Are whales eating too many fish, revisited.

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ABSTRACT

Has "scientific research has shown that whales consume huge quantities of fish making the issue a matter of food security for coastal nations", as stated in the St Kitts & Nevis Declaration of the International Whaling Commission? Building on other recent reviews, this paper assesses recent work presented by scientists in support of this view. Significant flaws are found in Murase *et al*'s (2007) recent publication on prey preference in two *Balaenoptera* species in the waters off Japan. The results of the research program on the influence of marine mammals on fisheries in the Barents Sea are compared with other Norwegian research on the same system. A model that includes fish and fisheries provides a good representation of what has happened in the system, and does so without including any information from marine mammal predation. Models based on the assumption that marine mammal predation is important in the system fail. This suggests that the influence of marine mammals on the fish-fisheries system in the Barents Sea is trivial. Where good data are available, there is no evidence to support the contention that marine mammal predation presents an ecological issue for fisheries. Suggestions that fisheries problems can be attributed to whales consuming huge quantities of fish distract attention from the root causes of these problems: fisheries mismanagement.

INTRODUCTION

In 2006, the International Whaling Commission (IWC) passed the *St Kitts & Nevis Declaration*. The declaration includes the statement, "ACCEPTING that scientific research has shown that whales consume huge quantities of fish making the issue a matter of food security for coastal nations and requiring that the issue of management of whale stocks must be considered in a broader context of ecosystem management since eco-system management has now become an international standard."

This statement raises two separate but related questions: has scientific research shown that "whales consume huge quantities of fish", and must whale stocks be "considered in a broader context of ecosystem management" because whales' consumption of fish is truly "a matter of food security for coastal nations"?

The perception that marine mammals consume fish, and this presents a problem for commercial fisheries is not new (Lavigne 2003). Nor is the issue new for the International Whaling Commission. To quote directly from another IWC resolution (from 2003), "In 1978 the Scientific Committee noted the problems arising when fishermen believe that cetaceans are responsible for declining coastal fish stocks, leading to killing of the cetaceans involved, *in the absence of scientific evidence of an actual relationship*" (from the annex of IWC Resolution 2003-1, italics added[1]). A workshop convened by the IWC Scientific Committee in 2002 concluded that "for no system at present are we in the position, in terms of data availability and model development, to provide quantitative management advice on the impact of cetaceans on fisheries, or of fisheries on cetaceans" (IWC, 2003).

Has our knowledge changed dramatically between 2003, when an IWC resolution noted the "absence of scientific evidence of an actual relationship" and the Scientific Committee accepted that it was not possible to provide quantitative management advice on the

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[1] Downloaded from: http://www.iwcoffice.org/meetings/resolutions/resolution2003.htm May 2008.

relationship between cetaceans and declines in coastal fish stocks, and 2006, when a resolution stated that "scientific research has shown that whales consume huge quantities of fish", or are other factors at play? This report reviews the claim that "whales consume huge quantities of fish making the issue a matter of food security for coastal nations".

Background

Human activities influence the manner in which marine ecosystems function. A recent analysis suggests that no oceanic area is free of human influence (Halpern *et al*. 2008), with over one-third of the world's oceans strongly affected. Fisheries substantially impact a significant proportion of the ocean (Halpern *et al*. 2008.). The Fisheries and Aquaculture Department of the Food and Agriculture Organization of the United Nations (FAO Fisheries) estimated that in 2005, 25% of the world's marine harvest fisheries were overexploited, depleted, or recovering from depletion; 52% were fully exploited; 20% moderately exploited and 3% underexploited (FAO 2006).

The problems created by industrial fisheries go beyond the fish stocks targeted. Fishing can have large scale, deleterious impacts on marine ecosystems generally (e.g. Pauly *et al*. 2002, Pauly *et al*. 2005), and can affect fish evolution (Jørgensen *et al*. 2007). Coupled with these is the recognition that historically, humans have overfished, creating ecological impacts that influence current ecosystem function (e.g. Jackson 2001, Jackson *et al*. 2001).

In all, the marine science community appears to be passing through a paradigm shift (Kuhn 1962) in its understanding of the effects of fisheries on the oceans. Some argue that the problems in fisheries management are overstated (e.g. Hilborn 2006). However, even a recent review that posited "the situation, although serious, is not catastrophic, and there are grounds for optimism" (Beddington *et al*. 2007 p 1713) does not suggest that maintaining the status quo is an acceptable option.

There are two main categories of interaction between marine mammals and fisheries (Lavigne 2003, p33): *operational interactions*, "physical encounters between marine mammals and fishing gear"; and *ecological interactions*, "that arise because of predation by marine mammals on commercially important fish stocks or their prey". When the IWC reviewed cetacean-fishery interactions in the late 1970s and early 1980s, the main form of interaction reported were operational – cetacean bycatch in fishing gear. This is probably also true today (e.g. Lewison *et al.* 2004), but as the call for culls focuses on ecological interactions, the review focuses on them.

DOES RESEARCH SUPPORT THE CLAIM THAT "WHALES CONSUME HUGE QUANTITIES OF FISH"?

Currently, two main sources of information back the "whales-eat-fish" argument – work by the (Japanese) Institute of Cetacean Research (ICR), principally whaling under Article VIII of the ICRW (hereafter, Article VIII whaling), and by the Norwegian government Institute of Marine Research (IMR) into aspects of the Barents Sea ecosystem.

ICR Article VIII whaling

Currently, the ICR runs two Article VIII programs, JARPN II in the North Pacific, and JARPA II in the Antarctic. Here I identify the major papers dealing with the "whales-eat-fish" issue, précis their findings and provide some general conclusions, then review the scientific merits of the recent paper in the refereed scientific literature from an Article VIII program that deals specifically with an aspect of the "whales-eat-fish" issue.

Reviews

Since the statement by the IWC SC in 2003, that "for no system at present are we in the position, in terms of data availability and model development, to provide quantitative management advice on the impact of cetaceans on fisheries, or of fisheries on cetaceans", relevant review papers are those by Kaschner and Pauly (2004); Gales *et al*. (2005); Holt (2006); and Leaper & Lavigne (2008).

Using a sophisticated, world-wide model of marine mammal habitat use (Kaschner *et al.* 2006), and estimates of food consumption by marine mammals, Kaschner and Pauly (2004) determined the spatial extent of overlap between marine mammals and fisheries, the extent to which marine mammals' diet overlapped with fisheries, and the amount that marine mammals eat. They concluded that "while we acknowledge that local interactions between marine mammals and fisheries do occur, we show that the conflation of marine mammal food consumption and human food security does not at all take the form suggested by the proponents of marine mammal culls". Further, they review the analytical and modeling approaches taken by proponents of culling, and demonstrate their weaknesses.

In a short review of the scientific value of the Japanese Article VIII whaling program in the Antarctic, Gales *at al*. (2005) point to conceptual weaknesses of the program, poor outcomes of the previous Article VIII whaling program and note the possible conflict of interest raised by the need to sell meat from the program to cover program costs.

Holt, in one major report (Holt 2006) and an update (Holt 2007), comprehensively deconstructs the assumptions underpinning, the data for and modelling processes of, claims by scientists employed by the ICR (Tamura and Ohsumi 1999, Tamura and Ohsumi 2000) that whales consume far more living marine resources than are landed by fisheries worldwide. Further, Holt suggests that in their selective use of data and modelling approaches, these reports seem to be aimed at demonstrating that whales eat the greatest amount of seafood possible. Finally, by reworking the data, Holt (2007) suggests that the results may be overestimated by almost two orders of magnitude.

Leaper and Lavigne (2008) address one specific - key - aspect of the same work, namely the estimate of metabolic rates. They demonstrate that claims made in the manuscripts by Tamura and Ohsumi (2000); Okamura *et al*. (2001); Tamura *et a*l. (2004) and Murase *et al*. (2005) are based on unrealistic estimates of whales' metabolic rates and using these unrealistic estimates leads to substantial overestimation of prey consumption by baleen whales.

A recent paper on the feeding energetics of *Balaenoptera* (Goldbogen *et al*. 2007, but see also Acevedo-Gutierrez *et al*. 2002) demonstrates that assumptions about the foraging energetics of minke whales derived from Blix and Folkow (1995) work must be wrong, as a key assumption made in that paper - that minke whales' energy expenditure is the same whether lunge feeding or cruising - has now been demonstrated to be incorrect. This means that all the calculations based on metabolic rates may be even more unreliable than Holt (2006) or Leaper and Lavigne (2008) suggest.

Murase et al. 2007

There is only one paper from Japanese Article VIII whaling on the "whales-eat-fish" argument (Murase *et al*. 2007) that has appeared in the scientific literature recently, and so has not been reviewed by previously. Another descriptive paper (Tamura and Fujise 2002) has also not been reviewed, but it includes no real data analysis, and adds little to what was well known from previous commercial whaling, so is ignored here.

Murase *et al*. (2007) investigated prey found in the forestomachs of whales killed while concurrent acoustic and trawl surveys of likely prey were carried out, approximately simultaneously. In doing so, they followed the research design used by scientists from what is now the Tromsø lab of IMR to ask similar questions on the foraging behaviour of minke whales in the Barents Sea (discussed below). The only references on baleen whales' foraging behaviour listed in Murase *et al.* (2007) are from this Norwegian work. Murase *et al*. (2007) use Manly's classical index of prey selection to assess whether minke whales demonstrate "prey selection".

Murase *et al.* (2007, p188) define prey preference and prey selection as, "preference is defined as the likelihood that an animal selects a particular resource given equal amounts of others, whereas selection is defined as the animal choosing a resource irrespective of amount of resources according to Johnson (1980)". Presumably what they mean is , "Use simply indicates consumption of a specific food. *Selection* implies that an animal is choosing among alternative foods that are available. Use is selective if foods are consumed disproportionately to their availability in the environment (Johnson 1980). Preference is independent of availability." (Litvaitis 2000, p 175).

TECHNIQUES

Is stomach sampling coupled with acoustic and trawl surveys the most appropriate technique to address questions on the foraging ecology of minke and Bryde's whales? When studying the foraging ecology of marine mammals, particularly large marine mammals that range over huge areas, it is important to design research programmes that ask questions at appropriate spatial and temporal scales. *Balaenoptera* are gulp feeders, ingesting large, discrete mouthfuls of water and prey items (Goldbogen *et al*. 2007). Therefore, *Balaenoptera* generally feed on prey that aggregate in large patches (schools or swarms), which tend to be monospecific. Sampling the forestomach contents of dead whales will reveal what whales' very recent meals were, and unsurprisingly in *Balaenoptera*, these all tend to be one species of schooling fish or crustacean. These general patterns have been well known for decades (Murase *et al*. 2007).

Stomach content analysis is a crude tool for investigating baleen whales' foraging ecology. Other studies have demonstrated foraging thresholds for *Balaenoptera* (Piatt and Methven 1992); differences in the foraging ecology of different *Balaenoptera* species (Tershy 1992);

differences in their foraging energetics (e.g. Croll *et al*. 2001; Acevedo-Gutierrez *et al*. 2002; Goldbogen *et al* 2007), and local ecological drivers of *Balaenoptera* foraging (e.g. Croll *et al*. 2005).

Foraging specializations are not uncommon in mammalian predators (and have been generally detected through behavioural studies), and the evolutionary ecology of foraging specializations is well described (e.g. Estes *et al*. 2003). One study has shown that individual minke whales can have foraging specializations (Hoelzel *et al*. 1989), which, if occurring elsewhere, may be of importance for their interactions with prey, but would be undetectable from this study's design. Yet this is ignored by Japanese Article VIII whaling and the Norwegian research program into marine mammals in the Barents Sea.

Observational studies of other cetacean species have demonstrated foraging specializations, that, had they been studied simply through stomach content analysis, would have been interpreted as prey-switching by a generalist predator. For example, there was a time when, based mainly on stomach samples, bottlenose dolphins (*Tursiops* spp.) were presumed to be generalist predators (e.g. Mead and Potter 1990). Behavioural studies over the past two decades have demonstrated conclusively that this is not the case. Bottlenose dolphins demonstrate sophisticated, specific behavioural specializations to foraging challenges (e.g. Sargent *et al*. 2007). Stomach sampling would never have provided this understanding of the role of these marine mammals in their ecosystems.

On the other hand, (and also from an observational study) Dunham and Duffus (2001) demonstrated that individual gray whales, *Eschrichtius robustus*, switched foraging tactics and prey species in response to short-term changes in prey availability. Further extensions of this work (Nelson *et al*. 2008) have demonstrated interannual spatiotemporal variation in foraging behaviour.

Even if minke whales are the generalist predator suggested by Murase *et al*. (2007) and Norwegian work (see below), prey selectivity indices such as Manly's are of little use if one is attempting to assess how prey mortalities change with different prey densities (for details, see Asseburg (2006), and also Garshelis (2000) for weaknesses in the Manly-Chesson index). This is supposed to be a key area of interest for the ICR's Article VIII whaling program.

Murase *et al*. (2007) do not add anything new to our understanding of the manner in which baleen whales interact with their prey. Apart from the example of gray whales mentioned above, there is a substantial scientific literature demonstrating the utility of other techniques to assess whales' foraging ecology. Among *Balaenoptera*, examples include research on blue whales (*Balaenoptera musculus*) off southern California (e.g. Fielder *et al*. 1998; Croll *et al*. 1998, Croll *et al*. 2005); and minke whales and other species around the Antarctic Peninsula (e.g. Thiele *et al*. 2004; Friedlaender *et al.* 2006).

BIASES

The sampling design is poor. The statement "the special blocks were set adoptively to acquire more samples" (p188), and the whales killed off-transect (e.g. shown in Figure 2 (b), small blocks 2, 3 and 4) suggest that the transect placement was ignored when killing whales. But Murase *et al*. (2007, p 186) state that the reason that older whaling data are not useful is

“Because fishing effort was concentrated on the high-density area of the cetaceans, samples from commercial whaling had inherent bias” (p187), and that “Random sampling of cetaceans should be required to remove the bias”. Murase *et al's* (2007) description of their sampling states that they also concentrated on areas where whales were at high densities, suggesting that their own data are biased.

The paper reports stomach samples from 44 minke and 32 Bryde's whales, killed in 2000 and 2001. Of these, 26 stomachs from minke whales, and 16 from Bryde’s whales were actually usable for analysis. In the cruise report for 2001 (Fujise, Tamura *et al*. 2002), 100 minke whales and 50 Bryde's whales are reported as killed. For 2000, the numbers were 40 and 43, respectively (Fujise, Kawahara *et al.* 2002). This means that less than one-fifth of the minke whales or Bryde’s whales killed produced samples that were usable in this study. This is an extremely poor ratio for usable samples from any scientific study, and suggests that the sampling design (i.e. killing whales to get their forestomach contents) is a poor technique for assessing diet.

There was also a strong gender bias in the minke whales killed in 2001 (93% were males, Fujise, Tamura *et al*. 2002 Table 9 p 17), but this is not mentioned in Murase *et al*. (2007). For Bryde's whales in 2001, in one sampling period 23% of animals taken were males (IWC Fujise, Tamura *et al.* 2002 Table 10 p17), in the other 73% were males, but this is not discussed either. Gender related differences in mammalian ecology have been discussed in the scientific literature for well over two decades (e.g. Clutton-Brock et al. 1982), and gender-related differences in the whale behaviour have been reported for over four decades (e.g. Chittleborough 1965). Despite this, Murase *et al.* (2007) consistently make population-level inference from their data, with no mention of gender bias.

MAKING INFERENCE FROM THESE DATA

The authors refer to Lindstrøm and Haug's (2001) list of four underlying assumptions regarding the sort of study described in this paper. Other assumptions include that a point sample from an individual animal at one stage in its annual movements provide representative data for that individual (highly unlikely, given our current knowledge of baleen whale foraging ecology); and that individuals sampled in short periods of space and time are representative of the entire population (apparently not the case here, given the gender bias in samples).

On the first of these points, Mikkelsen’s work on grey seals in the Faeroe Islands provides an example where stomach content analysis of marine mammals (killed specifically for scientific study) provided data that were unsuitable for making inference beyond the short time period where the animals were killed. Stomach content analysis suggested a summer diet of mostly gadoids, sandeels and catfish (Mikkelsen *et al*. 2002). Further analysis of trace elements from samples of the animals demonstrated that through the rest of the year, the seals’ diets included a substantial portion of cephalopods (Bustamante *et al*. 2004). This demonstrates that these seals diets overlap less with local fisheries than suggested by the stomach content analysis.

Do the data from Murase *et al*. (2007) provide any new information on the relationship between the distribution of whales and their prey in their study area during the time of the study? It appears so. Comparing their Figure 2 with their Figures 3 and 4, it seems that there were areas surveyed with high concentrations of anchovy and krill, but no whales. It is hard to be certain from the information available in the paper, but it appears that there were more areas with high concentrations of anchovy and krill with no whales present, than there were high concentrations of anchovy and krill with whales present.

This result may be important, but it is difficult to extract more from the data provided. Are the sites where whales were killed a representative sample of the areas where whales were observed? Perhaps so, although the skewed design (see above) suggests that killing was concentrated in areas where whales were known to be in high density. In 2001, most of the whales sighted were killed - in 2001 136 minke whales were sighted 100 of which were killed, and 77 Bryde's whales were sighted for 50 killed (sighting numbers from Fujise, Tamura *et al*. 2002 p5), so the areas where whales were killed appears to be a reasonable indicator of whales present.

This suggests that there are areas where whales' prey is abundant, but whales are absent. If correct, this would be an important finding, as it suggests that minke and Bryde's whales are not prey-limited. Unfortunately, the sampling effort in the study as published appears biased (see above), so it would be difficult to make strong inferences on what may be an interesting finding from the study. There are areas in the Northwest Pacific off Japan where there appear to be aggregations of minke or Bryde's whales' prey, but no whales, (at least during the period when research was conducted in those areas). The results from a research cruise on the Norwegian IMR's new vessel provide examples of how better field data could be collected and analysed (Doksæter *et al*. 2008; Skov *et al*. 2008).

Murase and coworkers' program is clearly derived from research, progams developed by the group now at the Institute of Marine Research, Tromsø. The collaboration between the two groups is demonstrated by at least one co-authored paper on JARPN work (**Lindstrøm,** Fujise *et al*. 1998). Has the IMR Tromsø group's work, and the models derived from it, resulted in better understanding of the system that they study than the work published by the ICR to date?

The Barents Sea

Research by IMR Tromsø.

A Norwegian research program aimed at understanding how predation by marine mammals influences the size of fish populations in the Barents Sea was established in the 1980s. This work has, unlike the ICR work, resulted in a series of publications in the refereed scientific literature since at least 1991. Currently, the program is based at the IMR laboratory in Tromsø.

The work included assessing the stomach contents of harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*) and northern minke whales, all involving lethal sampling (e.g. Nilssen *et al.* 1995; Haug *et al.* 1995; Haug *et al*. 1997; Haug *et al*. 2004). The programs that combined prey sampling with either scientific kills of seals (Lindstrøm *et al*. 1998) and carried out in conjunction with either Article VIII (e.g. Skaug *et al.* 1997) or commercial whaling (e.g. Smout and Lindstrøm 2007**)** provide the template used for the JARPN II Article

VIII whaling.

The papers describe the generalities of what and how much the animals eat (e.g. Nilssen, Haug *et al*. 1995, Haug, Lindstrøm *et al*. 1996; Folkow *et al.* 2000, Nilssen *et al.* 2000; Potelov *et al*. 2000; Lindstrøm *et al*. 2002), assess whether whales and seals have preferences for particular prey (e.g. Skaug *et al.* 1997; Lindstrøm, Harbitz *et al.* 1998; Wathne *et al.* 2000), including attempts to determine whether they demonstrate multi-species functional responses (e.g. Smout and Lindstrøm 2007) and attempt to model the influence of marine mammal predation on the fisheries of interest (e.g. Bogstad *et al*. 2000, Tjelmeland and Lindstrøm 2005).

Has this work over the past two decades resulted in an improvement to understanding the marine ecology of the Barents Sea, and the interactions between fisheries and marine mammals?

Fish and fishing in the Barents Sea

The industrial fishery for capelin in the Barents Sea expanded rapidly in the 1970s (Hjermann *et al*. 2004b). Landings peaked at a little less than three million tonnes in 1977. The Barents Sea capelin population collapsed from nearly nine million tonnes in 1975 to about one hundred thousand tonnes in 1987. The fishery was closed as a result. In the 22 years since the first closure, the capelin fishery has been open for eight years, and closed for fourteen (ICES 2007). The fishery has been shut from 2004 to 2007, and the current advice from ICES is for a zero quota for 2008 (ICES 2007).

On three occasions through twenty years, the capelin population has collapsed completely. A modelling approach to understanding the system, published in 2004, so including only the first two crashes, explains the historical data well (Hjermann *et al*. 2004a). Ecology and fisheries both play a role. Cod eat fatty, adult capelin. Despite being depleted, the Barents Sea cod is estimated to have a spawning stock biomass in the order of about six hundred thousand tonnes (ICES 2007). Young herring also eat capelin.

Hjermann et al's (2004a) modelling approach provides the following explanation for what has happened in the Barents over the past two decades. Overfishing capelin drove the initial collapse. Cod seek out capelin, even when capelin’s abundance is low, slowing the recovery of capelin from the first crash. The second collapse in the early 1990s was driven by the recovery of the herring population, and involved a mix of herring eating capelin larvae, and competing for food with older capelin. Again, cod predation slowed capelin recovery. Drivers for the current crash have yet to be studied.

Two important points emerge from Hjermann *et al*’s (2004a) paper. The first is that it explains existing data adequately: it represents a reasonable model of what has happened in the system. The second is that it does so without including any information from other predators. This suggests that the influence of other predators on the system is trivial. Predation by marine mammals is not needed to produce a model that explains the data.

Scenario C modelling

Another modelling approach dealing with the same system is described in a series of papers by Schweder and coauthors (e.g. Schweder *et al.* 1998, Schweder *et al.* 2000; Schweder 2005; Aldrin and Schweder 2005). Schweder (2005, p310) stated that the aim of the modeling exercise is "to evaluate the effect on the cod-, capelin-, and herring fisheries of managing minke whaling and harp sealing in the Barents Sea", i.e. the same system as that modeled by Hjermann *et al.* (2004a). This set of simulations initially modelled what will happen to fisheries of herring, cod, and capelin in the Barents Sea when northern minke whales are hunted (Schweder *et al.* 1998, 2000). The simulations were then extended to include harp seals (Schweder, 2005).

The model includes some strong assumptions that are unrealistic. For example, in the models, the authors "assume that the population dynamics of the minke whale is independent of stock status of herring, capelin and cod" (Schweder *et al.* 1998 p79). This same assumption holds for harp seals, which Schweder (2005) notes may be unrealistic, and that the species being modeled may interact in ways other than through predation.

When the data on harp seals are added the Scenario C model collapses (Aldrin and Schweder 2005, Figure 4). So despite several years' work, and 25,000 lines of C code (Schweder 2005), the modelling approach cannot inform management options for marine mammals, as was its intent. Yet a model without marine mammal predation hindcasts the system well (Hjermann *et al.* 2004). The weight of scientific evidence available at present indicates that whales eating fish is not an ecological problem for Norwegian fisheries.

Schweder (2005) wonders whether increased sealing will improve fisheries in the way that the members of the government and fishermen hope. But massive depletions of most of Europe's harbour seal populations in two epizootics (Harding *et al.* 2002; Härkönen *et al.* 2006) have not resulted in detectable improvements in fisheries landings. Studies elsewhere suggest that the effect of seals' predation on commercial fish is trivial compared with that of fisheries (e.g. Hansen and Harding 2006; Trzcinski *et al.* 2006; Matthiopoulos *et al.* 2008). Current monitoring of marine mammal populations and fisheries effort in Norwegian waters is almost certainly inadequate to detect a signal of change in fisheries landings from changes in the abundance of marine mammals.

CONCLUSION

Where good data are available, there is no evidence to support the contention that marine mammal predation presents an ecological issue for fisheries. It is not true that "scientific research has shown that whales consume huge quantities of fish", as has been pointed out elsewhere (Kaschner and Pauly 2004, Holt 2006, Leaper and Lavigne 2008). The research programs that support culling use antiquated field techniques, which tend not to generate data useful for addressing questions on the ecological role of marine mammals.

The coastal waters of the three nations leading the "whales-eat-fish" calls (Japan, Norway and Iceland) are almost all very highly impacted by human activities (Halpern *et al.*, 2008). Fisheries problems are mostly of their own making (e.g. Pauly *et al.* 2002, Pauly *et al.* 2003; Pauly *et al.* 2005), and represent a genuine threat to the food security of coastal nations. Suggestions that fisheries problems can be attributed to whales consuming huge quantities of fish distract attention from the root causes of these problems: fisheries mismanagement.

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