

Do Large Whales Have an Impact on Commercial Fishing in the South Pacific Ocean?

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Abstract

Although there is evidence that some populations of large whales in the Southern Hemisphere have increased in recent years, differences in feeding behaviour and migration patterns largely precludes direct competition between these and coastal and pelagic fisheries in the South Pacific Ocean. In particular, many of the whales that spend at least part of their year in the South Pacific make feeding migrations in summer to Antarctic waters where some estimates put their food intake at 90% of annual consumption. Others, such as female sperm whales (*Physeter macrocephalus*), which do not migrate from tropical/subtropical South Pacific waters, feed at depths greater than that usually occupied by species that are the targets of commercial fisheries, such as the tunas (*Thunnus* spp.). Thus, even though consumption by whales is high, dietary overlap with commercially fished species is relatively low as much of their feeding is in waters that are not exploited by fisheries. However, there are a number of anecdotal reports that some smaller cetacean species, in particular killer and pilot whales, take fish from longlines set in the region, although more are lost to sharks. However, it should be noted that any assessment of interactions between whales and fisheries is limited by a lack of qualitative and quantitative data. Abundance estimates, particularly for some of the smaller species in the South Pacific region, are only order of magnitude estimates. Furthermore, knowledge of food chains (and their interactions) for many cetaceans in the South Pacific is sketchy making assessment of their impact on local fisheries difficult.

Keywords

Large whales, trophic interactions, consumption, impacts

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1. Introduction

How much cetaceans compete with commercial fisheries is a relatively recent debate, one with advocates on both sides. One view is that because of their large body size and abundance marine mammals in general, and cetaceans in particular, have a major influence on the structure and function of marine communities.² The alternate view is that oceans and their constituent fauna exist in some kind of fluctuating, but largely steady, state in which biomass across size groupings (on a log scale) remains roughly constant.³ According to this view, marine mammals do not have a measurable impact on lower trophic levels. This debate is of more than academic interest when marine mammal populations occupy the same areas as commercial fisheries. Up until recently, the debate has concentrated largely on seal populations.⁴ More recently, the debate has shifted to whales, particularly the large baleen whales, which are now largely protected from commercial hunting. Some contend that whales are being protected at the cost of other predators that are the focus of commercial fisheries. Declining fish catches worldwide in recent times has fuelled this debate.

The massive depletion by commercial hunting of most of the large whales — over two million whales were taken in this century alone⁵ — pushed some species close to extinction and others to population levels that could threaten their recovery. The International Whaling Commission (IWC) was established in 1946 to manage the exploitation of whale stocks. One by one, the large whale species were protected.

² Bowen, W. D. (1997) Role of marine mammals in aquatic ecosystems. *Mar. Ecol. Prog. Ser.* 158, 267-274.

³ Sheldon, R. W., Prakash, A., Sutcliffe, W. H. (1972) *Limnol. Oceanogr.* 17, 327 – 340.

⁴ Beverton, R. J. H. (1985) Analysis of marine mammal-fisheries interaction. In: Beddington, J. R., Beverton, R. J. H. and Lavigne, D. M. *Marine mammals and fisheries*. Allen & Unwin, London.

⁵ Clapham, P. J., Young, S. B., Brownell, R. L. (1999) Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Rev.* 29, 35 - 60

Southern right whales were protected prior to the establishment of the IWC, in 1935.⁶ Blue whales were protected in 1965, fin whales in 1976 and sei whales in 1978.⁷ Faced with declining catches and with increasing opposition to whaling of the larger species, commercial whaling interests turned in the 1970s to smaller species, such as the minke whale. In 1986, a general moratorium on commercial whaling was declared. Most of the countries that are signatories to the International Convention for the Regulation of Whaling (ICRW)⁸ have adhered to the moratorium although 1,000 minke whales are still caught annually under different exceptions, including the “scientific research” exception under Article VIII of the ICRW.⁹ There is also recent data showing that other species, in particular southern right, humpback, pygmy blue and sperm whales, were caught after whaling of these species had been prohibited, indicating some level of non-compliance.^{10,11} Now however, increases in some whale populations¹² coincident with the ever-increasing demand for shrinking stocks of fresh fish worldwide, have raised new questions. One hypothesis, the possibility that whales are competing for commercial fish resources, has revived the debate over whether whaling operations should be resumed.¹³

⁶ Tormosov, D. D., Mikhailiev, Y. A., Best, P. B., Zemsky, V. A., Sekiguchi, K., Brownell, R. L. (1998) Soviet catches of southern right whales *Eubalena australis*, 1951 – 1971. Biological data and conservation implications. *Biological Conservation* 86, 185 – 197.

⁷ Cooke, J. G. (1995) The international Whaling Commission’s revised management procedure as an example of a new approach to fishery management. In *Whales, seals, fish and man* (Eds. A. S. Blix, L. Walloe and O. Ulltang).

⁸ International Convention for the Regulation of Whaling with Schedule of Whaling Regulations, Dec. 2, 1946, 62 Stat. 1716, T.I.A.S No. 19849, 161 U.N.T.S. 361. Article VIII of the ICRW provides that “any Contracting government may grant to any of its nationals a special permit authorizing that national to kill, take, and treat whales for purposes of scientific research subject to such restrictions as to number and subject to such other conditions as the Contracting Government thinks fit.”

⁹ Simmonds, M and Stroud, C. (1998) Whither whaling? *Nature*, 392, 541.

¹⁰ Yablokov, A. V. (1994) Validity of whaling data. *Nature*, Lond. 367 (6459), 108.

¹¹ Tormosov, D. D., Mikhailiev, Y. A., Best, P. B., Zemsky, V. A., Sekiguchi, K., Brownell, R. L. (1998) Soviet catches of southern right whales *Eubalena australis*, 1951 – 1971. Biological data and conservation implications. *Biological Conservation* 86, 185 – 197.

¹² Gulland, J. A. (1987) Seals and fisheries: a case for predator control. *Trends Ecol. Evol.*, 2, 102-103.

¹³ *ibid.*

The ecological role of cetaceans is poorly understood, largely because we "are faced with the intersection of three inexact disciplines: marine ecology, marine mammal population biology, and fisheries science."¹⁴ There is, however, a growing body of literature that, at the very least, is beginning to assess their importance.

Much of the revenue derived from the South Pacific Ocean, a breeding ground for many of the large whales, is from fishing, particularly for the various species of tuna. With large whales protected throughout the Pacific Ocean, concerns are being raised that if whales recover to pre-harvest levels they will directly or indirectly compete with these fisheries, directly, by feeding on sardine-like fishes that are fished commercially, or indirectly by competing for prey resources that are consumed by commercial fishes such as tunas. This review, therefore, examines the literature on the ecological position of whales in marine food webs and their interactions with other species to assess whether they may have an adverse impact on the South Pacific marine ecosystem. Three statements are addressed:

*Statement 1. Granting excessive protection to a particular element of the marine ecosystem will lead to disruption of the biological balance in the same manner as excessive harvesting.*¹⁵

*Statement 2. Cetaceans consume 500 million tons of marine living resources worldwide. Do they have an effect on fish or are they in competition with humans?*¹⁶

Statement 3. An increase in the number of whales in the Pacific will lead to a reduction in the number of fish (i.e. tuna).

¹⁴ Katona, S. and Whitehead, H. (1988) Are Cetacea ecologically important? *Oceanogr. Mar. Biol. Annu. Rev.* 26, 553 – 568.

¹⁵ Hiromichi Kaneko, *Are Whales and Humans headed for collision? - Some see competition over fish supplies a growing possibility*, THE NIKKEI WKLY., Dec. 14, 1998.

¹⁶ Tsutomu Tamur & Seiji Ohsumi (1999) Estimation of total consumption by cetaceans in the world's oceans' The Institute of Cetacean Research March 1999, tabled at IWC 51

This review, therefore, examines the above statements in light of the literature on the ecological position of whales in marine food webs.

There are four classes of marine mammals. These are the Cetacea, which includes the small and large whales and the dolphins; the Pinnipedia, which includes seals and sea lions, the Sirenia, which includes the dugongs, and the Carnivora (sea otters). Although this review is directed at the large whales, I will refer frequently to research on the pinnipeds (seals). Extrapolating from seals to cetaceans may not always be appropriate. However, as much of the work on marine mammal interactions has been carried out on the former, reference to them is made when data on cetaceans are lacking.

There are further gaps in the available information. For example, the main commercial fisheries operating in the South Pacific Ocean target tuna species. To examine the extent of interactions between whales and tuna several data sets are needed, including:

- distribution of whale and tuna populations;
- size of whale and tuna populations;
- composition of the diets of whales and tunas;
- annual energy budget of whales and tunas;
- data on whether food resources are a limiting factor

Even if all these data were available, (and they are not) there are other issues that need to be evaluated. Perhaps the most pressing of these is an understanding of the complexities of marine ecosystems. This review, then, will attempt to summarise some of these broader issues.

2. The study area

The Food and Agriculture Organisation (FAO) has divided the major fishing areas of the world's oceans into a number of 'statistical' areas for which data, including those on marine mammals, are available.¹⁷ The South Pacific Ocean is found within FAO areas 71 (western central Pacific) and 81 (south western Pacific)(Fig. 1). Useful data pertaining to this review have been tabulated in relation to these areas.¹⁸ The data on cetaceans presented here will refer to these areas except where otherwise stated. Data on tunas, however, are based on the western Pacific Yellowfin research area, which is bounded by latitudes 40° North and South, and Longitudes 120° East to 150° West.¹⁹ The information for the Southern Ocean is derived from south of latitude 60° S.

¹⁷ Northridge, S. P. (1984) World review of interactions between marine mammals and fisheries. FAO Fish Tech Pap. 251: 190 pp.

¹⁸ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J. Northw. Atl. Fish. Sci. 22, 173-187.

¹⁹ Anonymous (1998) Report of the eleventh meeting of the standing committee on tuna and billfish. Hawaii, U.S.A.

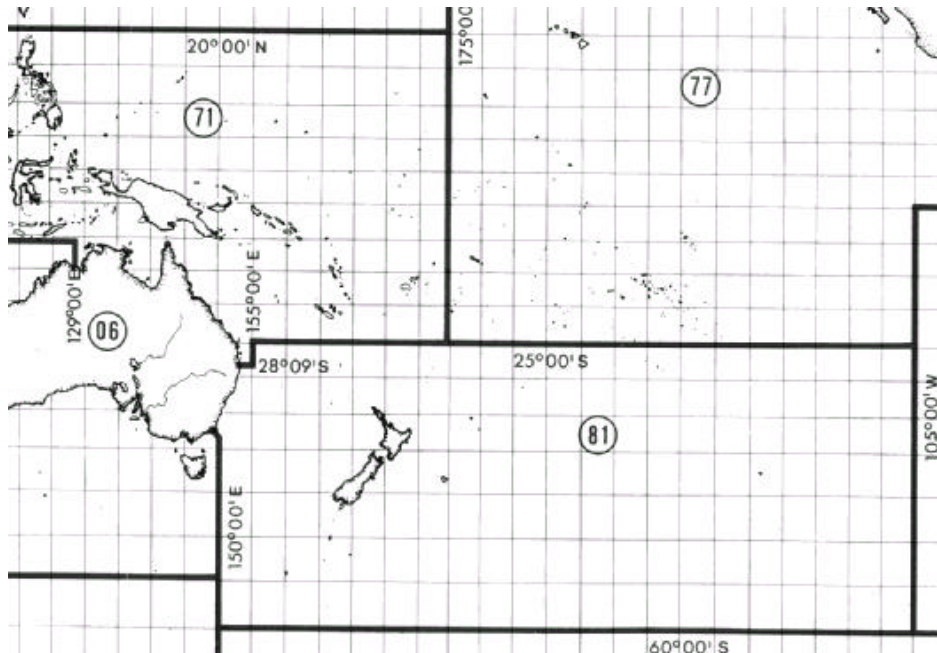


Figure 1: Map of South Pacific showing designated FAO areas 71 and 81. Data from Area 77 are not included as this area extends well into the North Pacific (taken from Northridge 1984)

3. Cetaceans in the South Pacific Ocean

Thirty one species of cetaceans have been recorded in the western Central Pacific (Area 71) and the South western Pacific (Area 81)²⁰ including seven large whale species that have been hunted commercially — the fin, blue, minke, sei, Bryde's, humpback and sperm whales. Twelve cetacean species are common in both these areas (Table 1). Estimates of their abundance in these areas are given only as orders of magnitude because of the imprecision of the data. Nevertheless, two species of larger whales — sperm and minke whales — stand out. According to one estimate, sperm whales may account for more than half the entire marine mammal biomass in the Pacific Ocean, and may number in the hundreds of thousands in the South Pacific

²⁰ Northridge, S. P. (1984) World review of interactions between marine mammals and fisheries. FAO Fish Tech Pap. 251: 190 pp.

Ocean.²¹ Minke whales, particularly in the southwest Pacific Ocean, also number in the hundreds of thousands, although they, like the larger baleen whales are presumed to migrate south to colder waters in summer to feed. The estimated number of killer whales and pilot whales in the same area is in the tens of thousands.²² However, here is no information to indicate whether the numbers for these species are increasing.

3.1 Are whale numbers increasing?

Since the moratorium on commercial whaling was imposed in 1986, there have been a number of studies to determine whether whale numbers are increasing. This has not been a simple task because of the wide ranges of the various species and their migratory behaviour, particularly in the case of larger whales. Also, since the effective end of commercial whaling there are no catch data from which population trends can be deduced and relatively few scientific surveys have been conducted. Consequently, estimating the abundance of the different whale species is very difficult – reliable estimates can only be made for those species, such as humpbacks and southern right whales, that breed close to shore and have distinctive features that allow for individual identification. Nevertheless, there is consensus that the numbers of some whale species are increasing.^{23 24 25}

With the possible exception of the minke whales, baleen whales worldwide were severely depleted by whaling. However, by 1993 the available evidence indicated that at least 77% of “monitorable stocks” were increasing.²⁶ More recent

²¹ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw. Atl. Fish. Sci.* 22, 173-187.

²² *ibid.*

²³ Gulland, J. A. (1988) The end of whaling? *New Scientist*. 29–October, 42 – 47.

²⁴ Best, P. B. (1993) Increase rates in severely depleted stocks of baleen whales. *ICES J. mar. sci.* 50, 169 – 186.

²⁵ Clapham, P. J., Young, S. B., Brownell, R. L. (1999) Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Rev.* 29, 35 - 60

²⁶ Best, P. B. (1993) Increase rates in severely depleted stocks of baleen whales. *ICES J. mar. sci.* 50, 169 – 186.

data indicates that this trend is continuing, with many whale populations in the Northern Hemisphere increasing. One report indicated that since 1979, whale populations off the east coast of America (Atlantic Ocean) may have doubled,²⁷ but added that there was so little data on limiting factors that this figure was only speculative. The status of baleen whales from the northern Pacific Ocean is unclear. Of the 10 stocks of blue whales, only the northeast Pacific Ocean stock has been monitored, and it appears to be increasing.²⁸

In the Southern Hemisphere, there is evidence for increases in a number of the large whales. Of the four stocks of southern right whales being monitored (there are 13 separate stocks) all have significantly increased.²⁹ All monitored stocks of Southern Hemisphere humpback whales are showing an annual rate of increase of around 10-12%.³⁰ The east Australian population, probably reduced to the low hundreds after whaling, was estimated at 3,200 in 1996.³¹ Monitoring of the populations of breeding humpback whales in the Southwest Pacific (Tonga, New Caledonia and French Polynesia), however, has not demonstrated any significant population increases in recent years, possibly due to recent revelations of illegal whaling in Antarctic waters south of this region.³² In 1988, the population of minke whales in the Southern Hemisphere was reported at approximately half a million.³³ A

²⁷ Kenney, R. D., Scott, G. P., Thompson, T. J. and Winn, H. E. (1997) Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. *J. Northw. Atl. Fish. Sci.* 22, 155- 171.

²⁸ Clapham, P. J., Young, S. B., Brownell, R. L. (1999) Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Rev.* 29, 35 - 60

²⁹ Best, P. B. (1993) Increase rates in severely depleted stocks of baleen whales. *ICES J. mar. sci.* 50, 169 – 186.

³⁰ Findlay, K. (2000) A first step towards a preliminary assessment of Southern Hemisphere humpback whales. Paper SC/52/IA5 (unpublished)

³¹ Brown, M. R., Field, M. S., Clarke, E. D., Butterworth, D. S. and Bryden, M. M. (1996) Estimate of abundance for east Australian humpback whales *M. novaeangliae* from the 1996 survey at Point Lookout, North Stradbroke Island. Paper SC/49/SH35 (unpublished)

³² Mikhalev, Y. (2000) Biological characteristics of humpbacks taken in Antarctic Area V by the whaling fleets *Slava* and *Sovietskaya Ukraina*. IWC Scientific Committee Paper SC/52/IA12

³³ Gulland, J. A. (1988) The end of whaling? *New Scientist.* 29–October, 42 – 47.

1992 estimate put the number at 760,000 individuals (\pm 250,000).³⁴ However, the IWC Scientific Committee agreed last year that new data indicated the minke population was significantly lower than this figure, and that until further analysis, there was no valid population estimate.

The evidence for other large whale species is less clear. Comparative estimates of abundance for some large whales in the Southern Hemisphere from sighting surveys between 1965/1978 and 1978/1988 showed that, although the numbers of humpback whales had increased, the numbers of blue, fin, sei and sperm whales had either decreased or stayed the same.³⁵ An earlier estimate indicated that sperm whales had increased in numbers but that killer and pilot whales had decreased.³⁶ There is no evidence to suggest that blue whale numbers are increasing. There are also little data on the abundance of Bryde's whale, the only non-migratory large whales in the South Pacific. One recent study reported an earlier (1980) estimate of 1,800 individuals in the Solomon Islands area, but could not determine from a more recent survey whether numbers of this species had changed.³⁷

Gulland's³⁸ conclusion that, overall, whale biomass is increasing is supported by more recent studies although this is not true in terms of all species.³⁹ Moreover, the

³⁴ Nishiwaki, S., Matsuoka, K. and Kawasaki, M. (1995) Abundance estimates of Southern Hemisphere minke whales in 1991/92 and 1992/93 seasons using data from Japanese whale research programme under special permit in Antarctic. Rep. Int. Whal. Commn 45, p. 441.

³⁵ Butterworth, D. S. and Geromont, H. F. (1996) On the consequences of longitudinal disaggregation of the Japanese scouting vessel data in the northward extrapolation of IWC/IDCR cruise estimates of abundance of some large whale species in the Southern Hemisphere. Rep. Int. Whal. Commn 46, p.664.

³⁶ Butterworth, D. S., Borchers, D. L., Chalis, S., De Decker, J. B. (1995) Estimates of abundance for Southern Hemisphere blue, fin, sei, humpback, sperm, killer and pilot whales from the 1978/79 to 1990/1991 IWC/IDCR sighting survey cruises, with extrapolations to the area south of 30 deg for the first five species based on Japanese scouting vessel data. Rep. Int. Whal. Commn. 45, p. 444.

³⁷ Shimada, H. and Pastene, L. A. (1995) Report of a sighting survey off the Solomon Islands with comments on Bryde's whale distribution. Rep. Int. Whal. Commn 45, 413 – 418.

³⁸ Gulland, J. A. (1988) The end of whaling? New Scientist. 29–October, 42 – 47.

³⁹ Best, P. B. (1993) Increase rates in severely depleted stocks of baleen whales. ICES J. mar. sci. 50, 169 – 186.

reported increases, however, have not brought numbers of most of the large whales to more than a small fraction of their pre-exploitation levels.

Table 1: Estimates of population size of 15 common cetaceans in the South Pacific Ocean (WP, world population; POP, Pacific Ocean population; WCP, western central Pacific Ocean population; SWP, southwest Pacific Ocean population; +, present but no estimate of abundance; -, absent; '00, hundreds; '000, thousands; '0 000, tens of thousands; '00 000, hundreds of thousands; '000 000, millions).

[Data sources: Northridge, S. P. (1984) World review of interactions between marine mammals and fisheries. FAO Fish Tech Pap. 251: 190 pp.

Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J. Northw. Atl. Fish. Sci. 22, 173-187.

IWC Special Meeting on worldwide status of right whales, Capetown, 1998.]

Family	Species	WP	POP	WCP	SWP
Balaenidae	Southern right whale	7,000	'00	+	+
Eschrichtidae	Gray whale	21,113	21,113	0	-
Balaenopteridae	Fin whale	115,500	45,045	+	22,000
	Blue whale	14,000	4,760	'00	'00
	Minke whale	860,000	120,400	'0 000	'0 000
	Sei whale	39,000	17,550	'000	'000
	Bryde's whale	112,000	96,320	+	'0 000
	Humpback whale	22,000	5,500	'00	'000
Ziphiidae	Tasman beaked whale	'000	2,700	'00	'00
Physeteridae	Sperm whale	1,900,000	1,178,000	'00 000	360,000
Delphinidae	Killer whale	80,000	25,600	+	'0 000
	Short-finned pilot whale	'00 000	180,000	'0 000	'0 000
	Common dolphin	'000 000	1,650,000	'00 000	'00 000

4. Impact of Whales on Fisheries

4.1 What do the large whales eat?

The feeding preferences of Cetacean species range from benthic feeders on invertebrates (gray whales), through large zooplankton feeders (e.g. blue, fin, minke, sei and humpback whales) to killer whales that feed on higher vertebrates and fish. Within baleen whale species, three feeding types are recognised: grazers, feeding usually on copepods (includes right whales); engulfers of krill and fish (finner whales); and foragers of the sea bottom (gray whales).⁴⁰ Pauly et al. summarised the

⁴⁰ Pivorunas, A. (1979) The feeding mechanisms of baleen whales. American Scientist, 67, 432 – 440.

trophic positions of 97 species of marine mammals.⁴¹ They divided the types of prey eaten into eight categories. Table 2 summarises the diets of common cetaceans in the South Pacific. Note that the large whales are predominantly planktonic feeders.

Beaks from 14 families of cephalopods were identified in sperm whale stomachs, underlining their importance as prey for this species.⁴² Histioteuthid and Octopoteuthid cephalopods were the main families identified. The size of cephalopod eaten increased with whale size, which indicates that larger whales foraged at greater depths, because cephalopod size usually increases with depth. This conclusion is supported by the occasional presence in large sperm whales of the giant squid *Architeuthis*, which inhabits great depths. The dependence of sperm whales on cephalopods is suggested by the fact that their distribution is matched to the distribution of their main prey – cephalopods, mainly species of Histioteuthidae and Ommastrephidae.⁴³ A major review of baleen whale food found that Bryde's whales -- the only true resident of the South Pacific and Coral Sea -- unexpectedly consumed euphausiids (mainly species of *Euphausia* and *Thyssanoessa gregaria*) rather than small fish.⁴⁴ Minke whales in the Northern Hemisphere mainly eat fish. In the northeast Atlantic Ocean, they eat mainly cod (*Gadus morhua*), herring (*Clupea harengus*) and capelin (*Mallotus villosus*) and euphausiids (*Meganyctiphanes* spp.).⁴⁵ In the northern Pacific Ocean, they feed mainly on pacific saury (*Cololabis saira*) and Japanese saury (*Engraulis japonicus*), but also some euphausiids (*Euphausia*

⁴¹ Pauly, D., Trites, A. W., Capuli, E. and Christensen, V. (1998) Diet composition and trophic levels of marine mammals. ICES Journal of Marine Science 55, 467 – 481.

⁴² Best, P. B., Canham, P. A. S. and Macleod, N. (1984) Patterns of reproduction in sperm whales, *Physeter macrocephalus* Rep. Int. Whal. Commn (Special Issue 6) 51 – 79.

⁴³ Northbridge, S. P. (1984) World review of interactions between marine mammals and fisheries. FAO Fish Tech Pap. 251: 190 pp.

⁴⁴ Kawamura, A. (1980) Review of food of baleen whales. Scientific Reports of the Whales Research Institute 32: 155-197.

⁴⁵ Nordoy, E. S. and Blix, A. S. (1992) Diet of Minke whales in the Northeastern Atlantic. Rep. Int. Whal. Commn. 42, 393- 398.

pacifica).⁴⁶ In contrast, minke whales in the Southern Hemisphere feed predominantly on krill (*Euphausia superba*), and secondly on lanternfish (family Myctophidae).⁴⁷

Table 2: Relative proportions of eight prey categories in the diets of 13 common cetaceans in the South Pacific Ocean (BI, benthic invertebrates; LZ, large zooplankton; SS, small squid; LS, large squid; SP, small pelagic fishes; MP, midwater fishes; MF, miscellaneous fishes; HV, higher vertebrates). The trophic level value refers to the level of the food chain at which the animal feeds (e.g. a low trophic level refers to a plankton feeder)
[Table adapted from Pauly et al. 1998]

Family	Species	Diet composition								Trophic level
		BI	LZ	SS	LS	SP	MP	MF	HV	
Balaenidae	Southern right whale		1							3.2
Eschrichtidae	Gray whale	0.9	0.1				0.05			3.3
Balaenopteridae	Fin whale		0.8	0.1		0.1	0.05	0.1		3.4
	Blue whale		1							3.2
	Minke whale		0.7			0.3		0.1		3.4
	Sei whale		0.8	0.1		0.1	0.05	0.1		3.4
	Bryde's whale		0.4			0.2	0.2	0.2		3.7
	Humpback whale		0.6			0.2		0.3		3.6
Ziphiidae	Tasman beaked whale									
Physeteridae	Sperm whale	0.05		0.1	0.6	0.1	0.05	0.2		4.4
Delphinidae	Killer whale			0.1	0.1	0.1		0.4	0.4	4.5
	Short-finned pilot whale			0.3	0.3	0.1	0.1	0.2		4.3
	Common dolphin			0.2	0.2	0.1	0.4	0.2		4.2

4.2 Seasonal differences and energetics

Most of the large whales found in the South Pacific during winter make long migrations to the Southern Ocean in the Austral summer to feed on krill and other species of zooplankton. The main feeding period in the Southern Ocean lasts between four to six months, although pregnant females may spend even longer feeding in the region. During that time, the daily intake of blue and fin whales is ~ 4% of body weight per day. However, for the remainder of the year these species consume only

⁴⁶ Tamura, T., Fujise, Y and Shimazaki, K. (1998) Diet of minke whales *Balaenoptera acutorostrata* in the north-western part of the North Pacific in summer, 1994 and 1995. Fisheries Science, 64, 71 – 76.

one tenth of their summer intake. With the marked seasonality in food supply, daily intake averaged over the year amounts to 1.2 – 1.6% of body weight per day.⁴⁸ This pattern appears to be true also for sei and humpback whales.⁴⁹ Southern right whales also journey south of 60°S in summer to feed mainly on krill (*Euphausia superba*), while copepods (*Calanus* spp.) are the dominant prey north of this latitude.⁵⁰ Stomach fullness levels are greater than 60% over summer (January to March) with stomach fullness falling below 20% in December and April, supporting earlier accounts that right whales fast when not in the feeding grounds.

Generalisations about the energetics of sperm whales are more difficult, as only the large males travel to Antarctic waters to feed in summer; females and young do not travel past 45° S. Nevertheless, the available data indicates that sperm whales consume ~ 3% of their body weight per day.⁵¹

4.3 How much do they eat?

Many estimates of food consumption by whales are extrapolated from that of other marine mammals. For example, Bax⁵² estimated that whales and seals are major predators of ground and midwater fishes in the Bering Sea. He reported that they consume an estimated 10% of the commercial fish stocks annually, compared with 5% by humans. Bax's study estimated that the amount of commercially important fish consumed by marine mammals was similar to or exceeded that taken by the

⁴⁷ Kawamura, A. (1994) A review of baleen whale feeding in the Southern Ocean. Rep. Int. Whal. Commn. 44, 261 – 271.

⁴⁸ Lockyer, C. (1984) Review of baleen whale (Mysticeti) reproduction and implications for management. Rep. Int. Whal. Commn (Special Issue 6) 27 – 50.

⁴⁹ Lockyer, C. (1981) Estimates of growth and energy budget for the sperm whale, *Physeter catodon*. In: Mammals in the Sea, 3, 489-504. FAO Fisheries Series (5) Rome, FAO.

⁵⁰ Tormosov, D. D., Mikhailiev, Y. A., Best, P. B., Zemsky, V. A., Sekiguchi, K., Brownell, R. L. (1998) Soviet catches of southern right whales *Eubalena australis*, 1951 – 1971. Biological data and conservation implications. Biological Conservation 86, 185 – 197.

⁵¹ *ibid.*

⁵² Bax, N. J. (1998) The significance and prediction of predation in marine fishes. ICES Journal of Marine Science 55, 997 - 1030

commercial fishery in five separate areas: South Georgia, Kerguelen Islands, southern Africa, northwest Atlantic and the Bering Sea. It was not clear from that study, however, what proportion was taken by whales. More specific accounts are available. In the Antarctic, whales consume between 34 and 43 million tonnes of krill a year,⁵³ 95% of which is estimated to be eaten by minke whales.⁵⁴ Kanwisher and Ridgway⁵⁵ postulated that sperm whales may consume more prey than the entire world fishery. The latter study, however, assumed high metabolic activity. A separate review of marine mammal metabolic rates indicated that many studies — including that of Kanwisher and Ridgway — overestimated rates by as much as a factor of two.⁵⁶

4.4 The importance of trophic niche and niche separation

Regardless of how much these animals eat, the issue at hand is whether large whales are having a substantial impact on other top predators such as commercial fishers. The greatest difficulty in predicting or assessing the impact of marine mammals on fisheries is in determining (firstly qualitatively then quantitatively) the food webs associated with the “predators” (whales and commercial fisheries). As early as 1924,⁵⁷ studies demonstrated that the complexity of predatory interactions rapidly becomes overwhelming. Indeed, potential interactions in even the simplest food chains make prediction highly uncertain. Nevertheless, Trites et al. provided a simplified trophic model that described the various pathways leading to commercial fisheries and marine mammals (Figure 2). They note the pathways leading to the “top

⁵³ Nicol, S. and Endo, Y. (1997) Krill fisheries of the world. FAO Fisheries Technical Paper. No. 37. Rome, FAO. 100p.

⁵⁴ Armstrong, A. J. and Siegfried, W. R. (1991) Consumption of Antarctic krill by minke whales. *Antarct. Sci.* 3, 13–18.

⁵⁵ Kanwisher, J. W., Ridgway, S. H. (1983) The physiological ecology of whales and porpoises. *Sci. Am.* 248, 110–120.

⁵⁶ Lavigne, D. M., Innes, S., Worthy, G. A. J., Kovacs, K. M., Scmitz, O. J., Hickie, J. P. (1986) Metabolic rates of seals and whales. *Can. J. Zool.* 64, 279–284.

⁵⁷ Hardy (1924) - missing

predators” are quite separate and join only at the lower trophic levels. This last point is perhaps the most critical, as it demonstrates that marine mammals and fisheries usually occupy different trophic niches. That is, the lower level food webs that support them are usually quite different. For example, the blue whale feeds mainly on zooplankton (mainly krill) in summer in the Southern Ocean, returning to warmer northern waters to breed. Tropical tunas, on the other hand, feed in the oligotrophic waters of the tropics. At times the groups overlap in both space and time, but because of their different feeding strategies they rarely compete for the same food.

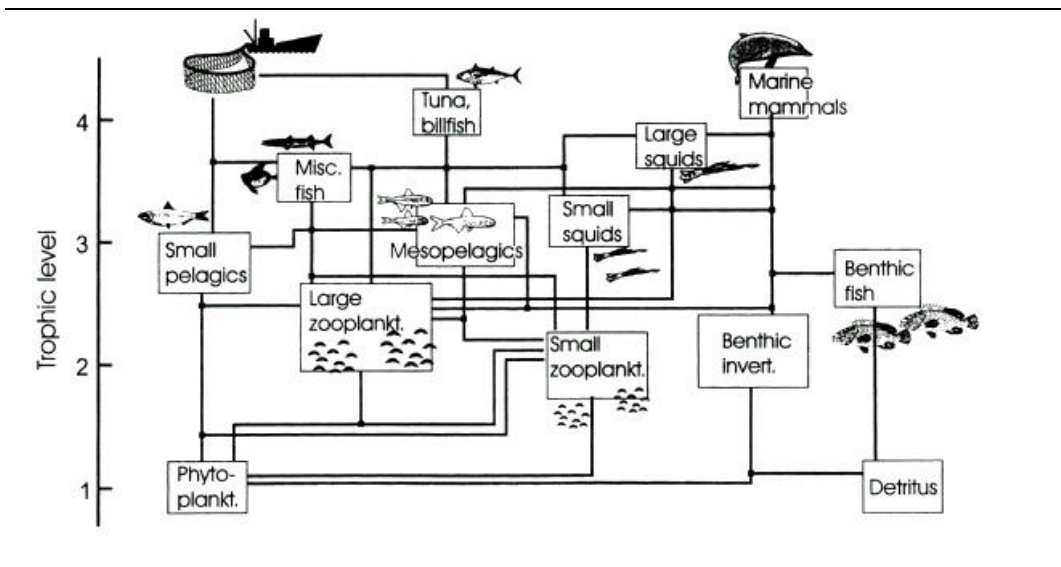


Figure 1: Schematic representation of a simplified food chain leading to marine mammals and fisheries (from Trites et al. 1997)

4.5 Evidence of impacts

To be sure, there are circumstances under which the food webs of some whales and commercial species overlap and direct competition occurs. For example, in the tropics, beaked whales can feed on bigeye tuna.⁵⁸ Killer whales “steal”

⁵⁸ Collette, B. B. and Nauen, C. E. (1983) FAO species catalogue. Vol. 2. Scombrids of the world. FAO Fish. Synop. (125), Vol. 2. 137 pp.

longline-caught tunas and billfish off eastern Australia.⁵⁹ In the Northern Hemisphere, the diet of minke whales from coastal Norwegian waters consists largely of commercial fish species including cod, herring, capelin and pollock. As these fishes were heavily exploited between 1970 and 1990 concern was raised whether increased numbers of minkes could disrupt the recovery of these species.⁶⁰ Continued predation by fin whales on young herring, a species that was overfished in the 1960s and 1970s in the North Sea, may have pushed the herring to extinction in the area.⁶¹ The overfishing of whales in the Southern Ocean was once thought to have led to a dramatic rise in crabeater seals.⁶² However, in none of these cases has it been possible to demonstrate whether the removal or increase of the whales was the main cause of the changes in the other populations.

There are more data available for seals. As seals generally feed on fish, it might be expected that determining the effect of their predation would be relatively simple. However, even when predation may be equivalent to commercial catches, there is still insufficient evidence to conclude that this predation drives the changes in the affected fish populations.⁶³

For example, the South African fur seal has been exploited for the past three centuries.⁶⁴ When the market for fur seal pelts collapsed in 1983, it was feared that the population would increase to the detriment of commercial fisheries in the area. However, these authors conclude “there is no scientific basis upon which to predict

⁵⁹ Whitelaw, A. W. and Unnithan, V. K. (1998) Synopsis of the distribution, biology and fisheries of the bigeye tuna (*Thunnus obesus*, Lowe) with a bibliography. CSIRO Marine Labs. Rep. 228.

⁶⁰ Nordoy, E. S. and Blix, A. S. (1992) Diet of Minke whales in the Northeastern Atlantic. Rep. Int. Whal. Commn. 42, 393- 398.

⁶¹ Katona, S. and Whitehead, H. (1988) Are Cetacea ecologically important? Oceanogr. Mar. Biol. Annu. Rev. 26, 553 – 568.

⁶² Bonner, W. N. (1982) Seals and man. Washington University Press. 170 pp.

⁶³ Beverton, R. J. H. (1985) Analysis of marine mammal-fisheries interaction. In: Beddington, J. R., Beverton, R. J. H. and Lavigne, D. M. Marine mammals and fisheries. Allen & Unwin, London.

⁶⁴ Butterworth, D. S., Duffy, D. C., Best, P. B. and Bergh, M. O. (1988) On the scientific basis for reducing the South African seal population. S. Afr. J. Sci. 84, 179– 188.

whether such reduction would have a positive or negative impact on sustainable yields of commercial fish species, nor is such a prediction likely to be possible in the immediate future.” Further, Punt and Butterworth⁶⁵ found that the effect of a seal cull on the hake fishery would be minimal and could “even be detrimental.”

Population regulation appears to only occur when the particular diet is specialised. Only in situations where there are few alternative food resources is there evidence that seals reduced fish abundance.⁶⁶ For example, gray whales, which feed by sucking sediment into their mouths, alter the seabed to the extent that the tube mats of small crustaceans are destroyed and replaced by other scavenging invertebrates.⁶⁷ In contrast, grey seals, which feed on a variety of mobile fish species, are unlikely to influence community dynamics because the mortality they cause is generally less than that caused by fishing, and is not restricted to a few species.⁶⁸

5. Other Natural Predators of Fish Stocks

Seals, dolphins, predatory fish and sea birds all consume prey that form part of commercial fish stocks, although fish generally are considered to take the greatest share of the available food source. Bax⁶⁹ reported that, in six widely separated areas, the ratio of consumption by fish to that taken by fishing ranged from 2:1 to as high as 35:1. Further, marine mammal consumption of prey, although higher than that of

⁶⁵ Punt, A. E. and Butterworth, D. S. (1995) The effects of future consumption by the cape fur seal on catches and catch rates of the Cape hakes. 4. Modelling the biological interaction between cape fur seals *Arctocephalus pusillus pusillus* and the cape hakes *Merluccius capensis* and *M. paradoxus*. S. Afr. J. Mar. Sci. 16, 255 – 285.

⁶⁶ Power, G. and Gregoire, J. (1978) Predation by freshwater seals on the fish community of Lower Seal Lake, Quebec. J. Fish. Res. Bd. Can. 35, 844 – 50.

⁶⁷ Oliver, J. S., Slattery, P. N. (1985) Destruction and opportunity on the sea floor: effects of gray whale feeding. Ecology. 66, 1965 – 1975.

⁶⁸ Harwood, J. and Croxall, J. P. (1988) The assessment of competition between seals and commercial fisheries in the North Sea and the Antarctic. Marine Mammal Science. 4, 13 – 33.

⁶⁹ Bax, N. J. (1991) A comparison of the fish biomass flow to fish, fisheries and mammals on six marine ecosystems. ICES Marine Science Symposia, 193, 217 – 224.

seabirds, was usually similar to that of fishing, and always lower than predatory fish. Similarly, in the eastern Central Pacific Ocean the amount of fish eaten by predatory fish is an order of magnitude higher than that by marine mammals.⁷⁰ There are exceptions. As previously mentioned, whales in the Antarctic consume between 34 and 43 million tonnes of krill per annum. Although this figure is less than that eaten by seals (63 – 130 million tonnes) and squid (30 – 100), it is more than consumption by fish (10 – 20) and seabirds (15 – 20).⁷¹ However, the smaller impact of fish in these waters may be the result of fewer species and the abundance of seals dominating the southern ocean food chain than in more temperate and tropical waters.

6. The impact of fishing on whales

6.1 Whaling

In this century, whalers shifted their focus the larger “right” and blue whales to the smaller fin, sei and minke whales – solely because whaling was so efficient that the stocks of the larger whales were nearly driven to extinction.⁷² Hunting of whales in Antarctic waters alone during the twentieth century has probably reduced their biomass by a factor of ten.⁷³ In fact, over two million whales have been taken in this century in the Southern Ocean alone.⁷⁴

The impact of whaling on whale populations in the Southern Hemisphere was so great that there is evidence of changes in some life-history characteristics of these

⁷⁰ Christensen, V. (1996) Managing fisheries involving predator and prey species. *Rev. Fish Biol.* Fish.6, 1 – 26.

⁷¹ (Bonner 1982, Nicol and Endo 1997) Bonner, W. N. (1982) *Seals and man*. Washington University Press. 170 pp.

⁷² Gulland, J. A. (1988) The end of whaling? *New Scientist*. 29–October, 42 – 47.

⁷³ Katona, S. and Whitehead, H. (1988) Are Cetacea ecologically important? *Oceanogr. Mar. Biol. Annu. Rev.* 26, 553 – 568.

⁷⁴ Clapham, P. J., Young, S. B., Brownell, R. L. (1999) Baleen whales: conservation issues and the status of the most endangered populations. *Mammal Rev.* 29, 35 - 60

whales. Notably, pregnancy rates increased and the age of sexual maturity decreased, particularly in the fin, sei and minke whales. In the minke whale this change was more pronounced: mean age of sexual maturity decreased from 12-13 years in the 1940's to 7-8 years by the early 1970s.⁷⁵ These changes were assumed to be the result of increased food availability brought about by the depletion of other balaenopterid whales, chiefly blue and humpback whales, in the Antarctic.⁷⁶ Lockyer⁷⁷ suggested that these changes were the result of reduced intraspecific and interspecific competition among the surviving whale species: the stocks of blue, humpback and right whales were depleted before fin, sei and minke whales were exploited. Whether the changes observed are directly due to competition, however, is unclear.⁷⁸ During the same period, populations of penguins and seals had also increased (by a factor of 3), perhaps also due to the decline in the larger whales,⁷⁹ suggesting that the ecosystem gap left by the harvested whales was quickly filled.

6.2. *Competition for primary production*

It seems on the available evidence that there is little direct competition for food resources between large whales (dolphins and seals may need to be addressed separately) and commercial fisheries. However, is there indirect competition between commercial fishing and whales for primary productivity, i.e., the rate at which organic compounds are formed by photosynthesis? The amount needed to sustain fishing

⁷⁵ Kato, H. (1987) Density dependent changes in growth parameters of the southern minke whale. *Sci. Rep. Whales Res. Inst.*, 38, 47 –73.

⁷⁶ Lockyer, C. (1979) Changes in growth parameters associated with exploitation of Southern Fin and Sei whales. *Rep. Int. Whale. Commn.* 29, 191.

⁷⁷ Lockyer, C. (1984) Review of baleen whale (Mysticeti) reproduction and implications for management. *Rep. Int. Whal. Commn (Special Issue 6)* 27 – 50.

⁷⁸ Clapham, P. J. and Brownell, R. L. (1996) The potential for interspecific competition in baleen whales. *Rep. Int. Whal. Commn* 46, 361 – 367.

⁷⁹ (Laws 1985, Kato 1987) Laws, R. M. (1985) The ecology of the Southern ocean. *Am. Sci.* 73, 26 – 40.

worldwide in 1995 was 8% of that produced by global aquatic primary production.⁸⁰ By ecosystem type this was as low as 2% for open ocean systems but as high as 35% in upwelling ecosystems. The latter figure compares very closely with the 35 – 40% figure for terrestrial ecosystems. However, in terrestrial systems there are technologies available for enhancing this productivity. Pauly and Christensen concluded that current concerns for the sustainability of fishing worldwide are justified.

Against this backdrop is the primary production required to sustain whales. FAO data on primary production in the Pacific Ocean showed a range of primary productivity from 98 to 272 g C per m² (average ~135 g C per m²).⁸¹ Of this, the amount needed to sustain marine mammals fell within a very narrow range -- 20 to 30 g C per m² -- in all the areas quantified. However, this figure is dominated by seals and dolphins; whales make up only a small component of this figure. Trites et al.⁸² believe that the similarity of these values worldwide suggests that marine mammals are fully exploiting available feeding niches such as the deep-sea scattering layer⁸³ (which is not generally exploited by commercial fishing operations). In contrast, the primary production needed to sustain the various fisheries worldwide is lower but more variable (5 - 20 g C per m²) depending on the resource being fished. One could argue that as fisheries take up more and more of this primary production, there could be less for other top predators, including whales. The converse argument would be that increasing whale numbers could affect the available primary productivity for fisheries. However, for either position to be realised there would firstly need to be

⁸⁰ Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature*. 374, 255 – 257.

⁸¹ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw. Atl. Fish. Sci.* 22, 173-187.

⁸² *ibid.*

⁸³ Defined as concentrations of plankton detectable by acoustics.

direct overlap for food between these ‘top predators,’ and secondly a relatively closed ecosystem. As there is evidence for neither, competition for primary productivity is unlikely.

7. Environmental Effects

Underlying the debate of whether whales are affecting commercial fisheries is the influence of changes in physical oceanographic conditions on ecosystem dynamics. There are many examples of interdecadal fluctuations in fish stocks, particularly those, such as anchovies, occurring at lower trophic levels.⁸⁴ These massive changes are usually linked to changed oceanographic conditions rather than to predatory or competitive interactions.⁸⁵ As evidence for such long-time-scale variability accumulates it is likely that this variability will be viewed as a normal condition for marine ecosystems. Bakun⁸⁶ proposed that the cyclic nature of environmental inputs into marine ecosystems far outweighs changes brought about by competition and predation. Recent data have suggested that changes in the long-term diets of minke whales in the North Pacific may be an example of their impact on prey stocks.⁸⁷ However, a more likely explanation is that the minkes, as opportunistic feeders,⁸⁸ were exploiting the cyclic nature of these prey stocks (both seasonally and interannually).

⁸⁴ Loeb, V. J. and Rojas, O. (1988) Interannual variation of ichthyoplankton composition and abundance relations off northern Chile, 1964 – 83. *Fish. Bull.*, U. S. 86, 1 – 14.

⁸⁵ Bakun, A. (1998) Ocean triads and radical interdecadal variation: bane and boon to scientific fisheries management. In : *Reinventing fisheries management*. (Ed. Pitcher, Hart and Pauly).

⁸⁶ *ibid.*

⁸⁷ Tamura, T., Fujise, Y and Shimazaki, K. (1998) Diet of minke whales *Balaenoptera acutorostrata* in the north-western part of the North Pacific in summer, 1994 and 1995. *Fisheries Science*, 64, 71 – 76.

⁸⁸ *ibid.*

8. The South Pacific Ocean

8.1 Pelagic fisheries

In the 1940s, the annual take from Pacific Ocean fisheries was about 2 million tons. By the early 1990s, this figure had risen to 50 million tons, and was either static or, in some areas, beginning to decline as resources were optimized or overfished.⁸⁹ Fisheries catch in the western central and southwest Pacific Oceans comprise a relatively small component of this total: about 3.5 million tons per annum.⁹⁰ In contrast to many Pacific fisheries, however, pelagic fisheries catches have risen markedly in recent times. For example, in the tuna fishery alone catches have risen from ~ half a million tons in the mid 1980s to ~2 million tons in 1997.⁹¹

Southern bluefin tuna, which is fished off New Zealand and as far north as 30° S along the eastern Australian coastline is depleted. However, further expansion in the yellowfin, albacore and skipjack fisheries is possible (and likely). The annual catch of yellowfin tuna in 1997 was 394,000 metric tons.⁹² Hampton⁹³ forecast that an annual catch rate of 600,000 – 800,000 metric tons (mt) of yellowfin “could be accommodated.” Similarly, the annual landing of skipjack could rise from the present level of 1 million mt to as much as 2 million mt. There is concern, however, that catches of bigeye, which have risen sharply in recent years to ~ 100,000 tons may be unsustainable.⁹⁴ The reason for this uncertainty is that as much as 50,000 t of juvenile

⁸⁹ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw. Atl. Fish. Sci.* 22, 173-187.

⁹⁰ Northbridge, S. P. (1984) World review of interactions between marine mammals and fisheries. *FAO Fish Tech Pap.* 251: 190 pp.

⁹¹ Anonymous (1998) Report of the eleventh meeting of the standing committee on tuna and billfish. Hawaii, U.S.A.

⁹² *ibid.*

⁹³ Hampton, J. (1993) Status of tuna stocks in the SPC area: a summary report for 1993. Sixth Standing Committee on tuna and billfish. Working paper 3. 51 pp.

⁹⁴ Anonymous (1998) Report of the eleventh meeting of the standing committee on tuna and billfish. Hawaii, U.S.A.

bigeye may be caught annually by the yellowfin purse seine fishery but not identified as such.⁹⁵

8.2 Diets of tunas

The diets of temperate and tropical tunas have been studied extensively. All consume a mixture of epipelagic fish, squid and crustacea, mainly in the upper 200 m, although feeding on mesopelagic fishes at greater depths has also been reported.⁹⁶ However, most prey eaten are generally found in the upper 200 m of the water column.⁹⁷ Komilova⁹⁸ suggested that yellowfin and bigeye tuna were separated by their vertical position in the water column, reflected in subtle shifts in the types of prey eaten by the two species.

8.3 Competition between tunas and whales

In the Pacific Ocean, Trites et al.⁹⁹ estimated that marine mammals consumed ~150 million tons of prey each year, three times the amount taken by fishing. They estimated that half of this amount was eaten by sperm whales. However, this was still well below the level taken by other predatory fish. For example, Olson and Boggs¹⁰⁰ estimated that yellowfin tuna in the eastern Pacific Ocean alone consumed between 4.3 and 6.5 million metric tons of prey. In approximately the same area, total

⁹⁵ (R. Campbell, CSIRO Marine Laboratories, pers. comm.).

⁹⁶ McPherson, G. R. (1991) A possible mechanism for the aggregation of yellowfin and bigeye tuna in the northwestern Coral Sea Qld Dept. Prim. Ind. Information series Q191013. 11 pp.

⁹⁷ Olson, R.J. & C.H. Boggs. 1986. Apex predation by yellowfin tuna (*Thunnus albacares*): Independent estimates from gastric evacuation and stomach contents, bioenergetics and cesium concentrations. Can. J. Fish. Aquat. Sci. 43: 1760–1775; Young, J. W., Lamb, T. D., Le, D., Bradford, R., Whitelaw, A. W. (1997) Feeding ecology and interannual variations in diet of southern bluefin tuna, *Thunnus maccoyii*, in relation to coastal and oceanic waters off eastern Tasmania, Australia. Environmental Biology of Fishes 50(3): 275–291.

⁹⁸ Komilova, G. N. (1980) Feeding of yellowfin tuna *Thunnus albacares*, and bigeye tuna *Thunnus obesus* in the equatorial zone of the Indian Ocean. J. Ichthyol. 20 (6), 111–119.

⁹⁹ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J. Northw. Atl. Fish. Sci. 22, 173–187.

¹⁰⁰ Olson, R.J. & C.H. Boggs. 1986. Apex predation by yellowfin tuna (*Thunnus albacares*): Independent estimates from gastric evacuation and stomach contents, bioenergetics and cesium concentrations. Can. J. Fish. Aquat. Sci. 43: 1760–1775.

consumption by marine mammals has been estimated at ~ 25 million tons.¹⁰¹ Of this, whales reportedly consumed ~ 35 %, which is a similar amount to the yellowfin but far less than the entire fish stock.

Regardless of the above figures, there are some fundamental differences between tunas and whales that make significant competition for food unlikely for all but a few species:

- First, most of the large whale species that frequent the South Pacific (mainly in winter) are there to conceive their young.¹⁰² This may be because newborns have limited thermoregulatory ability, or alternatively, because newborns would be vulnerable to predation by killer whales that summer in Antarctic waters.¹⁰³ Most observations indicate that the main feeding area for many of these whales, particularly blue, fin, sei, minke and humpbacks, is in the Southern Ocean.
- Second, it is the nature of the predation that is important – differences between size of fish taken by fisheries and fish predation indicate quite different impacts on mortality. Pauly and Christensen¹⁰⁴ estimated 25 to 35% of primary production was necessary to account for the recorded catches and discards. However, the same data indicated that the biomass consumed by fish is between 3 to 25 times greater than to the commercial catch. This incongruous relationship is possible only because natural predation removes more prey from lower trophic levels than fishing does. They concluded that trophic position and life-history stage are as

¹⁰¹ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw. Atl. Fish. Sci.* 22, 173-187.

¹⁰² Lockyer, C. (1984) Review of baleen whale (Mysticeti) reproduction and implications for management. *Rep. Int. Whal. Commn (Special Issue 6)* 27 – 50; Kasamatsu, F., Nishiwaki, S., Ishikawa, H. (1995) Breeding areas and southbound migrations of southern minke whales. *Marine – Ecology Progress Series* 119, 1 – 10.

¹⁰³ Cockeron and Connor 1999

important as species in describing the effects of predation in marine systems. One study¹⁰⁵ estimated that of the prey/catch by marine mammals and fisheries in the Pacific Ocean, only 35% overlapped, and most of that overlap was from dolphins and seals. Although the large whale species have a variety of prey preferences, much of these preferences were different from those of, for example, the different tuna species. Specifically, sperm whales feed predominantly at depths below that of the tunas, usually proximate to the deep scattering layer. There they feed mainly on mesopelagic fishes and cephalopods. That sperm whales also feed on large, deep ocean cephalopods including the giant *Architeuthis* spp. (which, because of its deep sea distribution, is only rarely recorded otherwise) underlines their close relationship not with surface waters but with the deep ocean. In contrast, yellowfin tuna, one of the ubiquitous tropical tunas, eats mainly epipelagic species¹⁰⁶ such as other scombrids (e.g. frigate tunas, *Auxis* spp.) and smaller cephalopods usually associated with the thermocline.

8.4 Interactions with fisheries

The interactions of marine mammals and fishing operations are an increasing problem worldwide, but investigations have mainly focused on seals and dolphins.¹⁰⁷ Recently, however, there have been reports of increasing numbers of killer and pilot whale interactions with the developing longline fisheries in the South Pacific and Indian Oceans. For example, in the developing domestic longline fishery off eastern

¹⁰⁴ Pauly, D. and Christensen, V. (1995). Primary production required to sustain global fisheries. *Nature*. 374, 255 – 257.

¹⁰⁵ Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. *J. Northw. Atl. Fish. Sci.* 22, 173-187.

¹⁰⁶ Olson, R.J. & C.H. Boggs. 1986. Apex predation by yellowfin tuna (*Thunnus albacares*): Independent estimates from gastric evacuation and stomach contents, bioenergetics and cesium concentrations. *Can. J. Fish. Aquat. Sci.* 43: 1760–1775; j. Young, pers. observ.)

¹⁰⁷ Dawson, S. M., Read, A., Slooten, S. (1998) Pingers, porpoises and power: uncertainties with using pingers to reduce bycatch of small cetaceans. *Biological Conservation*. 84, 141 – 146.

Australia longliners are reporting that some of their catches are stripped from the hooks by killer whales.¹⁰⁸ However, although this may be a problem in some instances, shark bites on hooked fish are a far more important factor affecting the value of the catch. There is no evidence of any interactions between the larger whales (i.e. sperm whales and the larger baleen species) and the longlines off eastern Australia.

9. The Three Statements Reviewed

Statement 1.

Granting excessive protection to a particular element of the marine ecosystem will lead to disruption of the biological balance in the same manner as excessive harvesting.

The complexity surrounding trophic interactions makes predicting outcomes for even the simplest trophic web very difficult, and has only been demonstrated for simplified freshwater systems. Models of multispecies interactions have shown that expected outcomes are rarely met. This is because each trophic level is affected by a mix of competition, predation and environment, the importance of each varying with the species concerned. Beverton¹⁰⁹ concluded that, even when food chains were dependent on a two-stage linkage, the outcomes were unpredictable. Most food chains are far more complex. Although the relationship between seals and man has been modelled extensively, rarely can researchers agree that seals have a measurable impact on a competing fishery. As it is relatively easier to gather the necessary population data for such models from seals than for whales, the task of predicting outcomes for the latter becomes even harder. Implicit in Statement 1 is the notion that

¹⁰⁸ Acoustic alarms trialed in the Northern Hemisphere show promise in reducing dolphin bycatch. Although not tested as yet on longlines, these might be developed as deterrents for larger cetaceans such as killer whales.

predation or competition drives ecosystem stability. However, as Bax (in press) noted “there is unlikely to be a single mechanism, rather a suite of factors affecting different life history stages (whose) effects are enhanced or diminished by environmental variability.”

Statement 2.

Cetaceans consume 500 million tons of marine living resources worldwide. Do they have an effect on fish or are they in competition with humans?

Assuming that the figure of 500 million tons is accurate then whale consumption represents less than 5% of annual secondary production, while humans eat about 1%.¹¹⁰ On that basis, the consumption by whales and humans fall within the same order of magnitude. However, the figure of 500 million tons is likely to be an overestimate. For example, to arrive at that figure a daily intake of 3.5% of body weight for baleen whales was used. Using the logic presented by Lockyer¹¹¹ the figure is likely to be half that.

Regardless of the accuracy of those figures, however, the real question is how close trophically the prey eaten by the whales is to commercial fishing. Trites et al.¹¹² estimated that the dietary overlap between marine mammals and fishes of commercial importance was only 35%, and even then much of the overlap occurred between seals and dolphins and the fisheries. For the large baleen whales, there appears to be little evidence of overlap with commercial fisheries within the South Pacific Ocean.

¹⁰⁹ Beverton, R. J. H. (1985) Analysis of marine mammal-fisheries interaction. In: Beddington, J. R., Beverton, R. J. H. and Lavigne, D. M. Marine mammals and fisheries. Allen & Unwin, London.

¹¹⁰ Ryther, J. R. (1986) Photosynthesis and fish production in the sea. In: Readings in marine ecology (Ed. J. R. Nybakken).

¹¹¹ Lockyer, C. (1984) Review of baleen whale (Mysticeti) reproduction and implications for management. Rep. Int. Whal. Commn (Special Issue 6) 27 – 50.

¹¹² Trites, A. W., Christensen, V. and Pauly, D. (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J. Northw. Atl. Fish. Sci. 22, 173-187.

Statement 3.

Increase in the number of whales in the Pacific will lead to a reduction in the number of fish (i.e. tuna).

There is evidence that the numbers of some species of whales are increasing, although they are nowhere near their pre-exploitation levels. However, have they increased to the level where they are competing with commercial fisheries in the Pacific? Taking the example of tropical tuna, which appear to be their closest competitors, there appears to be no direct evidence from the literature that competition is occurring. There are a number of reasons for this. With the exception of southern bluefin tuna, tunas feed largely in subtropical and tropical waters above the thermocline (although they can feed deeper) on a mix of fish, squid and crustacea. In contrast, the large whales make prolonged excursions to the Southern Ocean to feed mainly on Antarctic krill, copepods and cephalopods. Those that do not migrate have different feeding strategies that make competition unlikely. For example, female and young sperm whales are potential competitors of tuna, as, unlike male sperm whales, they do not make the journey south. However, the available literature indicates they consume at much greater depths than tuna and appear to eat mainly cephalopods. The large baleen whales, with the exception of Bryde's whale, spend the winter months in the tropics, but travel to the Antarctic to feed for the bulk of their annual energy intake. Bryde's whale, which is a tropical resident, feeds mainly on krill. It could be argued that the large migrating whales are actually transferring stored energy (as blubber) from the Southern Ocean to the tropics. Further, whales feeding at depth and defecating in the euphotic zone may help replenish nutrients above the

thermocline.¹¹³ If anything, it is overfishing on some species of tuna (e.g. bigeye tuna), which is potentially a more immediate threat to sustaining populations of tuna in the tropics.

10. Conclusion

Before industrialised fishing began, the marine environment, with all its components, would have evolved to a steady state (fluctuating environmental factors permitting). Therefore, in the past, when whale populations were far larger, there was obviously enough fish and plankton to sustain them, and enough left over to support the huge global fish stocks that have been exploited by modern day fisheries. The partial recovery of some whale populations over the past 30 years cannot begin to explain the decline in fisheries worldwide. A recent review of the ecological importance of cetaceans¹¹⁴ concluded that it was as yet unclear whether cetaceans have a “positive or negative effect on fisheries”, but that there is “no concrete evidence for cetaceans harming fisheries.” The available literature widely supports this perspective. However, the greatest hindrance to developing the argument further is lack of appropriate data, especially abundance and trophic data. In fact, given the available data, it is just as plausible that increasing the abundance of cetaceans has a positive effect on fisheries through the former preying on squid, a major predator of juvenile fish.

¹¹³ Kanwisher, J. W., Ridgway, S. H. (1983) The physiological ecology of whales and porpoises. *Sci. Am.* 248, 110 – 120.

¹¹⁴ Katona, S. and Whitehead, H. (1988) Are Cetacea ecologically important? *Oceanogr. Mar. Biol. Annu. Rev.* 26, 553 – 568.

11. Future Research

Recent studies have made some important steps in reviewing the available data and developing models to examine the potential impacts of the large whales in different ecosystems worldwide. However, the accuracy of any model depends on appropriate data. Unfortunately, data for the South Pacific Ocean is lacking for many cetacean species. Abundance estimates are, as Table 1 shows, nowhere near complete. A coordinated series of sighting surveys, particularly in the tropical South Pacific Ocean, could help fill some of these gaps. Further, data of feeding interactions for a number of whale species are lacking, particularly for the area of the South Pacific. Finally, for meaningful debate on whether whales are affecting the South Pacific ecosystem, ecosystem models specific to this region need to be developed. At present, many of the arguments that are raised are based on data and models developed for other regions, particularly in the Northern Hemisphere.

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