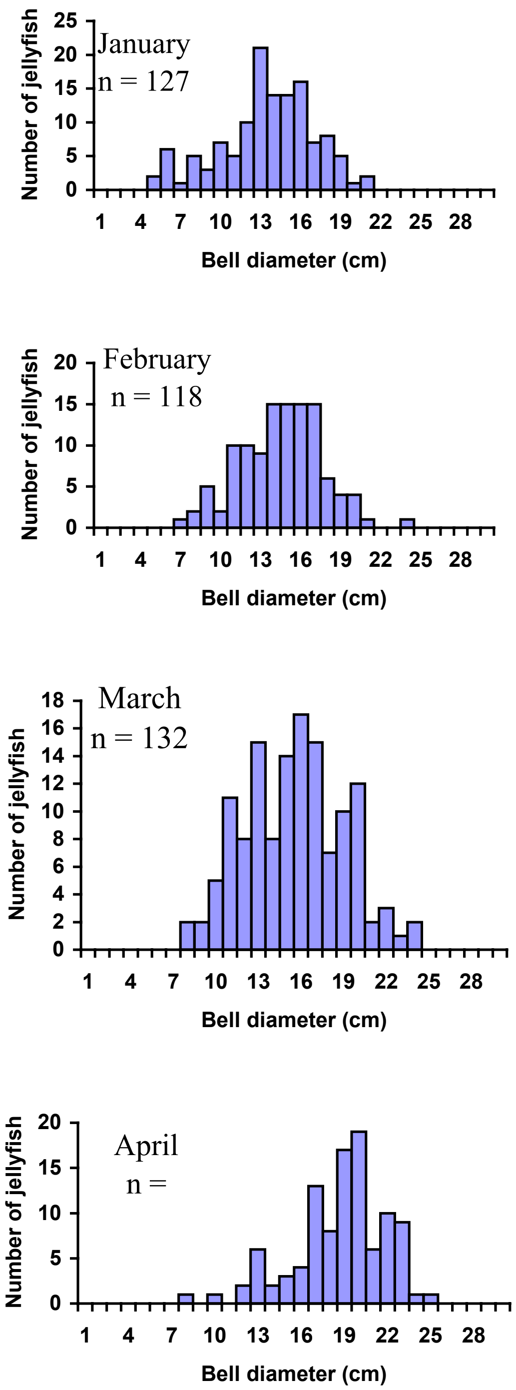


Figure 12. Size frequencies of *Catostylus mosaicus* from the Franklin River, Corner Inlet, January to April 2001.

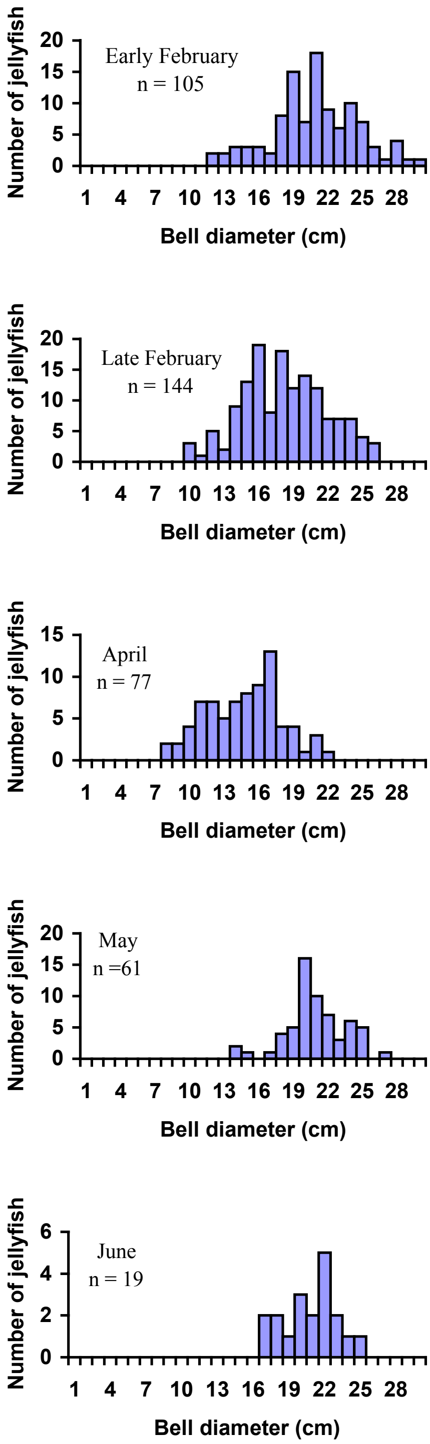


Figure 13. Size frequencies of *Catostylus mosaicus* from the Franklin River, Corner Inlet, February to June 2002.

In both 2001 and 2002, as well as in the earlier surveys reported by Hudson *et al* *(*1997) and Hudson and Walker (1998; 1999) large *Catostylus* were found at the start of the season. Hudson *et al.* suggest that these large individuals might have immigrated from elsewhere. A more probable explanation is that the large individuals seen at the start of the year were survivors from the previous year. There was clear evidence that some individuals survived through the winter of 2001. Local fishers in Port Phillip reported that occasional large jellyfish were seen during the winter months and large individuals were found on a trip to Corio Bay in November 2001.

The presence of large individuals which had survived from the previous year would explain why, as in both Port Phillip and Corner Inlet in 2002, the largest individuals and the greatest proportion of commercial size individuals could occur at the start of the season. If these only survived a month or two into the new season, the size of the largest individuals would decrease during the early part of the season, as over-wintering individuals died out, and then increase again as the new season's medusae continued to grow (cf Fig. 13).

Other possible explanations for the occurrence of large individuals early in the season are that there is some liberation of ephyrae in advance of the major production of medusae or that there is some over-wintering of ephyrae larvae which then reach a large size in advance of a major liberation of ephyrae in spring. Fancett (1986) found ephyrae of *Catostylus mosaicus* to be present in Port Phillip between September and March suggesting that liberation of ephyrae may occur from late winter or early spring through to autumn. In a study of jellyfish in the North Sea, Hay *et al*. (1990) found evidence for the overwintering of medusae. They reported that while ephyrae larvae are typically produced in spring and grow to maturity during summer, ephyrae may also be produced in autumn and over-winter.

General patterns of abundance and biomass.

The surveys carried out from 2000 to 2002 revealed considerable variation in jellyfish abundance and biomass. So few jellyfish were observed in 2000 that no abundance or biomass estimates were made. In subsequent years jellyfish were most abundant between January and June although the months when jellyfish were found and the length of the season varied between years. Jellyfish were abundant in Port Phillip and Corner Inlet during 2001. In 2002 they were less abundant than in 2001 but more abundant than in 2000. Few jellyfish were found in Western Port in either 2001 or 2002

Despite the large variations in abundance and biomass shown by the present work, and large variations shown in previous surveys (Hudson *at al.* 1997; Hudson and Walker 1998, 1999), the results of the present and of the earlier studies are generally consistent. This is particularly true for Port Phillip, the area for which most data exist.

During the present study, as in the earlier surveys, jellyfish were most consistently and abundantly found in Corio Bay and the Geelong Arm, along the western shore of the bay and in the north of the bay (strata 1 – 5 in the present study) and were absent or of lesser abundance along the eastern shore.

As in the surveys by Hudson *at al.* (1997) and Hudson and Walker (1998, 1999), biomass estimates in the current study had a large degree of uncertainty associated with them, although in the present work this uncertainty has been quantified by the addition of 95% Confidence Intervals to the estimates. However, it appears that jellyfish biomass during the last three years has not approached that seen in Port Phillip in 1997. In the present study, the maximum estimates for Corio Bay and the north of the Geelong Arm were for May 2001 and were 999 tonnes (or 3,638 tonnes if the upper 95% Confidence Interval is accepted) for Corio Bay, and 1,090 tonnes (upper Confidence Interval 5,177 tonnes) for the northern Geelong Arm. Highest estimates for these areas in 1997 were respectively 7,987 tonnes and 17,782 tonnes. The highest estimate for the western shore in the current study was 530 tonnes (upper Confidence Interval 1,760 tonnes) in March 2001 as compared with a maximum estimate of 14,805 tonnes in 1997.

Caution needs to be exercised in comparing the results of the present work with the earlier surveys carried out in Port Phillip. Although the authors (Hudson *et al*. 1997; Hudson and Walker 1998, 1999) of the earlier studies comment that numbers of jellyfish per transect were very variable, they do not appear to have carried out any transformation of the data before estimating abundance and biomass. In the present study the data have been (double square root) transformed, a procedure commonly applied to highly variable data which is not normally distributed. A few comparisons based on transformed and untransformed data from the present study indicate that biomass estimates from transformed data may only be 20% to 50% of those made from untransformed data. Some of the differences between estimates for 1997 and those for 2001 may result from whether or not transformed data was used; but even if the values for 1997 are reduced to 20% of those given, they still show biomass to have been greater in 1997 than in 2001. As a direct comparison with the earlier data, the highest values obtained in the present study were recalculated using untransformed data. The estimate for Corio Bay in May 2001 using untransformed data is 2,425 tonnes (upper Confidence Limit 6,490 tonnes), for the northern Geelong Arm in May 2001 is 3,216 tonnes (upper Confidence Limit 7,865), and for the western shore of Port Phillip in March 2001 is 2,156 tonnes (upper Confidence Limit 5,177 tonnes).

Surveys of Western Port in 1998 found only small numbers of small jellyfish in poor condition and no quantitative sampling was undertaken (Hudson and Walker 1998). A survey in 1999 found sufficient jellyfish, including a few of commercial size, in the North Arm to take quantitative samples and make an estimate of biomass (236 tonnes) but only small numbers of jellyfish, for which no abundance or biomass estimates were made, in the East Arm (Hudson and Walker 1999).

A general lack of jellyfish and low biomass estimates also characterised the surveys of Western Port carried out in the present study. Jellyfish were infrequent in the strata sampled although additional searching in the Yaringa boat haven (a private marina) and the inlets at Warneet and Tooradin did reveal small patches of immature jellyfish. No commercial size jellyfish were collected throughout the present study period. The largest jellyfish measured in 2001 was 22 cm in diameter and in 2002 the largest measured jellyfish was 12.5 cm in diameter. The largest biomass estimate was 8 tonnes (upper Confidence Interval 63 tonnes) in February 2001. Recalculated using untransformed data the highest biomass estimate becomes 137 tonnes (upper

Confidence Limit 295 tonnes).

The present surveys of Corner Inlet were much more extensive than those carried out by Hudson and Walker (1999), covering a wider area of the inlet and extending over 3 years. Nevertheless the same general patterns of distribution were apparent as were seen in the earlier work, and these patterns were consistent from year to year (in so far as this was discernible given the great variation in abundance from year to year).

Jellyfish were consistently most abundant in strata 1b (the Toora Channel), 2a (the Franklin River Channel into which the Franklin River opens), 2b (the Stockyard channel, adjacent to the Franklin River Channel and connecting to the mouth of the Franklin River), stratum 5 (into which the Albert River flows) and stratum 6 (adjacent to stratum 5) (Table 2). During 2000, the few jellyfish that were observed were adjacent to the Franklin and Albert rivers.

Although more extensive than the previous surveys of *Catostylus* undertaken in Port Phillip, Western Port and Corner Inlet, the present study has revealed both the same general patterns of distribution and the great levels of regional and annual variation in jellyfish abundance and biomass as were shown in the earlier surveys.

In contrast with the previous work (which concentrated mainly on Port Phillip), all three areas have been extensively surveyed with results showing that abundance and biomass are highest in Port Phillip and lowest in Western Port. The current developmental management plan for the fishery has total allowable catches (total wet weight of commercial size jellyfish) of 1,200 tonnes for Port Phillip, 100 tonnes for Western Port and 100 tonnes for Corner Inlet. Survey results indicate that a biomass of commercial size jellyfish equivalent to or exceeding the catch limit was present in Port Phillip and Corner Inlet in 2001 but not in 2002, and was not present in Western Port in any of the survey years.

Although six years of survey work have shown the same general patterns of distribution, the reasons for these patterns are not clear. In Corner Inlet there is an association of jellyfish distribution with freshwater input. In Western Port small jellyfish were commonly found in the Tooradin Channel and the Warneet channel, both areas which receive freshwater, and in Port Phillip jellyfish were commonly found around the mouth of the Werribee River. *Catostylus* has also been collected from the Yarra and Marybinong rivers in association with other studies undertaken by the Marine and Freshwater Resources Institute (Dr G. Parry, Marine and Freshwater Resources Institute, personal communication).

An association between *Catostylus mosaicus* and freshwater input has previously been reported. Although noting that *Catostylus* has a wide salinity tolerance (of 12 – 39), Kingsford and Pitt (1998) found that in some areas of New South Wales medusae were consistently more abundant close to rivers and also found that peaks in recruitment followed periods of heavy rain. They therefore suggest that freshwater may have a positive influence on the abundance of *Catostylus*.

Associations between *Catostylus*, freshwater and rainfall may partly explain annual fluctuations in abundance. The period from about 1996 to 1999 was one of the driest ever recorded for much of Victoria. The lack of *Catostylus* during 2000, and the reduction in numbers seen in the years prior to this, may possibly have been related to low rainfall and high salinity from 1996 onwards. There was increased rainfall during winter and spring 2000 and there were abundant jellyfish during 2001. However, there were few jellyfish again during 2002 although rainfall was not lacking during the autumn winter and spring of 2001. After examining data collected between 1785 and 1985, Goy *et al*. (1989) found that rainfall, along with temperature and atmospheric pressure, could be used to predict the occurrence of the jellyfish *Pelagia noctiluca* in the Mediterranean Sea. In this case lack of rainfall, coupled with high temperature and atmospheric pressure, appeared to be conducive to the occurrence of the jellyfish, probably because fine weather during the reproductive period was favourable to reproduction and to larval survival.

There may be a balance between too little and too much freshwater input since Lu *et al*. (1989 – quoted in Kingsford *et al.* 2000) found that while there was a positive correlation between riverine input and the edible jellyfish *Rhopilema esculentum* in Liaodong Bay, China, excessive freshwater input was associated with a decline in jellyfish abundance. The deleterious effects of low salinity may affect the medusoid or the polypoid stage. The absence of medusae of *Phyllorhiza punctata* from the Swan-Canning River estuary in Western Australia during the winter months is because winter rains reduce the salinity of the surface waters below that at which the medusae can survive (Rippingale and Kelly 1995). Salinity remains higher in the deeper (>5m) parts of the estuary and the scyphistoma stage can survive here over winter and produce ephyrae larvae the following spring as the temperature and the salinity of surface waters increase.

Laboratory experiments have indicated an interaction between salinity and temperature and the ability of scyphistomae to survive and reproduce. Scyphistomae of *Phyllorhiza punctata* died at salinities of or below 5 and were inactive at a salinity of 10. Above this level feeding and reproductive activity increased as temperature and salinity increased. Below a temperature of 20^{o}C the increase in activity was more marked at salinities of 20 and 25 than at 15 (Rippingale and Kelly 1995). The production of medusae by benthic polyps of *Chrysaora quinquecirrha* (a species found in North America) is also influenced by interactions between salinity and temperature. Laboratory experiments showed that the production of polyps and ephyrae from benthic polyps of *C. quinquecirrha* was reduced at the lowest (<11) and highest ($\geq$25) salinities tested and that temperature was not a significant factor in increasing ephyrae production at low salinities (5 – 20) but was a significant factor at high salinities (20 - 35) (Purcell *et al*. 1999).

However, while there is a clear association between the distribution of *Catostylus mosaicus* and freshwater input, and positive associations between other jellyfish species and freshwater have been reported, two areas of Port Phillip, Corio Bay and the Geelong Arm, which had relatively high numbers of jellyfish are areas where there is no extensive freshwater input.

While *Catostylus* may be found in New South Wales in all months of the year (Kingsford and Gillanders 1995; Kingsford and Pitt 1998) the occurrence of *Catostylus* medusae in Victoria, apart from some very limited capacity for overwintering, is clearly seasonal, although the length of the season varies. Fancett (1986) notes that *Catostylus* is at its southern limit in Port Phillip and suggests that low temperatures might be responsible for the disappearance of medusae over the winter. While this may be so, there is no indication that the shorter period over which *Catostylus were* seen in 2002 compared with 2001 is due to cooler autumn temperatures in 2002 (Table 4). Although there are regional variations in temperature within Port Phillip, mean temperatures, measured at the jellyfish sampling stations were, on average, slightly higher in April and May 2002 than in the corresponding months of 2001.

Table 5. Mean temperatures (^{o}C) at stations surveyed for jellyfish in Port Phillip.

A dash indicates no measurements were taken.

Year	Month					
	January	February	March	April	May	June
2000	-	21.8	20.4	19.2	15.8	-
2001	23.1	22.6	18.6	17	15.0	13.0
2002	19.1	19.4	19.5	18.2	16.3	-

The size of jellyfish, as well as population abundance, also varies considerably between years. During the period 1997 to 1999 there appears to have been a gradual decline in the maximum size of the jellyfish in Port Phillip. In 1997 and 1998 jellyfish over 30 cm in diameter were not uncommon and the largest jellyfish measured were over 40 cm in diameter. During 1999 few of the jellyfish measured exceeded 25 cm in diameter and none were 30 cm or more. The mean size of jellyfish captured in 1999 was 62% of that of the jellyfish captured in 1998 and 52% of that of the jellyfish captured in 1997 (Hudson and Walker 1999). During the present study the largest jellyfish measured during 2001 were 31.5 cm in diameter and only 1% of all the jellyfish measured were 30 cm or more in diameter. In 2002 the largest jellyfish measured was 33 cm in diameter. Only 2% of all jellyfish measured were 30 cm or more in diameter and these were all found in January and so had probably survived from the previous year. The reduction in size that occurred between 1997 and 1999 therefore appears to have persisted to the present time.

Annual variations in size are also found in the jellyfish *Aurelia aurita*. Schneider and Behrends (1994) report that in years when the population density of *A. aurita* in the Kiel Bight is high, medusa size is smaller than in years when abundance is low. They suggest that competition for food is the main factor governing size, with perhaps some minor effect due to temperature. Lucas (2001) reports that although inter-annual differences in size have been reported for *A. aurita* in Southampton water, a density-dependent relationship between abundance and size is not readily apparent. The lack of an obvious relationship between abundance and size suggests that factors in addition to food availability regulate size and population density. The small size of medusae in 1992 is suggested as being due to their appearance early in the year when a combination of low temperatures and low food availability would limit growth. Growth may also cease if energy is allocated to reproduction rather than to increase in size (Hansson 1997). The production of larvae also appears to be related to population density. In years when the abundance of *A. aurita* is high, relatively few larvae with a high organic weight and relatively high food stores are produced, and in years when the abundance of medusae is low they produce a high number of larvae of low organic weight (Schneider 1988).

The factors that have led to the apparently smaller size of *Catostylus mosaicus* in Port Phillip since 1997 are not clear, but are not obviously density dependent since abundance and biomass were higher in 1997 than in subsequent years.

Deterioration of jellyfish bells

As winter approaches, jellyfish are increasingly found in poor condition, with holes and cracks or fissures in the bell. While imperfections in the bell may affect the commercial value of the product, some jellyfish were encountered which simply disintegrated on capture or handling and these would be lost to processing entirely. The occurrence of a high proportion of individuals showing deterioration is often an indication that the demise of that population is imminent (Benjamin Ding, Director, David Glory Group, personal communication).

Jellyfish were most abundant in 2001. As a result the most size-frequency samples were obtained and it is the samples from this year, and particularly from Port Phillip and Corner Inlet, where jellyfish were most consistently found, which gave the best indication of seasonal deterioration in jellyfish bells (Table 6). In Port Phillip the incidence of bells showing holes or other deterioration clearly increased between January and May. The proportion of bells showing deterioration was always higher in Corner Inlet than in Port Phillip. The results presented are bay or inlet wide, but in Corner Inlet there were clear regional differences in the incidence of deterioration in some months. In March 2001 none of the jellyfish collected at Port Franklin and Toora showed deterioration but 78% of the non-commercial and 66% of the commercial jellyfish collected at Port Albert showed deterioration. The few samples collected in Western Port also showed regional differences in the incidence of deterioration. In March 2001 the incidence of deterioration was about 3.7% at Yaringa and 35% at Hastings.

Deterioration is associated with a pathogen which has been identified, by Department of Primary Industries, Water and Environment, Tasmania, Animal Health Laboratory, as *Photobacterium damselae ssp damselae*, a pathogen with a wide range of hosts including finsfish, lobsters, crabs and abalone Whether infection by the pathogen is the primary cause of deterioration, or whether infection is a secondary result of deterioration due to other causes, such the ageing of the population or the onset of less favourable environmental conditions, is not known.

Table 6. Prevalence of deterioration in jellyfish bells by area and by month.

Results are based on examination of jellyfish in size-frequency samples. The first value for each entry is the percentage of non-commercial size jellyfish showing deterioration and the second value is the percentage of commercial size jellyfish showing deterioration. NS indicates that no sample was taken.

Area	Month					
2001	January	February	March	April	May	June
Port Phillip	0,0	0,0	10,15	20,24	53,26	16,10
Corner Inlet	0,0	0,0	22,33	38,38	96,100	NS

In addition to deterioration of the bell, some individuals were observed in which oral arms were missing or in which the arms were very short and stumpy. In such individuals the bell counted for an unusually high proportion of the total weight.

An association was observed between *Catostylus mosaicus* and the isopod *Cymodoce gaimardii*. Frequently, after jellyfish had been stored in a fishbox and then removed to be weighed and measured, the isopods were present in the fishbox. In one instance an isopod was observed nestling in the space between the ventral surface of the bell and the attachment of the oral arms. *Cymodoce gaimardii* is a relatively common benthic species and the exact nature of the relationship with *Catostylus* (eg whether it is parasitic, symbiotic or of some other nature) has not been determined. Associations between jellyfish and isopods appear to be rare although one such a relationship has previously been described (Barham *et al*. 1969).

Problems in obtaining precise estimates of abundance and biomass

Difficulty in obtaining precise estimates of abundance is a consistent feature of studies on *Catostylus mosaicus*. Hudson *et al.* (1997) and Hudson and Walker (1998, 1999) remarked that 'great uncertainty' was associated with their biomass estimates for *Catostylus mosaicus*. Kingsford and Pitt (1998) note that large standard errors were associated with their estimates of the abundance of *Catostylus* in New South Wales. Similarly, the estimates made in the present study were not very precise, frequently having wide confidence intervals associated with them. Because jellyfish may show a highly aggregated distribution, the counts of abundance (ie jellyfish per transect) on which calculations of biomass are based may vary by several hundred to a thousand or more. This wide variation in counts results in a lack of precision in abundance estimates and therefore a lack of precision in biomass estimates.

Many statistical techniques require that the data to be analysed is normally distributed. Because the raw data for estimating total abundance (ie counts of jellyfish per transect) was not normally distributed, a double square root transformation was applied. The transformation produced a distribution which more closely approached the normal and also reduced the spread of values. Analysing the transformed data produced estimates of abundance which were approximately 20% to 50% of those obtained from analysing the raw data, and reduced the 95% confidence intervals although these were still fairly wide.

An obvious way to improve precision in future surveys of Port Phillip, Western Port and Corner Inlet using the methodology employed in the present study is to increase the number of samples taken. However the amount of sampling that can be undertaken for any survey is generally limited and the question that arises is how best to use the sampling capacity that is available.

Whether or not aggregations of jellyfish are encountered during random sampling has a considerable effect on estimates of abundance and biomass estimates (as seen from sampling in Corner Inlet during February and April 2001). To guard against the possibility that random sampling has been insufficient to detect aggregations, additional searching for aggregations could be undertaken. This can be accomplished fairly rapidly using a small vessel and visual observations. Aggregations that are found can be surveyed and the results incorporated into the final assessment of abundance and biomass.

An alternative approach might be to abandon random sampling in favour of searching for and sampling only aggregations. Sampling aggregations would provide estimates with narrower confidence intervals than those resulting from random sampling (because counts along transects within aggregations will be more uniform than counts along randomly selected transects). However, sampling aggregates would not provide statistically unbiased regional estimates. The estimates would refer only to the aggregates sampled and these are not permanent.

A redefinition of stratum boundaries might also be considered as a means of improving precision. The more homogeneous a stratum is (in relation to what is being sampled) the more precise will be the estimates made from sampling that stratum, other things being equal. The strata used in the current surveys were based on previous knowledge of jellyfish abundance. Patterns revealed by the present surveys are consistent with those reported previously and this finding, coupled with the extremely variable nature of jellyfish distribution, make it unlikely that strata can be redefined in order to make them more homogeneous with respect to jellyfish distribution. However, there might be some advantage in having fewer, larger strata.

For a given sampling effort, the more strata there are to be sampled, the fewer will be the samples allocated to each. The advantage of having samples divided amongst more, smaller strata is that data can be obtained on a regional basis. If the same number of samples is allocated to fewer, larger strata, resulting in an increased number of samples per stratum, the likelihood of estimates being heavily influenced by one or two extreme values is reduced. The trade off that has to be considered is therefore whether to have more strata and obtain regional estimates of abundance or fewer, larger strata, which may provide more precise estimates of abundance but provide less data on how abundance varies spatially.

Stratum size was a particular issue in Corner Inlet. Where strata incorporated intertidal areas intersected by subtidal channels they were further subdivided, effectively creating smaller strata (corresponding to the channels) each receiving only a small number of samples.

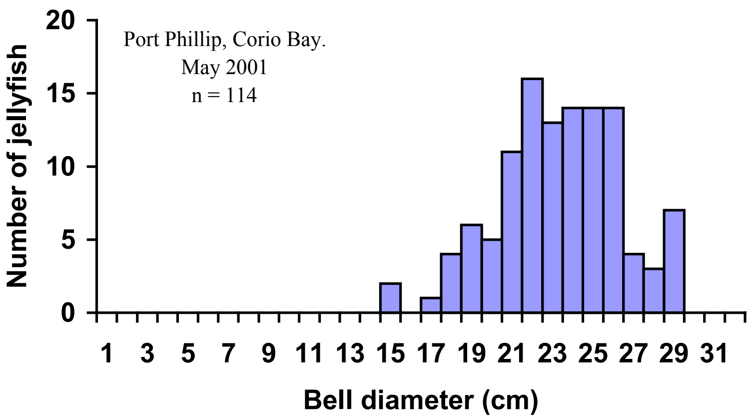
Apart from sampling effort and sampling strategy, which affect estimates of abundance and biomass, two other factors which may affect estimates of biomass are the size-frequency distributions of jellyfish in the areas sampled and factors affecting estimates of weight in relation to size.

In converting abundance to biomass, the estimated number of jellyfish is apportioned to size classes based on size-frequency data. On several occasions monthly samples taken from different areas in the same water body showed different size-frequency distributions. The question of how differing size-frequencies are used in biomass estimates needs to be considered because estimates made on the basis of different size frequencies may differ widely. For a bay-wide estimate of biomass it may be valid to combine different size frequencies, and if only one size frequency is obtained, this is all that can be used. But where two or more samples are obtained and show that there are regional differences, more accurate regional estimates will be obtained by using individual, not combined, size-frequencies.

For example, in May 2001 size-frequency samples in Port Phillip were obtained from two areas, Corio Bay and the northern part of Port Phillip (Fig. 14). The proportion of commercial jellyfish was 60% in the Corio Bay sample, 17% in the sample from the north of Port Phillip and 45% when the two size frequencies were combined.

If the combined size-frequency data is used, the proportion of commercial size jellyfish in Corio Bay and the Geelong Arm is under-estimated and the biomass of commercial size jellyfish is therefore also underestimated. Based on the size-frequency of jellyfish in Corio Bay the mean biomass estimate for commercial size jellyfish in the strata in Corio Bay and the Geelong Arm is 3,764 tonnes. Calculations based on the combined size frequency give a mean estimate of 2,768 tonnes, which is 996 tonnes, or 26%, lower than the estimate based on the Corio Bay size frequency.

Conversely, use of the combined sample over-estimates the proportion and therefore the biomass, of commercial jellyfish in the northern part of the bay (strata 5 and 6). Based on the combined size-frequency the mean biomass estimate for commercial size jellyfish in strata 5 and 6 is 47 tonnes. The biomass estimates using the size-frequency obtained in the north of the bay is 14 tonnes, which is 33 tonnes, or 70%, lower than the estimate based on the combined size frequency.



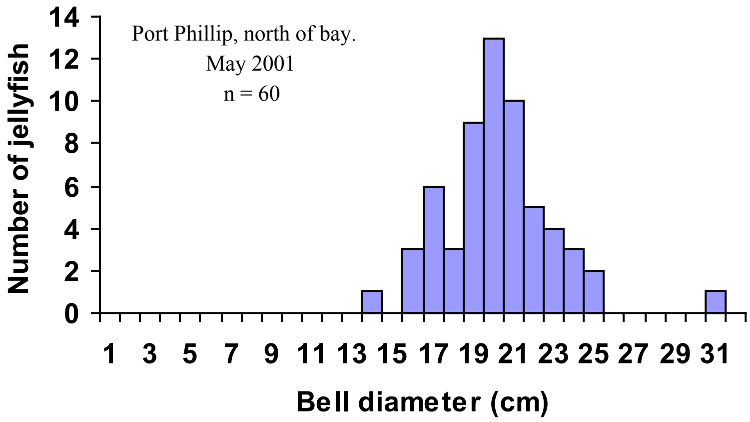


Figure 14. Size-frequency of *Catostylus mosaicus* at two localities in Port Phillip, May 2001.

A further factor which will affect estimates of biomass is any weight loss that may occur between the time that jellyfish are collected and the time that they are weighed. During the present study, *Catostylus mosaicus* were collected with a dipnet and stored in fishboxes. They were subsequently weighed on shore (which provided a more stable platform than the vessel used for sampling) using a battery-operated top-loading balance which was calibrated from time to time. Collection of jellyfish for size-frequency analysis and investigation of size/weight relationships was carried out as part of the sampling cruises to estimate jellyfish abundance. Depending on how long it took to collect sufficient jellyfish for a size-frequency sample, and whether this took place near the beginning or the end of the sampling cruise, a period of 3 to 4 hours could have elapsed between the capture of the first jellyfish and the start of weighing. During this period fluid drained from the jellyfish. To estimate how much weight loss might have occurred due to drainage of fluid, the weight of the fluid left in each fishbox at the end of weighing was determined and was related to the weight of the jellyfish taken from that box.

Based on the weight of drained fluid remaining in the fishboxes after the jellyfish had been weighed, jellyfish had lost about 10 – 20% of their weight by the time they were weighed (Table 7), and estimates of biomass may be accordingly underestimated. Factors influencing the level of weight loss were not investigated but are likely to include temperature, the time that elapses between jellyfish being captured and being weighed, and jellyfish size.

In their study of *Catostylus mosaicus*, Kingsford and Pitt (1998) state that jellyfish were measured in the field using spring balances that were frequently calibrated for accuracy but do not state whether any time elapsed between jellyfish being captured and being weighed. These authors describe jellyfish in New South Wales as weighing about 1 kg at 15 cm diameter, 2.5 kg at 20 cm diameter and 4 – 5 kg at the maximum size of 25 – 30 cm diameter. In the present study, Victorian *Catostylus* weighed much less at these sizes, being about 300 - 400g at 15 cm diameter, 700 g - 1 kg at 20 cm diameter and 2 – 3 kg at 30 cm diameter. Weights obtained during the current study were consistent with weights obtained during earlier studies of *Catostylus mosaicus* in Victoria (Hudson *et al.*1997; Hudson and Walker 1998, 1999). Actual comparisons of weight for size based on the formulas appearing in Hudson and Walker (1998), Kingsford *et al.* (2000), and derived during the present study are presented in Table 8.

Table 7. Estimates of weight loss due to fluid draining from jellyfish between the time that they were captured and the time that they were weighed

Sample location and date	Wt of jellyfish (kg)	Wt of fluid in fishbox (kg)	Total weight (kg)	Weight of fluid as % of total
Port Phillip Nov01	18.50	2.91	21.41	13.6
Port Phillip Nov01	19.53	2.56	22.09	11.6
Port Phillip Nov01	12.01	1.44	13.45	10.7
Port Phillip Jan02	24.22	5.00	29.22	17.1
Port Phillip Feb02	26.26	3.74	29.90	12.5
Port Phillip Feb02	24.44	5.98	30.42	19.7
Corner Inlet Feb02	25.37	5.68	31.05	18.3
Corner Inlet Feb02	22.06	5.0	27.06	18.5
Corner Inlet Feb02	22.87	5.16	28.03	18.4
Corner Inlet Feb02	21.34	4.78	26.13	18.3
Port Phillip Mar02	28.67	5.18	33.85	15.3
Port Phillip Mar02	26.20	4.13	30.33	15.8
Port Phillip Mar02	20.93	3.58	24.51	14.6
Port Phillip Mar02	22.30	4.16	26.46	15.7

Even if the assumption is made that jellyfish were measured immediately upon capture in the New South Wales study, and that no weight loss occurred prior to weights being taken, the differences in weight between jellyfish of a given size from New South Wales and Victoria are two to three-fold or more and are much greater than can be explained as due to any weight loss through drainage of fluid that occurred in the present study.

Table 8. Comparison of weight in relation to bell diameter for *Catostylus mosaicus* from New South Wales and from Port Phillip and Corner Inlet in Victoria.

Bell diameter is in centimetres. Weights are in grams and are estimated from regression equations.

Bell diameter	Locality			
	New South Wales[1]	Port Phillip[2]	Port Phillip[3]	Corner Inlet[4]
5	82	15	10	10
10	430	116	82	95
15	1134	376	286	348
20	2258	869	691	874
25	3853	1664	1369	1784
30	5961	2828	2394	3199

[1] Wet weight = 0.007x bell diameter(mm)$^{2.394}$ (Kingsford *et al.* 2000)
[2] Wet weight = 1.75x10^{-4} x bell diameter(mm)$^{2.91}$ (Hudson *et al.* 1998)
[3] Log$_{10}$wet weight= -1.1503 + 3.0664 x log$_{10}$bell diameter(cm), present study, April 2001
[4] Log$_{10}$wet weight= -1.2215 + 3.1998l x og$_{10}$bell diameter(cm), present study, Feb. 2002

Studies in New South Wales (Kingsford and Pitt 1998) indicated that the bell weight of commercial size jellyfish is 40% of total weight. However, results of the present work suggest that it is simplistic to assume a single conversion factor can be used to convert total biomass to bell biomass. While the relationship between bell weight as a proportion of total weight in the present study was not close, it was statistically significant. Bell weight as a proportion of total weight increased as size decreased and was commonly in the region of 46% to 53% for commercial size jellyfish. The actual biomass of bells yielded by a total biomass may therefore depend on the size-frequency of the jellyfish that are fished. The current developmental plan in Victoria sets the total allowable catch only in terms of total biomass. This makes sense if there is no single conversion factor for converting total to bell weight.

Irrespective of any assumptions made about the relationship between total weight and bell weight, it is important that the total allowable catch and catch reporting are made on the same basis. Kingsford *et al*. (2000) report that in New South Wales the allowable catch for jellyfish was set on the basis of total weight but fishers were reporting the catch as bell weight which (if not detected) could have resulted in them taking 2.5 times the intended allowable catch.

Traditionally it is the jellyfish bell which is processed. However, the oral arms can also be processed and at times, depending on market conditions, may be more commercially valuable than the bell (Tas Warne, local jellyfish fisher and processor). If the whole animal is to be processed, any concerns over potential pollution arising from the disposal of the oral arms are avoided.

Use of the jellyfish sampling net

The primary means of estimating jellyfish abundance in this study, as in studies in

NSW (Kingsford and Pitt 1998) and in earlier studies in Victoria (Hudson *et al*. 1997; Hudson and Walker 1998, 1999), was by making visual counts of jellyfish in surface waters. Where visibility was poor this meant counting jellyfish within the top 1m or less of the water column, but in many instances visibility through the water column was up to 6m.

However, it is known that jellyfish move up and down in the water column (Kingsford *et al.* 2000) and so one aspect of the study was to investigate whether more accurate population estimates could be made by sampling jellyfish from depths below those at which they could be counted from the surface. To this end the Australian Maritime College designed a sampling net that could be opened and closed. The ability to open and close the net is important since it means that the net can be employed at a particular depth and, by lowering the net closed, opening it at the desired depth and bringing it back to the surface closed, contamination of the sample by jellyfish at depths other than that sampled is prevented.

In practice, while the net could be successfully operated, it was not successfully used to improve the accuracy of abundance estimates.

During 2000 the net was widely used in Port Phillip but caught no jellyfish, presumably because of the virtual absence of jellyfish in that year. The net was not used in Western Port because of the general lack of jellyfish and because no suitable charter vessel was based in the bay, and it was not used in Corner Inlet because the water here is generally too shallow for the net to be used.

During 2001 jellyfish were plentiful, but in the absence of any abundance estimates from the previous year, the emphasis was on using visual counts to obtain abundance estimates. During 2002 the intention was to make a comparative study of abundance estimates made with and without the use of the net. A fishing vessel from which the net could be deployed was chartered for late April and early May, a period when jellyfish had been abundant in the previous year, but the cruise was cancelled because of the absence of jellyfish from Port Phillip Bay after March.

The use that was made of the net did suggest that it had a number of drawbacks as compared with just using visual counts to estimate abundance. The main drawbacks were inter-related and were those of cost and time. The size of the net was such that it could only be used from a commercial fishing boat. The cost of chartering a vessel capable of deploying the net was three to four times higher than that of running a small boat from which jellyfish abundance could be assessed visually. This extra cost was further compounded by the fact that use of the net increased the time required for the monthly surveys to be completed. The net was deployed while visual counts of jellyfish were made but the time required to deploy and retrieve the net meant that the time required to sample a transect was longer than if only a visual count had been made. In addition, the cruising speed of the trawler used in deploying the net was much lower than the speed of the small powerboat used when only visual sampling was undertaken. Taken together, handling time when the net was used, plus the slower cruising speed of the vessel from which the net was deployed, doubled the time for surveys to be completed as compared with the time required when doing counts from a small boat.

Because jellyfish are extremely patchy in their distribution many random visual samples contained no jellyfish and the resulting estimates of abundance had wide confidence intervals. The use of net sampling is unlikely to reduce the confidence intervals associated with abundance estimates since this method might also be expected to produce a high proportion of samples in which no jellyfish occur. Moreover, active searching for jellyfish is easy when they are at the surface of the water and can readily be seen, but it would not be so easy to search for sub-surface jellyfish using a net.

The problems of net use that have been discussed are not specific to the particular net designed for the present study but are likely to be encountered using any net that is of a sufficient size and adequate design to carry out sub-surface sampling of jellyfish. Kingsford and Pitt (1998) found that on calm days 92-98% of *Catostylus mosaicus* in Lake Illawarra were within 1 m of the surface. In many of the shallower areas of Port Phillip and Corner Inlet surveyed in the present work, the bottom was visible in depths of up to 6 or 7 m and jellyfish could be counted throughout the water column. Visual counts of jellyfish on calm, sunny days when they are likely to be within the top few metres of the water column probably remains the quickest and cheapest option for assessing abundance; and if some portion of the population is missed, because of murky water or because of jellyfish which are too deep to be visible from the surface, then the resulting underestimate of abundance could be considered as constituting a conservation measure.

Bycatch and other ecological considerations

The *Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*, administered by Environment Australia, came into force on 16 July 2000. Under this act assessment of the sustainability of a fishery must, in addition to considering impacts on the target species, also take into account the broader environmental implications of the fishery.

The fishery for *Catostylus* is a highly targeted one, with commercial size jellyfish being taken by dipnet (under the current management plan). Bycatch is therefore unlikely to be an issue. However the Victorian management plan does allow the use of a net to aggregate jellyfish. Kingsford *et al*. (2000) suggest that use of corralling nets could damage medusae. In addition, the use of nets would increase the chances of taking bycatch, at least temporarily until any individuals inadvertently confined within the net were released after all the commercial jellyfish had been taken by dip-net. Whether or not any damaged medusae would survive after release has not been studied. The survival rate amongst fish released from haul seining has been shown to be high (Knuckey *et al*. 2002) although any fishes confined in the presence of large numbers of jellyfish may suffer increased mortality. Environmental damage arising from the use of corralling nets is likely to be slight or non-existent. The disturbance to benthic communities of animals and plants by haul seining for bottom-dwelling fish species appears to be minor (Knuckey *et al*. 2002), and it is unlikely that confining jellyfish within a net, particularly if this is done within the top metre or two of the water will have any greater effect.

The role that *Catostylus mosaicus* occupies in food webs of local species is not known. Turtles and sunfish are known to eat jellyfish (Wells and Wellington 1992; Queensland Fisheries Service 2001) but these animals do not occur in Victoria (except as very occasional, chance visitors). Several species of leatherjackets are said to feed on *C. mosaicus* in New South Wales, Victoria and Tasmania (Coleman 1987) but there is no evidence for the consumption of *Catostylus* by fishes in Victoria. Diets of a wide range of fish have been investigated in Port Phillip (Parry *et al.* 1995; Officer and Parry 2000) and none have been found to consume jellyfish, although it is likely that jellyfish are rapidly digested and so the chances of finding them in gut samples are probably slight. Jellyfish may also be eaten by other jellyfish, sea anemones, cephalopods and crustaceans (Kingsford *et al*. 2000).

Besides being prey for various species, jellyfish may also play a structural role in the ecosystem and may influence other species through their role as predators (Kingsford *et al.* 2000).

A range of fish and invertebrate species are known to associate with jellyfish. The fish are predominantly juveniles, may receive protection from predation and may be able to feed on some of the food initially captured by the jellyfish (Hay *et al.* 1990). They may actively seek out jellyfish and their abundance may be related to the availability of jellyfish 'shelter space' (Hay *et al.* 1990). Jellyfish are voracious consumers of phyto- and zooplankton and the abundance and biomass of these planktonic organisms may be influenced by jellyfish abundance. Jellyfish may influence populations of larger fish either by consuming them while they are still in the egg or larval stage or by consuming the planktonic food on which they depend. The removal of zooplankton by jellyfish may reduce grazing pressure on phytoplankton which eventually increases sedimentation rates and, where water circulation is poor, may lead to an increased oxygen demand and eventual oxygen deficiency (Lindahl and Hernroth 1983). The carcases of jellyfish which die and sink to the sea floor will provide organic matter for benthic scavengers (Kingsford *et al*. 2000) but where large numbers of jellyfish are involved may increase oxygen demand (Lindahl and Hernroth 1983).

The ecological role of *Catostylus mosaicus* in Victorian embayments is unknown. Diets of the jellyfish *Cyanea capillata* and *Pseudorhiza haeckeli* have been studied in Port Phillip and include crustaceans, ascidian tadpoles, hydromedusae and fish eggs and larvae (Fancett 1988; Fancett and Jenkins 1988) and *Catostylus mosaicus* is reported to eat similar prey, generally within a size range (body length) of 1 to 3 mm (Queensland Fisheries Service 2001). Kingsford (1993) has shown that juvenile fish (*Trachurus* spp) are associated with *Catostylus mosaicus* in New South Wales and it may be assumed that there may also be some association between juvenile fish and *Catostylus mosaicus* in Victoria. The association between *Catostylus* and the isopod *Cymodoce gaimardii* (Milne Edwards, 1840), a common benthic species, has already been mentioned although the exact nature of this association is unknown.

In the absence of any detailed knowledge of the ecological relationships of *Catostylus mosaicus* in the Victorian marine environment, the ecological effects of fishing can only be considered in the broadest terms. That is, based on information appearing in the literature, and mostly about species other than *Catostylus mosaicus*, removal of *Catostylus mosaicus* might influence the degree of predation on planktonic organisms, could affect the survival and abundance of any species which associate themselves with *Catostylus mosaicus*, and could affect the supply of organic matter to the benthos when the jellyfish dies. Estimates of the biomass of *Catostylus mosaicus* in Port Phillip made between 1997 and 2002 range from more than 35,000 tonnes in 1997 to almost negligible in 2000. It is questionable whether the removal of biomass due to fishing, which will be size-selective and so not affect the entire population, will ever approach the levels of natural variations in biomass or whether, given the magnitude of natural variation, it would ever be possible to demonstrate broadscale ecological effects resulting from a fishery for *Catostylus mosaicus* in Victorian waters.

Analyses for chemical contaminants

Jellyfish for chemical analysis were collected from Corio Bay, Hobsons Bay and off the Werribee River. These are all areas where anthropogenic input of contaminants into Port Phillip is likely to be high. Corio and Hobsons bays are immediately adjacent to urban and industrial areas of Geelong and Melbourne. Werribee is a more rural area but is an area of extensive market gardening (with the potential for agricultural chemicals to leach into the bay) and the coast off Werribee receives treated sewage effluent from the Western Treatment Plant. Sixty jellyfish bells, 20 from Corio Bay, 20 from Werribee and 20 from Hobsons Bay, were analysed for heavy metals; 20 jellyfish bells, 10 from Corio Bay and 10 from Hobsons Bay, were analysed for total hydrocarbons, polycyclic aromatic hydrocarbons and organochlorine insecticides; and two composite samples of 10 commercial size bells, one from Werribee and one from Hobsons Bay, were analysed for tributyl tin. All samples were taken in March 2001. Tables showing the full results of chemical analyses are given in Appendix 4.

There are no specific listings in the *Food Standards Australia New Zealand* of maximum permitted levels of heavy metals in jellyfish. Where no maximum levels are set for a food it is because that food is considered to present a low public health risk. Levels of heavy metals in *Catostylus mosaicus* from Port Phillip were all below the maximum permitted levels listed in the Standards for molluscs, crustacea and fish There is no legal maximum level for zinc but levels in jellyfish were all below the median levels listed in the Standards as to be expected in crustaceans and fish.

Aluminium content was determined for the Werribee samples and, for comparison, analysis was also carried out on commercially available, ready to eat, jellyfish (Table 9). The *Food Standards Australia New Zealand* does not set maximum levels for aluminium nor does it give generally expected levels for this metal.

Aluminium levels in jellyfish from Werribee were low (generally <0.1 µg/g wet weight). In contrast, aluminium levels in the commercial product (1200 µg/g wet weight) were 10,000 to 60,000 times higher than in jellyfish from Werribee, presumably because of the use of alum in jellyfish processing (Hsieh *et al*. 2001).

Table 9. Metal concentrations (µg/g wet weight) in the bells of jellyfish, *Catostylus mosaicus*, collected from the mouth of the Werribee River, Port Phillip, March 2001 and in commercially prepared product.

Zn, zinc; Hg, mercury; Cd, cadmium; Pb, lead; As, arsenic (considered to be a metal for the purposes of setting food quality standards); Al, aluminium. ***.*** *Numbers in brackets at the head of each metal column show the range in maximum permitted concentrations (µg/g wet weight) allowed in fish, crustacea and shellfish listed in Food Standards Australia New Zealand (ANZFA 2001). The exceptions are zinc and aluminium. There is no legislation setting maximum limits for zinc or aluminium. The figures shown for zinc indicate median levels to be expected in crustaceans and fish. The Food Standards lists no data for expected levels of aluminium. CP, commercial product (total wet weight 144g)*

Wet weight of jellyfish (g)		Bell diameter (cm)	Metal: (µg/g wet weight)					
Total	Bell		Zn (5-25)	Hg (0.5-1)	Cd (2)	Pb (0.5-2)	As (1-2)	Al
982	642	21.5	1.0	0.0003	0.01	0.01	0.14	0.06
1191	752	23	1.0	0.0003	0.01	0.01	0.14	0.06
1520	791	24.5	0.7	0.0002	0.01	0.01	0.13	0.04
1061	630	22	1.1	0.0002	0.02	0.01	0.95	0.05
1229	730	23.5	1.2	0.0001	0.02	0.01	0.83	0.03
1702	1063	26.5	1.0	0.0001	0.01	0.01	0.54	0.12
1541	1082	23.5	1.1	0.0002	0.01	0.01	0.47	0.04
1357	760	24	1.1	0.0003	0.01	0.01	0.13	0.05
769	457	20.5	0.8	0.0002	0.01	0.01	0.32	0.03
1011	638	22	0.8	0.0002	0.01	0.01	0.02	0.03
1321	810	24	1.0	0.0002	0.01	0.01	0.54	0.02
978	591	22.5	0.5	0.0000	0.01	0.01	0.57	0.03
1188	754	24.5	0.4	0.0000	0.00	0.01	0.33	0.02
883	537	22	1.5	0.0001	0.02	0.02	0.71	0.04
1343	802	25.5	1.1	0.0002	0.02	0.01	0.30	0.04
1071	651	24.5	1.2	0.0002	0.02	0.01	0.25	0.04
1621	978	27.5	0.9	0.0001	0.01	0.01	0.32	0.04
1235	742	23.5	1.0	0.0003	0.01	0.01	0.22	0.04
817	516	20	1.1	0.0003	0.01	0.01	0.26	0.04
788	510	21	0.7	0.0001	0.01	0.01	0.35	0.03
CP	-	-	0.2	0.0014	0.00	0.05	1.13	1200

Compared with levels of the same metals in jellyfish from Werribee, the level of zinc in the commercial product was lower; the level of mercury was higher but was still below the maximum permitted level; cadmium was below detectable levels; the lead level was slightly higher but still well below the maximum permitted level; and the level of arsenic was slightly higher, lying above the maximum permitted level for seaweed and molluscs (1 µg/g wet weight) and below the maximum permitted level for crustaceans and fish (2 µg/g wet weight).

Although elevated levels of aluminium have been associated with Alzheimer's disease, Hsieh and Rudloe (1994) suggest that because jellyfish is usually consumed in small amounts it is unlikely to increase the dietary intake of aluminium significantly. They also note that a causal relationship between aluminium and Alzheimer's disease has not yet been demonstrated, but, because of the labour intensive nature of jellyfish processing and the increasing health consciousness of consumers, a rapid method of processing which does not involve alum is needed.

Metal levels in *Catostylus mosaicus* were not related to total weight, bell weight or bell diameter. There was one exception to this. A significant inverse relationship between bell diameter and arsenic (p=0.03) was found for the samples from Corio Bay. The significance of this relationship appeared to be due to the particularly high level of arsenic in the smallest jellyfish examined and became non-significant if this individual was excluded from the analysis. There was no relationship between arsenic and jellyfish weight or size in the samples from Hobsons Bay and Werribee.

There were some regional differences in concentrations of metals in the jellyfish examined (Table 10).

Table 10. Mean values (µg/g wet weight) of metals in bells of *Catostylus mosaicus* collected from Corio Bay, Hobsons Bay and Werribee in Port Phillip, March 2001.

Values for each locality are the means of 20 determinations; those joined by the same vertical line are not significantly different (p=0.05). C, Corio Bay; H, Hobsons Bay; W, Werribee.

Arsenic		Cadmium		Mercury	
Mean	Area	Mean	Area	Mean	Area
0.367	W	0.0265	C	0.00025	H
0.142	H	0.012	W	0.00018	W
0.131	C	0.011	H	0.00015	C

Lead		Zinc	
0.014	C	0.99	H
0.011	W	0.96	W
0.010	H	0.82	C

Arsenic concentrations were significantly higher in jellyfish from Werribee than in jellyfish from Hobsons Bay and Corio Bay; cadmium concentrations were significantly higher in jellyfish from Corio Bay than in jellyfish from Werribee or Hobsons Bay; and mercury was significantly higher in jellyfish from Hobsons Bay than in jellyfish from Corio. Levels of lead and zinc in jellyfish did not differ significantly between locations.

In the *Food Standards Australia New Zealand*, no maximum levels are set for total hydrocarbons and polycyclic aromatic hydrocarbons. However, analyses of the bells of *Catostylus mosaicus* from Corio Bay and Hobsons Bay showed that levels of these contaminants were mostly below detectable levels (of 2 µg/g wet weight for total hydrocarbons and 5 nanograms per gram wet weight for polycyclic aromatic hydrocarbons). One jellyfish from Corio Bay gave readings of 10 and 13 nanograms per gram wet weight for two polycyclic aromatic hydrocarbons (Pyrene and Benzo[k]fluoranthene). Because these readings were much higher than any of the other readings obtained the samples were re-analysed and again provided the same result. The reason for the unexpectedly high values for these compounds is not known.

The *Food Standards Australia New Zealand* does set maximum permissible levels for pesticide residues in food. If no specific levels are set for a pesticide, it specifies that the residue must be below detectable level. Residue levels were below the detectable limit (of 2 nanograms per gram wet weight) for all samples analysed

Concentrations of tributyl tin may be measured either as tributyl tin *per se* or just as tin. Concentrations are lower if only the tin component is measured. The World Health Organisation (WHO 1990) indicates that the daily consumption of 15 g of fish having a concentration of 400 nanograms of tin per gram wet weight (equivalent to a concentration of 1000 nanograms of tributyl tin per gram wet weight) is unlikely to be hazardous to a human weighing 60 kg. The concentration of tin in jellyfish bells from Hobsons Bay was less than 1 nanogram per gram wet weight and was below the limit of detection in the sample from Werribee.

Implications of research findings for management of the jellyfish fishery

Kingsford *et al.* (2000) discuss management options for jellyfish fisheries. In the following paragraphs their discussion is summarised very briefly and additional comments are added based on the findings of the current study. The headings are those used by Kingsford *et al*.

Stock boundaries and management.

A low risk management strategy would be to treat jellyfish populations within geographic entities such as bays and estuaries as separate stocks. A total allowable catch should be set for each geographic entity (Kingsford *et al*. 2000).

Whether or not the populations of *Catostylus mosaicus* in Port Phillip Western Port and Corner Inlet are part of a single (genetic) stock was not investigated in the present study. However, because of their geographical separation the probability that the population in any one of these areas contributes to populations in either of the other areas is extremely low. It would therefore make sense to consider each population as a separate stock and to set total allowable catch limits for each area separately. Based on sampling from 1998 to 2002 (Hudson and Walker 1998, 1999 and the present work) fisheries are more likely to be successful in Port Phillip and Corner Inlet than in Western Port. *Catostylus mosaicus* is also found in the Gippsland Lakes and it is unlikely that populations here contribute to populations in Port Phillip Western Port and Corner Inlet or, in return, receive recruitment from these areas. Should there be interest in establishing a jellyfish fishery in the Gippsland Lakes, this area too would need to be assessed and managed as a separate entity.

Assessment of stock abundance.

The most economical means of monitoring jellyfish abundance is probably by use of visual observations made from a small boat although, depending on circumstances, other means of monitoring, trawl surveys for example, may be required. Because jellyfish are short-lived and grow quickly, abundance and biomass may show rapid change. Fisheries-independent estimates of stock abundance should be done several times within the month before the fishing season starts, to allow for short term fluctuations in estimates of stock size, and should continue during the fishing season to provide ongoing estimates. Estimates of abundance and biomass should preferably have a measure of error associated with them (Kingsford *et al*. 2000).

The present study confirmed that the most economical means of monitoring jellyfish abundance is by visual observations made from a small boat. The net used for sampling during the first year of the work required the use of a larger vessel than was required for visual sampling; the larger vessel was more expensive to run; and the additional expense was compounded because sampling using a net from a large vessel took longer than carrying out counts from a small vessel. The net could not be used in Corner Inlet because the water here is too shallow for it to be deployed. Visual counts, on calm days when jellyfish are likely to be within the top metre or two of the water column, are probably the most practical and economical means of carrying out any future assessment of jellyfish abundance in relation to the fishery in Victoria.

Because jellyfish may show a very aggregated distribution, sampling which misses aggregations will tend to under-estimate abundance while sampling which targets aggregations, or in which aggregations are overly represented, may over-estimate abundance. Aggregations are not permanent but may be formed or dispersed with changing conditions of wind, tides and water currents. The extent to which jellyfish are aggregated or are dispersed relatively uniformly throughout the survey area will affect estimates of error since these are likely to be less when the population is dispersed. Carrying out several surveys prior to the start of fishing, and looking at the consistency (or otherwise) of the abundance estimates and their associated errors will provide a better estimate of stock size than will a single survey. Some measure of the error associated with the estimated abundance is also important in setting catch levels (see next section). The use of frequent surveys would also be useful for determining when a high proportion of the population has reached commercial size.

If catch levels are to be set by weight, estimating jellyfish abundance is only the first step in setting the catch. The next stage is to estimate the size-frequency of the population and then, knowing the relationship between size and weight, to estimate biomass. In some months size-frequencies varied between different areas within the same water body, and biomass estimates differed considerably depending on whether or not combined or regional size-frequency data were used in converting abundance to biomass. Consideration therefore needs to be given as to how much effort is going to be put into obtaining size-frequency samples (easy when jellyfish are aggregated, difficult when they are dispersed) for use in converting abundance to biomass.

Levels of exploitation

The question as to what proportion of biomass can be removed without compromising the stock is an important one for managers of any fishery. Based on studies of fishes it has been considered that stock behaviour becomes uncertain when levels are, depending on species, reduced to below 20% - 50% of the virgin stock. However, there is no comparative data for jellyfish and, given the short life-span of jellyfish medusae and their great temporal and spatial variation in abundance, it is likely that management strategies applicable to fish may not be applicable to jellyfish. A risk averse approach to exploitation should be taken, and the existence of the benthic phase may provide a buffer against the over-exploitation of the stock. Setting catch limits should not be the only method of limiting exploitation of the stock. Other mechanisms, such as size limits or closed seasons, should also be considered (Kingsford *et al.* 2000).

To some extent the exploitation of jellyfish stocks in Victoria is limited by the imposition of a size limit (which is discussed in a subsequent section). Once the size limit is accepted, strategies which involve leaving some specific portion of the initial biomass unfished are probably not applicable to jellyfish since all the stock is expected to have died within a few months of its appearance.

Over the course of the present study, jellyfish biomass has been estimated to vary from negligible in one year to several thousand tonnes the next. Because of the short life-span of jellyfish medusae and the high level of inter-annual abundance that they show, the total allowable catch (TAC) will need to be set anew for each year and for each area fished.

Once an estimate of the fishable biomass (ie biomass of jellyfish above the minimum commercial size) within an area has been obtained, some decision still has to be made as to how much of this biomass should be fished, bearing in mind that the estimated biomass may not be very precise. One suggestion would be to set the mean biomass as the TAC but if this is captured relatively quickly then to increase the biomass to some level in line with the predicted upper 95% Confidence Interval. For example, if the estimated total biomass was 2,500 tonnes with an upper confidence interval of 3,500 tonnes, the initial TAC could be set at 2,500 tonnes and if this catch was rapidly achieved one or more increments up to but not exceeding an extra 1,000 tonnes could be considered. Such a strategy is one in which the difficulty of making precise estimates of abundance is accepted; it tacitly assumes that rapid capture of the mean biomass does not indicate that biomass has been underestimated but reflects the degree of fishing effort or that the catchability of the jellyfish was high during fishing.

If the initial TAC were not achieved there might be some concern that the biomass had been overestimated and that the sustainability of the fishery was in question. However, catching success will be dependent on the degree to which jellyfish are aggregated since much higher catch rates will be possible if there is a high degree of aggregation than if the jellyfish remain relatively dispersed in their distribution. Failure to reach the TAC might therefore indicate that the jellyfish were not readily catchable rather than that biomass had been overestimated (assuming jellyfish do not disappear sooner than expected, as was the case in 2002). Failure to reach the TAC could also be related to the degree of fishing effort.

A strategy which involved alterations in the TAC within what is likely to be a relatively short fishing season would require both rapid and accurate reporting of the catch and the ability of management to make rapid changes to the TAC.

In their preliminary recommendations for the fishery in New South Wales, Kingsford and Pitt (1998) recommend that catch limits are set by bell weight, from which total weight can be estimated if required. If the entire animal is going to be processed, it might make more sense to set catch limits by total weight and to estimate the weights due to bells and to oral arms if these are required.

Size limits

Bell diameter, which shows a strong correlation with weight, is the measure that can probably be most easily used in setting a size limit. Most *Catostylus mosaicus* are mature by the time they have reached a bell diameter of 160 mm and the size limit should be set above this level to allow jellyfish to reproduce before they are fished. A size limit set on bell diameter is also one that fishers using dipnets can readily observe (Kingsford *et al.* 2000).

At present the developmental fishery in Victoria targets *Catostylus mosaicus* of 23 cm or more in diameter. Maturity may occur in medusae as small as 12 cm in diameter, and while this is not always the case maturity is generally achieved by the time medusae have reached a diameter of 16 cm (Pitt and Kingsford 2000); and so at any time a significant proportion of the reproductively mature population (in Victoria) will not be taken by the fishery.

In some invertebrates, scallops for example (McLoughlin 1994), fecundity increases with age. If fecundity in *Catostylus* also increases with age or size, the proportion of total egg production due to jellyfish 23 cm or more in diameter might be relatively more than the proportion of individuals of this size in the population would suggest.

In parts of Asia government regulations do not allow fishing for jellyfish towards the end of the season because they are at their largest and are reproducing (Hsieh *et al*. 2001). Although the fishery in Victoria targets larger individuals, the current size limit is well above that at which *Catostylus* becomes sexually mature and so there are potentially reproductive individuals in the population even when the largest ones have been removed. However, any relationship between size and fecundity (about which there are no data for Victorian populations) might become of more significance if there was a move to reduce the minimum size limit. If it became economically viable to capture and process smaller individuals, then the effects on total egg production of removing individuals nearer and nearer to the minimum reproductive size would need to be assessed.

Methods of fishing

Methods used in jellyfish fisheries around the world include dipnetting, various other forms of netting and benthic and pelagic trawling. With the exception of dipnetting all other methods have potential problems associated with one or more of the following: damage to the commercial portion of the jellyfish catch, damage to undersize jellyfish, the capture of benthic or pelagic bycatch and damage to the benthic environment. Dipnetting is highly targeted towards jellyfish of a commercial size and gives rise to no concerns regarding damage to undersize jellyfish, incidental bycatch or damage to the environment (Kingsford *et al*. 2000).

The Victorian developmental management plan does allow the use of a net to aggregate jellyfish. Environmental damage arising from the use of corralling nets is likely to be slight or non-existent, particularly if their use is confined to the top few metres of the water column. The extent to which netting may damage medusae of various sizes has not been investigated in Victoria, and it would be useful to do so. Similarly, it would be useful to investigate the survival of bycatch taken in association with jellyfish. The survival rate of fish released from haul seining is high but it is possible that fishes confined in the presence of large numbers of jellyfish may suffer increased mortality.

Temporal closures

Temporal closures are a potentially important tool in the management of jellyfish fisheries and have been used to protect juvenile jellyfish during a period of rapid growth and to prevent jellyfish being taken before they had spawned. The timing of any closures that are introduced should be flexible, rather than fixed, in recognition of the fact that periods of recruitment, growth and reproduction may vary from year to year (Kingsford *et al*. 2000).

The shortness of the season in Victoria means that it may be difficult to set temporal closures, but any period of closure that is set should be flexible and the need for, or timing of, any closure should be assessed anew each year.

In a typical year small individuals would be expected to dominate the population from January through to about March or April. There might be some value in delaying the start of the fishing season until the majority of individuals in the population had reached a diameter of 16 cm, at which size they should be reproductively mature. Extending any closure beyond March or April, or any period of closure at all, might be counterproductive if the season was short, as for example in 2002 when very few jellyfish were found after the end of March. Because deterioration of jellyfish bells increases as the season progresses, a prolonged closure could lead to inferior product being fished.

Where the population is dominated by small individuals, a closed period at the beginning of the season will allow any larger individuals that may be present to spawn, rather than being taken right at the start of the season. During 2002 a relatively high proportion of large individuals was found in the early months of the season, perhaps as the result of individuals surviving through the preceding winter. Had there been a fishery in 2002, closure during these early months would have significantly reduced any catch. Conversely, the recruitment of new medusae that year was low, and so the presence of large medusae at the start of the season may have contributed significantly to reproductive activity that year, a contribution which would have been lost if these medusae had been taken.

Spatial closures for jellyfishes

Rhizostome jellyfish, which include *Catostylus mosaicus*, are largely restricted to inshore locations, particularly estuaries and saline lakes, and within such areas there are often specific sites that regularly have the highest numbers of medusae. For these reasons, spatial closures, especially if combined with temporal closures, may be an effective management tool. Management options include the closure of areas that have high numbers of medusae or of polyps. The drawback is that the importance of areas for reproduction and recruitment may change from time to time (Kingsford *et al.* 2000).

Surveys in Port Phillip, Western Port and Corner Inlet do suggest that there are areas where jellyfish appear to be particularly abundant or are more likely to be found. These include Corio Bay and the western and northern shores of Port Phillip and around the mouth of the Franklin River in Corner Inlet. The potential for closing areas to act as reservoirs for jellyfish does therefore exist, although any attempt to close an area on the basis that medusae are always abundant there is not likley to find favour with industry. In contrast, attempts to protect areas of polyps, were their distribution known, would probably be supported as they would be seen as a measure to promote the production of medusae but not one of preventing their exploitation. Protection of areas of polyps would require protection of the benthic habitat and so is likely to affect other users (eg other fisheries, industries which discharge effluent to the area) rather than the jellyfish fishery itself.

The extent to which area closures could protect the medusae within them would depend on the extent to which medusae were retained within the area. The residence time of water in Corio Bay is thought to be weeks rather than days (Holmes 1989) and so closure of this area would probably provide some long-term protection to the medusae resident there; but water flow along the western shore of Port Phillip is more rapid and the protective value of closures in this area is more doubtful since medusae could be rapidly dispersed from any closed areas in that part of the bay.

Log books and fisheries statistics

It is essential in a jellyfish fishery to monitor the catch and obtain estimates of catch per unit effort. Catch should be monitored at the level of stocks. Because jellyfish aggregate, high catch per unit effort may be taken even if total abundance is low. Monitoring of the fishery may be through log books or the records of fishery-co-operatives that receive or process the catch. Some independent monitoring of the fishery through the use of observers would also be useful, particularly in relation to matters such as bycatch which fishers (in all fisheries) are often reluctant to report for fear that such data may be used to curtail their activities (Kingsford *et al*. 2000).

All fishers in Victoria are required to submit a catch and effort return detailing where and when they have fished, methods used and catch taken. Monitoring of catch through analysis of catch and effort returns is therefore readily achievable. If the management strategy is one which requires that catch and effort returns be analysed as the season progresses, to allow for modifications to catch limits for example, the major problem may be in ensuring that log books are submitted and analysed sufficiently rapidly for this to occur.

The benthic phase

The abundance of medusae is not only dependent upon successful sexual reproduction but also upon the survival and asexual reproduction of the polyp stage. The polyp stage is inconspicuous and much of what is known about the biology of polyps is derived from laboratory rather than field studies.

The substratum preferences of settling planulae larvae of *Catostylus mosaicus* are not known in detail, but Pitt (2000) found they were capable of settling on a variety of substrata. Few planulae settled on seagrass and these did not survive, perhaps indicating that settlement preferences are for hard or abiotic surfaces.

Various factors have been seen as important in providing the stimulus for initiating strobilation in scyphozoan polyps. These include changes in temperature, photoperiod and salinity (Pitt 2000). Interactions between these factors may also influence the rate or degree of strobilation (Rippingale and Kelly 1995; Purcell *et al*. 1999). Food supply is also likely to be important since Pitt (2000) found that polyps of *Catosylus mosaicus* strobilated only when they were fed.

Surveys along the coast of New South Wales showed that medusae of *Catostylus mosaicus* are most abundant close to rivers and lakes and that peaks of recruitment occur after heavy rain, prompting the suggestion that the polyp stage settles in or near rivers and is stimulated to produce ephyrae larvae by lowered salinity (Kingsford and Pitt 1998). In Corner Inlet, Victoria, there was a clear association between *C. mosaicus* and lowered salinity in and around the mouth of the Franklin River, which suggests that settlement of polyps takes place within the river. However, *C. mosaicus* were also particularly abundant in Corio Bay and here any correlation with lowered salinity is not so apparent as there are no major rivers or creeks running into the bay.

The longevity of *Catostylus mosaicus* polyps is not known with any certainty. Typically in Victoria small *Catostylus* appear early in the year (January and February) and, after a few months growth, disappear about May or June. This pattern suggests that the polyp stage over-winters and buds off ephyrae the following spring. Small medusae were sometimes encountered during autumn (eg in Western Port in May 2002), indicating that strobilation may not be confined to spring. *Catostylus* polyps are reported to live for 90 days or more and their life span could be considerably longer since the polyps of other jellyfish species live for up to one or two years (Kingsford *et al.* 2000). The longevity of *C. mosaicus* polyps is therefore sufficient for over-wintering to occur. If the polyp stage of *C. mosaicus* can survive from one spring to the next and produce ephyrae in two successive years, it would provide some buffer against long-term population collapse if there was a year in which few medusae were produced or if there was a year in which the medusae did not reproduce successfully.

Benefits

The project has provided extensive data on the seasonality, distribution and abundance of the edible jellyfish *Catostylus mosaicus* in Port Phillip, Western Port and Corner Inlet during 2000, 2001 and 2002. The project has shown that while there may be several thousand tonnes of commercially exploitable jellyfish in some years, there are great annual and spatial variations in abundance which means that it may not be possible for a fishery to operate every year or in all of the areas investigated. Because the life span of *C. mosaicus* is generally less than one year, the most efficient management of the fishery requires that biomass assessments and catch limits are set afresh each year so that in years of low abundance the stock may be protected by closure of the fishery or low catch limits, and in years when jellyfish are particularly abundant the industry is not constrained by nominal or arbitrarily low catch limits. Because *C. mosaicus* may be very aggregated in their distribution, it is difficult to obtain precise estimates of population abundance and biomass. Based on the experience gained during the present study, methods of increasing the precision of population estimates are discussed, as are other implications for the management of the fishery suggested by the results of the surveys. Jellyfish bells have been analysed for heavy metals, hydrocarbons, pesticides and tributyl tin. The results of these analyses show that these contaminants are present at levels which are low or undetectable and none pose any threat to human health when the jellyfish are processed and eaten. During the course of the study data on the abundance and distribution of jellyfish was provided to the holder of the fishing permit issued under the Developmental Fishery Management Plan. The permit holder was also provided with jellyfish which were used in instructing local fishers in methods of jellyfish processing.

Further Development

Results of the survey work suggest a number of management options, covering the assessment of jellyfish abundance and biomass, the setting of catch limits and size limits and consideration of area and seasonal closure, which need to be considered for inclusion into the future management of the fishery. An assessment needs to be made as to whether the use of corralling nets has any adverse impact on *Catostylus mosaicus* or on the capture and survival of bycatch. In more general terms, the factors which influence changes in abundance and the role of *C. mosaicus* in the marine ecosystems of Victoria are poorly understood. Both of these areas need investigation if there is to be any chance of predicting the likely success of the fishery each year and if the broader ecological consequences of removing jellyfish from the ecosystem are to be understood. If long-term studies to investigate the relationship between environmental conditions and jellyfish abundance are to be undertaken, estimates of abundance will be needed each year (since it is difficult to analyse long-term data sets if there are gaps in the data) and this will require fishery independent assessments of abundance, ideally in every year and definitely in years where there is no commercial fishery. Almost nothing is known about the polyp stage although the survival of this phase of the life-cycle is critical to the recruitment of the medusoid stage, which forms the basis of the fishery. There is therefore a need to investigate factors relating to the settlement, distribution, survival and reproduction of the polyp stage.

Planned outcomes

The present study has shown that, in Victoria at least, visual observations from a small boat, combined with sampling for size-frequency analysis and size/weight relationships, remains the most convenient means of assessing jellyfish biomass and abundance. An outcome of the study is therefore the recommendation that future surveys of jellyfish be conducted using a stratified random sample design and visual counts, as carried out in the present study.

Based on the current work, and a consideration of other studies relevant to jellyfish fisheries, a number of issues relevant to the management of the fishery have been identified and discussed (pp 59 to 65). These include problems in setting a total allowable catch when biomass estimates are imprecise, matters relating to the maintenance of sustainability in a population with high annual variability, and environmental issues related to the actual operation of the fishery and to the potential environmental effects of removing jellyfish from the ecosystem. A further outcome of the study is that awareness of these issues will help fisheries managers in drawing up management plans for a sustainable fishery.

Conclusion

Counts of jellyfish taken according to a stratified random sampling design provide a suitable means of estimating jellyfish abundance. If the size-frequency of individuals in the population and the relationship between jellyfish size and weight are known, estimates of abundance can be converted to estimates of biomass. However, because of the patchiness with which jellyfish are distributed, estimates generally have wide confidence intervals associated with them.

Visual counts of jellyfish on calm, sunny days, when they are likely to be within the top few metres of the water column, probably remains the quickest and cheapest option for assessing abundance. In many of the shallow areas sampled in Port Phillip and Corner Inlet, the bottom was visible in depths of up to 6 or 7 m and jellyfish could be counted throughout the entire water column. However, a number of conditions make counting difficult and can lead to underestimates of abundance and biomass. These are: areas of murky water; areas where light does not penetrate to the seafloor so jellyfish may be present but below the level at which they can be seen; and sea conditions that are sufficiently rough to cause jellyfish to sink below the surface and to limit visibility through the water column.

A sampling net was constructed and trialled in an attempt to ovecome the problems associated with visual counts. The net was not used as extensively as originally planned because of the unexpected disappearance of jellyfish towards the end of the sampling period. Nevertheless, the use that was made of the net suggested that while trawling for jellyfish was more complicated and more expensive than making visual counts, it would not provide more accurate estimates of abundance.

Sampling carried out during the 3-year study showed that the occurrence of medusae of the edible jellyfish *Catostylus mosaicus* in Victoria is seasonal. Small individuals generally appear in January or February, grow over the next few months and die out in autumn or early winter. Some individuals may survive through the winter so that a few large individuals may be present even at the start of the season. While populations of *C. mosaicus* are sufficiently large to support a commercial fishery in some years, annual variability in abundance and biomass is such that a fishery may not be possible every year. There is also considerable geographical variation in abundance and biomass. During survey work over the last three seasons there were too few jellyfish to support a fishery in 2000; jellyfish were abundant in 2001 and a fishery would have been possible; and jellyfish numbers were again reduced in 2002 although they were still more abundant than in 2000. In the three areas studied, jellyfish were most abundant in Port Phillip and then Corner Inlet and least abundant in Western Port. Any fishery for *Catostylus mosaicus* in Victoria will have to be capable of utilising a resource which is highly seasonal and only available in some years, and management of the fishery will have to be responsive to these same constraints.

References

ANZFA (2001) Australian and New Zealand Food Authority Food Standards Code. Barton, ACT.

Barham, E.G. and Pickwell, G.V. (1969). The giant isopod, *Anuropus*: A scyphozoan symbiont. *Deep-Sea Research* **16**, 525-529.

Bowles, K.C., Apte, S.C., Hales, L.T. (2002). Determination of butyltin compounds in natural waters using aqueous phase ethylation and off-line trapping followed by gas chromatography and quartz furnace-atomic absorption spectrometry. (CSIRO, Manuscript in preparation).

Coleman, N. (1987). Australian Sea life south of 30°S. Doubleday, Sydney and Auckland.

Dakin, W.J. (1987). Australian Seashores. Angus and Roberts NSW Australia.

Fancett, M.S. (1986). Species composition and abundance of scyphomedusae in Port Phillip Bay, Victoria. *Australian Journal of Marine and Freshwater Research* **37**, 379 – 384.

Fancett, M. (1988). Diet and prey selection of scyphomedusae from Port Phillip Bay, Australia. *Marine Biology* **98**, 503 – 509.

Fancett, M. and Jenkins G.P. (1988). Predatory impact of scyphomedusae on ichthyoplankton and other zooplankton in Port Phillip Bay. *Journal of experimental Marine Biology and Ecology* **116**, 63 – 77.

Field, D. (1999). A new Northern Territory fishery. *Professional Fisherman* November 1999, **13**.

Fisheries Division (2002). Developmental fisheries management plan, jellyfish (*Catostylus mosaicus*), 2002 – 2005. Fisheries Division, Department of Natural Resources and Environment, Victoria.

Gallina, A., Magno, F., Tallandini, L., Passaler, T., Umberto Caravello, G., Pastore, P. (2000). Simple and effective gas chromatographic mass spectrometric procedure for the speciation analysis of organotin compounds in specimens of marine mussels. An evaluation of the organotin pollution of the Lagoon of Venice. *Rapid Communications in Mass Spectrometry* **14**, 373-378.

Goy, J., Morand, P. and Etienne, M. (1989). Long-term fluctuations of *Pelagia noctiluca* (Cnidaria, Scyphomedusa) in the western Mediterranean sea. Prediction by climatic variables. *Deep-Sea Research* **36(2)**, 269 – 279.

Hansson, L.J. (1997). Effect of temperature on growth rate of *Aurelia aurita* (Cnidaria, Scyphozoa) from Gullmarsfjorden, Sweden. *Marine Ecology Progress Series* **161**, 145 – 153.

Hay, S.J., Hislop, J.R.G. and Shanks, A.M. (1990). North Sea Scyphomedusae: summer distribution, estimated biomass and significance particularly for 0-group gadoid fish. *Netherlands Journal of Sea Research* **25**, 113 – 130.

Holmes, N.J. (1989). Mussel-dominated communities along an environmental gradient in Corio Bay, Victoria. Marine Science Laboratories Technical Report No. 69. 21 pp Queenscliff, Victoria.

Hsieh, Y-H,P. and Rudloe,J. (1994). Potential of utilizing jellyfish as food in western countries. *Trends in Food Science and Technology* **5**, 225 – 229.

Hsieh, Y-H,P., Leong, F-M and Rudloe, J. (2001). Jellyfish as food. *Hydrobiologia* **451**, 11 – 17.

Huang, Y-W. (1988). Cannonball jellyfish (*Stomolophus meleagris*) as a food resource. *Journal of food science* **53(2)**, 341 – 343.

Hudson, R.J., Bridge, N.F., and Walker, T.I. (1997). Feasibility study for establishment of a Victorian Commercial Jellyfish Fishery. Project 92/125.31. Final Report to Fisheries Research and Development Corporation. Marine and Freshwater Resources Institute, Queenscliff.

Hudson, R.J. and Walker, T.I. (1998). Distribution of the Jellyfish *Catostylus mosaicus* in Port Phillip Bay and Western Port during April and May 1998. Marine and Freshwater Resources Institute, Queenscliff.

Hudson, R.J. and Walker, T.I. (1999). Distribution of the Jellyfish *Catostylus mosaicus* in Port Phillip Bay, Western Port and Corner Inlet during March – May 1999. Marine and Freshwater Resources Institute, Queenscliff.

Kingsford, M.J. (1993). Biotic and abiotic structure in the pelagic environment: importance to small fishes. *Bulletin of Marine Science* **52(3)**, 393 – 415.

Kingsford, M. and Gillanders, B.M. (1995). Fishery and research priorities for *Catostylus mosaicus*. Report for the Australian Nature Conservation Agency. 25 pp. Insitute of Marine Ecology, University of Sydney.

Kingsford, M and Pitt, K. (1998). Final Report 1998. Consultancy to undertake research on the timing of reproduction, abundance, stock assessment and genetics of the edible jellyfish *Catostylus mosaicus* in New South Wales waters. School of Biological Sciences, University of Sydney.

Kingsford, M.J., Pitt, K.A. and Gillanders, B.M. (2000). Management of jellyfish fisheries, with special reference to the order Rhizostomeae. In Oceanography and Marine Biology: an annual review (eds Gibson, R.N. and Barnes, M) **38**, 85 – 156.

Knuckey, I.A., Morison, A.K. and Ryan, D.K. (2002). The effects of haul-seining in Victorian bays and inlets. FRDC project 1997/210. Marine and Freshwater Resources Institute, Queenscliff.

Lindahl, O and Hernroth L. (1983). Phyto-zooplankton community in coastal waters off western Sweden – an ecosystem off balance? *Marine Ecology Progress Series* **10**, 119 – 126.

Louie, H.W. (1985). Determination of total mercury in fish: An improved method. *Analyst* **105,** 1311-17.

Lu, N., Liu, C. and Guo, P. (1989). Effect of salinity on larvae of edible medusae (*Rhipolema esculenta* Kishinouye) at different developmental phases and a review on the cause of jellyfish resources falling greatly in Liadong Bay. Acta *Ecologica Sinica* **9**, 304 – 309.

Lucas, C.H. (2001). Reproduction and life history strategies of the common jellyfish, *Aurelia aurita*, in relation to its ambient environment. *Hydrobiologia* **451**, 119 – 246.

McLoughlin, R.J. (1994). Sustainable management of Bass Strait scallops. *Memoirs of the Queensland Museum* **36(2)**, 307 – 314.

NOAA (1993). Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984-1992. Volumes I to IV. USA National Oceanic and Atmospheric Administration. Silver Spring Maryland.

Officer R.A. and Parry G.D. (2000). Effects of season, size, depth and time of day on diets of demersal fish in Port Phillip Bay. Marine and Freshwater Resources Institute Report 11:100pp.

Omori, M. and Nakano E. (2001). Jellyfish fisheries in south-east Asia. *Hydrobiologia* **451**, 19 – 26.

Parry G.D., Hobday D.K., Currie D.R., Officer R.A. and Gason A.S. (1995) The distribution , abundance and diets of demersal fish in Port Phillip Bay. CSIRO Port Phillip Bay Environmental Study Tech. Rep. 21.

Pitt, K.A. (2000). Life history and settlement preferences of the edible jellyfish *Catostylus mosaicus* (Scyphozoa:Rhizostomeae). *Marine Biology* **136**, 269 – 279.

Pitt, K.A. and Kingsford, M.J. (2000). Reproductive biology of the edible jellyish *Catostylus mosaicus* (Rhizostomeae). *Marine Biology* **137**, 791 – 799.

Prairie, Y.T. (1996). Evaluating the predictive power of regression models. *Canadian Journal of Fisheries and Aquatic Sciences* **53**, 490 – 492.

Purcell, J.E., White, J.R., Nemazi, D.A. and Wright, D.R. (1999). Temperature, salinity and food effects on asexual reproduction and abundance of the scyphozoan *Chrysaora quinquecirrha*. *Marine Ecology Progress Series* **180**, 187 – 196.

Queensland Fisheries Service (2001). Applications for a developmental fishing permit to harvest jellyfish (*Catostylus mosaicus*) in the Gulf of Carpentaria and Moreton Bay. 16pp. Queensland Fisheries Service, Department of Primary Industry, Queensland.

Rippingale, R.J. and Kelly, S.J. (1995). Reproduction and survival of *Phyllorhiza punctata* (Cnidaria Rhizostomeae) in a seasonally fluctuating salinity regime in Western Australia. *Marine and Feshwater Research* **46**, 1145 – 1151.

Schneider, G. (1988). Larvae production of the common jellyfish *Aurelia aurita* in the Western Baltic 1982 – 1984. *Kieler Meeresforschungen Sonderheft* **6**, 295 – 300.

Schneider, G. and Behrends, G. (1994). Population dynamics and the trophic role of *Aurelia au*rita medusae in the Kiel Bight and western Baltic. *ICES Journal of Marine Science* **51**, 359 – 367.

Southcott, R.V. (1982). Jellyfishes (Classes Scyphozoa and Hydrozoa). In Marine Invertebrates of southern Australia Part 1 (eds Shepherd, S.A. and Thomas, I. M), pp 115 – 159.

Sloan, N.A. and Gunn, C.R. (1985). Fishing, processing and marketing of the jellyfish, *Aurelia aurita* (L.), from southern British Columbia. *Canadian Industry Report of Fisheries and Aquatic Sciences* **157**, 29 pp.

UNEP/FAO/IAEA (1982). Determination of total cadmium, zinc, lead and copper in selected marine organisms by atomic absorption spectrometry. Reference methods for marine pollution studies No. 11. United Nations Environment Programme.

UNEP/IOC/IAEA (1992). Determination of petroleum hydrocarbons in sediments. Reference Methods for Marine Pollution Studies No. 20. . United Nations Environment Programme.

Wells.R.W. and Wellington, R. (1992). The potential exploitation of the brown jelly blubber, *Catostylus mosaicus*, in eastern Australian waters. *Sydney Basin Naturalist* **1**, 57 – 61.

WHO (1990). Environmental Health Criteria 116. Tributyltin Compounds. World Health Organization, Geneva.

Wootton, M., Buckle, K.A. and Martin, D. (1982). Studies on the preservation of Australian jellyfish (*Catostylus* spp.). *Food Technology in Australia* **34(9)**, 398 – 400.

Appendix 1: Intellectual Property

The intellectual property from this project will be shared between the Fisheries Research and Development Corporation and the Marine and Freshwater Resources Institute as outlined in the project contract. The Fisheries Research and Development Corporation will be acknowledged in all publications arising from the project.

Appendix 2: Staff

At the Marine and Freshwater Resources Institute

Mr Brett Abbot
Dr Noel Coleman
Mr Ian Duckworth
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At the Australian Maritime College

Ms Trudi Hogg
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Mr John Wakeford

Appendix 3: Cruise reports

Results of sampling in Port Phillip Bay

Sampling in 2000

During January 2000, sampling along transects within the strata defined in Port Phillip Bay was not undertaken. Instead field trips were devoted to trialing the jellyfish sampling net and to making some minor modifications to improve efficiency and ease of handling.

During February, 99 transects (a total of 275,022 m^2) were surveyed. *Catostylus* were only seen on 3 transects in stratum 7 (one transect had 15 *Catostylus* and 2 transects had 1 *Catostylus* each) and on four transects in stratum 6 (one transect had 5 *Catostylus*, one had 2 *Catostylus* and two transects had one *Catostylus* each). The jellyfish sampling net was deployed on the majority of transects but caught no jellyfish.

During March, 90 transects (250,020 m^2) were surveyed. One *Catostylus*, with an estimated bell diameter of 15 cm, was seen. The jellyfish sampling net was deployed on the majority of transects but caught no jellyfish.

During April, 75 transects (208,350 m^2) were surveyed. One *Catostylus* was seen in each of strata 5, 7 and 8 and 3 *Catostylus* in stratum 6. The jellyfish sampling net was deployed on the majority of transects but caught no jellyfish.

During May, 51 transects (141,678 m^2) were surveyed. Two *Catostylus* (estimated bell diameter 10 – 15 cm) were seen in stratum 5 and 7 *Catostylus* (estimated bell diameter 10 – 15 cm) were seen in stratum 8. In contrast to the paucity of *Catostylus* in all months, and of jellyfish in general during previous months, jellyfish belonging to the species *Pseudorhiza haeckeli* were widespread and abundant in stratum 8, with counts of up to 80 a transect, and were also present, though not so obviously abundant, in stratum 7. The jellyfish sampling net was deployed on the majority of transects but caught no jellyfish.

No sampling was carried out in June because of the lack of jellyfish in previous months.

Sampling in 2001

During 2001 sampling relied entirely on visual counts made from a small boat. The use of a small boat, as compared to a trawler, meant that field trips could be completed more rapidly because of the faster speed of the smaller vessel and because no time was spent in deploying the net. The use of a small vessel also reduced costs both because field trips were completed more rapidly and because the cost of operating the smaller vessel was less than that of chartering a trawler.

Because virtually no *Catostylus* had been seen during 2000, no random transect counts were carried out during the first cruise of 2001. Instead strata 1, 2 and 4 were systematically searched for jellyfish.

Jellyfish were absent from almost all of the areas searched, but a small patch of jellyfish was found at Werribee. Three transects were run through this patch and gave counts of 70, 80 and 557 jellyfish per transect. The size range of the jellyfish was 2.5 to 22 cm bell diameter with most being below 20 cm. The size-frequency histogram (Fig. A3.1) shows two groups of jellyfish, those with a diameter of 3 to 7 cm and those with a diameter of 11 to 22 cm (the absence of jellyfish of 19 cm diameter is assumed to be fortuitous and not related to any separation of year groups), suggesting that the smaller jellyfish had been spawned recently while the larger jellyfish had over-wintered from the previous season. Earlier surveys have also provided evidence for over-wintering of at least some jellyfish.

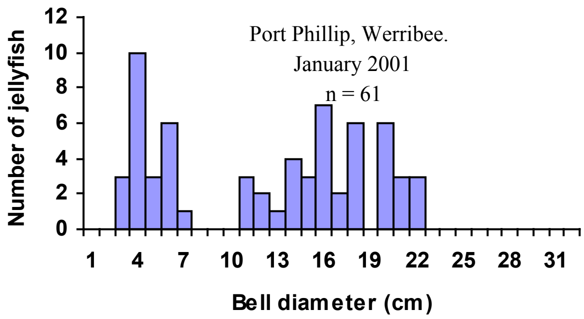


Figure A3.1. Size-frequency of *Catostylus mosaicus* off Werribee in Port Phillip, January 2001.

Enquiries made of fishers working in the east of Port Phillip revealed that none had seen any *Catostylus* and most reported that they generally appeared from February onwards. On the basis of these reports no further sampling was undertaken during January.

During February 87 transects (241,686 m^2) throughout the west and east of Port Phillip were sampled. *Catostylus* were abundant throughout Corio Bay, along the west coast and in the north of Port Phillip (strata 1, 2, 3, 4 and 5) but infrequent along the east coast (strata 6, 7 and 8). A size frequency sample taken in Corio Bay (Fig. A3.2) showed that although the population was dominated by small individuals (<10 cm diameter) large individuals, up to 28 cm in diameter, were not infrequent. These larger individuals were presumably present in Corio Bay during January even though no jellyfish were seen on the sampling cruise in that month.

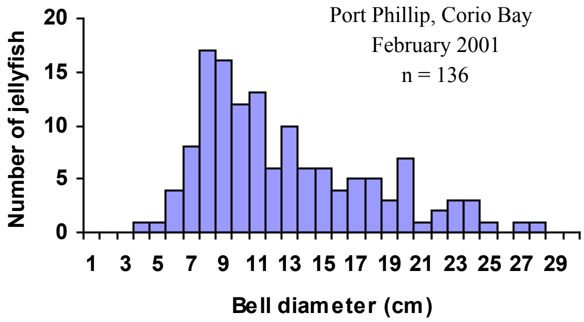


Figure A3.2. Size-frequency of *Catostylus mosaicus* in Corio Bay, February 2001.

An estimated 419 tonnes in total and 139 tonnes of commercial size jellyfish were present in the bay (Table A3.1).

Table A3.1. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, February 2001.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	8	69,934	498,196	1,848,557	20	145	537
2	6	153	12,641	97,892	<0.1	4	28
3	16	258,121	515,052	928,136	75	150	270
4	14	91,062	399,006	1,170,849	26	116	340
5	15	1,549	14,870	62,507	0.4	4	18
6	7	0	0	0	0	0	0
7	14	0	255	3,110	0	0.1	1
8	10	0	0	0	0	0	0
TOTAL	87	420,819	1,440,020	4,111,051	121.5	419.1	1194
			Commercial size jellyfish			Commercial size jellyfish	
1	8	4,616	32,881	122,005	7	48	179
					(3.1)	(23)	(84)
2	6	10	834	6,461	<0.1	1	9
					(<0.1)	(0.6)	(4)
3	16	17,036	33,993	61,257	25	50	90
					(12)	(23)	(42)
4	14	6,010	26,334	77,276	9	39	113
					(4.2)	(18)	(53)
5	15	102	981	4,125	0.1	1	6
					(<0.1)	(0.7)	(2.8)
6	7	0	0	0	0	0	0
7	14	0	17	205	0	<0.1	0.3
						(<0.1)	(0.2)
8	10	0	0		0	0	0
TOTAL	87	27,774	95,040	271,329	41.2	139.1	397.3
					(19.3)	(65.3)	(186)

During March 101 transects (280,578 m^2) throughout the west and east of Port Phillip were sampled. Jellyfish were abundant throughout Corio Bay, along he west coast of Port Phillip, in the north of the bay and southwards along the east coast of the bay as far as Frankston.

Size-frequency samples were taken at several localities around the bay (Fig. A3.3).

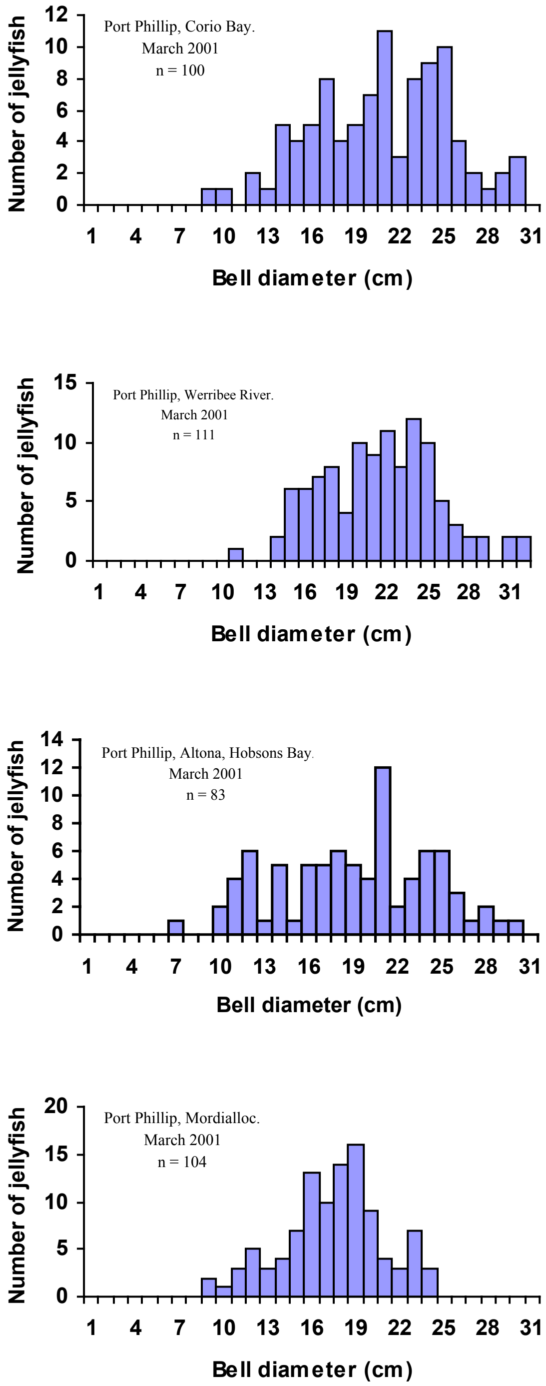


Figure A3.3. Size-frequency of *Catostylus mosaicus* at four localities around Port Phillip, March 2001.

Size frequencies were similar for samples taken in the west and north of the bay but there was an absence of larger individuals (>23 cm diameter) in the east of the bay.

Size frequencies were combined over all samples for calculation of biomass which, bay wide, was estimated as 1,320 tonnes in total and 731 tonnes of commercial size jellyfish (Table A3.2).

Table A3.2. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, March 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	9	6,180	121,447	656,937	5	103	557
2	5	300,852	654,761	1,255,220	255	555	1,064
3	15	111,677	625,310	2,076,460	95	530	1,760
4	15	0	2,664	38,413	0	2	33
5	16	10,407	110,346	482,203	9	94	409
6	8	232	13,290	95,344	0.2	11	81
7	16	1,670	30,063	158,164	1	25	134
8	10	1	1	113	<0.1	<0.1	0.1
9	7	0	0	0	0	0	0
TOTAL	101	431,019	1,557,882	4,762,854	365.3	1,320.1	4,038.1
			Commercial size jellyfish			Commercial size jellyfish	
1	9	1,863	36,616	198,067	3 (1.5)	57 (29)	308 (155)
2	5	90,707	197,410	378,449	141 (71)	307 (155)	589 (297)
3	15	33,671	188,531	626,053	52 (30.4)	294 (148)	975 (491)
4	15	0	803	11,582	0	1 (0.6)	19 (9.4)
5	16	3,138	33,269	145,384	5 (2.4)	52 (26)	226 (114)
6	8	70	4,007	28,746	0.1 (<0.1)	6 (3.1)	45 (23)
7	16	504	9,064	47,686	0.8 (0.4)	14 (7.1)	74 (37)
8	10	0	1	34	0	<0.1 (<0.1)	0.1 (<0.1)
9	7	0	0	0	0	0	0
TOTAL	101	129,953	469,701	1,436,001	201.9 (105.7)	731.1 (369)	2236.1 (1126)

Because of bad weather during April, which limited the field work that could be accomplished, only 46 transects (127,788 m^2) were sampled and the only size-frequency taken (Fig. A3.4) was from Corio Bay.

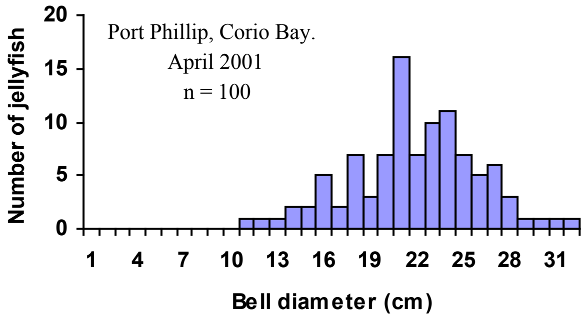


Figure A3.4. Size-frequency of *Catostylus mosaicus* in Corio Bay, April 2001.

Jellyfish were found only in the west of the bay. Total biomass was estimated as 810 tonnes and the biomass of commercial size jellyfish was estimated as 525 tonnes (Table A3.3).

Table A3.3. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, April 2001.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	8	45,777	398,111	1,608,114	76	660	2666
2	7	1,834	73,103	481,206	3	121	798
3	7	31	1,951	60,124	0.1	3	100
4	13	1,092	15,496	75,307	2	26	125
9	11	0	0	0	0	0	0
TOTAL	46	487,34	488,661	2,224,751	81.1	810	3689
			Commercial size jellyfish			Commercial size jellyfish	
1	8	21,057	183,131	739,732	51	440	1780
					(26)	(225)	(911)
2	7	844	33,627	221,355	2	81	533
					(0.9)	(42)	(273)
3	7	14	897	27,657	<0.1	2	67
					(<0.1)	(1.1)	(34)
4	13	502	7,128	34,641	1	17	83
					(0.6)	(8.7)	(42)
9	11	0	0	0	0	0	0
TOTAL	47	22,417	224,783	1,023,385	54.1	525	2463
					(27.5)	(276.8)	(1260)

During May 76 transects (211,128 m^2) throughout the west and east of Port Phillip were sampled. Jellyfish were abundant in Corio Bay, along the west coast of Port Phillip, in the north of the bay and southwards along the east coast of the bay as far as Frankston. By comparison with previous months few small jellyfish were found (Fig. A3.5)

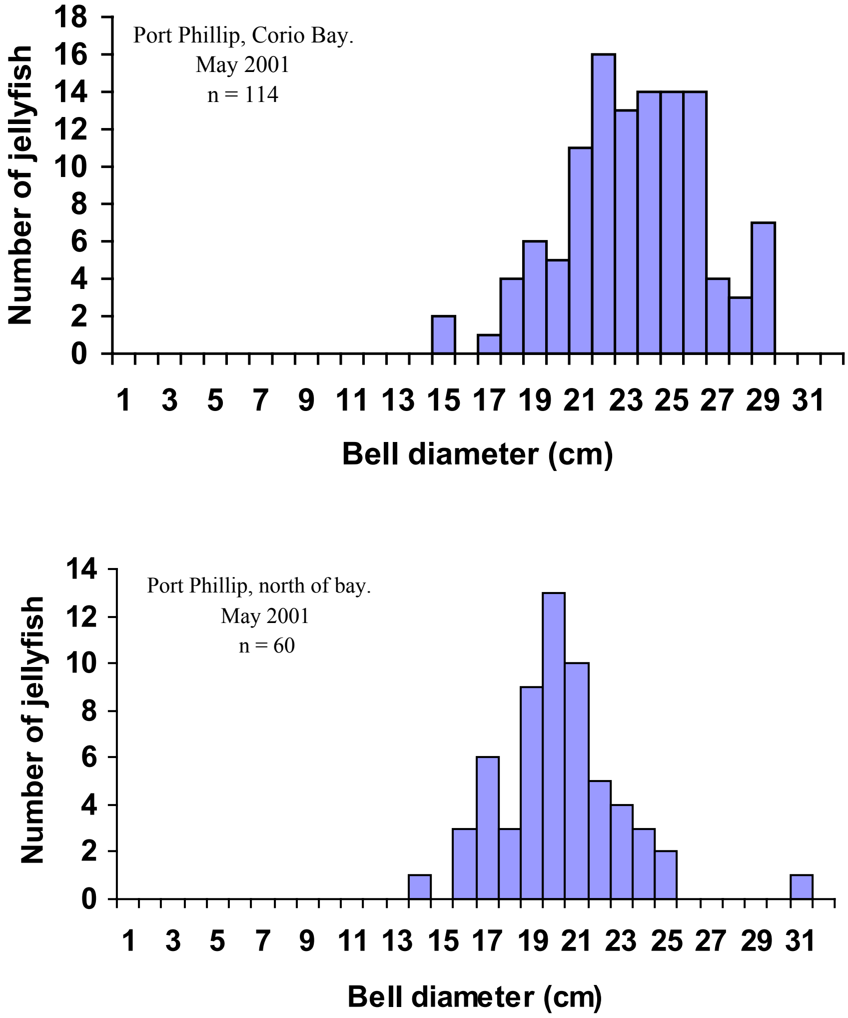


Figure A3.5. Size-frequency of *Catostylus mosaicus* at two localities around Port Phillip, May 2001.

The estimated total biomass was 4,754 tonnes and the estimated biomass of commercial size jellyfish was 3,013 tonnes (Table A3.4).

Table A3.4. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, May 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	6	139,309	951,865	3,467,043	146	999	3638
2	6	78,068	1,038,420	4,933,476	82	1090	5177
3	9	45,818	172,668	466,810	48	181	490
4	14	801,528	2,171,489	4,819,197	841	2279	5057
5	16	16,843	64,254	174,903	18	67	184
6	7	255	6,336	36,762	0.3	7	39
7	10	41,168	125,134	298,382	43	131	313
8	8	0	0	0	0	0	0
TOTAL	76	1,122,989	4,530,166	14,196,573	1,178.3	4,754	14,898
			Commercial size jellyfish			Commercial size jellyfish	
1	6	63246	432147	1574038	93	633	2306
					(47)	(322)	(1174)
2	6	35443	471443	2239798	52	691	3281
					(27)	(356)	(1671)
3	9	20801	78391	211932	30	115	310
					(16)	(59)	(158)
4	14	363894	985856	2187915	533	1444	3205
					(271)	(735)	(1632)
5	16	7647	29171	79406	11	43	116
					(5.7)	(22)	(59)
6	7	116	2877	16690	0.2	4	24
					(0.1)	(2.2)	(12)
7	10	18690	56811	135465	27	83	198
					(14)	(42)	(101)
8	8	0	0	0	0	0	0
TOTAL	76	509837	2056696	6445244	746.2	3,013	9,440
					(380.0)	(1,538.2)	(4807)

In June, only Corio Bay (seven transects, 19447 m^2) was sampled. While most of the jellyfish seen were large, there were small numbers of very small jellyfish (Fig. A3.6), suggesting that there had been a recent release of medusae.

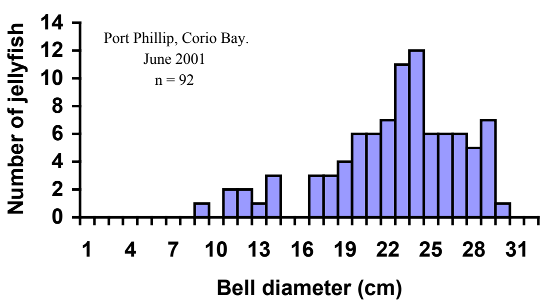


Figure A3.6. Size-frequency of *Catostylus mosaicus* in Corio Bay, June 2001.

The total biomass of jellyfish was estimated as 960 tonnes and the biomass of commercial size jellyfish as 754 tonnes (Table A3.5)

Table A3.5. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, June 2001.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
		All jellyfish			All jellyfish		
1	7	183,788	835,604	2,499,977	211	960	2,871
		Commercial size jellyfish			Commercial size jellyfish		
	7	108,251	492,170	1,472,486	166	754	2,255
					(87)	(399)	(1194)

Jellyfish are normally seen in Port Phillip within the period from late spring or early summer until late autumn or early winter, and have generally vanished by June or shortly thereafter. However, throughout the winter and early spring there were occasional reports, from other staff at the Marine and Freshwater Resources Institute and from fishers working in the area, of large jellyfish in Corio Bay. In November a field trip was made to Corio Bay. Small numbers of large jellyfish were seen. A sample of 33 individuals was collected. The smallest was 15 cm diameter but the majority (26) were of commercial size, ranging from 23 to 30 cm in diameter. Weights ranged from 600 to 2,500 grams. The presence of these large jellyfish is further evidence for the ability of jellyfish to survive through the winter.

Sampling in 2002

Initial sampling was by visual counts made from a small boat. More days and sampling time were lost through bad weather than in the previous two seasons. *Catostylus* were present during the first three months of the year, though not as abundantly as in 2001. A trawler was chartered for late April and early May in order to re-trial the jellyfish net as a means of investigating the vertical distribution of jellyfish in the water column and of refining abundance estimates. However, by the end of April jellyfish had disappeared from Port Phillip and so no work with the net was possible.

In January 89 transects (247,242 m^2) were sampled throughout Port Phillip. Eighty-four jellyfish were counted in Corio Bay (stratum 1), 3 in stratum 2 and 2 in stratum 5. The jellyfish in Corio Bay were all large with the majority of them being of commercial size and size-frequency histograms for June 2001 and January 2002 were very similar (figs A3.6 and A3.7). The population therefore appeared to consist of large individuals which had over-wintered and there was no indication of small, recently recruited medusae.

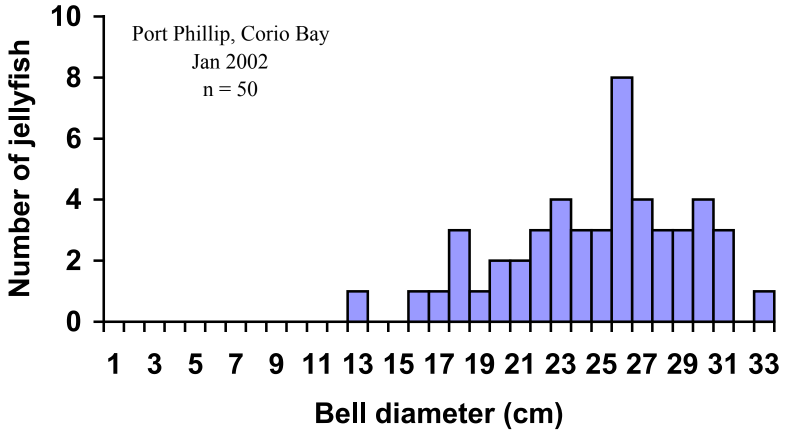


Figure A3.7. Size-frequency of *Catostylus mosaicus* in Corio Bay, January 2002.

The total biomass of the jellyfish in Corio Bay was estimated as 7.4 tonnes and the weight of commercial size jellyfish as 6.5 tonnes (Table A3.6)

Table A3.6. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, January 2002.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	7	1	4423	54753	<0.1	7.4	92
			Commercial size jellyfish			Commercial size jellyfish	
	7	0	3185	39422	0	6.5 (3.5)	81 (43)

During February 78 transects (216,682 m^2) around the bay were sampled. Numbers of jellyfish seen in Corio Bay were generally low and because of this no size-frequency samples were taken. Jellyfish size was generally large, consistent with the population still being composed chiefly of large individuals remaining from the previous year but a few smaller ones, possibly of recent origin, were seen.

Although few jellyfish were seen in Corio Bay, fishers working in the bay on the day that sampling was undertaken stated that when they hauled their seine nets at 5 am that morning they were clogged with large, brown jellyfish which were in poor condition and easily fell apart.

Jellyfish were found most abundantly in stratum 5 in the north of the bay and a size-frequency sample was collected off Altona (Fig. A3.8). Most of the jellyfish were brown in colour and a high proportion had holes in the bell and were of a poor consistency and easily fell apart. There were no small individuals.

No jellyfish were seen in strata 6 and 7 along the east coast of the bay and because of this, and inclement weather, strata 8 and 9 were not sampled.

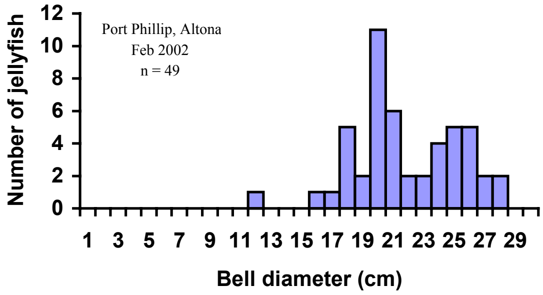


Figure A3.8. Size-frequency of *Catostylus mosaicus* off Altona, Port Phillip, February 2002.

Total biomass was estimated at 374 tonnes and the biomass of commercial size jellyfish at 62 tonnes (Table A3.7)

Table A3.7. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, February 2002.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	9	1763	28318	143549	2	30	152
2	8	0	206	3018	0	0.2	3
3	16	0	0	0	0	0	0
4	13	0	31	933	0	<0.1	1
5	15	10835	69683	246952	11	74	262
6	1	0	0	0	0	0	0
7	10	0	0	0	0	0	0
TOTAL	78	12,598	98,238	394,452	13	374.3	418
			Commercial size jellyfish			Commercial size jellyfish	
1	9	582	9,345	47,371	1 (0.6)	18 (9.6)	90 (49)
2	8	0	68	996	0	0.1 (<0.1)	1.8 (1)
3	16	0	0	0	0	0	0
4	13	0	10	308	0	0.1 (<0,1)	0.6 (0.3)
5	15	3,576	22,995	81,494	6.8 (3.7)	44 (24)	155 (84)
6	7	0	0	0	0	0	0
7	10	0	0	0	0	0	0
TOTAL	78	4,158	32,418	130,169	7.8 (4.3)	62.2 (33.6)	247.4 (134.3)

In March 99 transects (275,022 m^2) were sampled throughout the bay. *Catostylus* abundance was extremely low, and those that were seen were mainly in Corio Bay (stratum 1) and in the north of Port Phillip (Stratum 5). A size-frequency sample (Fig. A3.9) was taken in Corio Bay, the only area where jellyfish were sufficiently abundant to make taking a sample practicable, and consisted of relatively large individuals.

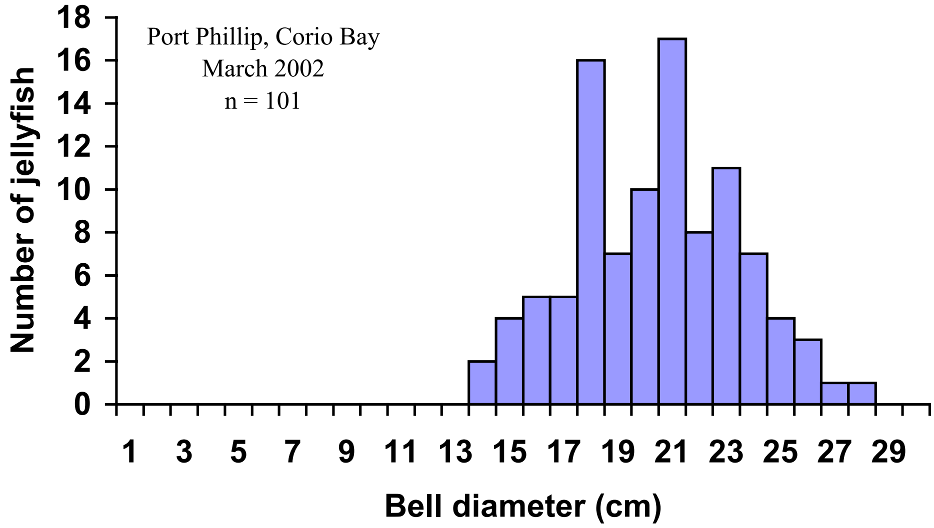


Figure A3.9. Size-frequency of *Catostylus mosaicus* in Corio Bay, March 2002.

Total biomass was estimated as 9 tonnes and the biomass of commercial size jellyfish as 3.9 tonnes (Table A3.8)

In April 99 transects (275,022 m^2) were sampled throughout the bay. Only one jellyfish, in stratum 1, was seen. Additional sampling was undertaken in Corio Bay, the area where jellyfish had been most abundant the previous month, but no jellyfish were found.

Eighty-five samples (236,130 m^2) were taken around the bay in May but no jellyfish were seen. In June only Corio Bay and the western shore of Port Phillip were surveyed. A few randomly chosen transects were surveyed but most time was spent actively searching. No jellyfish were encountered.

Table A3.8. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, March 2002.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	9	46	9039	81397	<0.1	8.9	80
2	6	0	129	3236	0	0.1	3.2
3	16	3	4	283	<0.1	<0.1	0.3
4	18	0	0	0	0	0	0
5	16	9	262	3658	<0.1	0.3	3.6
6	7	0	0	0	0	0	0
7	17	0	0	0	0	0	0
8	10	0	0	0	0	0	0
TOTAL	99	58	9434	88574	<0.1	9.3	87.1
			Commercial size jellyfish			Commercial size jellyfish	
1	9	12	2413	21733	<0.1	3.7	33
					(<0.1)	(1.9)	(17)
2	6	0	34	864	<0.1	<0.1	1.3
					(<0.1)	(<0.1)	(0.7)
3	16	1	1	76	<0.1	<0.1	0.1
					(<0.1)	(<0.1)	(<0.1)
4	18	0	0	0	0	0	0
5	16	2	70	977	<0.1	0.1	1.5
					(<0.1)	(<0.1)	(0.8)
6	7	0	0	0	0	0	0
7	17	0	0	0	0	0	0
8	10	0	0	0	0	0	0
TOTAL	99	15	2518	23650	<0.1	3.9	35.9
					(<0.1)	(1.9)	(18.5)

Results of sampling in Western Port

Sampling in 2000

There was no suitable boat that could be chartered in Western Port for using the jellyfish sampling net. Rather than pay the additional charter costs which would be involved in bringing a boat from Port Phillip, survey work in all years consisted entirely of visual observations made from a small boat.

Nineteen transects (52,782 m^2) were surveyed in February. Twenty-three *Catostylus* were seen over two transects in the north of stratum 1. Twelve of these were captured with a dipnet and ranged from 9 to 23 cm in bell diameter although only the largest one exceeded 20 cm in diameter.

In March, 48 transects (133,344 m^2) were surveyed. No *Catostylus* were spotted on any of the transects. However, some additional searching revealed *Catostylus* in the channel connecting Hastings with North Arm. A sample of these was collected. The majority were small (10 cm or less in diameter) and none were of commercial size

(Fig. A3.10).

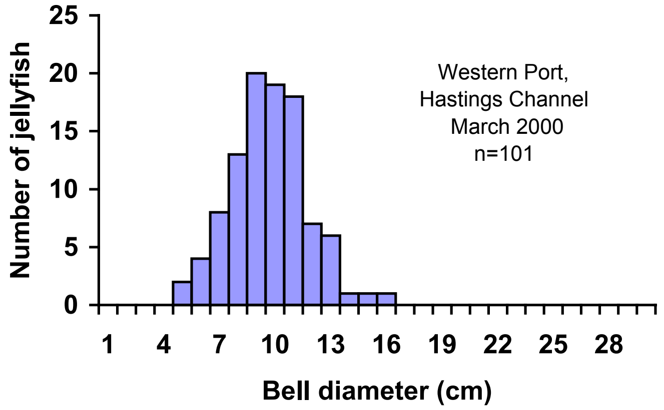


Figure A3.10. Size-frequency of *Catostylus mosaicus* in Hastings Channel, Western Port, March 2000.

In April, 48 transects (133,344 m^2) were surveyed. Only 9 *Catostylus*, all in stratum 1, were spotted on any of the transects, but during additional searching, *Catostylus* were found near to the boat ramp in Tooradin Channel (stratum 1). These *Catostylus* (Fig. A3.11) were generally smaller than those sampled in March.

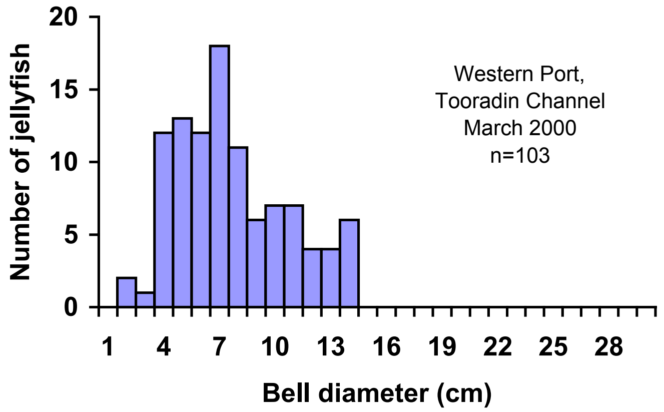


Figure A3.11. Size-frequency of *Catostylus mosaicus* in Tooradin Channel, Western Port, April 2000.

In May, 45 transects (125,010 m^2) were surveyed. No *Catostylus* were seen on any of the transects or during additional searching

Because of the paucity or absence of jellyfish in previous months, no field work was carried out in June.

Sampling in 2001

During January rough weather restricted sampling in the open waters of North Arm and East Arm to 2 transects in stratum 1 and 8 transects in stratum 2. No *Catostylus* were seen in stratum 1 and only 2 were seen in stratum 2. Additional searching was carried out in the sheltered areas of Tooradin Channel around Warneet, the Yaringa Boat Haven and Hastings Marina. Jellyfish, predominantly small and none of commercial size, were found in all of these locations (Fig. A3.12).

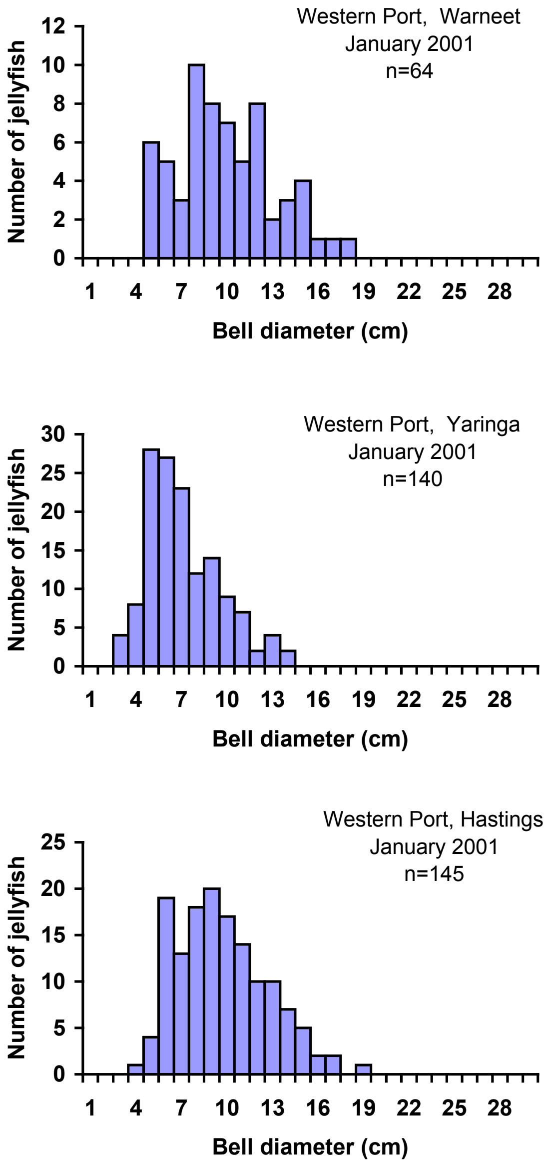
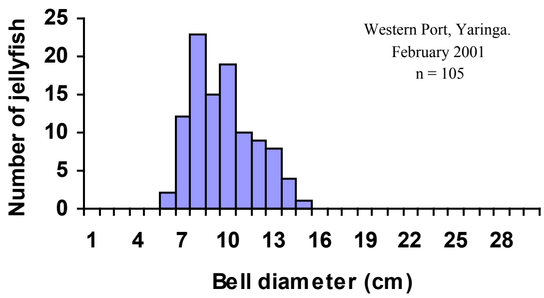


Figure A3.12. Size-frequency of *Catostylus mosaicus* at three locations in Western Port, January 2001.

During February 33 transects (91,674 m^2) were taken throughout Western Port. Size-frequency samples were taken at Yaringa and Hastings (Fig. A3.13) and showed jellyfish were still all under commercial size. There was some indication of growth with the major mode in the Yaringa samples moving from 6mm in January to 8mm in February and the major mode in the Hastings samples moving from 9 mm in January to 13 mm in February.



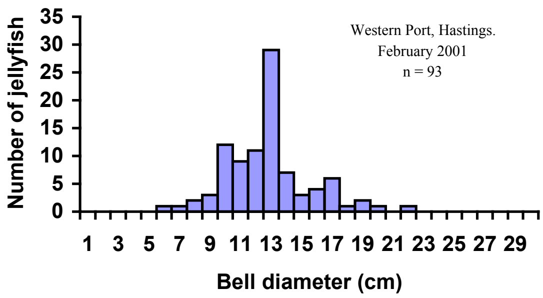


Figure A3.13. Size-frequency of *Catostylus mosaicus* at two locations in Western Port, February 2001.

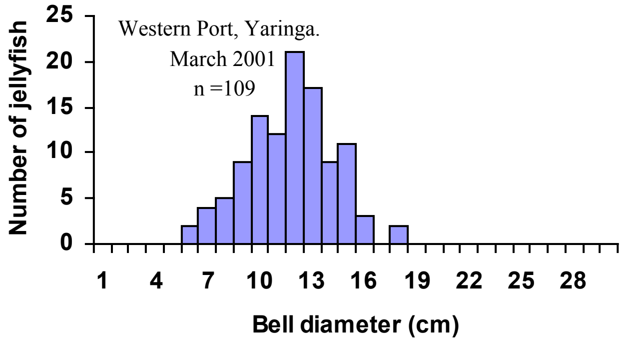
In February the biomass of jellyfish in Western port was estimated as 8 tonnes (Table A3.9)

Table A3.9. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Western Port, February 2001.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	9	268	18,691	138,835	<0.1	2.2	16.7
2	9	610	30,818	214,855	0.1	3.7	25.6
3	10	566	18,544	116,180	0.1	2.2	13.8
4	5	8	5,392	57,416	0	0.1	6.8
TOTAL	33	1,452	73,445	527,286	0.2	8.2	62.9

During March 51 transects (141678 m^2) were sampled throughout Western Port.

Jellyfish were seen only in North Arm. Samples taken at Yaringa and Hastings (Fig. A3.14) consisted entirely of jellyfish below commercial size.



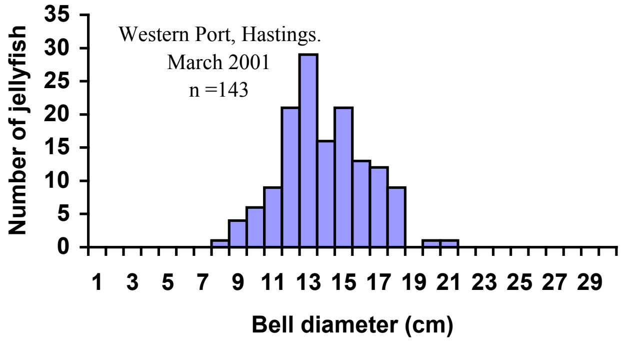


Figure A3.14. Size-frequency of *Catostylus mosaicus* at Yaringa and Hastings in Western Port, March 2001.

Total biomass was estimated at 3.5 tonnes (Table A3.10), a lower estimate than that made from samples taken in February

Table A3.10. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Western Port, March 2001.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1	13	775	16,949	94746	0.1	3.1	17.6
2	12	10	2,406	22390	<0.1	0.4	4.1
3	13	0	0	0	0	0	0
4	13	0	0	0	0	0	0
TOTAL	51				0.1	3.5	21.7

During April bad weather limited the amount of sampling that could be undertaken to 25 transects in strata 1 and 2. Only 19 jellyfish were seen, and numbers were therefore too low to take a size-frequency sample. However, jellyfish were still relatively abundant at the Yaringa boat haven and these were sampled. All were below commercial size (Fig. A3.15) and were in poor condition. Only about 10% of jellyfish in the sample were intact and over 50% of jellyfish had oral arms missing.

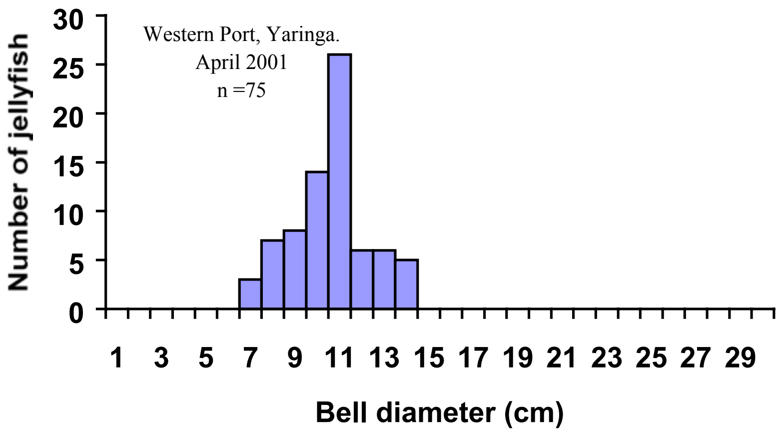


Figure A3.15. Size-frequency of *Catostylus mosaicus* at Yaringa in Western Port, April 2001.

During May 37 transects were made throughout the bay (13 transects in each of strata 1 and 2, 8 transects in stratum 3, 3 transects in stratum 4). Weather conditions shortened the initial cruise and because no jellyfish had been seen in 37 transects, and because only a few jellyfish had been seen in the previous month, no further sampling was undertaken.

No sampling was carried out in June.

Sampling in 2002

In January 53 transects (147,234 m^2) throughout Western Port were surveyed. No *Catostylus* were seen.

In February 51 transects (141,678 m^2) throughout Western Port were surveyed. Only 4 *Catostylus*, 1 in stratum 1 and 3 in stratum 2, were seen.

In April 26 transects (72,228 m^2) in North Arm (strata 1 and 2) were surveyed. Only 8 *Catostylus* were seen.

During May 28 transects (77,784 m^2) were sampled in the east of Western Port (strata 3 and 4). No *Catostylus* were seen. However, additional searching revealed a small patch of jellyfish in the Tooradin Channel. A size-frequency sample was taken and showed the majority to be less than 10 cm in bell diameter (Fig. A3.16).

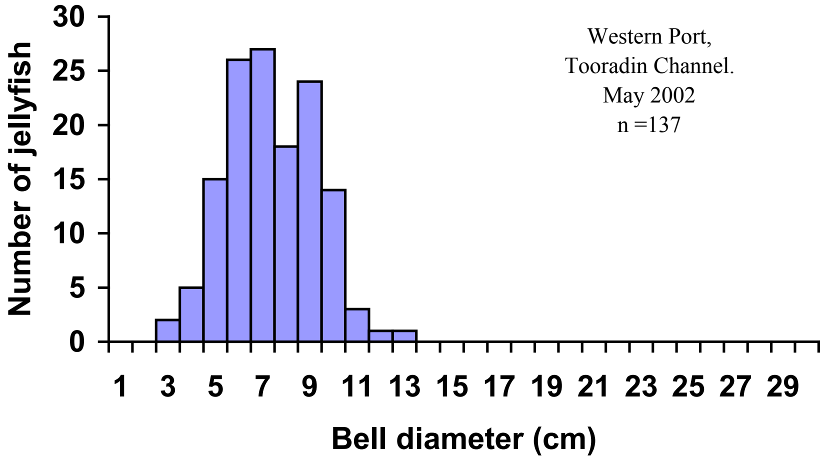


Figure A3.16. Size-frequency of *Catostylus mosaicus* in the Tooradin Channel, Western Port, May 2002.

Sampling in Corner Inlet

Sampling in 2000

In February 34 transects (94,452 m^2) were surveyed. Two hundred and four *Catostylus mosaicus* were counted on 5 transects in stratum 5, the majority (149) coming from a single transect just north of Sunday Island. Measurement of *Catostylus* from a transect near the mouth of the Albert River showed them to have a bell diameter in the range 6 – 18 cm (Fig. A3.17).

Sixteen *Catostylus* were seen on three transects in stratum 6, *Catostylus* were seen on two transects in stratum 1 and 8 jellyfish were spotted in areas of Corner Inlet outside the defined strata.

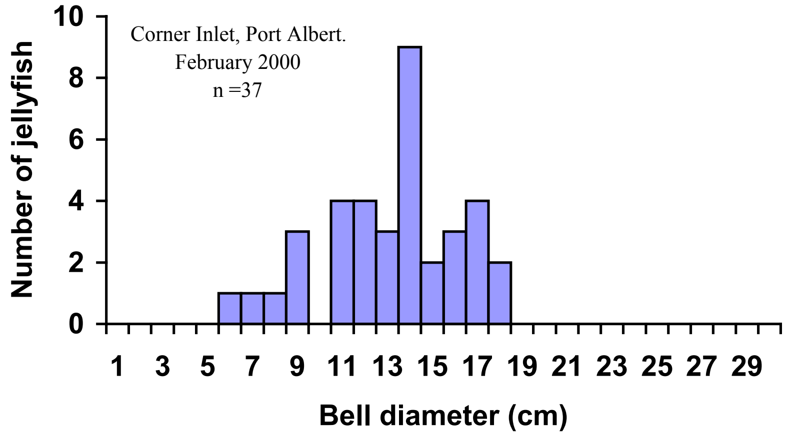


Figure A3.17. Size-frequency of *Catostylus mosaicus* Port Albert, Corner Inlet, February 2000.

In March, 77 transects (213,906 m^2) were surveyed. No *Catostylu*s were seen.

In April, 72 transects (200,016 m^2) were sampled. Only 2 small *Catostylus* were seen and these were on one transect in Stratum 1. A few small *Catostylus* were seen off Port Franklin although these were not in any of the randomly selected transects. As the result of some searching, 20 jellyfish were collected. All were small with bell diameters ranging from 3 to 7 cm.

In contrast to the very small numbers of *Catostylus* that were observed, ctenophores (unidentified) were abundant and widespread throughout strata 1, 2 and 3.

Because of the very small numbers of jellyfish that had been observed in Corner Inlet in the previous three months, stratified random sampling was not carried out during May. Instead, a visual survey was carried out throughout Corner Inlet and the Nooramunga from Port Franklin as far east as McLoughlans Beach. The strategy adopted was to travel at approximately 15 knots for one kilometre, looking on both sides of the boat, and then to slow down to idling speed for approximately 100m. The lower speed meant that it was possible to look deeper into the water column than at the higher speed.

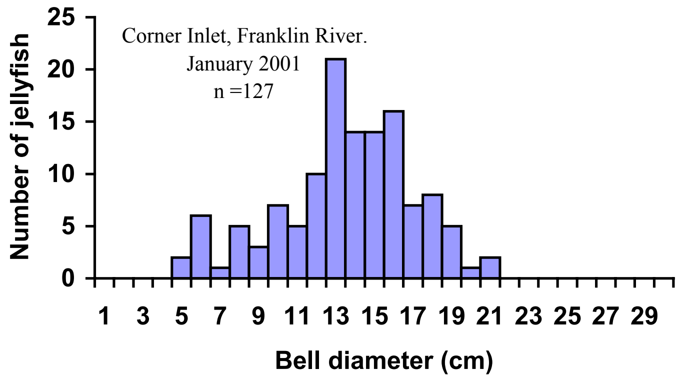
No jellyfish were seen throughout the entire area. Several commercial fishers were contacted and all reported that they had seen no jellyfish recently

Sampling in 2001

Because of the general lack of *Catostylus* seen in the previous season, emphasis in January 2001, the first cruise of the season, was on tracking down jellyfish wherever they were rather than doing random transects to estimate abundance. Contacts with local fishers (before going to Corner Inlet) indicated that jellyfish were present in the

Franklin River and that the most likely areas to find *Catostylus* were in those areas included in strata 1a, 1b, 2a, 5 and 6. Two days were spent sailing around these areas looking for jellyfish. Four transects (11,112 m^2) were surveyed in Stratum 2a, which includes the Franklin River, and five transect (13,890m^2) were surveyed in stratum 5 since relatively abundant jellyfish were seen in both of these locations.

Size-frequency samples were taken in the Franklin River and around Toora and Port Albert (Fig. A3.18). The largest individuals were found in the open waters of the inlet. Some commercial size individuals were found and these had presumably over-wintered from the previous year



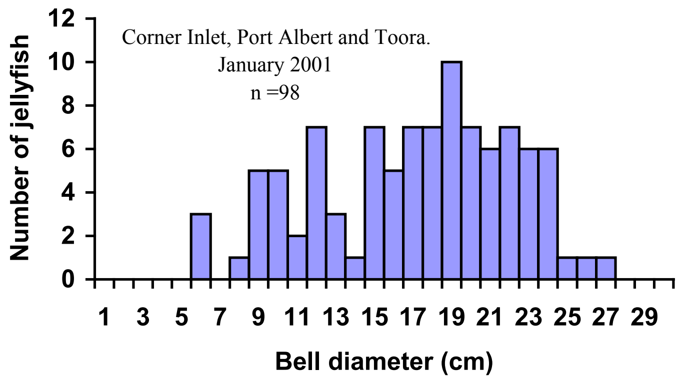


Figure A3.18. Size-frequency of *Catostylus mosaicus* in the Franklin River and around Toora and Port Albert, Corner Inlet, January 2001.

Biomass estimates gave a total of 859 tonnes of *Catostylus*, of which 198 tonnes was attributable to commercial size jellyfish, in the strata surveyed (Table A3.11).

Table A3.11. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, January 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
2a	4	34,251	79,295	158,642	15	35	71
5	5	1,331,074	1,851,562	2,511,560	592	824	1,118
TOTAL	9	1,365,325	1,930,857	2,670,202	607	859	1,189
			Commercial size jellyfish			Commercial size jellyfish	
2a	4	2,261	5,233	10,470	3.5	8.1	16
					(1.6)	(3.8)	(7.6)
5	5	87,851	122,203	165,763	137	190	258
					(64)	(89)	(121)
TOTAL	9	90,112	127,436	176,233	140.5	198.1	274.3
					(65.6)	(92.8)	(128.6)

During February, 44 transects (122,232m^2) throughout Corner Inlet were surveyed. *Catostylus* were widespread and size-frequency samples were obtained from 3 locations (Fig. A3.19). As in the previous month larger jellyfish were obtained in the open waters of the inlet than in the Franklin River.

The biomass of *Catostylus* was estimated at 106 tonnes of which 34 tonnes was attributable to commercial size jellyfish (Table A3.12).

As a result of searching beyond the randomly selected transects, a small, dense patch of jellyfish was found around the mouth of the Toora Channel. By sailing around it and plotting its boundaries, the area of the patch was estimated as 0.27 km^2. Counts were made on transects through the patch and the abundance and biomass of jellyfish in the patch were estimated (Table A3.13)

The Toora Channel is stratum 1b and has an area of 4.7 km^2. The random transect samples for this stratum provided a total estimate of 7 tonnes of jellyfish, but the dense patch of jellyfish contained an estimated 208 tonnes, thirty times as much as the estimate for the whole stratum based on random counts. The estimated weight of jellyfish in the patch was also nearly twice the estimate (106 tonnes) for all of the strata surveyed by random sampling.The confidence intervals for estimates made on the dense patch were also narrower than those made from the random transects because the counts made on transects through the patch were less variable than counts on the random transects.

This comparison shows that whether or not aggregations are encountered during sampling (either because they fall within the random sampling scheme or are found through additional searching) may have a substantial effect on abundance and biomass estimates.

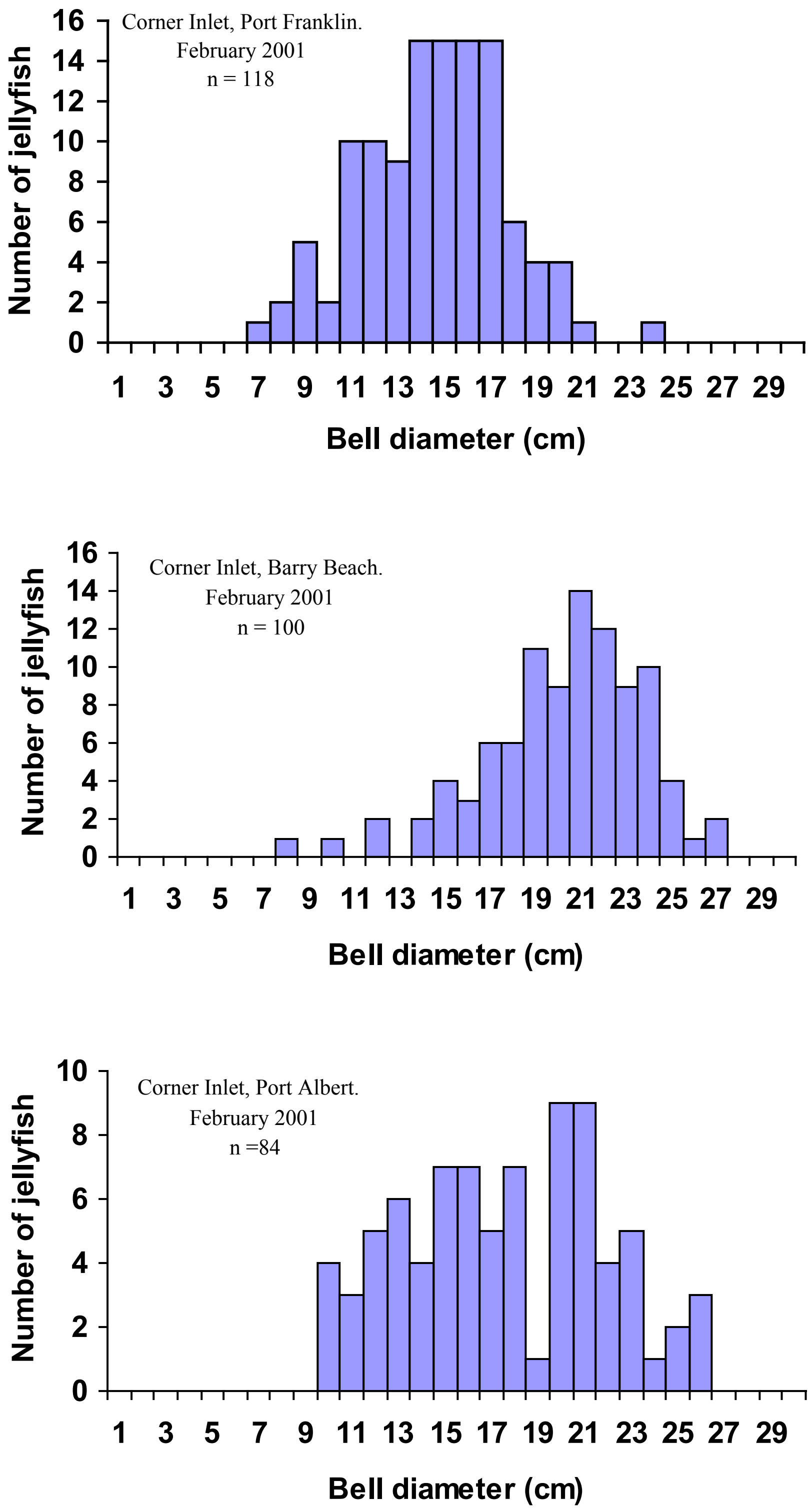


Figure A3.19**.** Size-frequency of *Catostylus mosaicus* from three locations in Corner Inlet, February 2001.

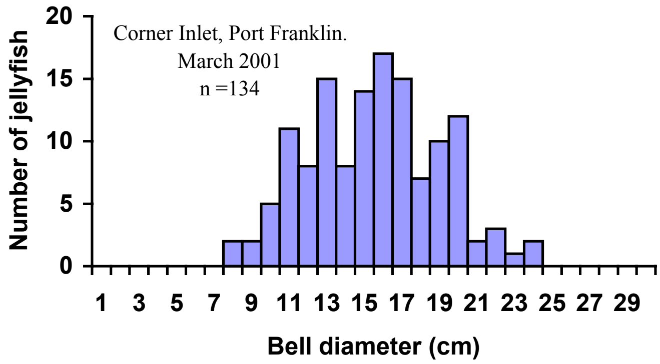
Table A3.12. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, February 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

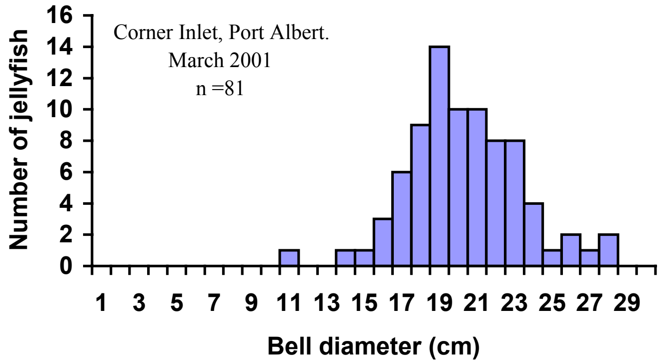
Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	4	0	0	0	0	0	0
1b	6	134	13,165	105,480	0.1	6.7	54
2a	3	0	8,816	161,331	0	4.5	83
2b	4	7	7,688	170,828	<0.1	4	88
2c	4	0	0	0	0	0	0
4	4	7	8,221	183,382	<0.1	4.2	94
5	9	10,816	166,818	834,175	5.6	86	429
6	10	0	1,870	23,708	0	1	12
TOTAL	44	10,964	206,578	1,478,904	5.7	106.1	760
			Commercial size jellyfish			Commercial size jellyfish	
1a	4	0	0	0	0	0	0
1b	6	18	1,900	14,345	<0.1	2.2	17.4
					(<0.1)	(1.1)	(9.5)
2a	3	0	1,199	21,941	0	1.5	26
						(0.8)	(14)
2b	4	1	1,046	23,233	<0.1	1.3	28
					(<0.1)	(0.6)	(15)
2c	4	0	0	0	0	0	0
4	4	1	1,118	24,940	<0.1	1.3	30
					(<0.1)	(0.6)	(16)
5	9	1,471	22,687	113,448	1.8	27	137
					(1)	(15)	(75)
6	10	0	254	3,224	0	0.3	3.9
						(0.2)	(2.2)
TOTAL	44	1,491	28,094	201,131	1.9	33.6	242.3
					(1)	(18.3)	(131.7)

Table A3.13. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in the aggregation found at the mouth of the Toora Channel, Corner Inlet, February 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1b	4	165,602	267,618	410,782	128	208	319
			Commercial size jellyfish			Commercial size jellyfish	
	4	48,025	77,609	119,127	58	94	145
					(31)	(51)	(79)

During March 74 transects (205,572m^2) were sampled. Jellyfish were widespread and size-frequency samples were obtained from three locations (Fig. A3.20). As in the previous month, Jellyfish were generally smaller around Port Franklin than at the other locations.





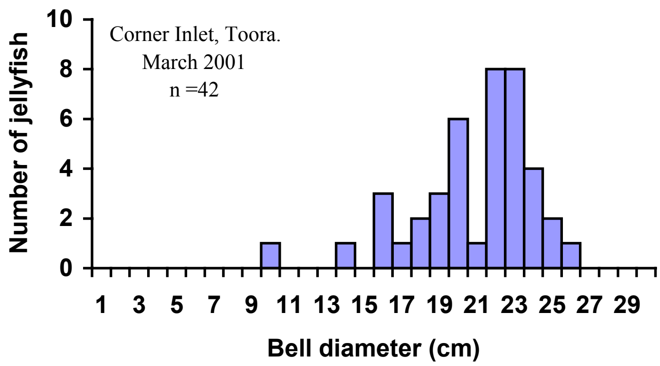


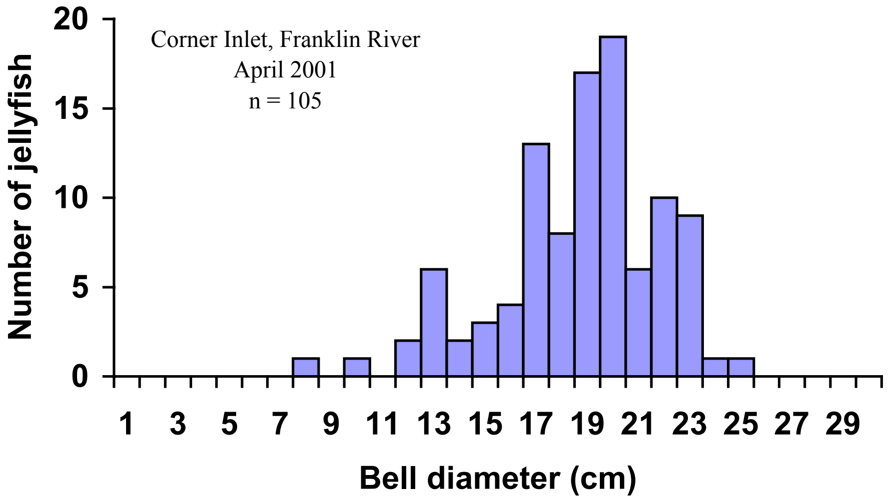
Figure A3.20. Size-frequency of *Catostylus mosaicus* from three locations in Corner Inlet, March 2001.

Total biomass was estimated as 233 tonnes and the biomass of commercial size jellyfish to be 71 tonnes (Table A3.14).

Table A3.14. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, March 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	8	10	387	2,515	<0.1	0.2	1.5
1b	4	772	15,157	56,8828	0.5	9	338
2a	4	14,227	175,880	813,921	8.5	105	484
2b	6	5,243	25,289	77,999	3.1	15	46
2c	4	98	7,390	56,182	0.1	4.4	33
3a	6	9,723	15,889	24,506	5.8	9.4	15
3b	6	0	87	2,254	0	0.1	1.3
4	12	832	8,328	35,601	0.5	5	21
5	12	20,517	126,965	442,025	12	76	263
6	12	1,901	15,716	62,161	1.1	9.3	37
TOTAL	74	53,323	391,088	2,085,992	31.7	233.4	1239.8
			Commercial size jellyfish			Commercial size jellyfish	
1a	8	1	54	352	<0.1	0.1	0.5
					(<0.1)	(<0.1)	(0.22)
1b	4	108	2,122	79,636	0.1	2.7	103
					(<0.1)	(1.3)	(48)
2a	4	1,992	24,623	113,949	2.6	32	147
					(1.2)	(15)	(70)
2b	6	734	3,540	10,920	1	4.6	14
					(0.4)	(2.2)	(6.7)
2c	4	14	1,035	7,865	<0.1	1.3	10.1
					(<0.1)	(0.6)	(4.8)
3a	6	1,361	2,224	3,431	1.8	2.9	4.4
					(0.9)	(1.4)	(2.1)
3b	6	0	12	316	0	<0.1	0.4
						(<0.1)	(0.2)
4	12	116	1,166	4,984	0.2	1.5	6.4
					(<0.1)	(0.7)	(3)
5	12	2,872	17,775	61,884	3.7	23	80
					(1.7)	(11)	(38)
6	12	266	2,200	8,703	0.3	2.8	11
					(0.2)	(1.3)	(5.4)
TOTAL	74	7,456	54,752	292,039	9.8	70.9	376.8
					(4.4)	(33.5)	(178.4)

During April 74 transects (205,572m^2) were sampled. Jellyfish were widespread and size-frequency samples were obtained from the Franklin River and Port Albert (Fig. A3.21). In contrast with samples taken in previous months, the jellyfish collected from the Franklin River were not noticeably smaller than those taken elsewhere in the Inlet.



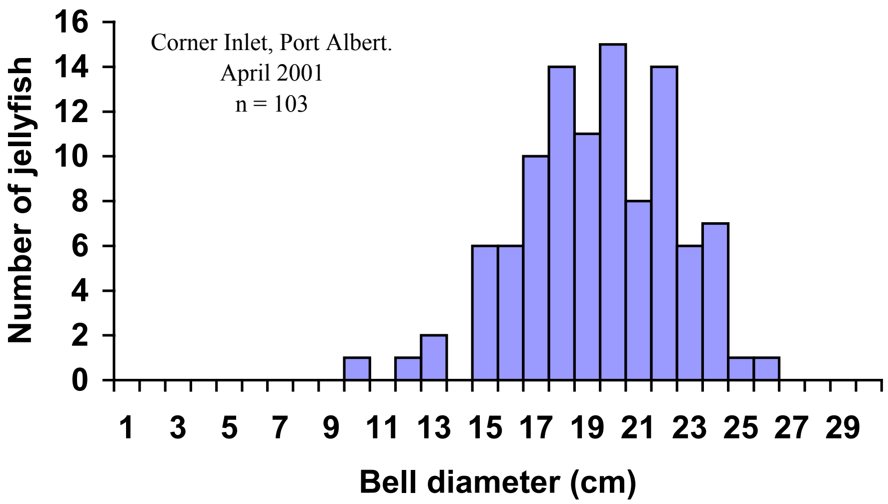


Figure A3.21. Size-frequency of *Catostylus mosaicus* from the Franklin River and Port Albert in Corner Inlet, April 2001.

Total biomass was estimated as 1,540 tonnes and the biomass of commercial size jellyfish to be 339 tonnes (Table A3.15).

Table A3.15. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, April 2001. *Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.*

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	8	0	40	598	0	<0.1	0.4
1b	7	775	4,965	17,563	0.5	3.5	12
2a	4	4,132	34,288	135,835	3	24	96
2b	6	27	2,276	17,735	<0.1	1.6	12
2c	4	70	82	6,325	<0.1	<0.1	4.4
3a	5	40	47	3,621	<0.1	<0.1	2.5
3b	6	0	245	3,033	0	0.1	2.1
4	12	5	758	6,647	<0.1	0.5	4.7
5	11	971,148	2,073,506	3,921,964	684	1,459	2,761
6	11	33795	71852	135500	24	51	95
TOTAL	74	1,009,992	2,188,059	4,248,821	711.5	1,539.7	2,990.1
			Commercial size jellyfish			Commercial size jellyfish	
1a	8	0	5	75	0	<0.1	0.1
						(<0.1)	(<0.1)
1b	7	97	621	2,195	0.1	0.7	2.7
					(<0.1)	(0.3)	(1.4)
2a	4	517	4,286	16,979	0.6	5.3	21
					(0.3)	(2.6)	(10)
2b	6	3	285	2,217	<0.1	0.3	2.8
					(<0.1)	(0.2)	(1.4)
2c	4	9	10	791	<0.1	<0.1	1
					(<0.1)	(<0.1)	(0.5)
3a	5	5	6	453	<0.1	<0.1	0.6
					(<0.1)	(<0.1)	(0.3)
3b	6	0	31	379	0	<0.1	0.4
						(<0.1)	(0.2)
4	12	1	95	831	<0.1	0.1	1
					(<0.1)	(<0.1)	(0.5)
5	11	121,394	259,188	490,246	151	322	609
					(75)	(161)	(305)
6	11	4,224	8,982	16,938	5.3	11	21
					(2.6)	(5.6)	(10)
TOTAL	74	126,250	273,509	531,104	157	339	659.6
					(77.9)	(169.7)	(329.3)

Four of the transects in stratum 5 were within a very dense patch of jellyfish which was found in the south of the stratum. By sailing around it and plotting its boundaries, the area of the patch was estimated as 2.74 km^2 (the area of the whole stratum is 21km^2). Using the counts from the four transects that occurred within the patch, the abundance and biomass of jellyfish in the patch were estimated (Table A3.16). The estimated mean biomass of the patch was higher than the estimate for the whole of stratum 5 based on all the random samples, and confidence intervals for the patch were smaller than those for the stratum as a whole The estimated mean biomass of the patch was also higher than the estimated mean biomass for all the strata sampled.

These results emphasise, as did those for February, the very large influence that jellyfish aggregations have on abundance and biomass estimates.

Table A3.16. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in the aggregation found in stratum 5, Corner Inlet, April 2001.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
5	4	1,680,554	2,715,827	4,168,672	1,183	1,912	2,934
			Commercial size jellyfish			Commercial size jellyfish	
5	4	210,069	339,478	521,084	261 (131)	422 (211)	648 (325)

In May 73 transects (202,794 m^2) were sampled. Conditions were relatively rough. The water was very murky, particularly round the mouths of the Albert and Tara Rivers, presumably due to sediment stirred up by windy conditions and to sediment carried into the inlet by recent heavy rains. Jellyfish were patchier in distribution and less abundant than in April. Only one size-frequency sample was taken (Fig. A3.22) and the majority of jellyfish in the sample were in poor condition with holes or cracks and fissures in the bell.

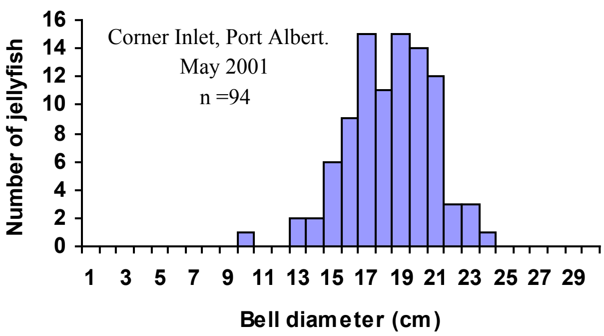


Figure A3.22**.** Size-frequency of *Catostylus mosaicus* from Port Albert, Corner Inlet, May 2001.

Total jellyfish biomass was estimated at 67 tonnes and the biomass of commercial size jellyfish at 5 tonnes (Table A3.17). These figures indicate a 96% reduction in biomass since the previous month's survey.

Table A3.17. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, May 2001. *N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.*

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	6	0	0	0	0	0	0
1b	7	39	813	4482	<0.1	0.5	2.6
2a	4	2806	14301	45345	1.6	8.1	26
2b	6	35	41	3160	<0.1	<0.1	1.8
2c	4	20	24	1807	<0.1	<0.1	1.0
3a	6	3	3	249	<0.1	<0.1	0.1
3b	6	0	1928	27855	0	1.1	16
4	11	0	279	3096	0	0.2	1.8
5	12	25099	87267	225365	14	50	128
6	11	1987	12699	44880	1.1	7.2	26
TOTAL	73	29989	117355	356239	16.7	67.1	203.3
			Commercial size jellyfish			Commercial size jellyfish	
1a	6	0	0	0	0	0	0
1b	7	2	35	193	<0.1 (<0.1)	(<0.1) <0.1	0.2 (0.1)
2a	4	121	615	1950	0.1 (<0.1)	0.7 (0.3)	2.1 (1)
2b	6	2	2	136	<0.1 (<0.1)	<0.1 (<0.1)	0.1 (<0.1)
2c	4	1	1	77	<0.1 (<0.1)	<0.1 (<0.1)	0.1 (<0.1)
3a	6	0	0	11	0	0	<0.1 (<0.1)
3b	6	0	83	1198	0	0.1 (<0.1)	1.3 (0.6)
4	11	0	12	133	0	<0.1 (<0.1)	0.1 (<0.1)
5	12	1079	37532	9691	1.1 (0.6)	4 (2)	10 (4.5)
6	11	85	546	1930	0.1 (<0.1)	0.6 (0.3)	2.1 (0.9)
TOTAL	73	1290	38826	15319	1.3 (0.6)	5.4 (2.6)	16 (7.1)

In June 22 transects (61,116 m^2) were surveyed. Only strata 5 and 6 were sampled as these were the strata where most jellyfish had been found in the previous month. Small numbers of jellyfish were seen on some transects. A few were caught and examined but because of low numbers no sample was taken for size-frequency analysis and length-weight correlations. Most jellyfish examined were in poor condition with holes and fissures in the bell and/or with stumpy tentacles. In some cases the bell appeared deformed or bulging in places. Most jellyfish seen were only small to medium in size with a bell diameter estimated to be less than 20 cm. Estimates of abundance were made but, in the absence of a size-frequency sample, no biomass estimates were made (Table A3.18).

Table A3.18. Estimated abundance and weight (plus upper and lower 95%

Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, June 2001. *N is the number of transects per stratum. No estimates of numbers of commercial size jellyfish or of weights were made because no size-frequency sample was obtained.*

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
5	11	0	495	5523			
6	11	0	192	2219			
TOTAL	22	0	687	7742			

Sampling in 2002

In January 51 transects (141,678 m^2) were sampled throughout Corner Inlet. No jellyfish were seen.

Corner Inlet was visited during the first week in February. Rough weather prevented any transects being sampled. However, jellyfish were found in the Franklin River and a sample of these was collected (Fig. A3.23). The sample included large individuals, which must have been present, but not detected, in the previous month.

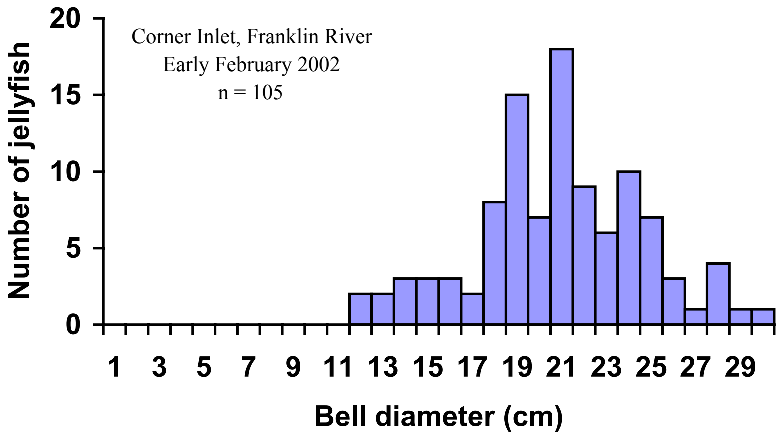
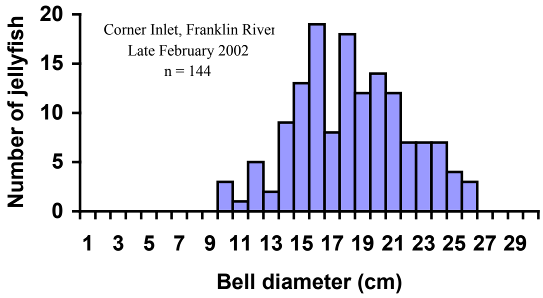


Figure A3.23. Size-frequency of *Catostylus mosaicus* from the Franklin River, Corner Inlet, early February 2002.

A further visit was made in the last week of February. Windy weather again prevented much of the Inlet being sampled. A sample of jellyfish was again obtained from the Franklin River where they were numerous (Fig. A3.24). Twenty-four transects were sampled in strata 5 and 6. Only a few jellyfish were seen and a small number were collected (Fig. A3.24). The size distribution of jellyfish from the Franklin River was similar to that of jellyfish from Port Albert although at the same time in the previous year jellyfish from the Franklin River had been generally smaller than those from elsewhere in the inlet.



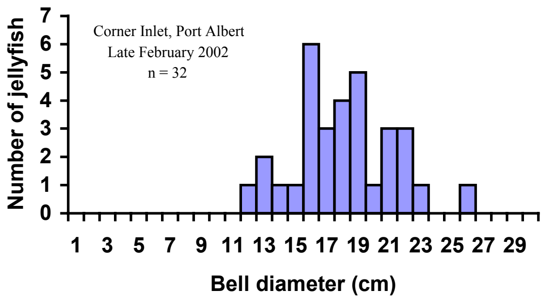


Figure A3.24. Size-frequency of *Catostylus mosaicus* from the Franklin River and Port Albert, Corner Inlet, late February 2002.

Total jellyfish biomass was estimated at 19 tonnes and the biomass of commercial size jellyfish at 6 tonnes (Table A3.19).

Table A3.19. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, late February 2002.
Estimates are based on all size-frequency samples. N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
5	12	1079	25323	144536	0.8	19	107
6	12	0	112	2177	0	0.1	1.6
TOTAL	24	1079	25435	146713	0.8	19.1	108.6
			Commercial size jellyfish			Commercial size jellyfish	
5	12	140	3292	18790	0.2 (0.1)	5.3 (2.3)	30 (13)
6	12	0	115	283	0	<0.1 (<0.1)	0.5 (0.2)
TOTAL	24	140	3407	19073	0.2 (0.1)	5.6 (2.3)	30.5 (13.2)

During April 70 transects (194,460 m^2) were sampled throughout Corner Inlet. Jellyfish were present on about 50% of the transects. Most individuals appeared to be medium to small in size but low numbers made taking a size-frequency sample impracticable. The only place where jellyfish were abundant was in the Franklin River and a size-frequency sample was taken here (Fig. A3.25). None of the jellyfish sampled were of commercial size. Total biomass was estimated as 24 tonnes (Table A3.20)

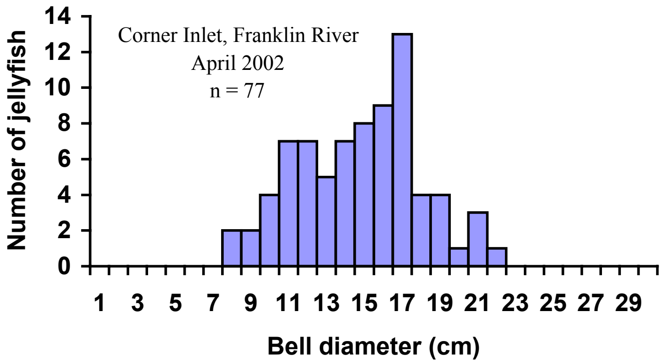


Figure A3.25. Size-frequency of *Catostylus mosaicus* from the Franklin River, Corner Inlet, April 2002.

Table A3.20. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, April 2002. *N is the number of transects per stratum. No commercial size jellyfish were taken in size-frequency samples for this month*

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	6	0	0	0	0	0	0
1b	7	28	786	4,733	<0.1	0.3	1.7
2a	4	2	2,602	58,041	<0.1	0.9	21
2b	4	0	445	9,179	0	0.2	3.3
2c	3	63	74	5,711	<0.1	<0.1	2.1
3a	7	0	0	0	0	0	0
3b	4	0	245	5,049	0	0.1	1.8
4	11	0	79	1,301	0	<0.1	4.7
5	12	19,876	59,327	139,899	7.2	22	51
6	12	13	1,049	8,056	<0.1	0.4	2.9
TOTAL	70	19,982	64,607	231,969	7.2	23.9	88.5

During May 62 transects (172,236 m2) were sampled throughout Corner Inlet. Jellyfish were very few in number except in and around the mouth of the Franklin River. In contrast to the sample taken in April, a sample taken from the Franklin River (Fig. A3.26) included jellyfish of commercial size.

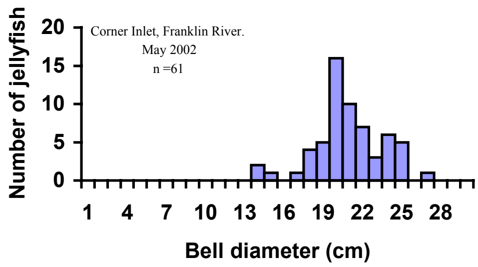


Figure A3.26. Size-frequency of *Catostylus mosaicus* from the Franklin River, Corner Inlet, May 2002.

Total biomass was estimated at 50 tonnes and the biomass of commercial size jellyfish at 18 tonnes (Table A3.21).

Table A3.21. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Corner Inlet, May 2002. *N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights.*

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
			All jellyfish			All jellyfish	
1a	6	1	1	75	<0.1	<0.1	0.1
1b	4	0	106	2,183	0	0.1	1.7
2a	4	875	64514	488,341	0.7	50	380
2b	3	112	132	10,112	0.1	0.1	7.9
2c	3	0	0	0	0	0	0
3a	10	0	0	0	0	0	0
3b	2	0	0	0	0	0	0
4	6	0	0	0	0	0	0
5	11	0	12	344	0	<0.1	0.3
6	13	0	2	56	0	<0.1	<0.1
TOTAL	62	988	64767	501,111	0.8	50.2	390
			Commercial size jellyfish			Commercial size jellyfish	
1a	6	0	0	18	0	0	<0.1(<0.1)
1b	4	0	26	536	0	<0.1 (<0.1)	0.6 (0.3)
2a	4	215	15,864	120,083	0.2 (0.1)	18 (11)	138 (82)
2b	3	28	32	2,487	<0.1 (<0.1)	<0.1 (<0.1)	2.9 (1.7)
2c	3	0	0	0	0	0	0
3a	10	0	0	0	0	0	0
3b	2	0	0	0	0	0	0
4	6	0	0	0	0	0	0
5	11	0	3	85	0	<0.1 (<0.1)	0.1 (<0.1)
6	13	0	0	14	0	0	<0.1 (<0.1)
TOTAL	62	243	15,925	123,223	0.2 (0.1)	18 (11)	141.6 (84)

Because of the low numbers of jellyfish seen in strata 5 and 6 in May, no transects were sampled in these strata in June. Instead active searching for jellyfish was conducted throughout the strata. Only two jellyfish were seen.

In contrast to the situation in May, jellyfish were scarce in and around the mouth of the Franklin River. Nineteen jellyfish were collected after an hour and a half searching and these were all medium to large (Fig. A3.27). Although a few of the jellyfish collected were in good condition, others were very poor and fell apart on being handled or had several holes in the bell.

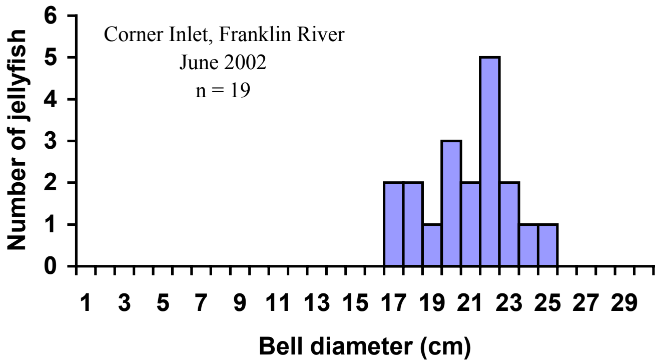


Figure A3.27. Size-frequency of *Catostylus mosaicus* from the Franklin River, Corner Inlet, June 2002.

Appendix 4: Chemical analyses.

Table A4.1. Metal concentrations (µg/g wet weight) in the bells of jellyfish, *Catostylus mosaicus*, collected from Corio Bay, Port Phillip, March 2001.
Zn, zinc; Hg, mercury; Cd, cadmium; Pb, lead; As, arsenic (considered to be a metal for the purposes of setting food quality standards). Numbers in brackets at the head of each metal column show the range in maximum permitted concentrations (µg/g wet weight) allowed in fish, crustacea and shellfish listed in Food Standards Australia New Zealand (ANZFA 2001). The exception is zinc. There is no legislation setting maximum limits for zinc. The figures shown indicate median levels to be expected in crustaceans and fish.

Wet weight of jellyfish in grams		Bell diameter (cm)	Metal (µg/g wet weight)				
Total	Bell		Zn (5-25)	Hg (0.5-1)	Cd (2)	Pb (0.5-2)	As (1-2)
190	107	12	1.1	0.0002	0.04	0.02	0.32
668	375	18.5	1.1	0.0000	0.03	0.02	0.15
2228	1433	28.5	0.6	0.0002	0.01	0.00	0.08
1489	811	24.5	0.9	0.0002	0.03	0.01	0.17
796	495	20	1.0	0.0000	0.02	0.02	0.19
875	462	20.5	0.6	0.0001	0.03	0.01	0.09
1718	995	27	0.9	0.0004	0.03	0.02	0.16
2796	1616	29	0.7	0.0001	0.03	0.01	0.09
1403	734	23.5	0.5	0.0002	0.01	0.01	0.00
1698	938	25.5	0.9	0.0002	0.05	0.02	0.22
987	686	22.5	0.6	0.0002	0.01	0.01	0.05
875	517	21.5	0.8	0.0002	0.01	0.01	0.11
1476	830	24.5	0.8	0.0001	0.03	0.01	0.11
1619	945	26	1.1	0.0002	0.03	0.01	0.13
1387	782	24.5	0.8	0.0002	0.02	0.01	0.11
1171	817	25.5	0.7	0.0000	0.03	0.02	0.11
1107	634	22	1.0	0.0001	0.04	0.02	0.18
1537	867	25	0.9	0.0002	0.02	0.01	0.15
520	340	19.5	0.8	0.0001	0.03	0.02	0.11
1323	805	24	0.6	0.0002	0.03	0.02	0.09

Table A4.2. Metal concentrations (µg/g wet weight) in the bells of jellyfish, *Catostylus mosaicus*, collected from the mouth of the Werribee River, Port Phillip, March 2001, and in commercially prepared product.
Zn, zinc; Hg, mercury; Cd, cadmium; Pb, lead; As, arsenic (considered to be a metal for the purposes of setting food quality standards): Al, aluminium. ***.*** *Numbers in brackets at the head of each metal column show the range in maximum permitted concentrations (µg/g wet weight) allowed in fish, crustacea and shellfish listed in Food Standards Australia New Zealand (ANZFA 2001). The exceptions are zinc and aluminium. There is no legislation setting maximum limits for zinc or aluminium. The figures shownin the zinc column indicate median levels to be expected in crustaceans and fish. The Food Standards lists no data for expected levels of aluminium.*

Wet weight of jellyfish in grams		Bell diameter (cm)	Metal (µg/g wet weight)					
Total	Bell		Zn (5-25)	Hg (0.5-1)	Cd (2)	Pb (0.5-2)	As (1-2)	Al
982	642	21.5	1.0	0.0003	0.01	0.01	0.14	0.06
1191	752	23	1.0	0.0003	0.01	0.01	0.14	0.06
1520	791	24.5	0.7	0.0002	0.01	0.01	0.13	0.04
1061	630	22	1.1	0.0002	0.02	0.01	0.95	0.05
1229	730	23.5	1.2	0.0001	0.02	0.01	0.83	0.03
1702	1063	26.5	1.0	0.0001	0.01	0.01	0.54	0.12
1541	1082	23.5	1.1	0.0002	0.01	0.01	0.47	0.04
1357	760	24	1.1	0.0003	0.01	0.01	0.13	0.05
769	457	20.5	0.8	0.0002	0.01	0.01	0.32	0.03
1011	638	22	0.8	0.0002	0.01	0.01	0.02	0.03
1321	810	24	1.0	0.0002	0.01	0.01	0.54	0.02
978	591	22.5	0.5	0.0000	0.01	0.01	0.57	0.03
1188	754	24.5	0.4	0.0000	0.00	0.01	0.33	0.02
883	537	22	1.5	0.0001	0.02	0.02	0.71	0.04
1343	802	25.5	1.1	0.0002	0.02	0.01	0.30	0.04
1071	651	24.5	1.2	0.0002	0.02	0.01	0.25	0.04
1621	978	27.5	0.9	0.0001	0.01	0.01	0.32	0.04
1235	742	23.5	1.0	0.0003	0.01	0.01	0.22	0.04
817	516	20	1.1	0.0003	0.01	0.01	0.26	0.04
788	510	21	0.7	0.0001	0.01	0.01	0.35	0.03
Commercial product (144g)	-	-	0.2	0.0014	0.00	0.05	1.13	1200

Table A4.3. Metal concentrations (µg/g wet weight) in the bells of jellyfish, *Catostylus mosaicus*, collected from Hobsons Bay, northern Port Phillip, March 2001. *Zn, zinc; Hg, mercury; Cd, cadmium; Pb, lead; As, arsenic (considered to be a metal for the purposes of setting food quality standards). Numbers in brackets at the head of each metal column show the range in maximum permitted concentrations (µg/g wet weight) allowed in fish, crustacea and shellfish listed in Food Standards Australia New Zealand (ANZFA 2001). The exception is zinc. There is no legislation setting maximum limits for zinc. The figures shown indicate median levels to be expected in crustaceans and fish.*

Wet weight of jellyfish in grams		Bell diameter (cm)	Metal (µg/g wet weight)				
Total	Bell		Zn (5-25)	Hg (0.5–1)	Cd (2)	Pb (0.5– 2)	As (1–2)
2376	1373	28.5	1.2	0.0003	0.02	0.02	0.14
2099	1055	27.5	1.4	0.0001	0.01	0.00	0.21
805	482	20.5	0.8	0.0002	0.01	0.02	0.14
1311	875	24.5	0.5	0.0004	0.01	0.01	0.08
913	513	21	1.4	0.0003	0.01	0.01	0.17
1586	841	26	1.3	0.0003	0.01	0.02	0.18
1213	692	24.5	1.3	0.0003	0.01	0.01	0.16
1384	717	23	0.5	0.0001	0.00	0.00	0.02
981	517	20.5	1.3	0.0003	0.01	0.01	0.23
1262	706	22.5	1.2	0.0004	0.02	0.01	0.15
675	401	19	0.5	0.0002	0.02	0.01	0.11
1340	762	23.5	1.2	0.0003	0.02	0.02	0.13
595	314	17.5	0.4	0.0001	0.00	0.01	0.03
1473	812	24	0.8	0.0002	0.01	0.01	0.15
515	394	21	0.9	0.0004	0.01	0.01	0.25
666	368	18.5	1.4	0.0004	0.01	0.00	0.15
904	542	20.5	1.4	0.0003	0.02	0.01	0.23
531	289	19.5	0.6	0.0001	0.00	0.01	0.12
696	411	20.5	0.6	0.0001	0.01	0.00	0.02
524	302	16	1.1	0.0002	0.01	0.01	0.17

Table A4.4. Mean values (µg/g wet weight) of metals in bells of *Catostylus mosaicus*

collected from Corio Bay (C), Hobsons Bay (H) and Werribee (W) in Port Phillip, March 2001.
Values for each locality are the means of 20 determinations; those joined by the same vertial line are not significantly different (p=0.05).

Arsenic		Cadmium		Mercury	
Mean	Area	Mean	Area	Mean	Area
0.367	W	0.0265	C	0.00025	H
0.142	H	0.012	W	0.00018	W
0.131	C	0.011	H	0.00015	C

Lead		Zinc	
0.014	C	0.99	H
0.011	W	0.96	W
0.010	H	0.82	C

Table A4.5. Concentrations (µg/g wet weight) of total hydrocarbons in the bells of jellyfish, *Catostylus mosaicus*, collected from Corio Bay, Port Phillip, March 2001.

Wet weight of jellyfish in grams		Bell diameter (cm)	Total hydrocarbons (µg/g wet weight)
Total	Bell		
1988	1260	30	<2
3021	1540	29.5	<2
1793	922	24	<2
1078	638	20	<2
1372	728	22.5	<2
1370	805	23	<2
2167	1246	27	<2
2577	1518	28	<2
2013	1169	24.5	<2
1128	629	21.5	<2

Table A4.6. Concentrations (µg/g wet weight) of total hydrocarbons in the bells of jellyfish, *Catostylus mosaicus*, collected from Hobsons Bay, northern Port Phillip, March 2001.

Wet weight of jellyfish in grams		Bell diameter (cm)	Total hydrocarbons (µg/g wet weight)
Total	Bell		
1429	905	21.5	<2
1328	787	24	<2
1900	1020	25	<2
1477	853	24	<2
1768	984	25.5	<2
2772	1551	29.5	<2
2110	1274	27.5	<2
1721	896	24	<2
1423	807	24	<2
1309	699	23	<2

Table A4.7. Concentrations (nanogram per gram wet weight) of polycyclic aromatic hydrocarbons in the bells of jellyfish, *Catostylus mosaicus*, collected from Corio Bay, Port Phillip, March 2001.

Total jellyfish weight (gm)	1988	3021	1793	1078	1372	1370	2167	2577	2013	1128
Bell weight (gm)	1260	1540	922	638	728	805	1246	1518	1169	629
Bell diameter (cm)	30	29.5	24	20	22.5	23	27	28	24.5	21.5
Naphthalene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluorene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	10
Benz[a]anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chrysene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[b]fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[k]fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	13
Benzo[a]pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Indeno[1,2,3-cd]pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Dibenz[a,h]anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[ghi]perylene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Table A4.8. Concentrations (nanogram per gram wet weight) of polycyclic aromatic hydrocarbons in the bells of jellyfish, *Catostylus mosaicus*, collected from Hobsons Bay, northen Port Phillip, March 2001.

Total jellyfish weight. (gm)	1429	1328	1900	1477	1768	2772	2110	1721	1423	1309
Bell weight (gm)	905	787	1020	853	984	1551	1274	896	807	699
Bell diameter (cm)	21.5	24	25	24	25.5	29.5	27.5	24	24	23
Naphthalene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluorene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Phenanthrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benz[a]anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Chrysene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[b]fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[k]fluoranthene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[a]pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Indeno[1,2,3-cd]pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Dibenz[a,h]anthracene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Benzo[ghi]perylene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Table A4.9. Concentrations (nanograms per gram wet weight) of organochlorine insecticides in the bells of jellyfish, *Catostylus mosaicus*, collected from Corio Bay, Port Phillip, March 2001.
Numbers in brackets after some insecticide names are maximum allowable concentrations (nanograms per gram fresh weight) listed in Food Standards Australia New Zealand (ANZFA 2001). If no maximum allowable concentration is set, the concentration should be below the detectable limit.

Total jellyfish weight (gm)	1988	3021	1793	1078	1372	1370	2167	2577	2013	1128
Bell weight (gm)	1260	1540	922	638	728	805	1246	1518	1169	629
Bell diameter (cm)	30	29.5	24	20	22.5	23	27	28	24.5	21.5
α-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
β-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Lindane (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
δ-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor (50)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Aldrin (100)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor Epoxide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
α-Endosulfan	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
O,p'-DDE (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Diledrin (100)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endrin	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
β-Endosulfan	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4,4'DDD (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endrin Aldehyde	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endosulfan Sulfate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Pp'-DDT (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Methoxychlor	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table A4.10. Concentrations (nanograms per gram wet weight) of organochlorine insecticides in the bells of jellyfish, *Catostylus mosaicus*, collected from Hobsons Bay, northern Port Phillip, March 2001.
Numbers in brackets after some insecticide names are maximum allowable concentrations (nanograms per gram fresh weight) listed in Food Standards Australia New Zealand (ANZFA 2001). If no maximum allowable concentration is set, the concentration should be below the detectable limit.

Total jellyfish weight (gm)	1429	1328	1900	1477	1768	2772	2110	1721	1423	1309
Bell weight (gm)	905	787	1020	853	984	1551	1274	896	807	699
Bell diameter (cm)	21.5	24	25	24	25.5	29.5	27.5	24	24	23
α-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
β-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Lindane (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
δ-BHC	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor (50)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Aldrin (100)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor Epoxide	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
α-Endosulfan	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
O,p'-DDE (1000)	<2	<2	<2	<2	<2	3	<2	<2	<2	<2
Diledrin (100)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endrin	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
β-Endosulfan	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
4,4'DDD (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endrin Aldehyde	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Endosulfan Sulfate	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Pp'-DDT (1000)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Methoxychlor	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Table A4.11. Concentrations (nanograms per gram wet weight) of tributyltin in the bells of jellyfish, *Catostylus mosaicus*, collected from from the mouth of the Werribee River and from Hobsons Bay, Port Phillip, March 2001.
The sample for each locality was a composite of 10 bells of commercial size (a diameter of 23 cm or more). Only the tin has been measured.

Locality	Tributyltin
Hobsons Bay	0.6
Werribee	<0.2

Appendix 5: *Catostylus* makes news in the Geelong Advertiser.

Article published 27 August 2002.

6 ▮ GEELONG ADVERTISER, TUESDAY 27 AUGUST 2002

Jellyfish exports on the table

NICOLE MAYNE

JELLYFISH from Port Phillip Bay could soon be served up on dinner plates all over Asia.

The tasty delicacy — which grows to the size of a football — is being eyed for the lucrative Chinese export market.

International fisheries company the David Glory Group has already set up a processing plant in Queenscliff.

Executive director Carsten Elkjaer said it hoped to extend its operations to Geelong, which would become the centre of Victoria's jellyfish industry.

He said there was great potential for a commercial jellies fishery in the region.

"Last year it was just unbelievable," Mr Elkjaer said.

"You could have caught hundreds of tonnes daily."

The catostylus mosaicus jellyfish found in Port Phillip Bay is related to popular edible species in Asia.

Hundreds of thousands of tonnes of the fish, which is served dried with the tentacles removed, are consumed every year.

Mr Elkjaer said David Glory had investigated converting part of the old Port Authority building into a process plant for the jellyfish.

But the cost of upgrading the facility to meet quarantine inspection standards would have been too great.

Instead, the group hoped to find an existing fisherman who could process the species locally.

A three-year study by Queenscliff's Marine and Freshwater Resources Institute recently found the bay could sustain commercial fishing of the jellyfish.

Project leader Dr Noel Coleman said increased demand for the food had opened up great opportunities.

But while several thousand tonnes could be fished from the bay, the numbers fluctuated between seasons.

"There is certainly potential — there is interest there," Dr Coleman said.

"One of the problems is the numbers are very, very variable so it would not be consistent."

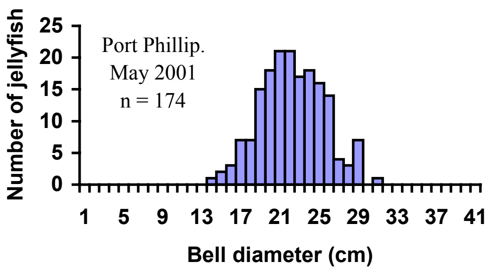
The study found Corio Bay had a particularly high yield.

FOR SALE: Dr Noel Coleman holds a jellyfish at Barwon Heads yesterday. Port Phillip Bay jellyfish are being eyed for the lucrative Chinese export market. Photo: TONY KERRIGAN

Appendix 6: Survey of jellyfish in Port Phillip, May 2003.

Sampling for the FRDC project finished in 2002, but, as part of the management of the developmental fishery in Victoria, a survey of jellyfish was undertaken in Port Phillip in May 2003.

Jellyfish were abundant throughout the bay including strata 6 and 7 on the eastern shore. They were dispersed throughout the bay and no large aggregations were found. Although a few small jellyfish (estimated to be about 15 – 20 cm in diameter) were seen, those taken in size frequency samples were, on average, much larger than any encountered in the previous 3 years of sampling. The majority had a bell diameter of 30 cm or more and the largest had a bell diameter of 41 cm (Fig. A6.1.) As in 2001, the smallest jellyfish were collected in the north of the bay.



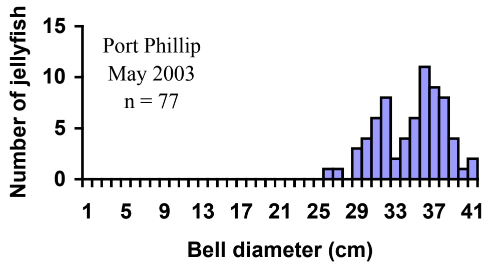


Figure A6.1. Size-frequency of *Catostylus mosaicus* in samples from Port Phillip, May 2001 and May 2003.

Regressions relating total weight to bell diameter showed that, for a given size, jellyfish collected from Port Phillip in May 2003 were heavier than those collected in May 2001 (Table A6.1). They were also heavier than jellyfish collected from Port Phillip in any other months over the last three years but weight for size was still not as great as that reported (Kingston and Pitt 1998) for populations in New South Wales (see also Table 8 in the present report).

Table A6.1. Comparison of weight in relation to bell diameter for *Catostylus*

mosaicus from Port Phillip, May 2001 and May 2003.
Nc indicates no jellyfish of this size were collected in the size-frequency samples

Bell diameter (mm)	Predicted weight (g) from samples taken May 2001[1]	Predicted weight (g)from samples taken May 2003[2]
200	699	1335
250	1402	2108
300	2184	3060
350	Nc	4193
400	Nc	5509

[1] Log_{10} total weight = 3.1164 x $\log_{10}$ bell diameter – 1.2097 ($r^2 = 0.89$, $p < 0.0001$)
[2] Log_{10} total weight = 3.0453 x $\log_{10}$ bell diameter – 1.0081 ($r^2 = 0.94$, $p < 0.0001$)

Values for bell weight as a percentage of total weight ranged from 35 to 61 with a mean value of 46. Most values were within the range 43 – 53%. There was no statistically significant correlation between percentage bell weight and bell diameter.

The total weight of commercial jellyfish in Port Phillip in May 2003 was estimated as 3,028 tonnes (Table A6.2).

Table A6.2. Estimated abundance and weight (plus upper and lower 95% Confidence Intervals) of the jellyfish *Catostylus mosaicus* in Port Phillip, May 2003.
N is the number of transects per stratum. Commercial size jellyfish are those with a bell diameter of 23 cm or more. Numbers in brackets in the weight columns for commercial size jellyfish are bell weights. All the jellyfish taken in size-frequency samples were commercial size.

Stratum	N	Abundance			Weight (tonnes)		
		Lower CI	Mean	Upper CI	Lower CI	Mean	Upper CI
		Commercial size jellyfish			Commercial size jellyfish		
1	9	283	5,701	31,095	1	21	117
					(0.5)	(10)	(55)
2	7	220,247	595,306	1,319,205	831	2245	4975
					(389)	(1052)	(2330)
3	36	6,400	33,623	108,244	24	127	408
					(11)	(59)	(191)
4	19	9	1,406	12,157	<1	5	46
					(<0.5)	(2.5)	(21)
5	19	20,337	102,075	321,222	77	385	1211
					(36)	(180)	(567)
6	6	130	9,714	73,707	<1	36	278
					(<0.5)	(17)	(130)
7	16	7,253	55,351	211,635	27	209	798
					(13)	(98)	(374)
8	8	0	0	0	0	0	0
TOTAL	120	254,659	803,176	2,077,265	960	3028	7833
					(449.5)	(1418.5)	(3668)

The fact that *Catostylus mosaicus* were abundant and widespread throughout Port Phillip in May 2003 when none had been found in May the previous year, and that the individuals were larger than those found anywhere during the previous 3 years, serves to emphasise the great variability shown by populations of this species.