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Summary of SBT diet studies in relation to SPF species

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Contents

Executive Summary

Southern bluefin tuna *Thunnus maccoyii* (SBT) diets have been collected from both the Great Australian Bight (GAB) and southeast Australian waters. The earliest collections were in the 1930s followed by more detailed collections in the 1990s in south eastern Australia (with only a few samples taken since then) and 1999-2005 in the GAB. All of these data sets indicate that the diets of SBT in the GAB are not as broad as those off eastern Australia.

All of the data taken in the GAB are from juvenile SBT that feed mainly on squids and small fish, such as sardines, blue sprat and anchovies. The diets off eastern Tasmania are more varied, both inshore and offshore and between years. SBT caught inshore are faster growing juvenile fish, eating twice as much per day and concentrating on fewer species than are taken by the larger sub-adult offshore fish. There was a lot of variation between individuals, but combining samples across all the small inshore fish taken in the 1990s showed that jack mackerel, redbait and arrow squid were the most common prey. In offshore fish caught in the 1990s, squid dominated the diets, though a significant number of fish also contained jack mackerel. No jack mackerel were found in the diets of SBT taken since 2000 off eastern Australia but these were all larger fish from offshore NSW. Also far fewer samples were taken post-2000 and so it is not possible to say whether the later samples reflect real diet shifts, responding to changed species availability as the oceanographic conditions have changed over that time or whether the naturally high variability meant the samples taken just happened not to contain any mackerel. It could even be a combination of both causes.

Overall, the diet data indicate that SBT feed opportunistically on any available pelagic prey.

In developing the ecosystem models of the GAB and south eastern Australia, we use the diet data to help define the model structure. The models can then be used to explore what happens if particular species (e.g. jack mackerel) are depleted. These models indicate that small “forage” fish (such as jack mackerel, sardines and anchovies) do not have the same key role that forage fish have in productive upwelling ecosystems, such as the Benguela or Humboldt currents. In those upwelling ecosystems enormous forage fish schools feed on the plankton rich waters, the forage fish then become prey to many of the other species in the ecosystem – larger fish (including tunas), sharks, seabirds and marine mammals. In Australian waters however, the forage species are not as abundant, the system is not as productive, and so a combination of other food sources including squid, krill and mesopelagic fishes also help to support the system. This means that depleting the forage species does not have the same effects off Australia compared to those upwelling systems.

The magnitude of the effects of depletion of forage species depends on the model assumptions. There are multiple tuna stocks included in the Atlantis model, with those in southern waters (i.e. Great Australian Bight region and waters off Tasmania and Victoria) modelled on SBT and the stock along the rest of the east coast of Australia based on the more tropical tuna and billfish. The high variation in the diets of tuna (i.e. all tuna and billfish species included in the Atlantis tuna group, but particularly SBT diets from southern Australia) inshore versus offshore, between individuals and across the different years suggests that tuna have a flexible diet, eating whatever they can find at the time. Atlantis uses that information to allow its tuna stocks to switch between prey species; as one prey declines (e.g. sardines) they feed on other pelagic species (e.g. squid) and so the tuna are fairly robust to environmental variation and shifts in abundance of individual prey species. In contrast, the Ecopath with Ecosim model tries to maintain a similar diet through time and so registers larger effects when a prey species' abundance changes.

There have been oceanographic shifts in the GAB, but most particularly off Eastern Australia over the last 20 years. This has affected the distribution and abundance of the species that live there. To understand what those changes have done to the diets of SBT living in the region requires new data. The existing models have used all the available data (not just for SBT) to check that their dynamics correctly reproduce conditions in the 1990s and early 2000s. To be sure that what the models say about conditions now and into the future are accurate, new diet data are required.

1 Introduction

The purpose of this report is to document and comment on the importance of Small Pelagic Fishery (SPF) species in the diets of southern bluefin tuna *Thunnus maccoyii* (SBT). The SPF species discussed here are: common jack mackerel *Trachurus declivis* although a more generic group of *Trachurus* spp. (possibly the Peruvian jack mackerel *Trachurus murphyi* and yellowtail scad *T. novaezelandiae)* were also included; redbait *Emmelichthys nitidus* and Australian sardine *Sardinops sagax*. Anchovy *Engraulis australis* is included here for completeness: it is a small pelagic fish but not an SPF-regulated species. There are several dietary studies that have been conducted in Australian waters, the results of which vary according to location, timing and with the size of the fish sampled. It is important to acknowledge these as factors that contribute to the variability of the diets of all fish, not just SBT.

Here we document all data from published sources and provide an overall analysis based on dietary data for SBT caught during CSIRO projects held in the CSIRO PESCI (Pelagic Ecosystems Stomach Contents Investigation) database that was constructed initially for the storage of SBT diet data collected by Young *et al.* (1997).

2 Studies of SBT diet

The Expert Panel on a Declared Commercial Fishing Activity (2014) collated dietary data for a range of predators of SPF species including marine mammals, seabirds, large and smaller teleosts, sharks and cephalopods (see Table 4.2 in Expert Panel Report). The data were segregated into that from the Great Australian Bight (GAB) and that from eastern Australia and Tasmania and are depicted in conceptual foodwebs illustrated in the report (p. 38-39). These data are representative of the dietary information used in all Atlantis and EwE ecosystem models constructed for southern Australia ecosystems, however, each model preferentially uses region-specific data where these are available. The data for southern bluefin tuna *Thunnus maccoyii* (SBT) are described in detail in the following sections but it should be noted that many higher trophic level predators had an equally high reliance on SPF species. In addition, a study of juvenile SBT from 1997-2010 from south-western Western Australia is also described.

2.1 GAB

Table 1 presents the data from a range of reports and publications for the GAB. Some of the data have been reported in several publications. The data covering the longest time period (1999-2005) is reported in Caines (2005) and includes juvenile SBT caught in the eastern GAB. A larger data set (n=94) from 2001-2005 – including data from Caines (2005), Ward et al. 2005 and Page (unpublished data) – was summarised by Page et al. (2011). These data were the basis for the SBT diet input into the eGAB ecosystem model of Goldsworthy et al. (2011, 2013) but were averaged and modified during the balancing and tuning process of the model; therefore the resulting "model diet" does not exactly match the original dietary data.

Table 1: Average contribution of SPF species, anchovy, squid and other fish to the diet of juvenile SBT in the GAB (does not include other categories). Data from original studies, modelling studies and reports as noted. (* *Trachurus* spp. in the GAB studies could include both T. declivis and *T. novaezelandiae*). Note that there is large variability within each sample set, not shown here.

Area	Australian anchovy	Australian sardine	Jack mackerel*	Blue mackerel	Redbait	Other fish	Squid	Total SPF (exc. anchovy)
GAB[1] (n=41) 1999-2000	8.4	50	0.9	29.2	-	8.9	2.7	80.1
GAB[2] (n=93) 2001-2004	25.1	49	6.2		6.3	1.1	11.9	61.5
GAB[3] (n=15) S Spencer Gulf 2005	6.6	0	51.3	0.2	13.1	0.1	28.4	64.6
GAB[3] (n=66) west region 2005	21.5	47.4	7.7	0	7.9	0.7	14.4	63.0

Area	Australian anchovy	Australian sardine	Jack mackerel*	Blue mackerel	Redbait	Other fish	Squid	Total SPF (exc. anchovy)
GAB[3] (n=?) All data 1999-2005	18.2	37.1	17.2	-	9	1	17.5	63.3
GAB[4, EP] (n=94)	21.4	37.4	3.2	0.7	12.1	3.9	18.3	53.4
GAB[4,5] Model input data	7.5	42.8	7.2	6.1	18.2		18.2	74.3

[1]Ward *et al.* (2006) juveniles collected in 1999-2000; [2] Ward *et al.* (2005) juveniles caught between 2001-2004; [3] Caines 2005 (Table 2.3): juveniles collected 1999-2005; [4, EP] Page *et al.* (2011) in Goldsworthy *et al.* 2011; [5]Goldsworthy *et al.* 2013.

Serventy (1956) characterised the diets of SBT in South Australia as being not as varied as those of eastern Australia – eating mainly clupeoids, including pilchards (sardines), blue sprats and anchovies. That dietary pattern largely still holds, although *Trachurus* spp. and redbait also appear to be important in some of the analyses, although this view is perhaps biased by one small sample (SSG).

There were no diet data for adult SBT from the GAB (Dr B. Page DEWNR pers. comm. 17 April 2015).

2.2 Eastern Australia

The data on diets of juvenile SBT were collected from 1992-1994 (Young *et al.* 1997) with some later samples added (Young *et al.* 2010) and are maintained in the CSIRO Pelagic Ecosystems Stomach Contents Investigation database (PESCI: Cooper *et al.* 2009). From 1992-2005 inclusive, stomachs contents from a total of 1457 SBT captured from throughout the eastern Australian EEZ from 32- 45°S have been examined (Table 2).

The majority of SBT (n=1219) were taken off eastern Tasmania in 1992-1994 in a study by Young *et al.* (1997). The diet varied widely across 92 prey taxa including 36 species of fish, 16 species of squid and 25 species of crustacea and also in size of prey. They found diets differed between inshore and offshore fish, most probably due to prey availability but also because the SBT sampled inshore were generally younger and smaller (sub-adult) (<150 cm fork length, LCF) than those (adult) sampled offshore (>150 cm LCF). Inshore fish ate more food (2.69% of body weight per day, compared to 0.81% BW d^{-1} for offshore fish) but across a lower diversity of prey (38 prey taxa versus 78). Inshore fish ate mostly jack mackerel (45.8% by weight), redbait (30.5%) and juvenile arrow squid (14.1%). Macrozooplankton occurred most frequently in offshore fish diets, but contributed very little by weight; while cephalopods actually contributed most by mass (54.1%) followed by jack mackerel (24.5%).

Young *et al.* (1997) also found that “offshore” diets could be characterised based on the water masses the SBT occupied. Warm, cool or intermediate water masses have characteristic crustacea, zooplankton, squid and fish communities and this is reflected in the diets of the SBT foraging there. Other emergent patterns reflected changes in the relative abundance of certain prey – e.g. amphipods have decreased in SBT diets, while crab megalopa increased, salps (which appeared in diets in from 1993) and cephalopods have became more common as crustaceans have decreased with changes in sea surface temperature in the region.

Table 2: Diet compositions (calculated as mean annual %) for southern bluefin tuna in eastern Australia reported in literature and from the whole PESCI database, some of which has been reported in the literature. There is large variability among samples within each data set, not shown here.

Area	Australian anchovy	Australian sardine	Jack mackerel*	Blue mackerel	Redbait	Other fish	Squid	Total SPF (exc. anchovy)
Tas[1] inshore 40-130cm (n=353)	0.5		45.8	-	30.5	9.2	14.1	76.8
Tas[1] offshore 74-192cm (n=870)	-	1.0	24.5		1.4	16.3	54.1	26.9
East Aust[2] <100cm (n=316)		1.18	47.9		15.32	12.43	22.33	64.4
East Aust[2] >100 cm (n=1047)		1.09	28.5		6.65	31.14	30.03	36.24
PESCI ≤100 cm n=298	-	5.66	50.6	-	13.94	10.19	17.44	70.2
PESCI >100 cm n=930	0.6	2.42	21.02	-	3.15	42.2	26.6	26.59

[1] Young *et al.* 1997; [2] Young *et al.* 2010.

More samples from mostly larger SBT taken from the northern regions of eastern Australia during a study of large predators (Young *et al.* 2010) were added to the original dataset for SBT (Table 2). The similarity in composition of the smaller fish (≤100 cm) of Young *et al.* (2010) to that of Tasmanian 'inshore fish' of Young *et al.* (1997) is because they were a subset of the first study. In the later study, the additional fish were caught in offshore waters of the Tasman Sea and were mostly >100 cm, as were the larger fish in the earlier study off Tasmania.

PESCI database analysis

A total of 1457 SBT were sampled off eastern Australia, including Tasmania, from 1992-2005; of these, 1225 contained food (84%). The majority of the samples (n=1054) were collected during 1992-1994, with a further 206 taken in 1995. Since then sampling has only been incidental: 3 were collected in 1996, 6 in 1997, 7 in 2004 and 14 in 2005. These data have largely been described in Young *et al.* (1997, 2010).

We have re-analysed the whole data set by size and year, so that all samples (including those not previously published in Young *et al.*, 1997, 2010) could be considered in a unified and consistent way (the previous analyses had used slightly different methods and sizes classes). This analysis is summarised in Table 2 and Appendix A.1; it treats small fish as those ≤100cm LCF (Appendix Table A1) and large as >100cm LCF (Appendix Table A2). The annual frequencies of occurrence (%FO) and the annual proportional compositions by weight (%W) of prey items were determined for each of the small and large fish datasets. The mean of the annual values for both parameters were also determined across all years (excluding the 1996 sample of small fish because n=1 that year) and the contribution to the diet by SPF species are provided in Table 2.

This treatment (means of means) smooths some of the interannual variability in prey composition, but allows small sample sizes a greater relative weighting. To provide an alternative view, an overall frequency of occurrence and composition by weight was determined by combining all samples across years by size, down-weighting the importance of the smaller sample sizes of the later years. As no samples were collected in the later years for small fish, there is little difference between the two methods for fish ≤100cm (Appendix Table A1); however there is more of a difference for larger fish data (Appendix Table A2). A more detailed size-based analysis was undertaken by Young *et al.* (2010).

Of all fish containing food, jack mackerel (*T. declivis*) occurred in 39% (0-41% per year) of the small fish (Appendix Table A1) and in 18% (0-40% per year) of large fish (Appendix Table A2). Similarly, redbait (*E. nitidus*) occurred annually in 13% (0-26%) of smaller fish compared to 3% (0-15%) of larger fish. Sardines occurred in 2% (0-23%) of small and 6% (0-40%) large fish. Arrow squid (*Nototodarus gouldi* and *Argonauta nodosa*) occurred in 13 % (0-40%) and 19% (0-100%) respectively of large fish and 13% (3-31%) and about 5% (0-16%) respectively of small fish. There was a greater diversity of cephalopods eaten by larger fish than by smaller fish. The wide variability in the diet contribution per species is a reflection of the patchy nature of the schooling dynamics of both predator and prey species.

Jack mackerel was by far the most important prey (especially for fish taken in the 1990s) contributing an annual average of nearly 51% (0-61%) by weight to the diet of small fish (Table 2, Appendix Table A1) and about 21% (0-36%) for large fish (Table 2, Appendix Table A2). Redbait were the next major prey contributing 14% (0-19%) to small fish diet and about 3% (0-16%) to large fish diets; sardines contributed about 6% (0-21%) to small and 2% (0-15%) to large fish diets. Arrow squid contributed 7% by weight to both small and large fish, with other cephalopods contributing an additional ~10% of to small fish diets and nearly 20% to large fish diets.

In 2004-5 only 21 large fish were sampled so these results need to be viewed with caution (Appendix Table A2). Jack mackerel and redbait were not eaten at all but other species such as *Gonostoma* (bristlemouths) contributed 80% by weight to the 2004 large fish diet (n=7). Other important prey species were *Brama brama* (pomfret), which contributed nearly 13% (0-45%) to large fish diet by weight but only 0.1% to small fish diet. Amphipods (*Phronima*) were frequently occurring in small and large fish diets, 7% and 13% respectively, but contributed only 0.5% by weight. In 2005 , *Scomberesox saurus* (sauries) occurred in 29% of large fish stomachs (n=14) and contributed about 45% by weight and *Cubiceps* sp. (cubeheads) occurred in 21% of large fish stomachs contributing 15% by weight. Anchovies were also eaten occasionally and only in small amounts.

In summary, recent SBT diet in eastern Australia is widely varied and supports the observations of Serventy (1956), of being “extraordinarily varied” and reflecting “the relative components of macrozooplankton and smaller nekton of the area in which it has been caught”. Serventy (1956) observed prey from small pelagic amphipods and euphausids to large fish such as 350mm jack mackerel (*Trachurus novaezelandiae*). This latter species however is now known as yellowtail scad, which is more common in the warmer coastal waters off NSW whereas jack mackerel *T. declivis* is more common in the cooler Tasmanian water. The SBT in the study of Serventy (1956) were caught off St Helens in June 1940 and were large, comparable to those taken offshore by Young *et al.* (1997) and to those taken off NSW in 2004-5 (Young *et al* 2010). Serventy (1956) found that "jack mackerel" (*sensu* Serventy (1956)) of 200-300mm length were commonly found in SBT of 20-30lbs (i.e. probably 3+ and older fish of LCF>83 cm). Other fish consumed were sardines (to 200mm) and anchovy (50-150 mm), jack mackerel ("scad"; *T. declivis*) up to 230mm, barracouta (*Thyrsites atun*) to 200mm, redbait (*E. nitidus*) to 210mm, Australian salmon (*Arripis trutta*), gemfish (*Rexea solandri*), blue sprats (*Stolephorus robustus;* now *Spratelloides robustus*), myctophids and eels. This is quite similar to the finding by Young *et al.* (1997) who showed that the inshore fish ate prey of lengths <125mm but offshore fish took significantly smaller and more numerous prey. Altogether these data support an interpretation that SBT feed opportunistically on available pelagic prey of which the SPF species comprise a considerable proportion.

Generally the diets of the fish from 1938-1952 observed by Serventy consisted of "small feed" which varied seasonally from anchovies (*Engraulis australis*) and sardine (*S. neopilchardus* or *sagax*) in the late 1930s to krill (*Nyctiphanes australis*) in 1940s. It also includes larval fish, such as *Macroramphosus molleri* (now *gracilis*), *Scomberesox forsteri* (now *saurus*), *Caranx* (now *Pseudocaranx*) *georgianus* and mackerel and clupeoid juveniles. The mackerel fry" ranged from 25-100mm TL, sardines 20-100mm TL and anchovy 30mm. A wide variety of other fish "fry" were found also measuring < 100mm. Unusual Tasmanian records were of a 28 lb (~13kg) SBT off southeastern Tasmania having eaten juvenile toothed whiptails (*Lepidorhynchus denticulatus*), a species normally found on the mid-upper slope and another fish caught off Cape Pillar having eaten "fry (38-48mm) of Australian perch *Percalates colonorum*", probably *Macquaria colonorum* an estuarine fish not known in Tasmania but obviously a misidentification of a similar species. Arrow squid and krill (*Nyctiphanes australis*) were also commonly eaten.

Overall, the diets of SBT caught in the 1990s are similar to those caught 50 years earlier in their wide variety of prey and high interannual variability. Moreover, the prey species are similar. With regard to the species of the SPF – notably jack mackerel *T. declivis* and redbait *E. nitidus* – Young *et al.* 1997 found these species of importance in the diets of the juvenile SBT from inshore Tasmanian waters. The analysis of the PESCI data re-confirms that conclusion. However, that importance varies annually (and even between individuals), as was found in the earlier studies of Serventy (1956). The high importance of SPF in the 1990s diet studies coincides with high catch rates in the Jack Mackerel fishery off Tasmania, supporting the hypothesis that the SBT were opportunistically consuming the readily available jack mackerel at the time. No jack mackerel were found in the stomachs sampled in 2004-5 but the 2004-5 sample size was very small (n=21 compared to that of the 1990s (n=909) and the fish were larger specimens taken in offshore waters of NSW.

Young *et al.* (1997) hypothesized that SBT migrations coincide with autumnal blooms of phytoplankton that when they occur as in the 1990s support large populations of *Nyctiphanes australis*. In the 1980s and again in the 1990s, jack mackerel on the shelf fed in the surface waters on krill and were targeted by both tuna and the purse–seine fishery. However, in later years, oceanographic conditions were unfavourable for the formation and maintenance of the productivity required for krill blooms and the jack mackerel remained in sub-surface schools or moved to the southern tip of Tasmania (Harris *et al.* 1992), thus the purse seine fishery was less able to catch them. There is no evidence to indicate whether there was a subsequent decline of jack mackerel in SBT diets for inshore fish off Tasmania assuming that SBT are more than able to dive to depth to find them. Nevertheless, Young *et al.* (1997) and Serventy (1956) suggested the breadth of SBT diet strongly indicates an opportunistic feeding habit. Prey-switching is therefore a strategy that needs to be acknowledged in the modelling studies.

2.3 Western Australia

Diets of juvenile SBT collected off south-western Western Australia between 117°E to 125°E from 1997-2010 were examined by Itoh et al.(2011). Over the 11 year study period samples were collected by trolling during recruitment monitoring studies during December through March in each year of two periods, 1997-2003 and 2007-2010. The fish collected ranged between 33-86 cm FL mostly been assigned age 1. The fish were mostly collected on the shelf from the coast to the shelf-edge. Of the 720 fish collected, 636 had prey in their stomachs.

Teleosts constituted well over 90% by number and by volume of the diet, with crustacea and cephalopods comprising the remainder. Of the teleost prey, sardines, anchovy, blue mackerel and jack mackerel were the dominant prey species (Table 3). Interannual comparison of frequencies of occurrence showed a wide variability for each of the main prey ranging from 0-58% for sardine, 0-37% for anchovy, 0-60% for blue mackerel and 0-73% for jack mackerel (Itoh *et al.* 2011). In general, Itoh *et al.* (2011) found that sardines occurred mostly in diets from inshore fish while jack mackerel was dominant from those caught on the shelf edge, and blue mackerel were somewhat intermediate but slightly more frequent closer to the shelf edge. Prey size varied from 5-240 mm with majority between 30-50 mm, however the major fish prey were also found at larger sizes classes (>70 mm). Pilchards were mostly between 130-190 mm.

Table 3. Diets of juvenile SBT by %volume taken off south western Western Australia from 1997-2010.

Area	Australian anchovy	Australian sardine	Jack mackerel*	Blue mackerel	Redbait	Other fish	Squid	Total SPF (exc. anchovy)
SW WA 33-86cm (n=636)	8.2	27.4	14.2	16.7	-	39.1	2.1	58.3

Itoh *et al.* (2011) concluded that the preference for teleosts in young SBT was similar to that of similar–aged fish in previous studies by Serventy (1956), Young *et al.* (1997) and Ward *et al.* (2006). However, sardines were not as dominant in diets of fish from in this study compared to those of Serventy (1956) and slightly older fish of Ward *et al.* (2006). Itoh *et al.* (2011) suggested that sardine proportions probably varied depending on location on the shelf and availability such as when large mortalities of sardines occurred in 1995 and 1998-99 although the lack of specific data in Serventy (1950) did not allow further inferences to be made.

Diets of fish caught north of C. Leeuwin (on the west coast) were much more variable as they were on the east coast and included leatherjackets, box fish, *Gonorynchus greyi*, *Sphyraena obtusata (*now *pinguis)*, garfish, cephalopods and *Squilla* larva (Serventy 1956).

These data support the observations from the GAB and east coast Australia, but were not included in the calculations for the dietary matrix used in the ecosystem models, as they were not specific to the models' domains.

2.4 Modelling studies based on trophic interactions

Bulman *et al.* 2011

The study by Bulman *et al.* (2011) explored the food webs of two ecosystems: those on the east coast of Australia—the East Bass Strait (EBS) model and a variant—and that in the GAB—the eGAB model. The aim was to describe the most dominant food web interactions with specific reference to the target species of the SPF and their responses to various pressures, such as changing productivity and fishing pressure. The ecosystem models were constructed using Ecopath with Ecosim (EwE; Christensen and Pauly 1992, Christensen *et al.* 2004).

The "tuna" diets in the original EBS model (Bulman *et al.* 2006), the version used to consider the potential effects depletion of small pelagic species (Smith *et al.* 2011, Johnson *et al.* 2011), and the variant model which was a hypothetically based on the redbait fishery off eastern Tasmania, were based on data of both yellowfin tuna *Thunnus albacores* (Young *et al.* 2001) and SBT (Young *et al.* 2010). The EBS model represented the "tuna" diet composition by % wet weight as: 15.9% redbait, 22.8% jack mackerel, ~1% sardines and anchovy, 0.5 % mesopelagics, 7% squid, with 50% imported i.e. over the course of the year about half the diet of the tuna was sourced outside the model domain to account for the tuna's migratory nature and offshore movements out of the model domain. These compositions became the basis of all the work done with this model. As prey species abundance shifts, EwE will represent shifts in encounter rates. EwE can also represent intentional prey-switching but this was not enabled in either of the models discussed in Bulman *et al.* (2011), which used the default EwE option of disabling such switching behaviour.

The purpose of the Bulman *et al.* (2011) study was to determine whether the small pelagic species exerted a wasp-waist control on the local ecosystem, similar to that found in large upwelling systems supporting large sardine fisheries such as the Benguela or Humboldt ecosystems. This study showed such control wasn't the case for the Australian species and in fact mesopelagic fishes, krill and squid had a more influential role in the ecosystem dynamics. However some interactions between the SPF species and their predators or prey were sensitive to the type of control or vulnerability imposed. The small pelagic species, including sardine, anchovy and squids, figured in nearly half of all the most sensitive interactions in the GAB model but in less than 20% in the EBS system, suggesting that they were not as important in the EBS. Redbait and jack mackerel were bottom-up controlling tuna meaning that increases in biomass would result directly in increasing tuna. Redbait were involved in one-fifth of the 25 interactions in the EBS but only one in the GAB. In the GAB, middle-out control was found in the tuna/blue mackerel/small zooplankton pathway but at the same time pelagic sharks top-down controlled blue mackerel.

The EwE model of the eastern Great Australian Bight (eGAB) used diet data from studies specific to the GAB (Goldsworthy *et al.* 2011, 2013). The composite diet used for this model was: 6.1% blue mackerel, 7.2% jack mackerel, 18.2% redbait, 7.5% anchovy, 42.9% sardine and 18.2% arrow squid and no import (Goldsworthy *et al.* 2011, 2013). Diet data were sourced from Caines (2005), Ward *et al.* (2006) and Page *et al.* (2011). Results from this study of the eGAB ecosystem highlight the importance of small pelagic fish to the higher trophic levels, the trophic changes resulting from loss and recovery of apex predator populations, and the potential pivotal role of changing cephalopod biomass in regulating trophic flows. It was hypothesized that 'predator gaps' that resulted from reduced fur seal, SBT and shark biomass in the past were filled by cephalopods, which can increase biomass quickly in response to reduced predation pressure and competition for small pelagic fish.

Atlantis

The other ecosystem modelling platform used in south eastern Australia is Atlantis (Fulton *et al.* 2007). Atlantis-SE and Atlantis-SPF have both been fit primarily to the SBT data summarised in Young et al (1997). A comparison of average Atlantis-SPF (model) realised diets versus average (real world) observed diets are given in Figure 1. The model results are similar to the observed and when plotted at the level of an individual (i.e. if the model is sampled in the same way real world tuna are) then the model and real observations do not cluster separately. Figure 1 also presents average realised Atlantis-SPF diets for the case where there is depletion of SPF species due to current fishing mortality rates being increased five-fold. The modelled SBT in this case have switched to eating more "other fish" and squid. While flexibility of this magnitude and more may exist in real world diets, as hinted at by the data for later years in the PESCI database, and the mobile predatory habits of the species, it cannot be definitively stated either way based on available data, due to the small sample sizes of SBT post 1995. Both for model validation and better understanding of the current system dynamics new diet data is needed.

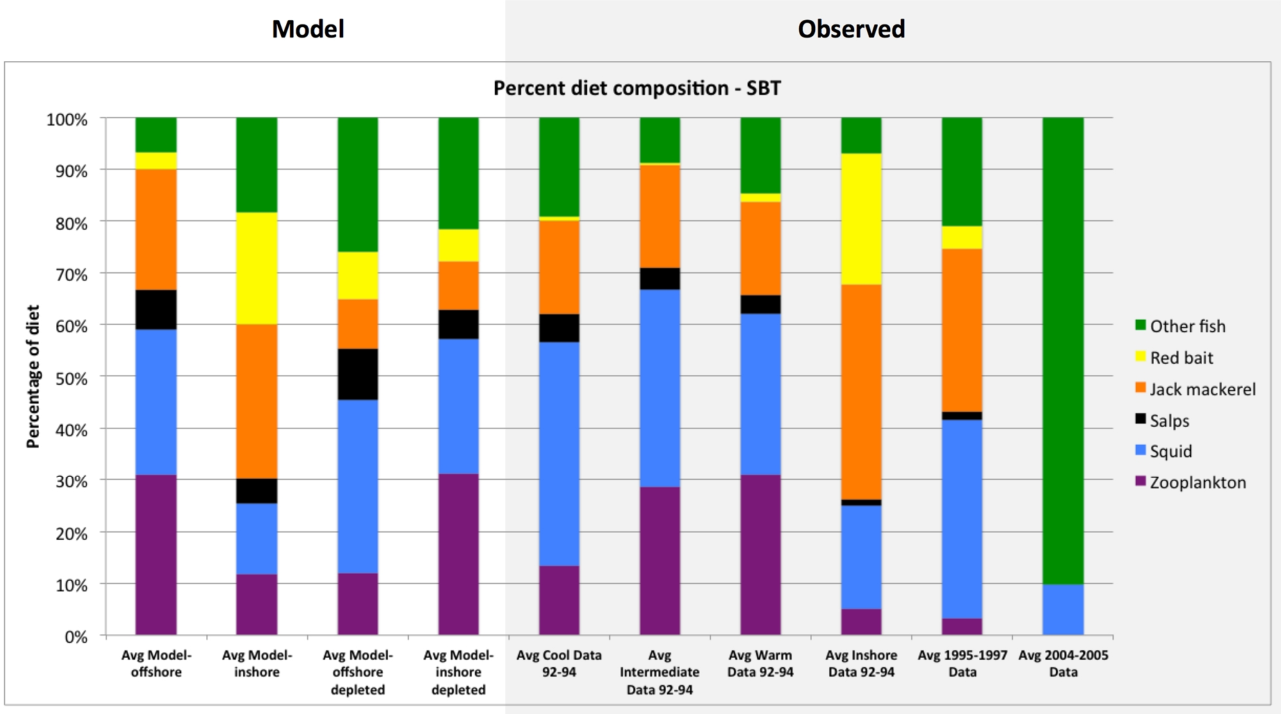

Figure 1. Comparison of diet composition of SBT with modelled diets predicted by Atlantis

Atlantis models were used in the MSC depletion study (Smith *et al.* 2011, Johnson *et al.* 2011) to predict the effects of reducing the biomass of small pelagic species, mesopelagics, squid and krill, and to compare those results with those of the EBS EwE model. Comparing outcomes across the models, EwE predictions were usually much more sensitive to the depletion of SPF species, due to the lack of prey-switching and other limitations of the model structure. For instance, reducing jack mackerel to 40% of unfished status resulted in a 20% reduction of tuna and billfishes in EwE but only minor changes in biomass in Atlantis (Johnson *et al.* 2010). The response of the EwE model depletion of small pelagic fishes was also greater than that seen in Atlantis, though both predicted an increase in tuna biomass (as a result of a complicated mix of direct and indirect interactions that ultimately saw tuna benefit from small declines in competitors and predators). In contrast, the depletion of species such as squid and krill were more influential in both models (Johnson *et al.* 2010, Smith *et al.* 2011).

Smith *et al.* (2015) used a new variant of the Atlantis ecosystem model (Atlantis-SPF) to explore the Harvest Control Rules relating to the SPF. Atlantis-SPF resolved the SPF species and their dietary interactions in detail. Smith *et al.* (2015) found that if the SPF species were depleted (singly or in combination) there were only relatively minor impacts on other parts of the ecosystem. In contrast to other regions (e.g. off Peru and in the Benguela), which show higher levels of dependence on similar forage species, Smith *et al.* (2015) concluded that the southeast Australian ecosystem does not appear to be highly dependent on SPF target species.

All the modelling studies of south eastern Australia (Goldsworthy *et al.* 2013; Bulman *et al.* 2011; Smith *et al.* 2011, 2015) are in agreement that if the system is exploited to the levels defined under the current harvest strategy then it is unlikely that there will be adverse environmental impacts to the broader ecosystem and that this is because SPF species are apparently not as influential in this system as small pelagic species in other upwelling systems. The agreement between the models on this outcome despite differences in the model assumptions provides a level of confidence in the robustness of the outcome. For example, while Atlantis does allow for prey switching, and so may be more buffered from potential detrimental effects if such switching is not in reality seen in all age classes of tuna, the Ecopath with Ecosim models have no such capacity and so should be conservative in terms of the ability of the ecosystem (and specifically tuna) to adapt to cope with any depletion of small pelagic fish.

3 Conclusion

Overall, the diets of SBT caught off eastern Australia in the 1990s are similar to those caught 50 years earlier in terms of their wide variety of prey, but also in the similarity of prey species and the high interannual variability. With regard to the SPF target species – notably jack mackerel (*T. declivis*) and redbait (*E. nitidus*) – they were important in the diets of the juvenile SBT from inshore Tasmanian waters during 1992-95 (~50% and 14% respectively). The analysis of the PESCI data re-confirms that conclusion. SPF species were much less important in the diets of large fish caught offshore (21% and 3%) likely due to lack of availability. The relatively high reliance on jack mackerel particularly in the 1990s studies coincides with high catch rates in the Jack Mackerel Fishery off Tasmania supporting the hypothesis that the tuna were opportunistically consuming the readily available jack mackerel present at the time. Young *et al.* (1997) hypothesized that the jack mackerel were feeding on large populations of *Nyctiphanes australis* (fed in turn by autumnal blooms of phytoplankton). Oceanographic conditions that occurred in more recent years have not supported the same productivity of krill and the jack mackerel schools have remained sub-surface and not available to a near shore purse-seine fishery. The presence of juvenile and sub-adult SBT is also variable and dependent on the state of depletion of the global stock, strength of year class recruitment e.g. weak in the late 1990s and early 2000s, and interannual variability of preferred oceanographic conditions.

In a later study, in 2004-5, only large SBT off NSW were sampled and no jack mackerel or redbait were found in their stomachs. While this might reflect differences in prey distribution and availability, the sample size is very small compared to the 1990s study and there were no samples of small tuna collected in the 2000s off eastern Australia. Fish from the GAB in the early 2000s showed a higher reliance on sardines and much less importance of jack mackerel or redbait (again probably reflecting the availability of prey within the area of capture) while those caught off south western WA generally showed less reliance on sardine.

The breadth of the diet seen across the many studies (from Serventy (1956) onwards) strongly supports an opportunistic feeding habit suggested by Young *et al.* (1997). To reflect this flexibility in diet requires "prey-switching" strategies to be considered in modelling studies. To date only the Atlantis model representation has included switching beyond that due to simple changes in rates of encounter as prey abundance shifts. With their current parameterisation, the EwE models do not allow for a high degree of prey variability and so modelled predators are less able to compensate for declines in their prey, leading to responses that are more dramatic.

The Atlantis modelling suggests very little response by tuna to declines in the SPF species from increasing fishing pressure (Smith *et al.* 2015). However, it needs to be acknowledged that while these model mechanisms are consistent with given data currently available, much of that data is now quite old. Furthermore oceanographic shifts have occurred in the system (Hobday and Pecl 2014) and new diet data needs to be collected to verify that the model projected shifts in species abundance and diet compositions reflect current circumstances.

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5 Appendices

A.1 SBT diet composition PESCI database analysis

Table A1: Dietary composition by frequency of occurrence (%FO) and proportion by mass (%W) of small (≤100cm LCF) SBT caught during CSIRO studies 1992-2005.

	1992			1993			1994			1995			1996			Mean annual (ex 1996)	Overall	Mean annual ex 1996	Overall
Prey Species	n	**%FO**	%W	n	**%FO**	%W	n	**%FO**	%W	n	**%FO**	%W	n	**%FO**	%W	**%FO**	**%FO**	**%W**	**%W**
Crustacea																			
Brachyscelus crusculum	14	8.7	0.14	10	11.36	0.07	0	0.00	0.0	1	7.692	0.09	0	0	0	6.94	8.39	0.08	0.10
Copepoda nd	0	0	0	0	0	0	1	2.86	0.002	0	0	0	0	0	0	0.71	0.34	<0.001	<0.001
Decapod megalopa nd	9	5.6	0.05	8	9.09	0.07	3	8.57	0.01	0	0	0	0	0	0	5.81	6.71	0.03	0.05
Gennadas spp.	0	0	0	1	1.14	0.003	0	0	0	0	0	0	0	0	0	0.28	0.34	0.001	0.001
Hyperiidea nd	6	3.76	0.24	2	2.27	0.07	1	2.86	0.004	3	23.08	0.15	0	0	0	7.98	4.03	0.12	0.15
Isopoda nd	1	0.63	0.001	1	1.14	0.001	0	0	0	0	0	0	0	0	0	0.44	0.67	<0.001	0.001
Nyctiphanes australis	1	0.63	0.11	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.34	0.03	0.06
Platyscelus ovoides	5	3.11	0.01	4	4.55	0.01	1	2.86	0.01	0	0	0	0	0	0	2.63	3.36	0.01	0.01
Phronima sedentaria	17	10.56	0.28	14	15.91	0.14	3	8.57	0.05	0	0	0	0	0	0	8.76	11.41	0.12	0.19
Phrosina semilunata	12	7.45	0.07	5	5.68	0.020	1	2.86	0.004	0	0	0	0	0	0	4.00	6.04	0.02	0.04
Stomatopoda nd	0	0	0	0	0	0	3	8.57	0.06	0	0	0	0	0	0	2.14	1.01	0.02	0.01
Caridae	0	0	0	0	0	0.00	0	0	0	1	7.69	0.04	0	0	0	1.92	0.34	0.01	0.001
Euphausiidae	1	0.62	<0.001	7	7.955	0.19	0	0	0	0	0	0	0	0	0	2.14	2.68	0.05	0.05

Prey Species	1992 n	1992 %FO	1992 %W	1993 n	1993 %FO	1993 %W	1994 n	1994 %FO	1994 %W	1995 n	1995 %FO	1995 %W	1996 n	1996 %FO	1996 %W	Mean annual (ex 1996) %FO	Overall %FO	Mean annual ex 1996 %W	Overall %W
Remains - Crustacea	1	0.62	0.001	1	1.14	0.001	0	0	0	1	7.692	0.03	0	0	0	2.36	1.01	0.01	0.002
Mollusca																			
Argonauta nodosa	0	0	0	14	15.91	8.45	1	2.86	0.54	0	0	0.00	0	0	0	4.69	5.03	2.25	2.50
Cephalopod beak(s)	17	10.56	0.04	7	7.95	0.03	5	14.29	0.24	3	23.08	0.13	0	0	0	13.97	10.74	0.11	0.07
Lycoteuthis lorigera	0	0	0	1	1.14	0.01	5	14.29	15.11	0	0	0	0	0	0	3.86	2.01	3.78	2.39
Nototodarus gouldi	14	8.67	17.60	8	9.09	3.07	1	2.86	2.10	4	30.77	5.93	0	0	0	12.85	9.06	7.18	10.61
Ocythoe tuberculata	1	0.62	0.08	4	4.55	2.31	0	0	0	0	0	0	0	0	0	1.29	1.68	0.60	0.70
Teuthida nd	35	21.74	6.48	10	11.36	2.58	1	2.86	0.54	2	15.38	0.32	0	0	0	12.84	16.11	2.48	4.22
Todarodes filippovae	0	0	0	0	0	0	1	2.86	1.80	0	0	0	1	100	100	0.71	0.67	0.45	0.44
Octopodidae	0	0	0	1	1.14	0.20	1	2.86	2.16	2	15.38	0.06	0	0	0	4.84	1.34	0.60	0.40
Ommastrephidae	2	1.24	0.36	1	1.14	0.01	2	5.71	5.40	5	38.46	0.44	0	0	0	11.64	3.36	1.55	1.06
Pisces																			
Brama brama	0	0	0	2	2.27	0.24	0	0	0	0	0	0	0	0	0	0.57	0.67	0.06	0.07
Cubiceps caeruleus	0	0	0	2	2.27	4.44	0	0	0	0	0	0	0	0	0	0.57	0.67	1.11	1.27
Emmelichthys nitidus nitidus	**21**	**13.04**	**13.20**	**17**	**19.32**	**19.89**	**9**	**25.71**	**15.09**	**1**	**7.692**	**7.52**	**0**	**0**	**0**	**16.44**	**16.11**	**13.93**	**15.21**
Gasterochisma melampus	0	0	0	0	0	0	1	2.86	1.94	0	0	0	0	0	0	0.71	0.34	0.49	0.31
Hippocampus spp.	0	0	0	1	1.13	0.02	0	0	0	0	0	0	0	0	0	0.28	0.34	0.01	0.01
Lepidoperca pulchella	3	1.86	0.81	1	1.13	0.23	1	2.86	2.00	0	0	0	0	0	0	1.46	1.68	0.76	0.81
Sardinops neopilchardus	**2**	**1.24**	**1.27**	**1**	**1.13**	**0.31**	**0**	**0**	**0**	**3**	**23.08**	**21.06**	**0**	**0**	**0**	**6.36**	**2.01**	**5.66**	**1.42**
Scopelosaurus spp.	1	0.62	0.43	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0.34	0.11	0.23

Prey Species	1992			1993			1994			1995			1996			Mean annual (ex 1996)	Overall	Mean annual ex 1996	Overall
	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	%FO	%FO	%W	%W
Sternoptyx spp.	0	0	0	1	1.13	0.01	0	0	0	0	0	0	0	0	0	0.28	0.34	0.002	0.003
Streetsia challengeri	0	0	0	0	0	0	1	2.86	0.004	0	0	0	0	0	0	0.71	0.34	0.001	0.001
Thyrsites atun	9	5.59	8.95	2	2.27	1.12	1	2.86	0.90	0	0	0	0	0	0	2.68	4.03	2.74	5.15
Trachurus declivis	**66**	**40.99**	**47.81**	**33**	**37.5**	**49.18**	**13**	**37.14**	**44.89**	**5**	**38.46**	**60.68**	**0**	**0**	**0**	**38.52**	**39.26**	**50.64**	**48.07**
Paralepididae	2	1.24	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.31	0.67	0.003	0.01
Pentacerotidae	0	0	0	1	1.14	0.02	0	0	0	0	0	0	0	0	0	0.28	0.34	0.01	0.01
Hemiramphidae	1	0.62	0.25	0	0	0.00	0	0	0	0	0	0	0	0	0	0.16	0.34	0.06	0.13
Myctophidae	2	1.24	0.22	2	2.27	0.21	1	2.86	5.85	0	0	0	0	0	0	1.59	1.68	1.57	1.10
Osteichthyes nd	13	8.07	1.14	29	32.96	5.47	6	17.14	1.12	4	30.77	3.51	0	0	0	22.24	17.45	2.81	2.44
Otolith(s)	0	0	0	3	3.41	0.02	2	5.71	0.02	0	0	0	0	0	0	2.28	1.68	0.01	0.01
Remains - Osteichthyes	21	13.04	0.28	3	3.41	1.47	2	5.71	0.04	1	7.69	0.04	0	0	0	7.46	9.06	0.46	0.57
Other																			
Algae nd	9	5.59	0.12	0	0	0	0	0	0	0	0	0	0	0	0	1.40	3.02	0.03	0.06
Polychaeta nd	2	1.24	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0.31	0.67	<0.001	0.001
Pronoe capito	0	0	0	1	1.14	0.002	0	0	0	0	0	0	0	0	0	0.28	0.34	<0.001	0.001
Salpidae	0	0	0	5	5.69	0.09	1	2.86	0.01	0	0	0	0	0	0	2.13	2.01	0.02	0.03
Pyrosoma spp.	2	1.24	0.04	0	0	0	1	2.86	0.12	0	0	0	0	0	0	1.02	1.01	0.04	0.04
Remains - Unidentified	0	0	0	1	1.14	0.05	0	0	0	0	0	0	0	0	0	0.28	0.34	0.01	0.01
N_{full} / Total prey wt (g)	161		18436	88		10045	35		5558	13		1108	1		55		298		35204

Table A2: Dietary composition by frequency of occurrence (%FO) and proportion by mass (%W) of large (>100cm LCF) SBT caught during CSIRO studies 1992-2005.

	1992			1993			1994			1995			1996			1997			2004			2005			Mean annual	Overall	Mean annual	Overall
Prey	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	%FO	%FO	%W	%W
Crustacea																												
Acanthephyra quadrispinosa	1	0.55	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	<0.001	<0.001
Brachyscelus crusculum	17	9.39	0.04	22	9.65	0.13	6	2.01	0.003	5	2.59	0.003	0	0	0	0	0	0	0	0	0	0	0	0	2.95	5.38	0.02	0.03
Decapod crustacean nd	0	0	0	1	0.44	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	0.001	0.002
Decapod megalopa nd	10	5.52	0.03	38	16.7	0.39	15	5.02	0.09	7	3.63	0.03	0	0	0	0	0	0	0	0	0	0	0	0	3.85	7.53	0.07	0.12
Eupronoe spp.	0	0	0	1	0.44	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	<0.001	<0.001
Funchalia spp.	0	0	0	0	0	0	1	0.33	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	<0.001	<0.001
Gennadas spp.	0	0	0	1	0.44	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	<0.001	0.001
Gnathophausia ingens	0	0	0	1	0.44	0.07	3	1.00	0.10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18	0.43	0.02	0.05
Hyperiidea nd	5	2.76	0.03	3	1.32	0.002	2	0.67	0.001	37	19.2	0.83	0	0	0	2	40	17.8	0	0	0	0	0	0	7.99	5.27	2.34	0.28
Isopoda nd	1	0.55	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	<0.001	<0.001
Parathemisto spp.	0	0	0	0	0	0	1	0.33	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	<0.001	<0.001
Phronima sedentaria	66	36.5	2.68	75	32.9	0.69	90	30.1	0.90	13	6.74	0.05	0	0	0	0	0	0	0	0	0	0	0	0	13.27	26.24	0.54	0.84
Phrosina semilunata	6	3.31	0.03	19	8.33	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.46	2.69	0.01	0.01
Platyscelus ovoides	2	1.1	0.002	17	7.46	0.07	8	2.68	0.01	5	2.59	0.03	0	0	0	0	0	0	0	0	0	0	0	0	1.73	3.44	0.01	0.02
Sergestes arcticus	0	0	0	0	0	0	2	0.67	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.22	<0.001	0.001
Vibilia spp.	0	0	0	0	0	0	0	0	0	1	0.52	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	<0.001	<0.001
Penaeidae	1	0.55	0.002	0	0	0	1	0.33	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0.22	<0.001	0.001
Euphausiidae	1	0.55	0.003	21	9.21	0.04	17	5.69	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.93	4.19	0.02	0.04
Euphausia spinifera	0	0	0	0	0	0	1	0.33	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.003	0.01
Stomatopoda	0	0	0	1	0.44	0.00	7	2.34	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.35	0.86	0.001	0.004

	1992			1993			1994			1995			1996			1997			2004			2005			Mean annual	Overall	Mean annual	Overall
Prey	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**%FO**	**%FO**	**%W**	**%W**
Caridae	0	0	0	3	1.32	0.01	2	0.67	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.54	0.001	0.002
Remains - Crustacea	3	1.66	0.002	4	1.75	0.003	0	0	0	13	6.74	0.01	0	0	0	0	0	0	0	0	0	0	0	0	1.27	2.15	0.002	0.003
Mollusca																												
Argonauta nodosa	15	8.29	1.45	87	38.2	20.43	10	3.34	0.88	5	2.59	0.17	0	0	0	5	100	10.38	0	0	0	0	0	0	19.05	13.12	4.16	4.32
Argonauta spp.	0	0	0	0	0	0	0	0	0	2	1.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.22	0.001	0.002
Brachioteuthis spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7.14	0.48	0.89	0.11	0.06	0.02
Cavolinia spp.	1	0.55	0.001	5	2.19	0.004	1	0.33	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.38	0.75	0.001	0.001
Cavolinia uncinata	0	0	0	0	0	0	2	0.67	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.22	<0.001	<0.001
Cephalopod beak(s)	19	10.5	0.05	13	5.7	0.02	35	11.71	0.03	61	31.6	0.05	0	0	0	3	60	0.05	1	14.3	0.02	1	7.14	0.01	17.62	14.30	0.03	0.03
Diacria trispinosa	0	0	01	2	0.88	0.001	1	0.33	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.15	0.32	<0.001	<0.001
Enoploteuthis spp.	0	0	0	0	0	0	1	0.33	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.003	0.01
Gastropoda nd	0	0	0	1	0.44	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	<0.001	<0.001
Histioteuthis spp.	0	0	0	4	1.75	0.10	24	8.03	0.49	5	2.59	0.01	0	0	0	2	40	14.97	0	0	0	0	0	0	6.55	3.76	1.95	0.26
Lepidoteuthis spp.	0	0	0	3	1.32	0.001	1	0.33	<0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.21	0.43	<0.001	<0.001
Lycoteuthis lorigera	0	0	0	10	4.39	0.29	66	22.07	10.44	5	2.59	0.47	0	0	0	0	0	0	0	0	0	0	0	0	3.63	8.71	1.40	3.92
Lycoteuthis spp.	0	0	0	0	0	0	0	0	0	5	2.59	0.34	0	0	0	0	0	0	0	0	0	0	0	0	0.32	0.54	0.04	0.08
Nototodarus gouldi	11	6.08	8.47	39	17.1	12.66	51	17.06	13.28	43	22.3	7.10	0	0	0	2	40	11.38	0	0	0	0	0	0	12.81	15.70	6.61	10.02
Octopus spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14.3	6.30	0	0	0	1.79	0.11	0.79	0.12
Ocythoe tuberculata	0	0	0	19	8.33	3.20	1	0.33	0.89	2	1.04	0.001	0	0	0	2	40	0.04	0	0	0	0	0	0	6.21	2.58	0.52	0.90
Onychoteuthis spp.	0	0	0	0	0	0	0	0	0	1	0.52	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	<0.001	<0.001
Sepioteuthis australis	1	0.55	1.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	0.19	0.22

	1992			1993			1994			1995			1996			1997			2004			2005			Mean annual	Overall	Mean annual	Overall
Prey	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**n**	**%FO**	**%W**	**%FO**	**%FO**	**%W**	**%W**
Teuthida nd	46	25.4	12.1	20	8.77	3.20	36	12.0	3.91	29	15	0.55	0	0	0	0	0	0	1	14.3	0.88	0	0	0	9.44	14.2	2.58	3.84
Teuthowenia pellucida	0	0	0	1	0.44	0.03	0	0	0	1	0.52	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.22	0.01	0.01
Todarodes filippovae	0	0	0	13	5.7	5.36	9	3.01	1.62	4	2.07	0.96	1	0.33	36.49	0	0	0	0	0	0	0	0	0	1.39	2.90	5.55	2.33
Octopodidae	11	6.08	0.83	11	4.82	0.46	2	0.67	0.05	27	14	0.03	0	0	0	0	0	0	0	0	0	0	0	0	3.20	5.48	0.17	0.22
Omma-strephidae	11	6.08	3.05	9	3.95	1.34	18	6.02	5.98	30	15.5	0.03	0	0	0	1	20	0.01	0	0	0	1	7.14	2.57	7.34	7.53	1.62	2.93
Remains - Teuthida	0	0	0	0	0	0	0	0	0	5	2.59	0.12	0	0	0	0	0	0	1	14.3	1.03	1	7.14	5.02	3.00	0.75	0.77	0.25
Pisces																												
Alepisaurus brevirostris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7.14	6.38	0.89	0.11	0.80	0.25
Brama brama	7	3.87	22.97	9	3.95	10.55	1	0.33	1.43	12	6.22	45.44	0	0	0	0	0	0	0	0	0	1	7.14	24.72	2.69	3.23	13.14	17.57
Cubiceps baxteri	2	1.1	2.03	2	0.88	0.71	3	1.00	0.28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.37	0.75	0.38	0.52
Cubiceps caeruleus	3	1.66	2.03	5	2.19	1.89	1	0.33	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.52	0.97	0.50	0.66
Cubiceps pauciradiatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	21.4	15.01	2.68	0.32	1.88	0.59
Emmelichthys nitidus nitidus	**8**	**4.42**	**5.53**	**4**	**1.75**	**1.00**	**47**	**15.72**	**16.12**	**7**	**3.63**	**2.57**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3.19**	**7.10**	**3.15**	**7.37**
Engraulis australis	0	0	0	0	0	0	8	2.68	0.52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.33	0.86	0.06	0.19
Gasterochisma melampus	0	0	0	0	0	0	1	0.33	0.31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.04	0.11
Gonorhynchus gonorynchus	0	0	0	1	0.44	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	0.01	0.02
Gonostoma elongatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	28.6	80.78	0	0	0	3.57	0.22	10.10	1.55
Hippocampus spp.	3	1.66	0.04	7	3.07	0.04	1	0.33	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.63	1.18	0.01	0.01
Hyporhamphus melanochir	0	0	0	0	0	0	6	2.01	0.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.65	0.05	0.14
Lactoria diaphana	1	0.55	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	0.01	0.01
Lagocephalus spp.	0	0	0	0	0	0	2	0.67	0.19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.22	0.02	0.07

Prey	1992			1993			1994			1995			1996			1997			2004			2005			Mean annual	Overall	Mean annual	Overall
	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	%FO	%FO	%W	%W
Lampanyctus spp.	1	0.55	0.02	1	0.44	0.004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.12	0.22	0.003	0.004
Lepidoperca pulchella	2	1.1	0.41	1	0.44	0.16	2	0.67	0.27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.28	0.54	0.11	0.19
Macroramphosus scolopax	1	0.55	0.08	1	0.44	0.03	0	0	0	2	1.04	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.43	0.03	0.04
Oreosoma atlanticum	0	0	0	0	0	0	1	0.33	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.001	0.004
Phosichthys argenteus	0	0	0	1	0.44	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	0.01	0.01
Plagiogeneion rubiginosum	1	0.55	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	0.03	0.03
Pseudopentaceros richardsoni	0	0	0	0	0	0	1	0.33	1.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.13	0.39
Sardinops neopilchardus*	**2**	**1.1**	**1.01**	**5**	**2.19**	**1.81**	**2**	**0.67**	**0.29**	**5**	**2.59**	**1.19**	**0**	**0**	**0**	**2**	**40**	**14.88**	**0**	**0**	**0**	**0**	**0**	**0**	**5.82**	**1.72**	**2.40**	**0.92**
Sardinops sagax	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1.04**	**0.19**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.13**	**0.22**	**0.02**	**0.05**
Scomberesox saurus scomberoides	0	0	0	0	0	0	3	1.00	0.05	0	0	0	0	0	0	0	0	0	1	14.3	2.13	4	28.6	45.13	5.48	0.86	5.91	1.83
Scopelosaurus spp.	2	1.1	0.39	1	0.44	0.48	1	0.33	0.13	6	3.11	1.96	0	0	0	0	0	0	0	0	0	0	0	0	0.62	1.08	0.37	0.66
Psenes pellucidus	0	0	0	0	0	0	0	0	0	1	0.52	0.42	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	0.05	0.10
Pteraclis velifera	1	0.55	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	0.03	0.03
Pterycombus petersii	0	0	0	0	0	0	0	0	0	1	0.52	0.63	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	0.08	0.15
Sternoptyx spp.	0	0	0	0	0	0	1	0.33	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.001	0.003
Sudis atrox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	14.3	3.68	0	0	0	1.79	0.11	0.46	0.07
Symbolophorus barnardi	1	0.55	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0.11	0.001	0.001
Tetragonurus cuvieri	0	0	0	0	0	0	1	0.33	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.04	0.12
Tetragonurus spp.	0	0	0	0	0	0	0	0	0	2	1.04	0.84	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.22	0.10	0.20
Thyrsites atun	9	4.97	4.14	9	3.95	1.76	9	3.01	1.15	2	1.04	0.09	0	0	0	0	0	0	0	0	0	0	0	0	1.62	3.12	0.89	1.34
Trachurus	**46**	**25.4**	**27.58**	**54**	**23.7**	**26.35**	**86**	**28.76**	**36.09**	**52**	**26.9**	**27.21**	**1**	**0.33**	**29.44**	**2**	**40**	**21.45**	**0**	**0**	**0**	**0**	**0**	**0**	**18.14**	**25.91**	**21.02**	**28.71**

Prey	1992			1993			1994			1995			1996			1997			2004			2005			Mean annual	Overall	Mean annual	Overall
	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	n	%FO	%W	%FO	%FO	%W	%W
declivis																												
***Trachurus* spp.**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**2.59**	**2.82**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.32**	**0.54**	**0.35**	**0.68**
Gempylidae	0	0	0	0	0	0	0	0	0	2	1.04	0.57	1	0.33	30.37	0	0	0	0	0	0	0	0	0	0.17	0.32	3.87	0.59
Paralepididae	0	0	0	0	0	0	2	0.67	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.22	<0.001	0.001
Tetraodontidae	1	0.55	0.21	2	0.88	0.64	1	0.33	0.08	1	0.52	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0.29	0.54	0.12	0.18
Monacanthidae	0	0	0	1	0.44	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	0.01	0.01
Pentacerotidae	0	0	0	1	0.44	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.05	0.11	0.004	0.01
Carangidae	0	0	0	0	0	0	0	0	0	2	1.04	0.32	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.22	0.04	0.08
Triglidae & Peristediidae	0	0	0	0	0	0	0	0	0	1	0.52	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	<0.001	<0.001
Hemiramphidae	1	0.55	0.004	1	0.44	0.003	0	0	0	2	1.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.43	0.002	0.004
Myctophidae	1	0.55	1.45	0	0	0	0	0	0	2	1.04	0.003	0	0	0	0	0	0	0	0	0	0	0	0	0.20	0.32	0.18	0.21
Osteichthyes nd	17	9.39	0.83	50	21.9	3.65	69	23.08	1.04	61	31.6	3.69	1	0.33	3.70	0	0	0	1	14.3	2.46	0	0	0	12.58	21.40	1.92	2.14
Serranidae	0	0	0	0	0	0	1	0.33	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.04	0.11	0.01	0.03
Remains - Osteichthyes	14	7.73	0.27	7	3.07	0.14	10	3.34	0.02	8	4.15	0.30	0	0	0	0	0	0	3	42.9	2.72	2	14.3	0.60	9.43	4.73	0.51	0.22
Otolith(s)	0	0	0	5	2.19	0.01	6	2.01	0.001	18	9.33	0.03	0	0	0	0	0	0	0	0	0	0	0	0	1.69	3.12	0.005	0.01
Other																												
Algae nd	11	6.08	0.11	4	1.75	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.98	1.61	0.02	0.02
Refuse	0	0	0	0	0	0	0	0	0	1	0.52	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0.06	0.11	0.002	0.004
Pyrosoma spp.	0	0	0	9	3.95	1.52	14	4.68	1.18	47	24.4	0.71	0	0	0	2	40	2.55	0	0	0	0	0	0	9.12	7.74	0.74	0.88
Salpidae	2	1.1	0.04	33	14.5	0.43	5	1.67	0.02	17	8.81	0.08	0	0	0	1	20	0.40	0	0	0	0	0	0	5.76	6.24	0.12	0.11
Scyphozoa nd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	20	6.06	0	0	0	0	0	0	2.50	0.11	0.76	0.02
Unidentified Remains	1	0.55	0.02	0	0	0	1	0.33	0.02	2	1.04	<0.001	0	0	0	0	0	0	0	0	0	1	7.14	0.07	1.13	0.54	0.01	0.01
n_{full}/ total prey wt (g)	**181**		**24134**	**228**		**31203**	**299**		**61569**	**193**		**41247**	**3**		**2545**	**5**		**690**	**7**		**3288**	**14**		**6736**		**930**		**171412**

* *Sardinops neopilchardus* synonymous with valid species *S. sagax*

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