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Food Webs of Demersal Fish in Port Phillip Bay

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EXECUTIVE SUMMARY

Information on the distribution, abundance, diets and feeding rates of fish were integrated to construct food webs representing the most important trophic links in Port Phillip Bay. Food webs were constructed for each of four ecologically distinct regions of the Bay, and for two times of year, summer/autumn and winter/spring.

Food webs indicate that sand flathead was the dominant predator in all but shallow regions of Port Phillip Bay. The pebble crab, *Philyra undecimspinosa*, was a very important prey in deep regions of the bay. Total consumption of prey by all fish was greater during summer/autumn than during winter/spring due mostly to migration of fish into Port Phillip Bay in early summer. The total consumption of prey by all fish in Port Phillip Bay was also greater in deep than in shallow regions, probably due to fewer invertebrate predators and fewer trophic 'levels' in deep regions.

The total consumption of prey by fish was lowest in Corio Bay where the exotic worm, *Sabella spallanzanii*, a species unpalatable to fish, is now the dominant organism. Two other exotic species recently introduced into the bay, the bivalve mollusc, *Corbula gibba*, and the crab, *Pyromaia tuberculata*, have been incorporated into important trophic links in deep regions of the Bay.

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1. INTRODUCTION

Food webs provide a simple means of representing patterns of energy and material flow between organisms that prey on each other. They were used conceptually by the earliest ecologists (Darwin 1859; Hardy 1924; Elton 1927) and have continued to be the subject of considerable interest by theoretical ecologists (Paine 1988). Food webs are also of considerable practical value. They enable the biological concentration of toxins and pollutants to be better understood, and allow an assessment of the likely consequences of an increase or decrease in the abundance of a particular predator or prey.

Direct effects of exotic species on native species can also be determined from trophic links where the exotic species provides a new source of food for predatory fish. However, as food webs model only predation links they cannot anticipate the results of altered competitive interactions caused by exotics or other species. It is also important to recognise that although food webs indicate likely interactions they complement, rather than replace, the need for experimental studies designed to determine more explicitly how populations interact (Cohen *et al.* 1993).

In fisheries science the need for accurate food webs has been increasing as fisheries ecologists have become more concerned with managing whole ecosystems. Where there are strong predator-prey interactions within exploited fish populations management of fisheries stocks based on several single species models is likely to be inadequate (Dann 1987; Hansson *et al.* 1996). A holistic approach to management is particularly important in large embayments like Port Phillip Bay, Victoria, where many different impacts are likely to increase progressively as the large human population around its perimeter increases further. Increases in fishing activity within the Bay and in recreation and urbanisation around the Bay's shores have directly impacted some species (Hobday *et al.* 1996). However, the consequences of these impacts on the ecosystem as a whole are difficult to determine without an understanding of the links between major ecological processes in the ecosystem.

Energy pathways described in trophic models provide an efficient summary of many of the important links within ecosystems. Such models require an estimation of the distribution, abundance, diets, and feeding rates of the dominant species. Knowledge of temporal changes in these factors may further refine trophic models. Previous analyses of the spatial variation in fish communities, benthic invertebrates and sediment type have suggested that four different depth-correlated ecological regions occur in Port Phillip Bay (Parry *et al.* 1995). Fish diets differ between these regions (Parry *et al.* 1995) and between seasons (Officer and Parry 1995). In the present study information on spatial and temporal differences in fish diets was integrated with estimates of fish abundance and feeding rates to construct a simple model of the trophic structure of demersal fish communities in four regions and during two periods of the year in Port Phillip Bay.

Cohen *et al*. (1993) discuss many of the past deficiencies of food webs that have restricted both their theoretical and practical uses. Their major recommendations were that methods should be as explicit as possible and that food webs should be as exhaustive as possible. They also made four more detailed recommendations:

1. Diets of species (or life-history stages of species where necessary) should be reported rather than aggregating these into higher taxonomic groupings;
2. All species in the area should be included in the food web;
3. The strength of links in the food web should be measured quantitatively where possible and
4. Graphical representations of food webs should be accompanied by data in tabular or list form.

All of these recommendations have been adopted in this study, except that resources were only available to include fish and their direct prey in food webs.

2. METHODS

Fish were collected with a wing trawl net (47 m long, 13 m wing spread, 5 m opening height and 45 m between trawl doors with a 44 mm codend liner) at 22 depth-stratified stations in Port Phillip Bay between 1990 and 1994 (Baywide stations), and at four of these depth-stratified stations near St Leonards at quarterly intervals during 1994 (St Leonards stations) (Figure 1). Sampling stations were located on transects perpendicular to the coastline. Trawl shots were taken at depths of approximately 7, 12, 17, and 22 m. The duration of each trawl shot was 5 minutes, measured from the time load cell clamps were attached until the winch commenced the retrieval of the net. Data obtained using a netsond indicated that the net was probably fishing for an additional 2 minutes during its retrieval.

A Furuno GP 500 GPS Navigator connected to a colour video plotter was used for all position fixing and was accurate to within 15-25 m in 95% of fixes. Where inaccuracy exceeded 25 m due to intentional degradation of the system (selective availability) this was obvious on the plotter. The speed of the net across the ground, 2.1-2.5 knots, was estimated from the latitude and longitude at the start and finish of each shot and the duration of each shot.

The Baywide stations were trawled annually between February and April between 1990 and 1994 (Parry *et al.* 1995). These data were used to estimate the mean biomass of each species per shot in four ecologically different regions of Port Phillip Bay (Parry *et al.* 1995). Regional differences in diet were determined from stomach contents of fish trawled at Baywide stations during February 1994 (Parry *et al.* 1995). Diurnal and seasonal changes in diet were measured by trawling the St Leonards stations throughout four 24 hour periods at quarterly intervals during 1993 and 1994 (Officer and Parry 1995). Regional differences in diet were also determined at the St Leonards stations.

Stomach contents or gut contents from the anterior half of the gut, for those species without a distinct stomach, were analysed for all species according to the methods described by Parry *et al*. (1995) and Officer and Parry (1995). Species of prey were identified by comparison with an extensive reference collection of benthic invertebrates from Port Phillip Bay. The identity of each species in the reference collection was confirmed by Drs. G. Poore (crustaceans) and R. Wilson (polychaetes) and Ms S. Boyd (molluscs) from the Museum of Victoria.

Statistical analyses of the effects of depth and location on fish diets indicated that they differed between four regions: Corio Bay, shallow stations (7 m), intermediate stations (12 and 17 m) and deep stations (22 m) (Officer and Parry 1995; Parry *et al.* 1995). Analyses of the effects of ‘seasons’ on fish diets suggested that the diets of fish differed between two times of the year: summer/autumn and winter/spring (Officer and Parry 1995). These classifications were used to calculate food consumption and to construct food webs for each region for the Baywide and St Leonards stations, and for both times of year at the St Leonards stations.

Most species in Port Phillip Bay did not show diurnal feeding rhythms (Officer and Parry 1995) which meant that field feeding rates could not be measured directly for these species. Consequently total food consumption per day was estimated for each species at 3% of the total fish biomass for that region and time period.

This assumption was consistent with reported values of food consumption for other species (Edgar and Shaw 1995a). Food consumption was expressed in units of g/ha by dividing the average weight of each species per shot by the average area swept in a trawl shot, 3.15 ha, (45 m, the distance between trawl doors) ¥ (700 m, the average length of a trawl shot).

For the Baywide stations the average weight of each fish species caught per shot in each region was obtained from the mean over the five year period (1990-94). For the St Leonards stations the average weight of each fish species caught per shot was estimated from the mean of all data for the appropriate region and time of year. For each fish species the amount consumed of each prey item was estimated by multiplying the percentage volume of each prey item in the diet by the total calculated food consumption. The percentage volume of each prey item was obtained from Parry *et al*. (1995) for the Baywide stations and from Officer and Parry (1995) for the St Leonards stations.

Within each region, or region and time of year, the amount of each prey item consumed was compared across all fish species. The 10 or 20 most important interactions (greatest estimated biomass consumed) between fish and their prey were represented graphically in food webs. These 10 or 20 interactions defined 'important' predators and prey taxa which were explicitly included in the food web. Interactions that were ranked between the 20th and 40th most important were also included explicitly in food webs where either the prey or predator were included as part of the 20 most important interactions. The remaining prey and predators were included only as part of aggregated groups of prey or predators and were obtained by summation of all the relevant taxa. The total amount of food consumed by all fish in each region and time of year was estimated by summation of the food consumed by each fish species.

Seasonal differences in feeding rates of sand flathead, sparsely spotted stingaree and eastern shovelnose stingaree were considered at St Leonards by estimating the mean volume of prey in stomachs of fish of average length sampled in different seasons. None of these species showed diurnal changes in diet or total volume of prey (Officer and Parry 1995). A linear regression of total prey volume versus fish length was calculated for each period of trawling (April 1993, August 1993, December 1993, February 1994) and used to predict the total prey volume consumed by fish of average length. Differences between these predicted volumes in different periods were then compared.

3. **RESULTS**

Food webs showing the 20 most important interactions between predators and their prey for each depth region averaged over the entire bay during summer/autumn (Feb-Apr) are shown in Figures 2a-d, while those for each depth region near St Leonards and averaged over all seasons are shown in Figures 3a-c. Seasonal changes in food webs are shown for the St Leonards stations, by contrasting food webs during summer/autumn and winter/spring for shallow, intermediate and deep regions (Figures 4a & b, 5a& b, and 6a & b, respectively). Summary food webs showing the 10 most important interactions between predators and prey are given in Figure 7.

Sand flathead has the highest biomass of any fish in Port Phillip Bay, except in shallow regions (Parry *et al.* 1995). Consequently, in shallow regions (Figure 2a), including Corio Bay (Figure 2b), sand flathead do not dominate the trophic structure as they do in regions of intermediate depth (Figure 2c, 3b) and in deep regions (Figure 2d, 3c).

In shallow regions there were more prey (Figure 2a) included in the 20 most important trophic links than in regions of intermediate depth (Figure 2c) or deep regions (Figure 2d). In Corio Bay there were more species of fish (Figure 2b) contributing to the 20 most important trophic links than in other regions, but fewer (Figure 2b) prey species than in all but deep regions. In shallow regions the main trophic links were with eagle ray, globefish and eastern shovelnose stingaree, while in Corio Bay smooth stingray formed the strongest linkage (with pilchards), and eastern shovelnose stingaree remained important but sand flathead and yank flathead formed stronger linkages with individual prey than globefish.

The dominance of sand flathead in intermediate and deep regions was indicated by approximately 50% of the 20 strongest predator-prey linkages being with sand flathead (Figures. 2c-d, 4b-c). At intermediate depths the other important trophic links with predators were with eagle ray, eastern shovelnose stingaree and banjo ray (Figure 2c). Sparsely spotted stingaree, while abundant at intermediate depths (Parry *et al.* (1995), had a diverse diet and therefore were not strongly linked with any particular prey item. The pebble crabs, *Phlyxia intermedia* and *Philyra undecimspinosa*, the polychaete, *Glycera cf. americana,* and the spider crab, *Halicarcinus rostratus,* were amongst the 10 most important prey at intermediate depths at Baywide and St Leonards stations. Fish, especially sandy sprat, and the predatory mollusc, *Philine angasi,* were important only at the St Leonards stations and ascidians and the polychaete, *Artacamella dibranchiata,* were only important at the baywide stations. In deep regions the other important trophic links were with eagle ray, sparsely spotted stingaree and smooth stingray (Figure 2d). The four main prey items in deep regions were fish, the amphipod, *Byblis mildura,* the predatory mollusc, *P. angasi,* and the pebble crab, *P. undecimspinosa,* (Figures 2d, 4c).

The pebble crab, *Philyra undecimspinosa,* was extraordinarily abundant in the diets of many species of fish at deep baywide stations during February 1994 (Parry *et al.* 1995). Food webs constructed from these data (Figures 2d and 7) provided another representation that further emphasised the importance of *P. undecimspinosa* during this sampling. At the deep St Leonards station *P. undecimspinosa* was an important prey of sand flathead and sparsely spotted stingaree (Figure 2c), but it was not the dominant prey of most predatory fish (Figure 2c, see also Officer and Parry (1995)).

Feeding rates (measured as mean volume of stomach contents) did not change significantly between seasons for sand flathead, eastern shovelnose stingaree or sparsely spotted stingaree (Figure 8). However feeding rates were lower for both species of stingaree and higher for sand flathead during August.

In shallow regions eagle ray and wobbegong shark were responsible for five of the most significant trophic linkages during summer/autumn (Figure 4). The absence of these five strong linkages with these predators during winter/spring accounts for most of the differences between seasons, as four of the remaining important prey species (the crabs *Nectocarcinus integrifrons* and *Philyra undecimspinosa*, and the worms *Lumbrineris cf. latreilli* and *Glycera cf. americana*, Figure 4) were included amongst the 20 most important trophic interactions in both periods. In intermediate depths the five most important invertebrate prey (*Phlyxia intermedia, Philine angasi, P. undecimspinosa, G. cf. americana* and *Halicarcinus rostratus*, Figure 5) were the same in summer/autumn and winter/spring. Eagle rays were less important predators and fish, especially sandy sprat, were more important prey during winter/spring (Figure 5). In deep regions five of the prey included in the 20 most important trophic linkages were the same in summer/autumn and winter/spring (*Byblis mildura, P. undecimspinosa, Clymenella* sp.1, *P. angasi* and *H. rostratus*, Figure 6). The main differences in food webs between summer/autumn and winter/spring were the greater importance of predation by eagle rays during summer/autumn and the greater importance of predation by greenback flounder during winter/spring.

Comparison of the total consumption of food by fish between regions in Port Phillip Bay indicates that food consumption decreased from deep to shallow regions and was lowest in Corio Bay. The total consumption of food by fish was higher in summer/autumn than in winter/spring (Table 1).

Table 1 Comparison of total prey consumption (g/ha/day) by fish (all species combined) between different regions in Port Phillip Bay (Baywide) and near St. Leonards, and at different times of year near St. Leonards.

	Corio	Shallow	Intermediate	Deep
Baywide	269	500	745	647
St. Leonards	.	356	483	698
Summer/Autumn	.	439	621	848
Winter/Spring	.	273	344	546

4. DISCUSSION

Food webs shown in Figures 2 to 7 provide reliable comparisons between different regions and times of year. The main sources of error in these food webs result from deficiencies in data on diets, unreliable estimates of the abundance of fish and poor estimates of feeding rates.

In this study most effort was directed towards obtaining quantitative measurements of dietary composition and accurate estimates of fish abundance. Food webs were based on diets obtained from the detailed analysis of the gut contents of 6358 fish and fish abundance estimates were based on 219 trawl shots. Hence the sources of error should be unimportant except where a small number of very large fish were caught. Thus the representation of wobbegong shark (only 2 specimens caught), smooth stingray and, to a lesser extent, eagle ray may be inaccurate as abundance estimates may be unrepresentative and dietary composition was based gut analysis from only a small number of fish.

In our study the most abundant fish showed no diurnal pattern in stomach fullness, which suggests that they feed at similar rates throughout the day (Officer and Parry 1995). Therefore further studies are required to estimate feeding rates from measurements of gut evacuation rates (Sainsbury 1986). There is a large and expanding literature on methods for estimating feeding rates of fish in the field (Elliott and Persson 1978; Sainsbury 1986; Hansson *et al.* 1996), and particularly on models to estimate gut evacuation rates (Jobling 1986; Boisclair and Marchand 1993; Salvanes *et al.* 1995). While there have been significant improvements in the development of more accurate models of gut evacuation to improve estimates of feeding rates, it is clear that rate of digestion depends significantly on the type of food being consumed in the field. Consequently, the predictions of even the best gut evacuation models are only as good as the data available on diets in the field. Consequently, we believe that our emphasis on obtaining high quality data on diets of fish was appropriate.

Many demersal fish species consume ~3% of their body weight in food per day (reviewed by Edgar and Shaw (1995a)). The use of this approximation for all species of fish in our study has undoubtedly created some inaccuracies, but as these affect all regions and time periods similarly, comparison of food webs between regions and time periods remains valid. The energy flow along particular pathways will be under-estimated for particularly active fish species and for particularly small fish as food consumption is proportionately greater in small individuals and species (metabolic rate=$aW^{0.75}$, eg. Parry (1983)). Similarly, food consumption of very inactive species and of very large species will be over-estimated. As many of the same species occur in the food webs and differences in the size of the same species between regions are small (Officer and Parry 1995; Parry *et al.* 1995) the comparative differences in energy partitioning between regions remains accurate. Estimates of total consumption of all fish in our food webs are 269-848 g/ha/day = 9.8-30.9 g/m^2/yr (Table 1). These values may be compared to the annual production of small fishes in Western Port (1.6-3.8 g/m^2/year over unvegetated and vegetated seagrass flats respectively, Edgar and Shaw (1995b)). As gross food conversion efficiency, the ratio of production to consumption is usually between 0.1 and 0.3 (Christensen and Pauly 1993), our consumption estimates are similar to those expected from production estimates in Western Port and provides further support for the approximations used in the calculation of feeding rates in our study.

Seasonal changes in food webs may result from changes in diet (Officer and Parry 1995), changes in the abundance of fish due to migration or mortality, or changes in feeding rate. While there were some changes to food webs due to seasonal changes in diet the most obvious changes were due to migration of fish. Total food consumption by fish in all regions was higher in summer/autumn than in winter/spring (Table 1). These differences and many changes to food webs between different times of the year (Figures 4, 5 and 6) were due largely to migration of fish (wobbegong shark, and particularly eagle rays) into Port Phillip Bay during early summer. Seasonal differences in feeding rates were not significant for the three species for which data were available (Figure 8). However both species of stingaree showed lower feeding rates during the colder months and, as many fish consume less during winter (Stone and Jessop 1994), seasonal differences in feeding rates may be under-estimated. In contrast the feeding rate of sand flathead was higher during winter due to higher consumption of fish (Officer and Parry 1995), and coincided with the period of rapid gonad growth (Brown 1977). As feeding rates were assumed to equal 3% of total weight/day for each species, these non-significant, but possible, seasonal influences on feeding rates did not contribute to seasonal differences observed between food webs (Figures 4, 5 and 6).

Total consumption by fish decreased progressively from deep to shallow regions for both the Baywide and St Leonards stations, and was lowest in Corio Bay. The efficiency of trawling was probably lower on shallow seabeds with greater topographic relief than on flatter seabeds in deeper regions. At a site in 14 m depth near St Leonards trawl nets caught 20% more fish on the same seabed after it had been flattened by scallop dredges (Parry, unpublished data). Differences in the efficiency of the net between shallow and deep regions may under-estimate the abundance of fish in shallow compared to deep regions, but this effect is unlikely to explain all the regional differences observed.

Differences in total consumption by fish between regions do not appear to reflect differences in primary production in the water column between regions. Primary production/m^3 is highest in shallow regions but the increased depth of the water column in deeper regions means that primary production/m^2 is similar throughout Port Phillip Bay (R. Royle, Monash University, Department of Ecology and Evolutionary Biology, personal communication).

The relatively high consumption by fish in deep versus shallow regions suggests that fish are either over-exploited in shallow regions, and are therefore unable to consume all available resources, or, more probably, that the trophic links are shorter in deeper water. The dominance of *Philyra undecimspinosa* is particularly obvious in this region. While the diet of this species is unknown, observations in shallow water on the related pebble crab *P. laevis* (Parry, personal observations) suggest that this species can feed either as an active predator or as a detritivor. If *P. undecimspinosa* is a detritivor the relatively high production of fish food in this central deep muddy region may be largely because there are fewer intermediate invertebrate predators and therefore fewer trophic levels. The exceptionally low amount of food consumed by fish in Corio Bay is of interest as this region is now dominated by the exotic worm *Sabella spallanzanii* which is rarely, if ever, eaten by fish.

The only exotic species that were included in the 20 most important linkages in any of our food webs were the bivalve *Corbula gibba* and the crab *Pyromaia tuberculata.* Both species were consumed by globefish in shallow regions (Figures 2a, 4a), but particularly in intermediate (Figures 2c, 3b, 5a) and deep regions (Figures 2d, 3c, 6b).

That these exotic species were found mostly in deep regions where globefish were uncommon (Parry *et al.* 1995), suggests that higher predation by more numerous globefish in shallow regions may be responsible for their depth distribution. The significant increase in globefish populations in the deep region of Port Phillip Bay since the mid 1970s (Hobday *et al.* 1996) is consistent with the predictions of our food webs. These examples also draw attention to the exclusion from our food webs of trophic links to taxa other than fish. *C. gibba* is a prey of the predatory mollusc *Philine angasi* (Parry, personal observations) but this species is itself a very important prey in shallow regions (Figure 2a, 3b) but particularly in intermediate (Figure 2b, 5a, 5b) and deep regions (Figure 2d, 3c, 6 a, 6b). Thus the trophic consequences of increased abundance of *C. gibba* cannot be predicted accurately without inclusion of invertebrate predators.

The uncertainties of predicting the impact of exotic species also illustrate one of the limitations of food webs in general. They model predator-prey interactions exclusively. Where exotic species compete with or alter the habitats of native species the outcomes of their interactions with native species cannot be predicted from food webs alone. For example, the large sabellid *Sabella spallanzanii* (and possibly the small sabellid *cf. Jasmineira* = *Euchone* sp.) does not appear in our food webs apparently because it is unpalatable to native fish (Parry, unpublished data). However *S. spallanzanii* may compete with native species, and apparently provides a habitat for little rock whiting (Parry *et al.* 1995). Hence its most likely impact on local food webs may be through an increasing importance of little rock whiting in the diets of fish predators such as yank flathead.

5. CONCLUSION

The food webs presented here summarise the main trophic interactions in Port Phillip Bay. Other important ecological processes in the bay remain poorly documented. The most significant of these would appear to be competitive interactions between native and abundant exotic species, and the effects of physical and other human disturbances on the ecology of the Bay. The strength of competitive interactions with exotic species can only be determined experimentally and the effects of physical disturbance and many of the cumulative human impacts can only be detected by long-term monitoring.

As fish stocks are one of the primary resources to be protected in Port Phillip Bay, long term monitoring of the important trophic interactions identified in this study may prove a valuable and cost-effective means of recognising human impacts and natural disturbances of importance to fish communities.

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8. FIGURES

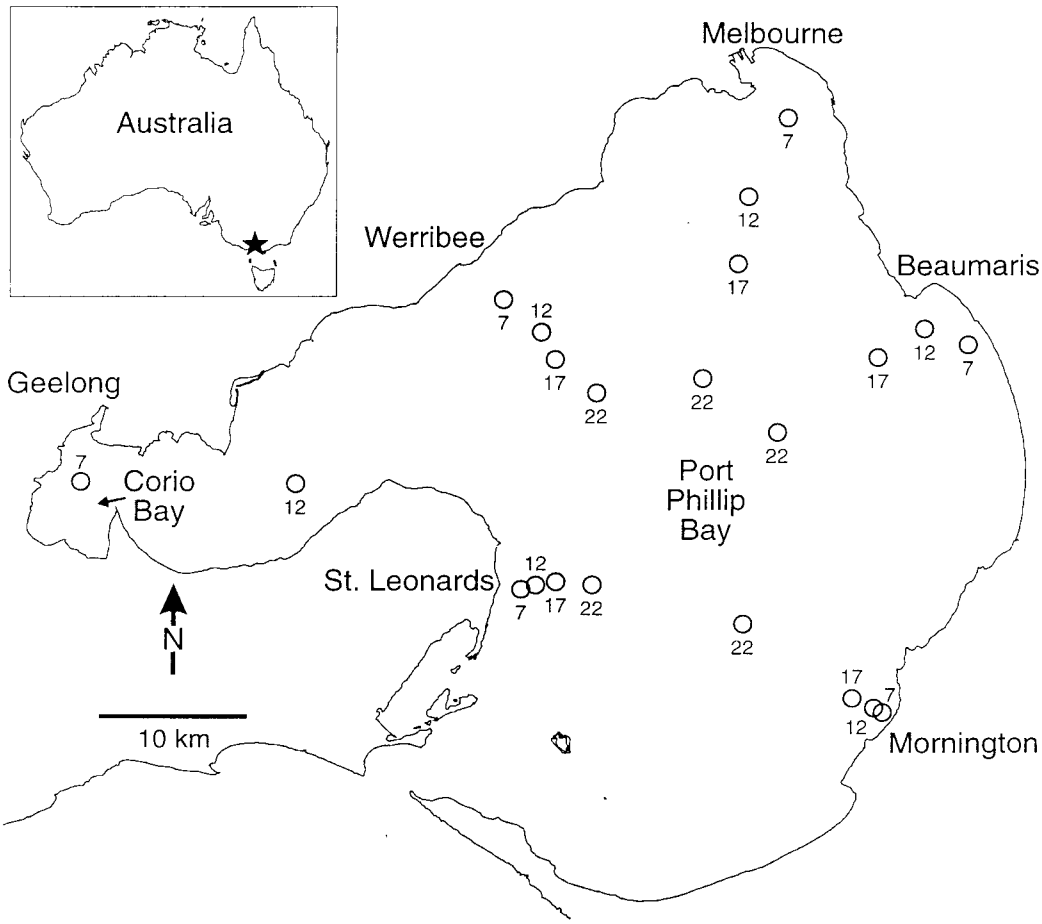


Figure 1. The location of Port Phillip Bay (inset) and the location of the trawl stations sampled within it. The depth of each station is given in metres.

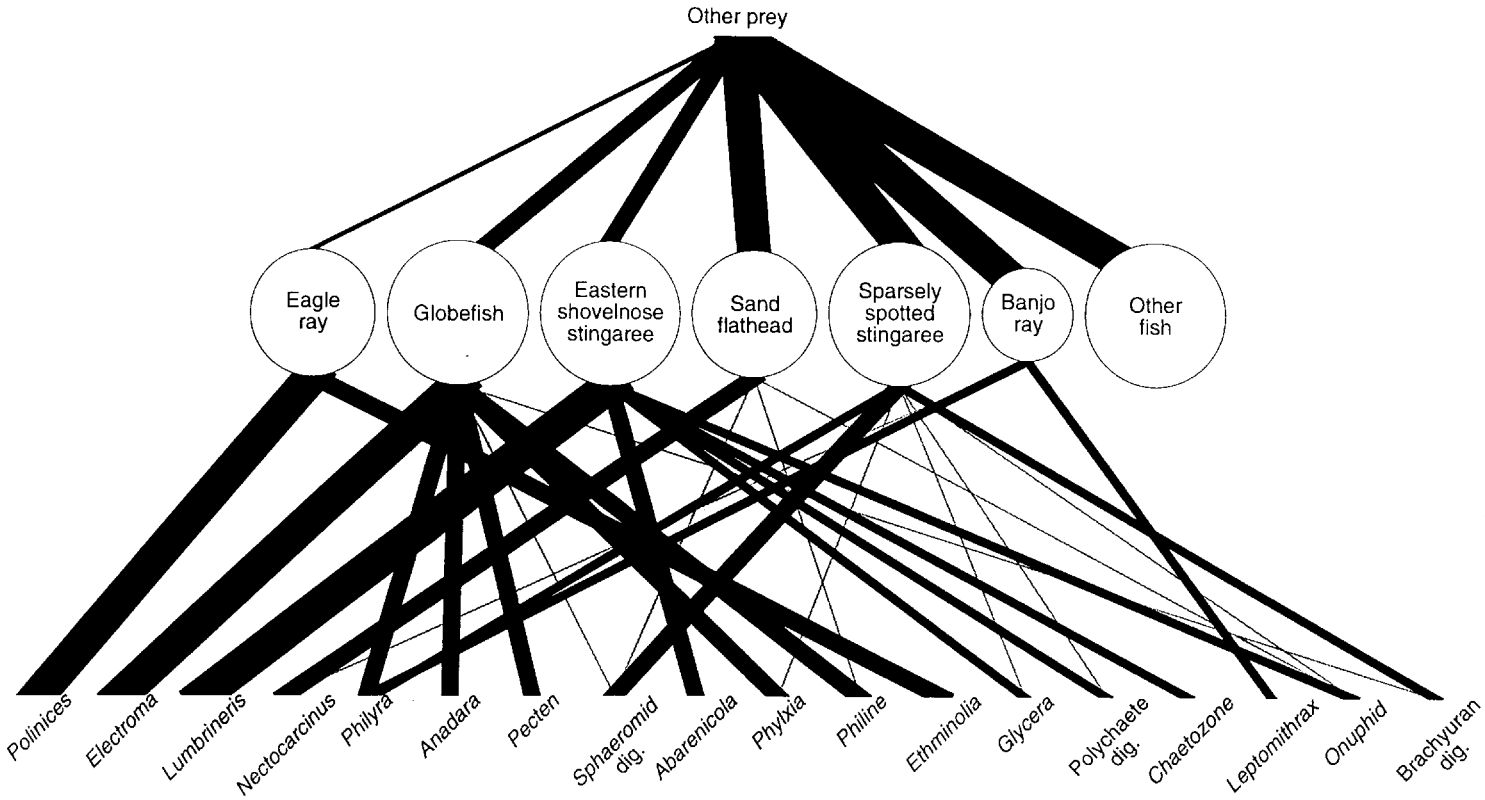
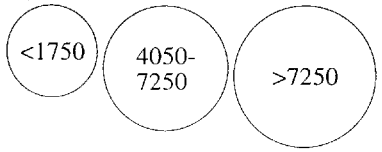


Figure 2 (a). Food web for shallow regions of Port Phillip Bay showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



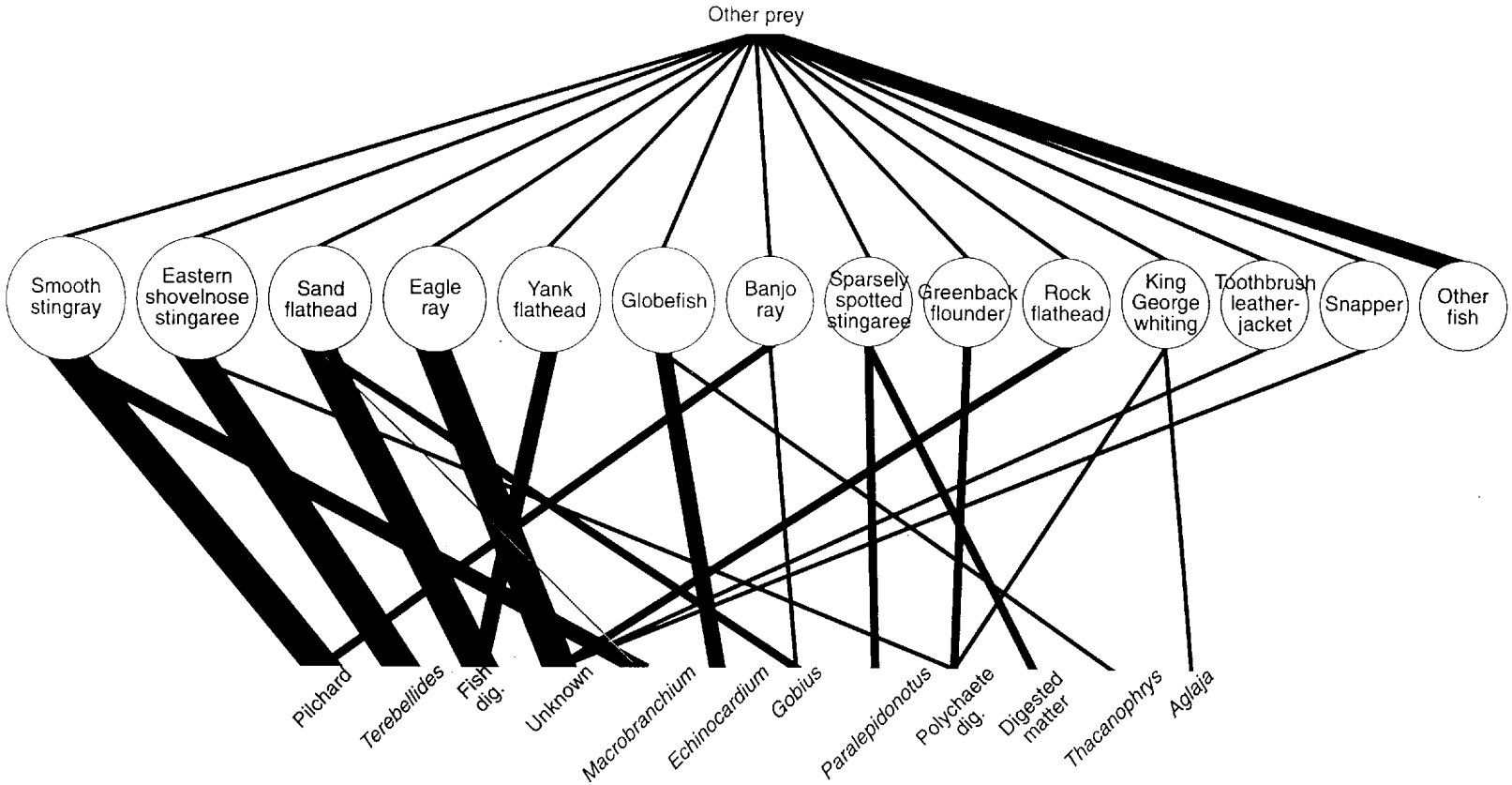


Figure 2 (b). Food web for Corio Bay showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot):
Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.

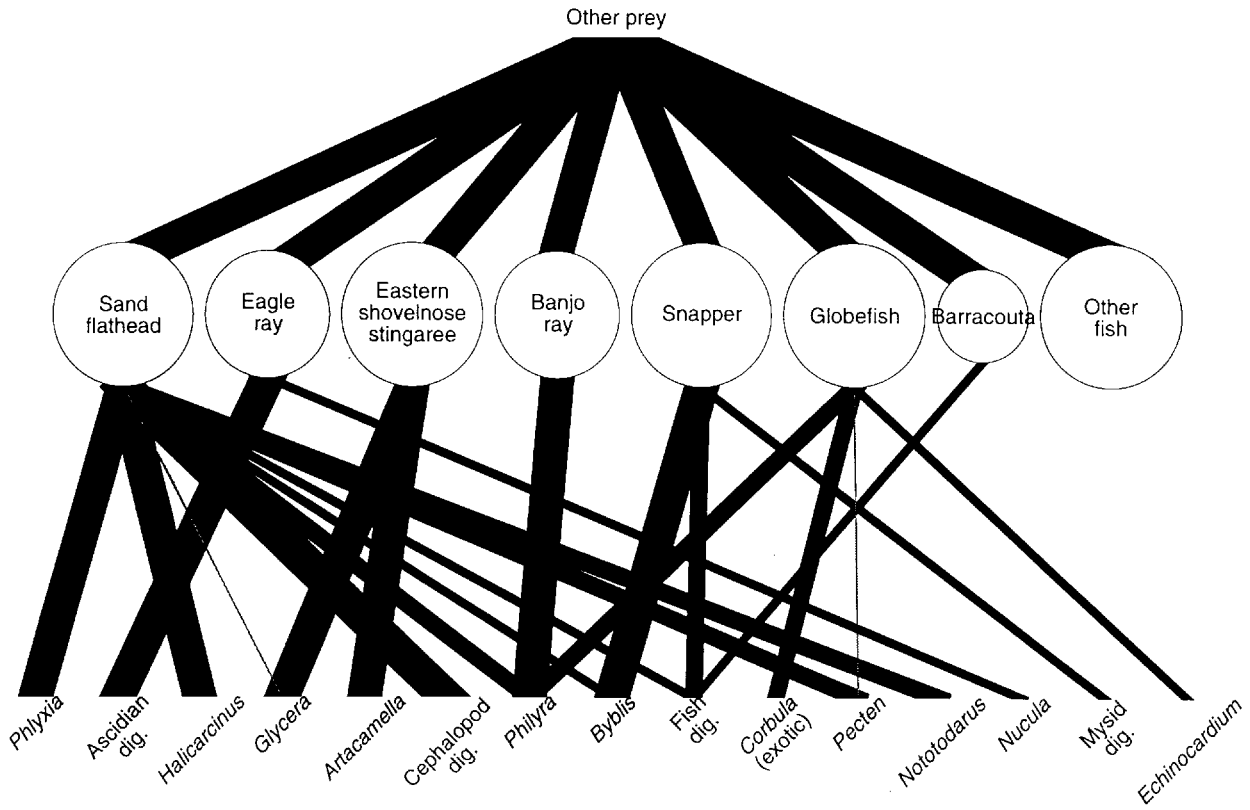
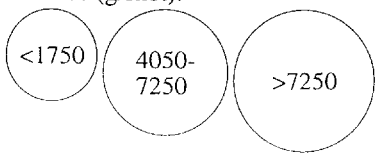


Figure 2 (c). Food web for intermediate depths of Port Phillip Bay showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot):
Line widths indicate the biomass of prey consumed (g/ha): 5-10 10-20 >20.



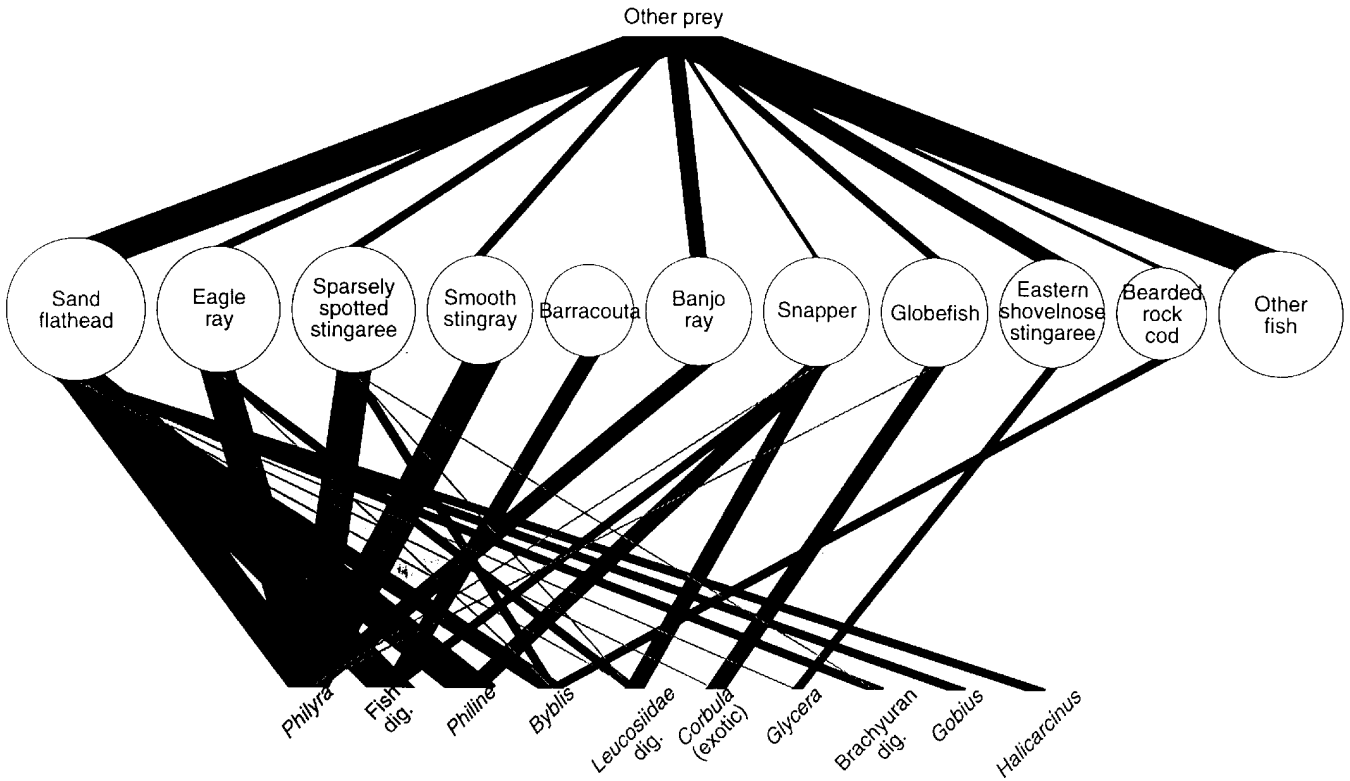
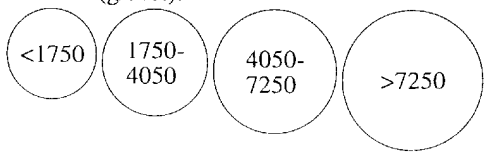


Figure 2 (d). Food web for deep regions of Port Phillip Bay showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



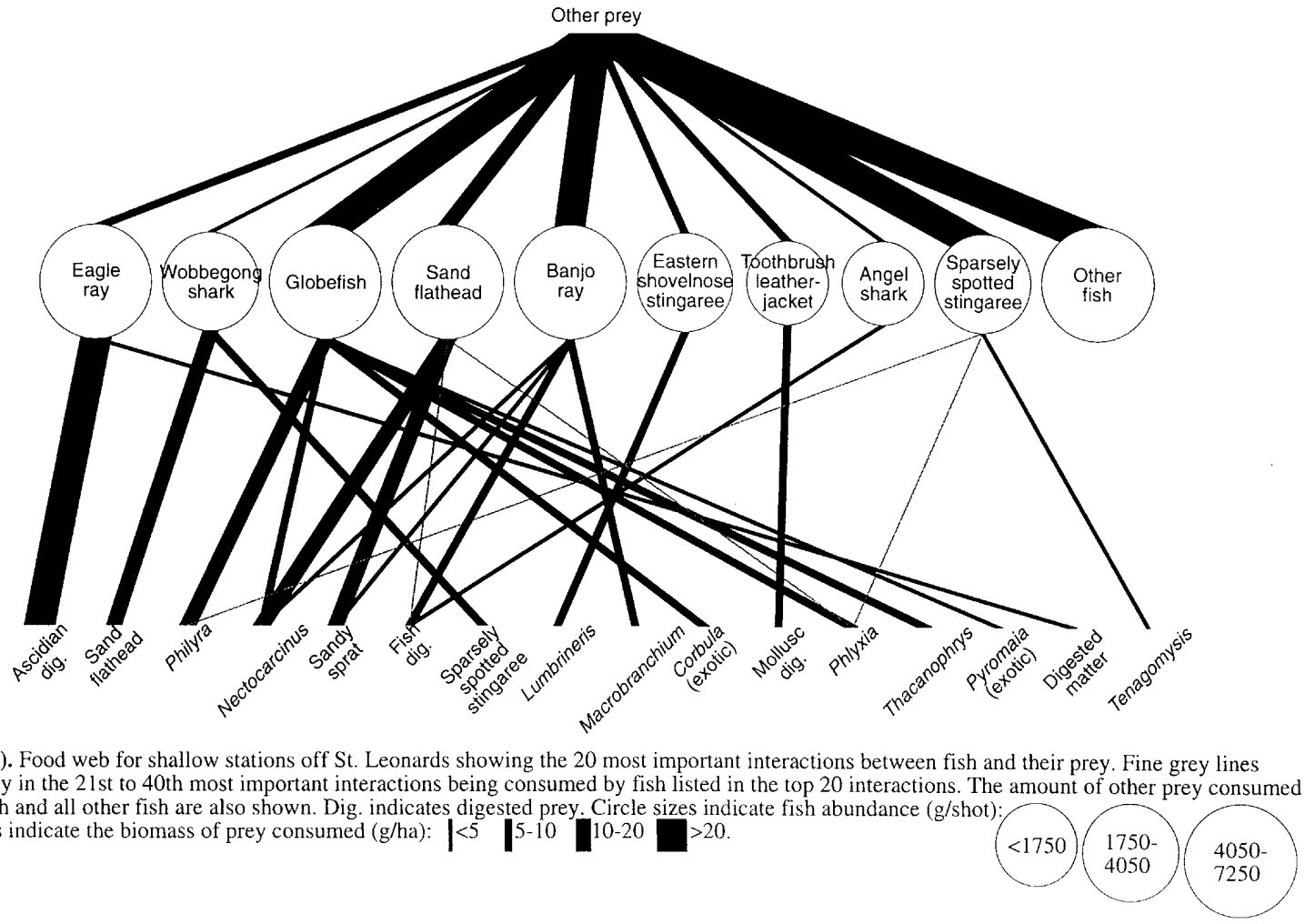


Figure 3 (a). Food web for shallow stations off St. Leonards showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.

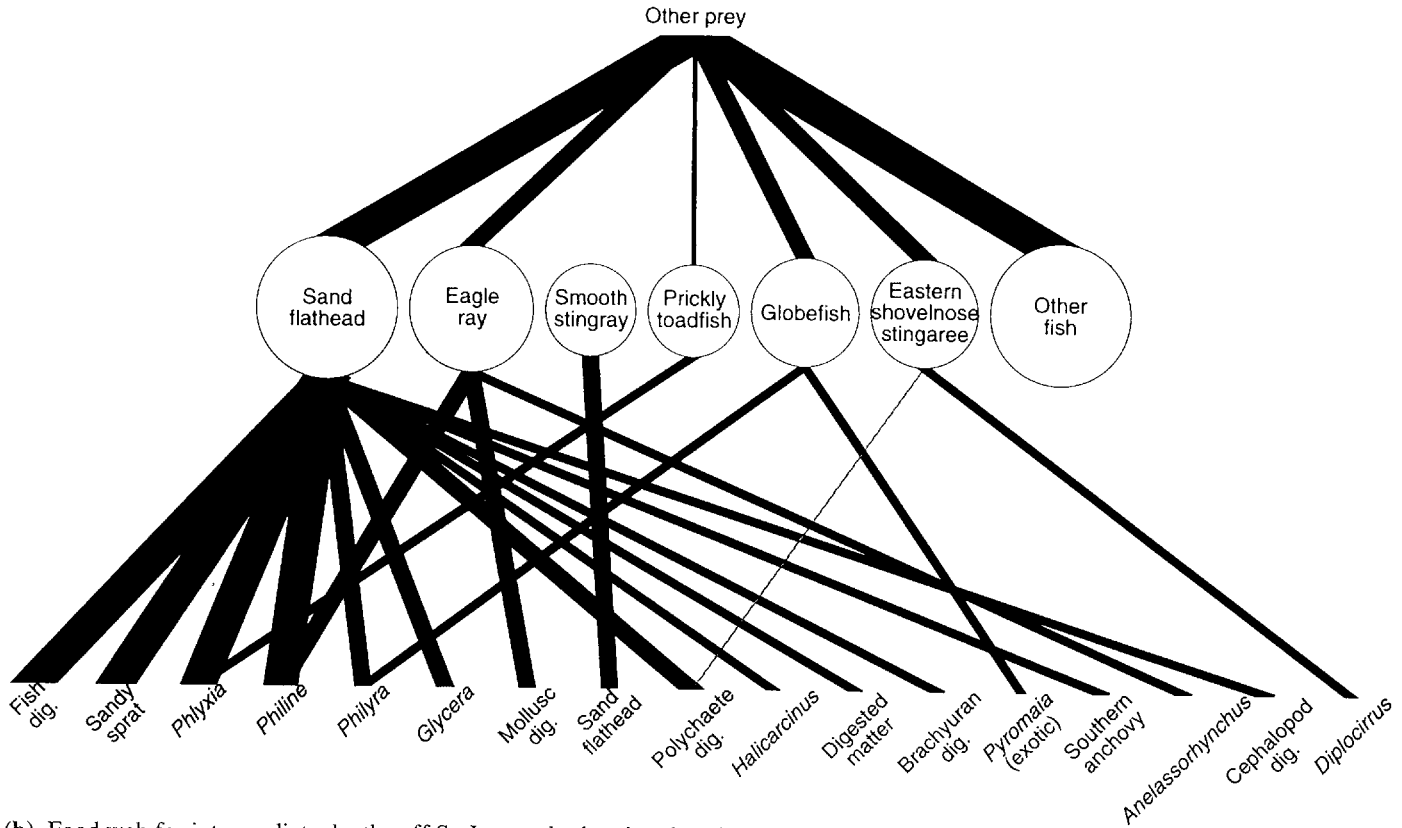
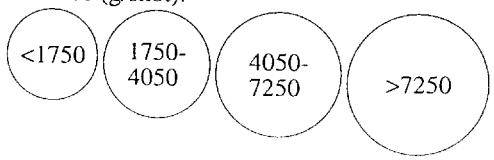


Figure 3 (b). Food web for intermediate depths off St. Leonards showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



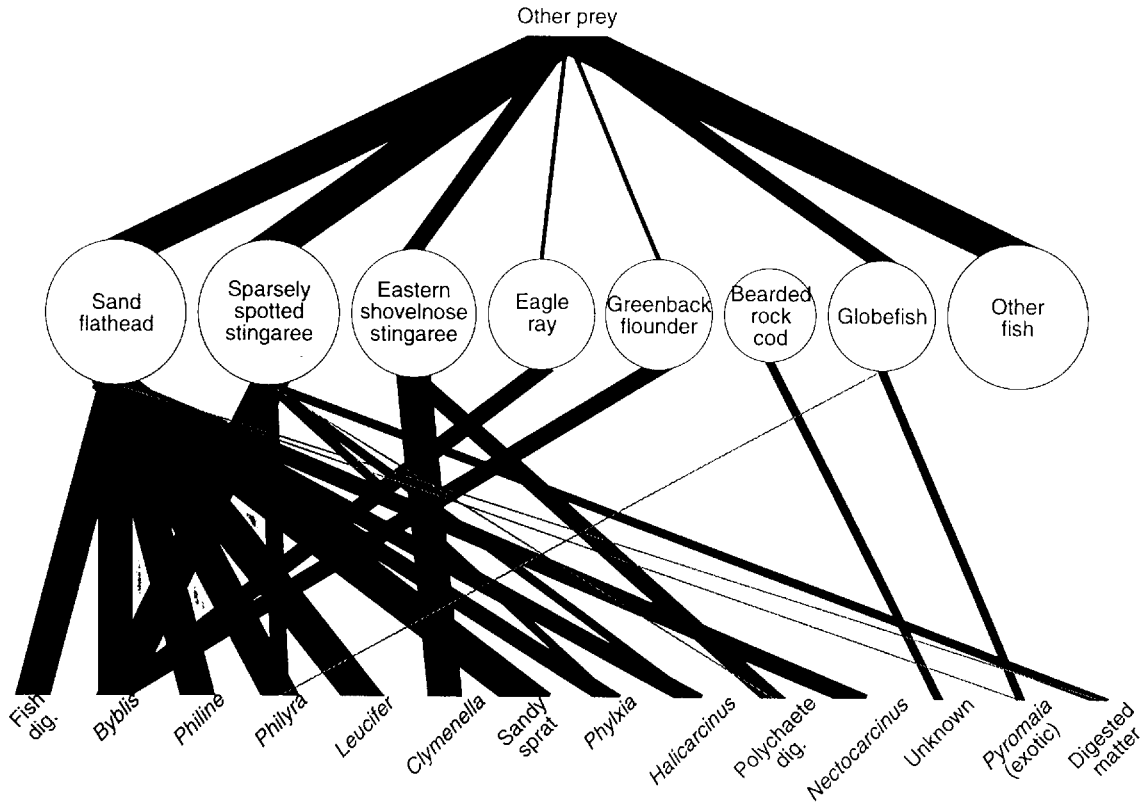
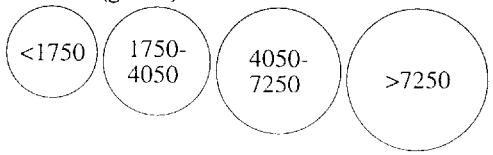


Figure 3 (c). Food web for deep stations off St. Leonards showing the 20 most important interactions between fish and their prey. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot):
Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



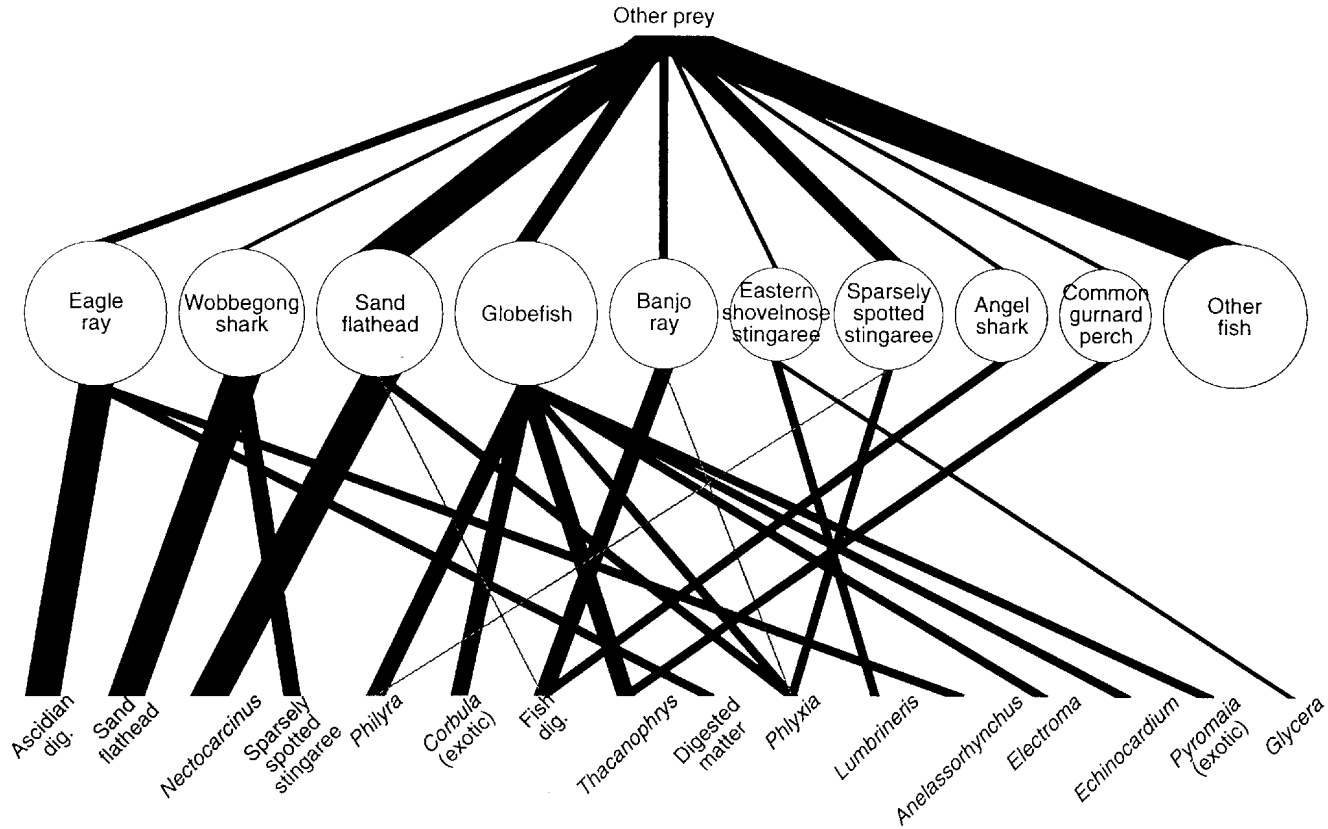
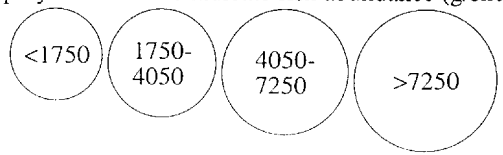


Figure 4 (a). Food web showing the 20 most important interactions between fish and prey for fish collected in Summer/Autumn at shallow stations off St. Leonards. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



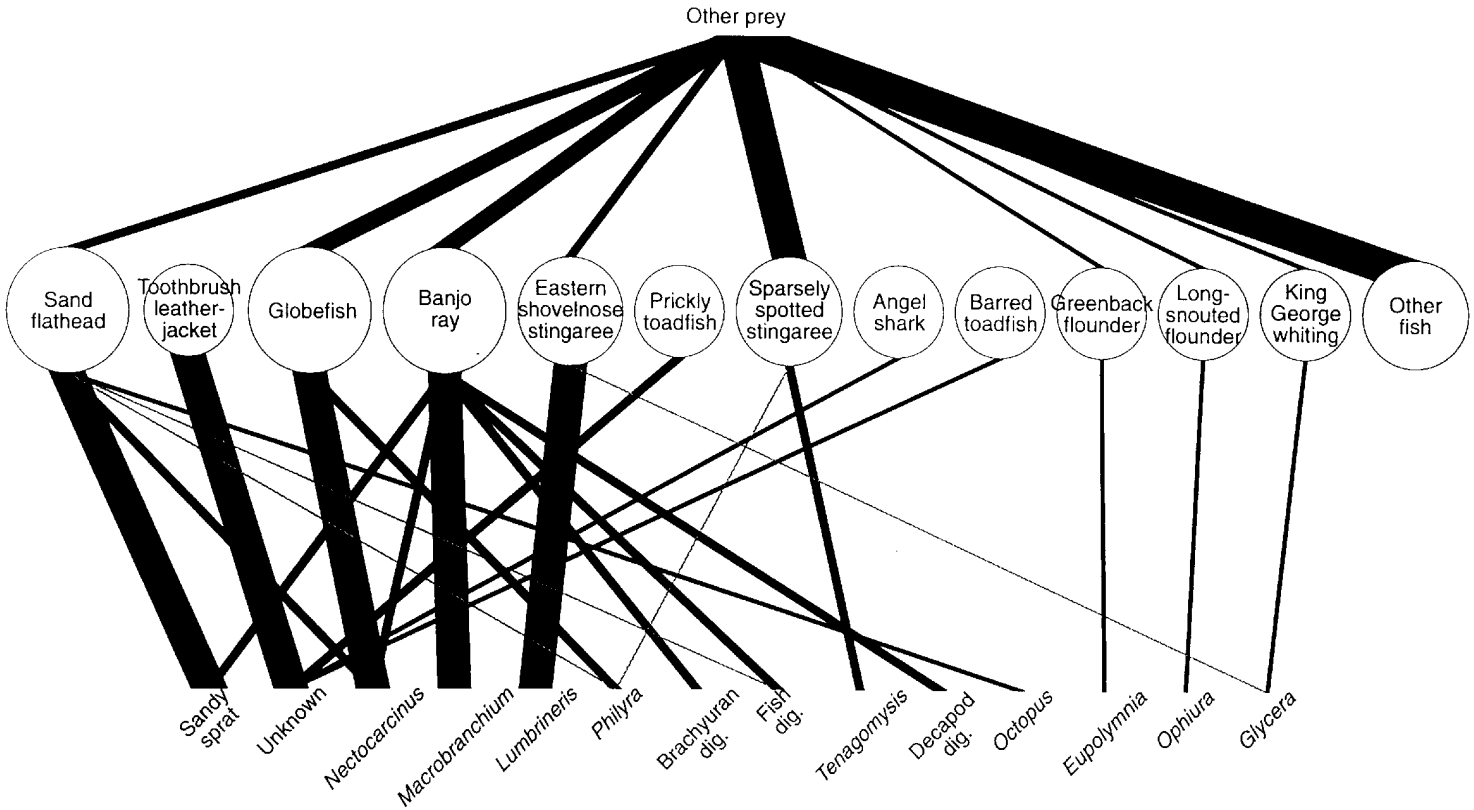


Figure 4 (b). Food web showing the 20 most important interactions between fish and prey for fish collected in Winter/Spring at shallow stations off St. Leonards. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.

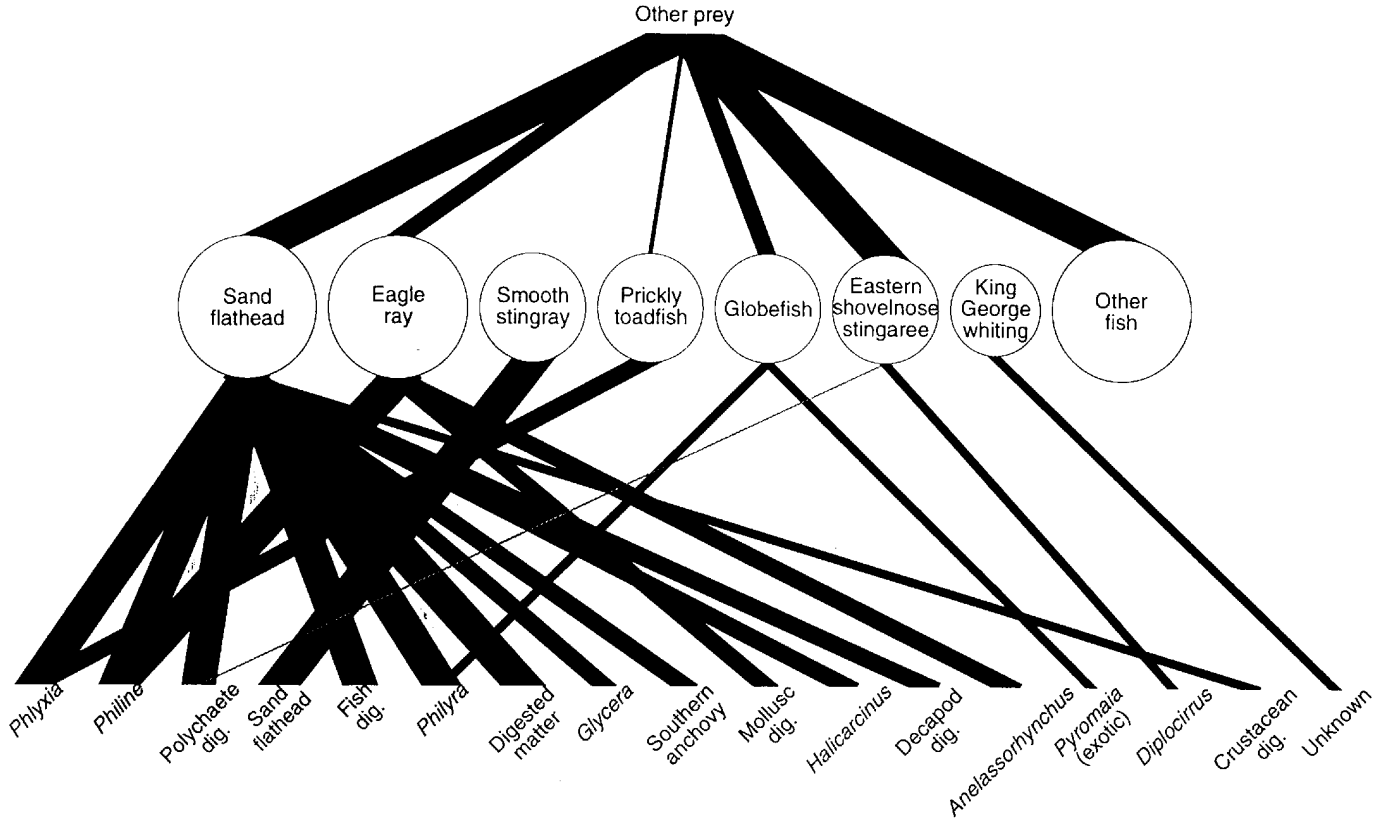
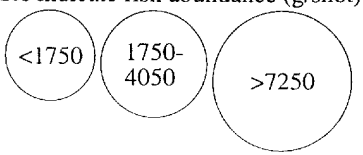


Figure 5 (a). Food web showing the 20 most important interactions between fish and prey for fish collected in Summer/Autumn at intermediate depths off St. Leonards. Fine grey lines indicate prey in the 21st - 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish is also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



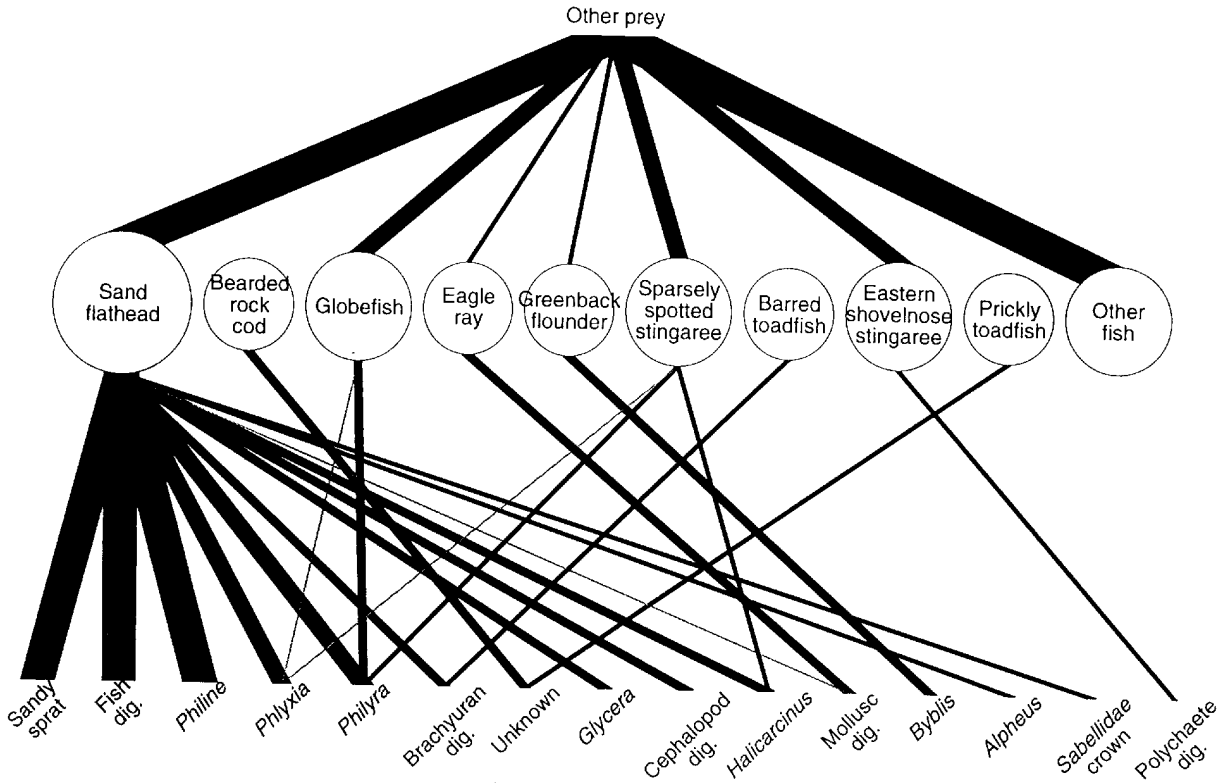


Figure 5 (b). Food web showing the 20 most important interactions between fish and prey for fish collected in Winter/Spring at intermediate depths off St. Leonards. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.

<1750 1750-4050 >7250

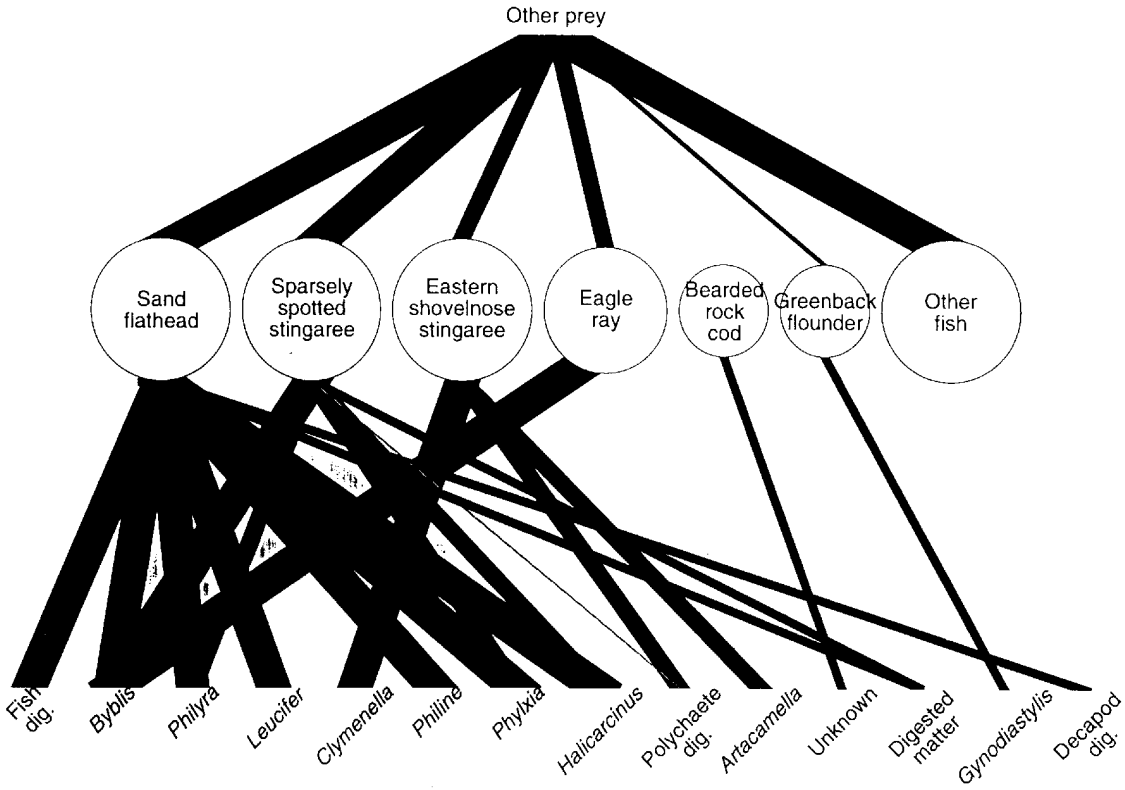
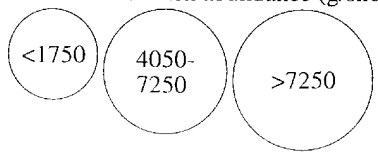


Figure 6 (a). Food web showing the 20 most important interactions between fish and prey for fish collected in Summer/Autumn at deep stations off St. Leonards. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.



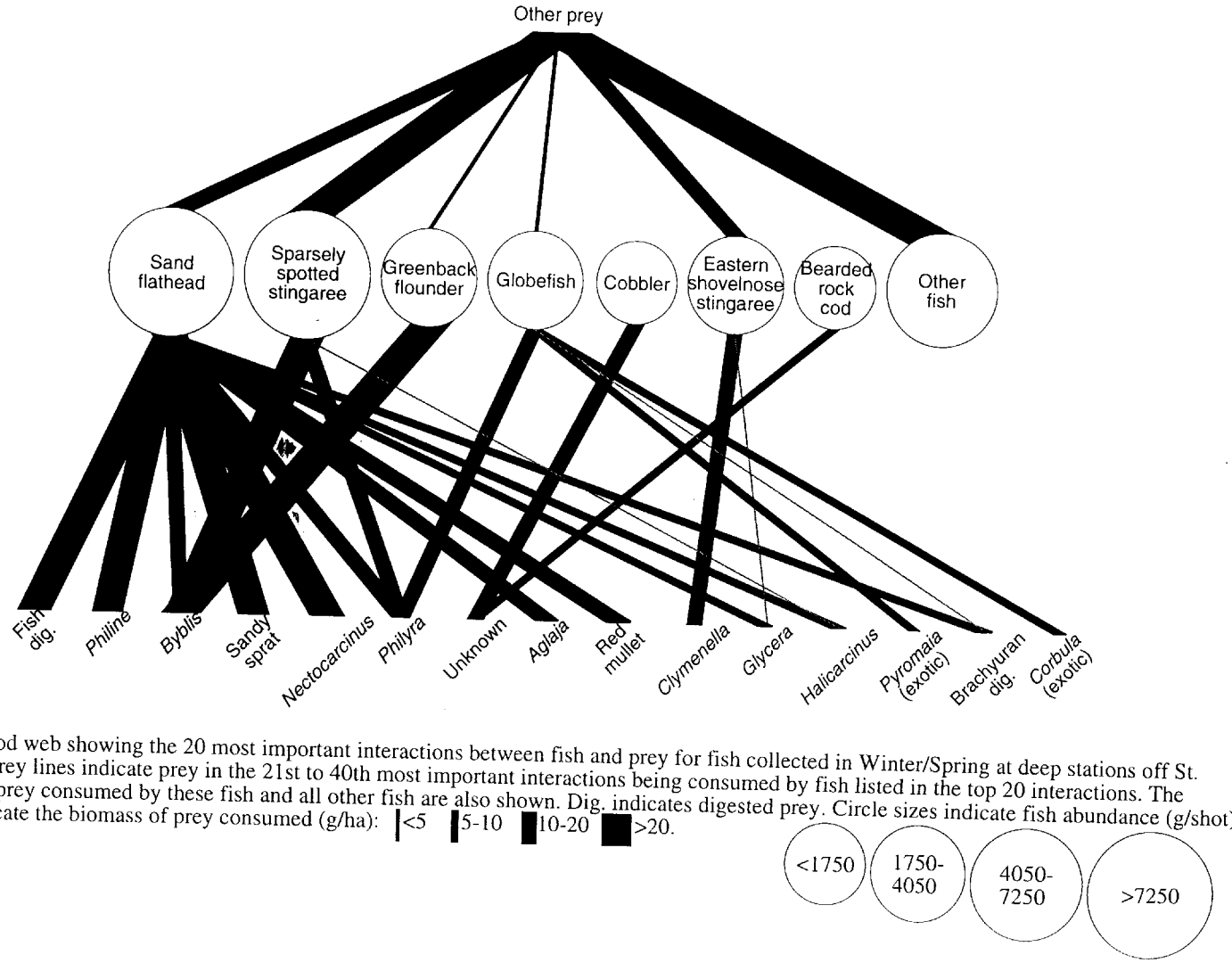
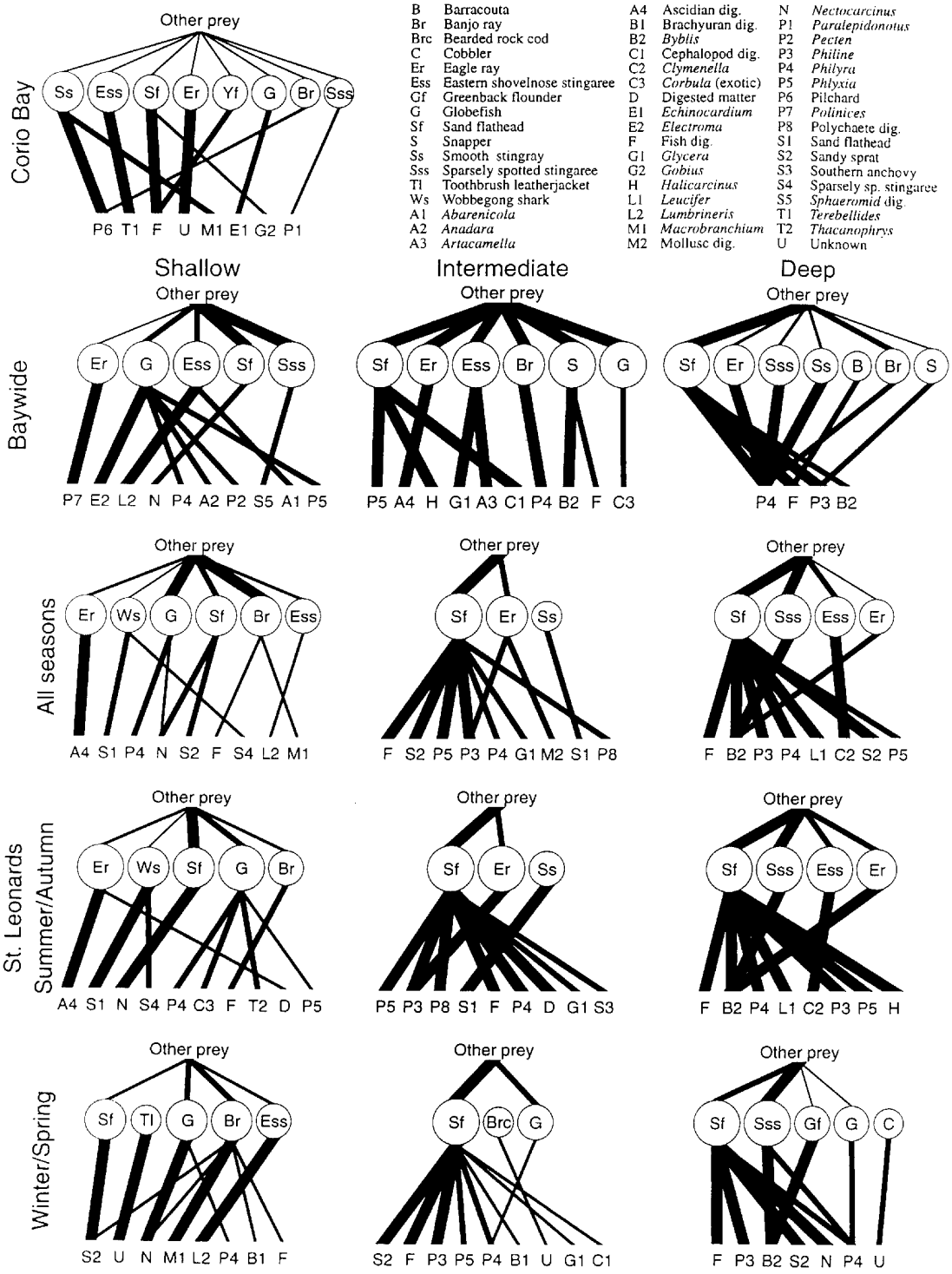


Figure 6 (b). Food web showing the 20 most important interactions between fish and prey for fish collected in Winter/Spring at deep stations off St. Leonards. Fine grey lines indicate prey in the 21st to 40th most important interactions being consumed by fish listed in the top 20 interactions. The amount of other prey consumed by these fish and all other fish are also shown. Dig. indicates digested prey. Circle sizes indicate fish abundance (g/shot): Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20.

Figure 7. Food webs for 13 divisions of Port Phillip Bay showing only the ten most important interactions between fish and their prey.
Line widths indicate the biomass of prey consumed (g/ha): <5 5-10 10-20 >20
Circle sizes indicate fish abundance (g/shot): <1750 1750-4050 4050-7250 >7250



B	Barracouta	A4	Ascidian dig.	N	*Nectocarcinus*
Br	Banjo ray	B1	Brachyuran dig.	P1	*Paralepidonotus*
Brc	Bearded rock cod	B2	*Byblis*	P2	*Pecten*
C	Cobbler	C1	Cephalopod dig.	P3	*Philine*
Er	Eagle ray	C2	*Clymenella*	P4	*Philyra*
Ess	Eastern shovelnose stingaree	C3	*Corbula* (exotic)	P5	*Phlyxia*
Gf	Greenback flounder	D	Digested matter	P6	Pilchard
G	Globefish	E1	*Echinocardium*	P7	*Polinices*
Sf	Sand flathead	E2	*Electroma*	P8	Polychaete dig.
S	Snapper	F	Fish dig.	S1	Sand flathead
Ss	Smooth stingray	G1	*Glycera*	S2	Sandy sprat
Sss	Sparsely spotted stingaree	G2	*Gobius*	S3	Southern anchovy
Tl	Toothbrush leatherjacket	H	*Halicarcinus*	S4	Sparsely sp. stingaree
Ws	Wobbegong shark	L1	*Leucifer*	S5	*Sphaeromid* dig.
A1	*Abarenicola*	L2	*Lumbrineris*	T1	*Terebellides*
A2	*Anadara*	M1	*Macrobranchium*	T2	*Thacanophrys*
A3	*Artacamella*	M2	Mollusc dig.	U	Unknown

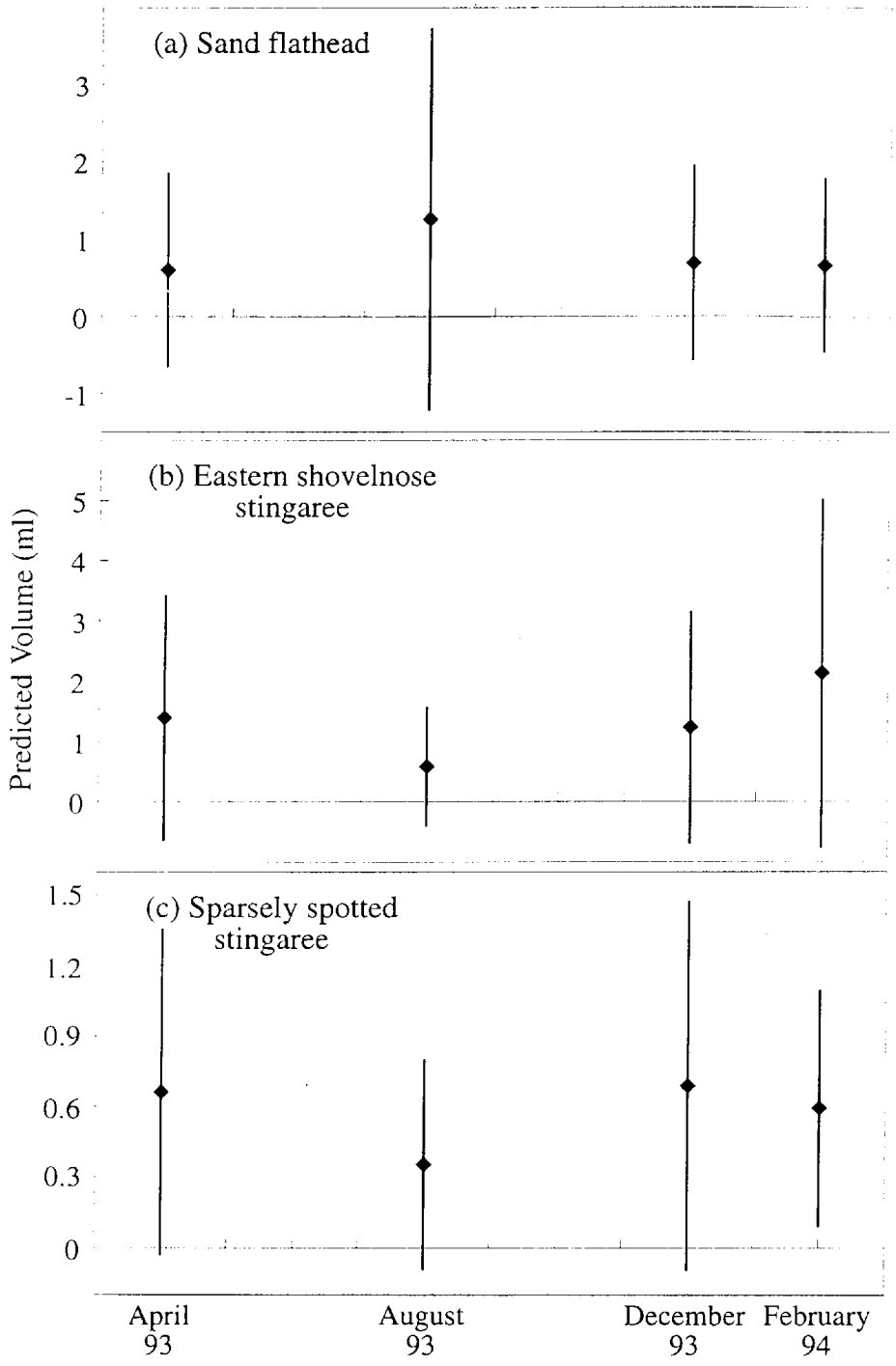


Figure 8. The predicted volume of prey consumed at different times of year by (a) sand flathead, (b) eastern shovelnose stingaree and (c) sparsely spotted stingaree of mean length. Standard errors for predicted prey volumes are shown.