FISHING GREEN

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The use and perceived misuse of natural resources utilized for food production have become major issues in many places in the world, and California is among the leaders in public awareness and regulation. Sustainable harvesting and processing, and avoiding foods that have high energy consumpton in their production and/or transportation, are all coming under increased attention.

Fishing green implies that fisheries are harvested at a sustainable level, and many are now advocating harvesting fisheries resources at levels below the maximum sustainable level (i.e lower than the economic maximum long-term yield). For example, federal management now includes 'buffers' that set annual quotas less than the maximum biological yield. Other elements of fishing green can be achieved in three major ways: (1) reduce the harvest of foods that have high energy costs in their production, capture or transportation, (2) reduce harvest of high trophic level species that require a large amount of primary production to replace their numbers, (3) support efficiency in the production of fishery resources. The metric for this new way of measuring sustainability is "calories in vs. calories out".

Although not well known, purse-seine fisheries for small pelagic species have energy costs that are comparable to those found in the most energy-efficient food crops. Recent studies clearly show that the energy required in the production of foods from fisheries, farming and animal husbandry is highly variable (Pelletier et al 2011, Woods et al 2010). Tyedmers (2008) showed that the energy required in the transport of seafoods was more dependent upon the mode of transport than the miles transported; transport by sea being far more efficient than trucking or air tranport. Tyedmers' (2001) analysis of the energy used in a wide range of North Atlantic fisheries demonstrated that purse-seine fisheries are by far the most energy efficient. **Evidence presented here shows that the California purse-seine fishery for coastal pelagic species (squid, sardine, mackerels and anchovy) is among the most energy efficient food production systems in the world.**

Reduce Harvest of Foods with High Energy Costs in Their Production:

Direct fuel energy inputs to fisheries account for between 75 and 90% of the total energy input required in the harvest of marine species (Tyedmers 2001). The remaining 10 to 25% includes direct and indirect energy inputs associated with vessel construction and maintenance, providing fishing gear, and labor. There is a wide range of energy costs in different fisheries. Fisheries for benthic species and high trophic level pelagic species tend to be more energy intensive than targeted pelagic trawling or purse-seining for small or mid-sized pelagic species. More passive techniques such as gillnetting, hook-and-line and trapping tend to have somewhat lower energy costs than trawling, but long-lining for high seas species such as tunas and billfishes requires relatively high energy costs (Tyedmers 2001).

To demonstrate the wide range of energy inputs needed to harvest different species using different fishing gear types, I have extracted a number of examples from the literature and have included a number of examples taken from local California fisheries (Figure 1,Table 1). For comparative purposes, the fuel consumption of a number of mostly European and North American fisheries is expressed in common units (i.e. gallons of fuel used to land one metric ton (gal/mt) of fish or shellfish).

Fisheries for lobsters have very high fuel usage, with landings averaging 717 gallons of fuel per metric ton landed. Shrimp trawl fisheries are also very inefficient fuel consumers (271 gal/mt). Tyedmers (2002) points out that the 5 'low-bycatch' shrimp fisheries he examined burned a total of 136 million liters of fuel in the process of landing 149,000 tonnes of shrimp. Groundfish fisheries have a wide variety of gear types, including otter trawl, long-line, gillnets, and landings in these fisheries: trawl fisheries consumed an average of 176 gal/mt and non-trawl fisheries consumed (213 gal/mt). Hook and line fisheries for large pelagic species, salmon, tunas and billfish also have very high fuel usage varying from 95 to 460 gal/mt with an average of 258 gal/mt.

In contrast, fisheries for small and medium sized pelagic species that commonly school or shoal are much more fuel-efficient. Mid-water and pelagic trawl fisheries used an average of 20 gal/mt of fish. The most efficient of these fisheries (Pacific hake) used only 9 gal/mt of hake. . Purse-seine fisheries for small pelagic fishes and squid are the most fuel-efficient of all the fisheries averaging only 13 gal/mt caught. An example is from a representative sample of California purse-seiners that target coastal pelagic species: these boats used only 6 gal/mt. (Table 2).

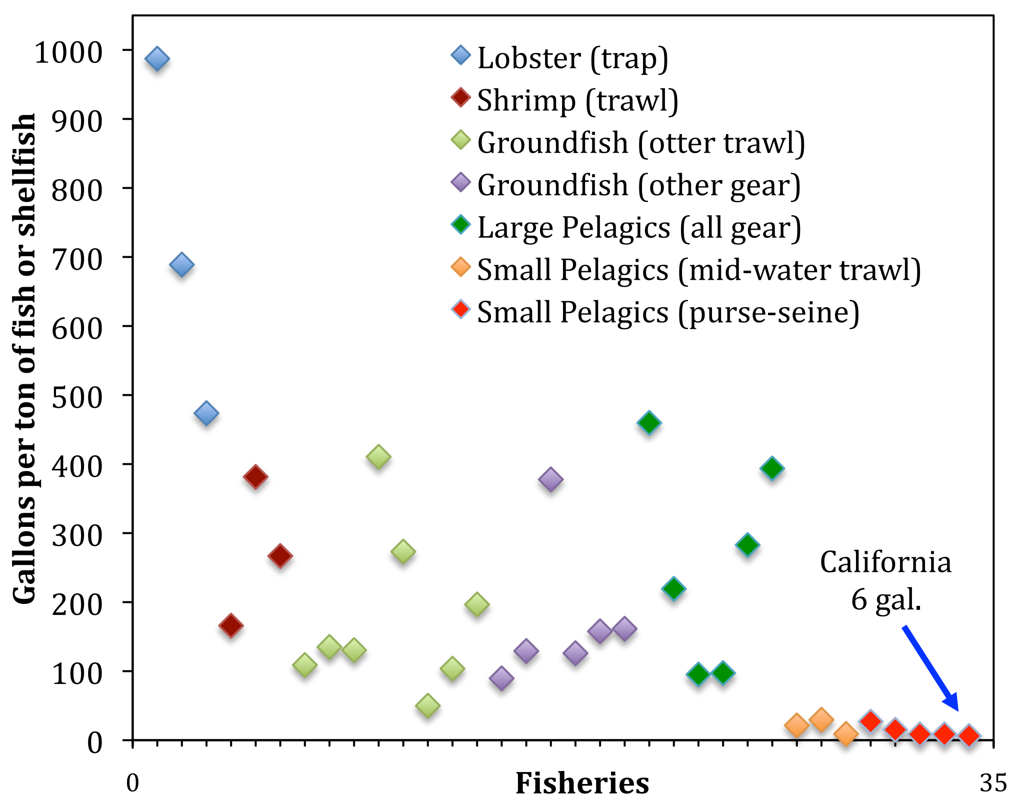


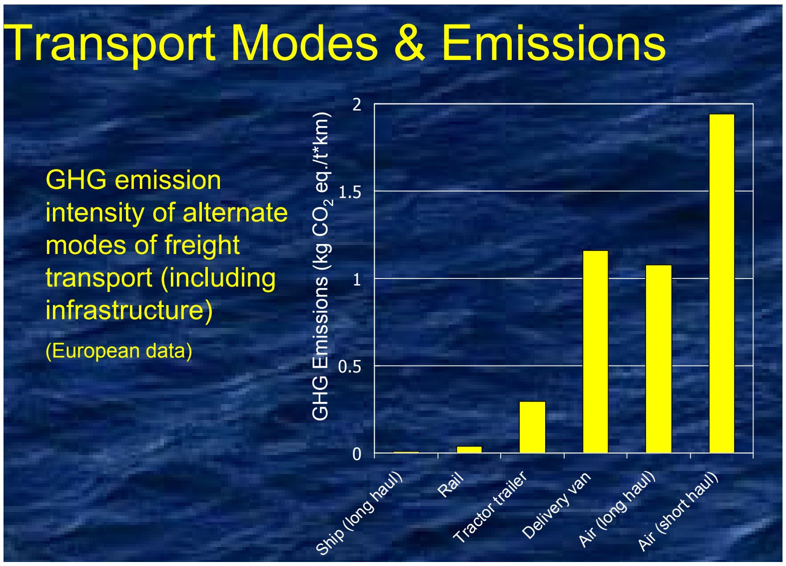
Figure 1. Gallons of fuel burned to land a metric ton of fish or shellfish in a range of fisheries targeting different species and using different fishing gear.

In comparing the fuel required to produce field crops vs fish and shellfish, it is clear that terrestrial food production systems have as wide a range of fuel usage as fisheries (Table 1). The most efficient field crops – corn, soybeans, wheat and potatoes –have comparable fuel efficiency (i.e. 8-24 gal/mt) to the pelagaic trawl and purse-seine fisheries for small pelagic species. Energy useage to produce pork

(108 gal/mt) and beef (179 gal/mt) in the UK are comparable to trawl fisheries for bottomfish. Hot-house tomato production in the UK requires 787 gal/mt which is greater than the average fuel usage for lobster fisheries.

Reduce Consumption of Foods with High Transportation Costs.

"Food miles' are often used as an example of the energy use of the transportation segment of the food delivery system. However, Tyedmers (2008) states that transport often makes a small contribution to overall emissions related to seafood production, and the mode of transport is more important than the miles (Figure from Tyedmers (2008).



One example given by Tyedmers (2008) describes the differences in the emissions due to the air transport of fresh Alaska salmon to San Francisco and the surface transport of Alaska frozen/smoked salmon to San Francisco. The transport emissions from the fresh salmon was nearly 20 times that from the transport of frozen/smoked salmon. Tyedmers' study also found the greenhouse gas emissions (GHG) for long haul shipping were by far the lowest of any transport method. In the California squid fishery, where much of the landings are transported by sea to Asia for processing and then some are returned to the US for consumption, the carbon footprint is among the lowest of global fisheries. In contrast, emissions from air transport of live California lobster to consumers in Asia are likely to be similar to those in the air transport of fresh Alaska salmon to San Francisco.

Summary: Combining the two major sources of energy usage and carbon emission, production and transport, it is clear that California's purse-seine fishery has extremely low energy usage for production and low energy usage for transport. California's trawl fisheries have average energy usage for both production and transport, while California's lobster fishery has very high energy usage for both production and transport.

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Table 1. Fuel consumption of fishing vessels in relation to landings (gallons of fuel per metric ton of fish or shellfish).

Country	Gear	Species	gal/mt
TRAWL (SHRIMP)			
Canada	Trawl	shrimp	166
Norway	Trawl	shrimp	381
Iceland	Trawl	shrimp	267
		Average	271
TRAWL (FISHES)			
Canada 1999[1]	Trawl	redfish, flatfish, cod	109
Norway 1998[1]	Trawl	cod, saithe, haddock	135
Iceland 1997[1]	Trawl	cod, redfish, saithe	131
Germany 1998[1]	Trawl	cod, plaice, haddock	411
Japan (in USA) 1971[2]	Trawl	rockfish, pollock, blackcod	273
Washington 1971[2]	Trawl	rockfish, cod, hake	50
Monterey 2000-3[3]	Trawl	rockfish, blackcod, flatfish	104
Monterey 2010-2[3]	Trawl	flatfish, sandabs, halibut	197
		Average	176
OTHER BOTTOM GEAR			
Canada 1999[1]	Dredge	scallops	90
Canada 1999[1]	Long-line	cod, haddock, hake	129
Canada 1999[1]	Gillnet	cod, saithe, halibut	378
Norway 1998[1]	Long-line	cod, haddock, ling	126
Iceland 1997[1]	Long-line	cod, haddock, dab	158
Iceland 1997[1]	Hand-line	cod, saithe, redfish	161
		Average	213
LOBSTER			
Norway[1]	Trap	lobster	987
California[3]	Trap	lobster (Santa Cruz Is.)	689
California[3]	Trap	lobster (Point Loma)	474
		Average	717
LARGE PELAGICS			
Canada 1999[1]	Long-line	swordfish, tuna	460
NE Pacific 1990s[4]	Troll	salmon	219
NE Pacific 1990s[4]	Purse-seine	salmon	95
Global[5]	Purse-seine	tuna	97
Global[5]	Long-line	tuna	283
Global[5]	Pole and line	tuna	394
		Average	258
PELAGIC TRAWL (pelagic fishes)			
Iceland `1997[1]	Pelagic trawl	capelin, herring, whiting	21
Germany 1998[1]	Pelagic trawl	mackerel, herring, sardine	30
USA Oregon[6]	Pelagic trawl	hake	9
		Average	20

PURSE SEINE (small pelagic fishes and squid)			
Norway1998[1]	Purse-seine	herring, whiting, mackerel	27
Iceland 1997[1]	Purse-seine	herring, capelin	15
Canada 1999[1]	Purse-seine	herring, capelin, mackerel	8
USA East Coast 1999[1]	Purse-seine	menhaden	8
USA California[3]	**Purse-seine**	**squid, sardine, mackerel**	**6**
		Average	13

COMPARATIVE FIELD CROPS AND MEAT PRODUCTION

USA[7]	corn	16
USA[7]	soybean	24
UK[8]	milling wheat	16
UK[8]	potatoes	8
UK[8]	carrots	11
UK[8]	milk	16
UK[8]	pork	108
UK[8]	beef	179
	tomato (hot-house)	787

[1]Tredmers (2001); [2]Wiviott and Mathews (1975); [3]unpublished data; [4]Tredmers (2004) [5]Tyedmers and Parker (2012), [6] Philbin (1980) . [7]Woods et al 2010. [8] Ziesmer 2007.

Table 2. Fuel usage, landings in lbs. of fish per pound of fuel for 10 Southern California CPS purse-seiners in 2010.

Boat	Fuel (Gal)	Squid	Sardine	Mackerel	Anchovy	Total lbs	gal/mt
1	36,000	5,867,880	5,041,322	202,771		11,111,973	7.14
2	20,868	4,400,000				4,400,000	10.46
3	26,650	9,381,360	2,560,759		891,798	12,833,917	4.58
4	15,039	6,218,158	578,470		613,357	7,409,985	4.47
5	35,557	6,493,596	7,496,542	478,111	5,905	14,474,154	5.42
6	19,101	6,111,121	336,430			6,447,551	6.53
7	20,911	6,606,189	5,823,135	411,620	16,855	12,857,799	3.59
9	23,035	3,155,841	937,370	43,617		4,136,828	12.28
10	26,577	1,980,247	3,461,362	584,060		6,025,669	9.72
12	24,000	7,000,000	960,000	300,000	250,000	8,510,000	6.22
Total	247,738	57,214,392	27,195,390	2,020,179	1,777,915	88,207,876	6.19