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Fishing gear associated with global marine catches II. Trends in trawling and dredging

R. Watson [a,*], C. Revenga [b], Y. Kura [b]

[a] UBC Fisheries Centre, Aquatic Ecosystems Research Laboratory, 2202 Main Mall, Vancouver, BC, Canada V6T 1Z4
[b] World Resources Institute, 10 G Street, NE, Washington, DC 20002, USA

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Abstract

A new method for associating global marine catch statistics with fishing gears has allowed the creation of maps which detail the changing use of fishing gears such as trawls and dredges from the 1950s to the present. These gears, often associated with high impacts on benthic communities, are associated with a wide range of demersal fish, molluscan and crustacean catch. The use of these gears has increased globally since the 1950s when it accounted for more than 40% of reported catches to a peak in most areas such as North America and Europe in the 1980s. This increase extended into the 1990s along the coast of Argentina particularly for squid. Dredging, usually associated with the catch of bivalves, often peaked later than trawling but had begun to decline in most areas by the 1990s.

Keywords: Fishing gear; Database; Fish catch; Trawl; Dredge

1. Introduction

Bottom trawls and dredges are among the most destructive fishing gears in use (Engel and Kvitek, 1998), with the capacity to greatly disrupt benthic ecosystems in shallow as well as in deep sea waters. Typically bottom trawls are large nets that are pulled across the seabed held open by the drag on large planning surfaces called boards or doors. These are usually heavily weighted and scour the bottom, while the bottom edge of the net tends to break off brittle bottom flora and fauna such as sponges and corals, and disturb the underlying substrate. Dredges are basically a metal-toothed bar or blades which dig into the seabed and scoop molluscs into a steel reinforced net.

Although the degree of damage depends on a number of factors, including the frequency and intensity of trawling, and the type of seabed habitat, the destruction of seafloor habitats is a factor in the decline of some fishing stocks in heavily trawled areas (Watling and Norse, 1998). Besides the immediate impacts on bottom sediments and turbidity, broader impacts on benthic habitats and on bottom-living species can last decades or even centuries.

A recent study by the United States National Research Council (NRC, 2002) on the impact of bottom trawling and dredging on the marine environment concluded that repeated trawling can shift marine species composition toward small opportunistic species – such as sea stars and small short-lived clams – while reducing the overall biomass of the area by removing aquatic vegetation and bottom-dwelling animals. Studies of the impact of shrimp trawling in the Great Barrier Reef Marine Park in Australia, for example, showed that a single trawl removed 5–25% of the bottom-dwelling organisms, and that repeated trawling had a cumulative impact (Poiner et al., 1998). Trawling has been shown to alter the trophic structure of benthic invertebrate communities (Jennings et al., 2001). In deep ocean habitats the impacts are potentially greater. After study of deep ocean slope sites, Cryer et al. (2002) inferred that trawling probably changes benthic community structure and reduces biodiversity over broad spatial scales.

* Corresponding author. Tel.: +61 3 6224 8574; fax: +1 604 822 8934.
E-mail address: r.watson@fisheries.ubc.ca (R. Watson).

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Another major impact of bottom trawling is the large incidental catch of non-targeted species. Some of this bycatch is retained for sale, but a portion of it – often a large portion – is returned to the sea, usually dead or dying. In general, fishing gears that are towed along the bottom seem to have the highest bycatch rates. According to Alverson et al. (1994), the top 20 highest discard ratios (the ratio of target species to discards, by weight) are dominated by bottom trawl fisheries where only one-fifth or less of the catch is usually retained. A recent review of the different fishing gears used in the United States and their impact on ecosystems confirms that bottom-trawling rigs, bottom gillnets and dredges have the worst ecological impacts (Morgan and Chuenpagdee, 2003; Chuenpagdee et al., 2003; NRC, 2002).

Given the concern about the use of trawl and dredge gears there is necessarily much concern about where they deployed, and how their use has changed in recent years. There is potential to impact critical habitats such as coral reefs and seagrass areas (Kaiser et al., 2002). There is also concern about their use in deepwater and in unregulated high seas areas (Hall-Spencer et al., 2001; Cryer et al., 2002; Fossa et al., 2002). Using a new gear associated global database described in a companion paper (Watson et al., this volume) we are able to characterize the associated catches of these gears, and examine patterns of their use globally.

2. Methods

For each organism or group of organisms reported in the global catch database developed by the Sea Around Us Project (SAUP) based on FAO and other data sources (Watson et al., 2004), Watson et al. (this volume) associated gear type as defined by von Brandt (1984). They found it possible to associate the majority of global catch records with up to five gear types in order of importance and to extrapolate these associations to all global catch records. In this way it was possible to use the mapped results of the SAUP (Watson et al., 2005) to produce maps of catches by all gear types annually since 1950.

3. Results

3.1. Global catch by trawl and dredge

The reported composition of trawl and dredge catch is quite diverse. Broken down by major ISSCAAP groupings (i.e., the broad taxonomic groups reported by FAO), the largest catches were of shrimps and prawns, followed by several fish groups (Table 1). The mollusc groups such as clams, cockles, arkshells, scallops, pectens and oysters were taken predominately by dredge gear. Other gear types, such as purse seine, took the majority of the catch reported for some groups,

Table 1
Breakdown of average global catch (tonnes) taken by bottom trawl, dredge or other gear into FAO's 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) groups annually for the 1970s and 1990s

ISSCAAP group	1970s				1990s			
	Bottom trawl	Dredge	Other	Total	Bottom trawl	Dredge	Other	Total
Shrimps, prawns	6122435	–	125715	6248150	2385189	–	362072	2747261
Marine fishes (not elsewhere included)	2888503	–	781301	3669804	1203034	–	819991	2023025
Sharks, rays, chimaeras	2051973	–	231250	2283223	452837	–	315361	768198
Squids, cuttlefishes, octopuses	473612	–	710634	1184246	1528082	–	1351549	2879631
Salmons, trouts, smelts	29425	–	2917770	2947195	32509	–	2107267	2139779
Lobsters, spiny-rock lobsters	26454	–	125954	152408	40964	–	180348	221312
Craylets, squat lobsters	24180	–	85338	109518	5478	–	66441	71919
Sea-spiders, crabs	6793	–	340082	346875	205694	–	878659	1084353
Krill, planktonic crustaceans	5514	346	1906	7766	5122	1326	169793	176241
Flounders, halibuts, soles	–	–	202757	202757	833190	–	201686	1034876
Cods, hakes, haddocks	–	–	9035767	9035767	2005888	–	8457450	10463338
Redfishes, basses, congers	–	–	2729229	2729229	2549853	–	3847493	6397346
Jacks, mullets, sauries	–	–	2110889	2110889	327645	–	2675150	3002795
Herrings, sardines, anchovies	–	–	16762081	16762081	1646588	–	23738200	25384788
Tunas, bonitos, billfishes	–	–	6679086	6679086	914	–	9097174	9098088
Mackerels, snoeks, cutlassfishes	–	–	3417313	3417313	1133641	–	7829777	8963418
Abalones, winkles, conchs	–	48718	55431	104149	–	89719	74097	163816
Oysters	–	396565	1204	397769	–	243544	1476	245020
Mussels	–	179948	304374	484322	–	93881	229813	323694
Scallops, pectens	–	344358		344358	–	1208742	–	1208742
Clams, cockles, arkshells	–	630222	76865	707087	–	919170	122870	1042040
Sea-squirts and other tunicates	–	1166	4190	5356	–	1663	4895	6558
Horseshoe crabs and other arachnoids	–	6	24	30	–	276	–	276
Sea cucumbers and other echinoderms	–	37937	39808	77745	–	13042	104452	117494
Total	11628889	1639266	46738968	60007123	13356628	2571363	62636014	79564005

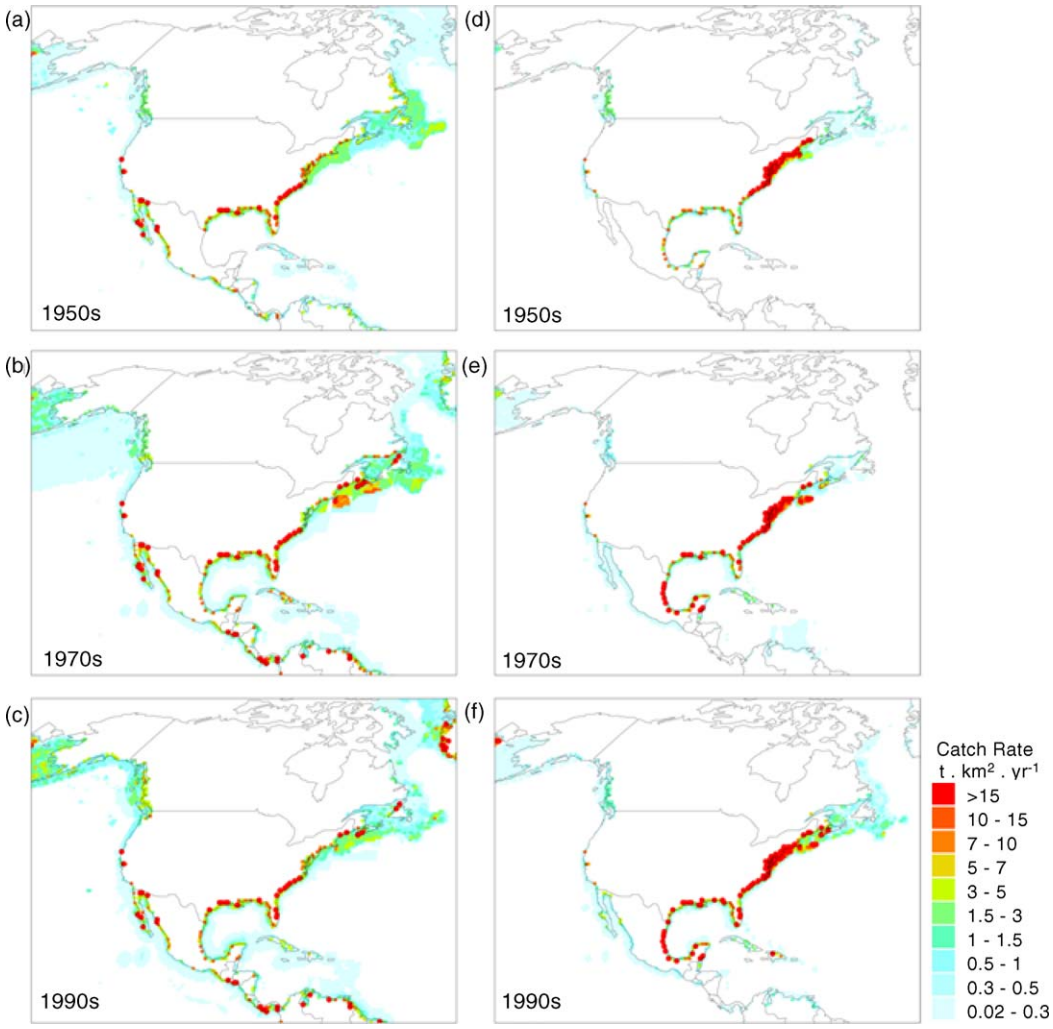

Fig. 1. Maps of catch rate (tonnes km^2 year^{-1}) associated with bottom trawl (a–c) and dredge gears (d–f) from North America for the 1950s, 1970s and 1990s.

largely pelagic species, such as the group 'Tunas, Bonitos and Billfish'.

3.1.1. North America

Mapped catch rates of all animals combined taken by bottom trawl and dredge gears reveal many changes since the 1950s (Fig. 1). In the 1950s the highest catch rates for either type of gear were along the mid to northern seaboard of the US (Fig. 1a and d). By the 1970s, the bottom trawl and dredge fisheries had increased their ranges, particularly to northern Alaska and the west coast of Canada. Most notable here were the major bottom trawl fisheries for pandalid shrimps, king crabs (*Paralithodes*) and yellowfin sole (*Monochirus luteus*). Also by the 1970s, bottom trawl fisheries along the northeast coast of North America for haddock (*Melanogrammus aeglefinus*) and sea catfishes (Ariidae) fisheries had declined, followed by the decline of fisheries for silver hake (*Merluccius bilinearis*) by 1977.

Notwithstanding individual declines, bottom trawl and dredge fisheries continued to expand each decade and peaked in the 1980s when major trawl areas included much of Alaskan waters, northern Washington, areas of the Gulfs of California and Mexico, as well as Nova Scotia. Along the North American northeast coast there were increases in catch of bottom trawled yellowtail flounder (*Limanda ferruginea*), summer flounder (*Paralichtys dentatus*), American plaice (*Hippoglossoides platessoides*) and pandalid shrimps. Along the southeast coast of North America and into the Gulf of Mexico, there were increases in the catch of bottom trawled Atlantic seabob (*Xiphopenaeus kroyeri*) and sea catfishes (Ariidae). Along the west coast of the U.S. there were increases in trawled Pacific Ocean perch (*Sebastes alutus*), tonguefishes (Cyanoglossidae) and rockfishes (Scorpaenidae).

By the 1990s, catches from bottom trawling were in general decline. Along the northeast coast, there were reductions in Flounder catches. Along the southeast and into the Gulf of Mexico there were declines in catches of the northern pink shrimp (*Penaeus duorarum*). Other bottom trawl fisheries that increased after the 1970s and along the north-

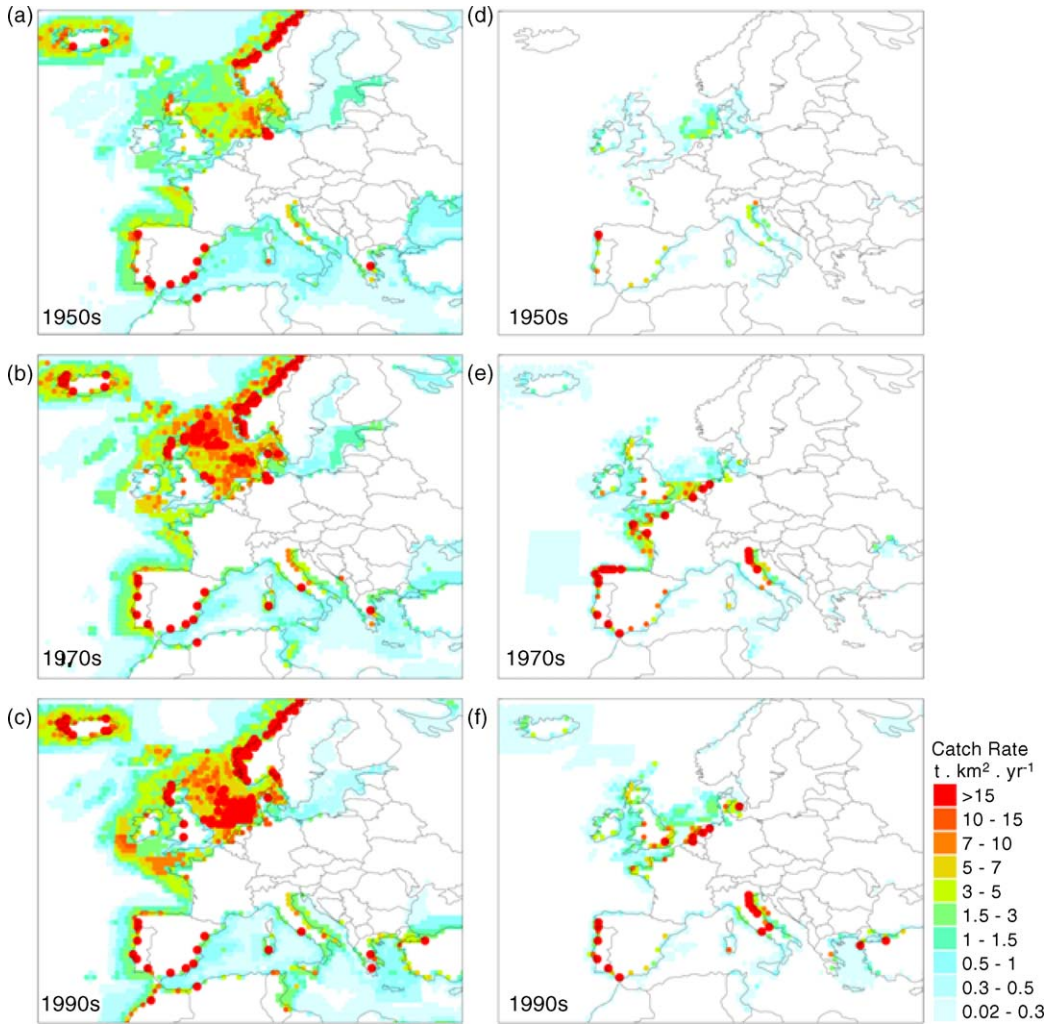

Fig. 2. Maps of catch rate (tonnes km^2 $year^{-1}$) associated with bottom trawl (a–c) and dredge gears (d–f) from Europe for the 1950s, 1970s and 1990s.

east coast included fisheries for northern prawn (*Pandalus borealis*), Greenland halibut (*Reinhardtius hippoglossoides*), American angler (*Lophius americanus*) and piked dogfish (*Squalus acanthus*). Further south, there was an increase in trawl fisheries that took rays (*Raja*) and shrimp (*Penaeus*). Along the northwest coast and into Alaska increases in bottom trawled catches included yellow sole (*M. luteus*), Pacific cod (*Gadus macrocephalus*), the lesser sand eel (*Ammodytes marius*) and rock sole (*Lepidopsetta bilineata*). Along the southwest trawled catch of common squid (*Loligo*) increased.

The catch of dredge fisheries in North America increased after the 1950s. The increases along the East coast included Atlantic surf clam (*Spisula solidissima*) in the north and the American cupped oyster (*Crassostrea virginica*) to the south. Along the northwest coast, there were increases in the weathervane scallop (*Patinopecten caurinus*), striped Venus (*Chamelea gallina*), Pacific cupped oyster (*Crassostrea gigas*) and Stimpson's surf clam (*Spisula polynyma*). Some dredge fisheries peaked before the 1990s; these include those for the calico scallop (*Argopecten gibbus*) in the southeast and for scallops (Pectindae) in the southwest. By the 1990s, the dredge fishery for the American cupped oyster (*C. virginica*) had declined and that for the ocean quahog (*Arctica islandica*) had increased in the northeast. In the southwest there was a decline in dredged catches of the Pacific cupped oyster (*C. gigas*).

3.1.2. Europe

The expansion of bottom trawl and dredge fisheries in Europe was as strong as in North America (Fig. 2). Though historically fisheries in the North Sea predate many others in the Western World, there was nevertheless a clear increase in intensity from the 1950s until about 1980.

Starting from the 1950s, there was an increase in bottom trawl catch of sand lances (*Ammodytes*) and Atlantic horse mackerel (*Trachurus trachurus*). At this time, there was a decrease in catches of ocean perch (*Sebastes marinus*). For dredge fisheries there were increases in catches of the great Atlantic scallop (*Pecten maximus*).

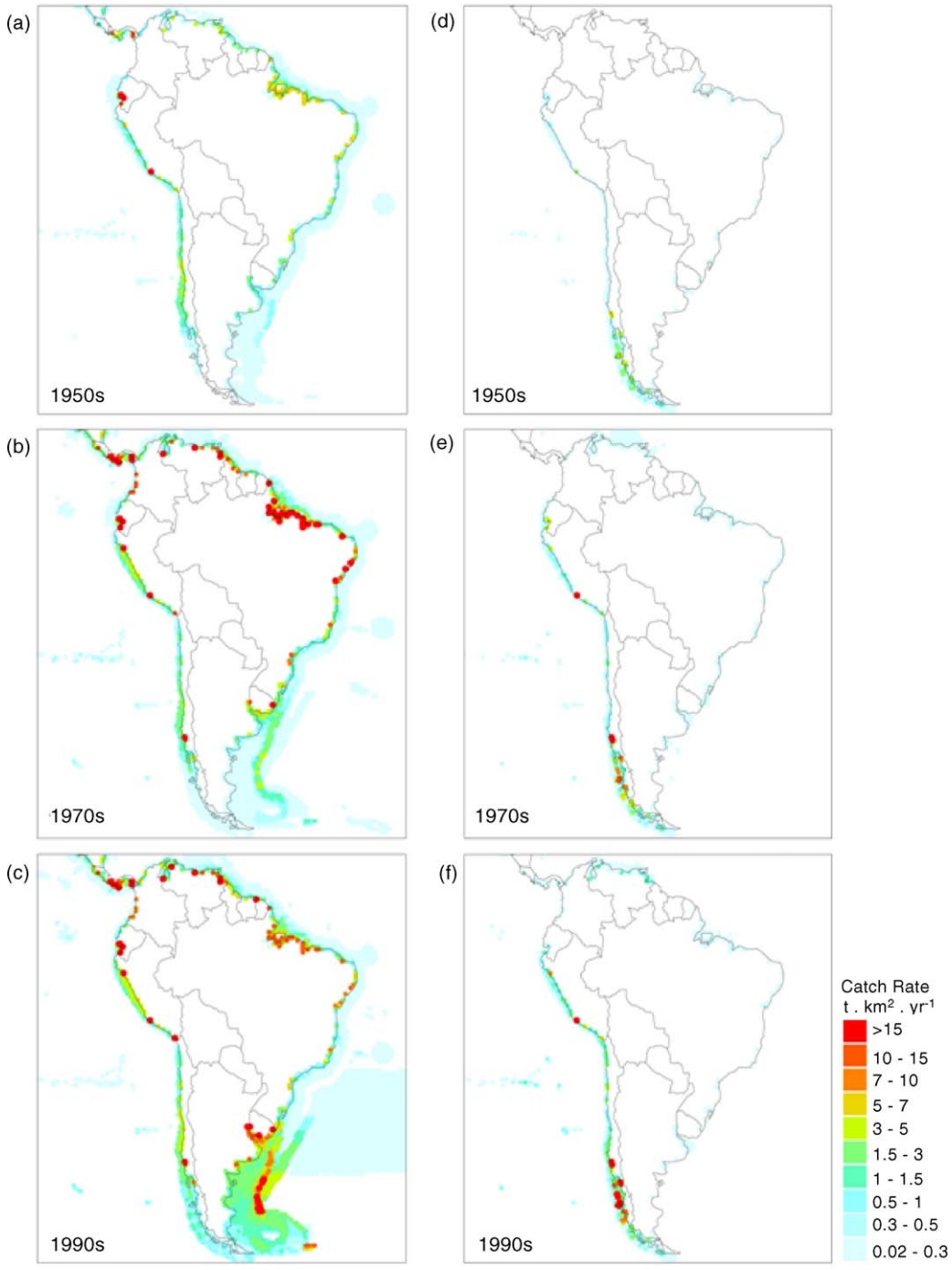

Fig. 3. Maps of catch rate (tonnes km^2 year^{-1}) associated with bottom trawl (a–c) and dredge gears (d–f) from South America for the 1950s, 1970s and 1990s.

There were peaks in the catch of some bottom trawl fisheries after the 1970s and these included those for haddock (*M. aeglefinus*), saithe (*Pollachius virens*) and some sand lances. The dredge fisheries for the blue mussel (*Mytilus edulis*) and cupped oysters (*Crassostrea*) also peaked. Most expansion occurred offshore on the northern boundary of the North Sea.

In the 1990s there were increases in catches of bottom trawled northern prawn (*P. borealis*) and dredged common cockle (*Cerastoderma edule*). By this time, the area of maximum trawl catch rates had contracted to the North Sea closer to Germany and Denmark (Fig. 2c).

3.1.3. South America

Along the coasts of South America (Fig. 3), there has been a steady expansion in trawl and dredge-related catch up to and including the 1990s, especially along the coast of Argentina. Here the biggest bottom trawl expansion was the fishery for Argentine short-finned squid (*Illex argentinus*) in the mid

1980s. There was a steady expansion in the trawl fishery for the Argentine hake (*Merluccius hubbsi*) and southern blue whiting (*Micrormesistius australis*). Along the west coast of South America, where purse seine gear dominates, the bottom trawl fisheries for southern hake (*Merluccius australis*) and Peruvian hake (*M. gayi peruanus*) expanded after the 1950s. In the 1990s, parallel to that along the Argentine coast, there was an increase in the catch of the southern blue whiting. Changes along South America since the 1950s were less than those shown in North America.

Dredge fisheries in this part of the world are minor compared to those based on other fishing gears. Along the Argentine coast there was an increase in the 1990s in catch of scallops (Pectinidae), and along the coasts of Peru and Chile, the dredge catch of Taca clam (*Protothaca thaca*), Peruvian calico scallop (*Argopecten purpuratus*), carrot squat lobster (*Cervimunida johni*) and slipper cupped oyster (*Crassostrea iredalei*) increased after the 1950s.

3.1.4. Africa

Along the coast of Africa there has been an expansion in the catch rates associated with bottom trawl gear. This expansion first occurred along the Western Sahara, Senegal and the Gambia, and by the 1970s included the coast of Namibia and the south of Angola. Isolated areas of the Gulf of Guinea were also involved (Fig. 4). There was some increase along Mozambique and the north coast of Madagascar. Dredge fisheries were not important in these time periods and therefore are not described here.

Along NW Africa, there were increases in the trawled catches of cuttlefishes (Sepiidae) and the common sole (*Solea solea*) after the 1950s. By the 1970s, there was a peak in catches of trawled Senegalese hake (*Merluccius senegalensis*), large-eye dentex (*Dentex macrophthalmus*), porgies (Sparidae), rays (*Raja*) and Atlantic horse mackerel (*T. trachurus*). Similarly along the SW coast of Africa, trawling for hakes, especially the Benguela hake (*Merluccius polli*) and for dentex (*Dentex* spp.) also peaked in the 1970s. As these declined in the 1990s, others increased including fisheries for octopus (Octopodidae) and sea catfishes (Ariidae) in the NW, and Atlantic horse mackerel in the SW.

3.1.5. Asia

Maps of Asia show a steady expansion in reported catch rates for bottom trawl and dredge associated fisheries (Fig. 5). Throughout the region, there was an increase in the trawled catch of cuttlefish (Sepiidae) after the 1950s.

In the trawl fisheries of the East China Sea and the Sea of Japan there were declines in the catch of yellow croaker (*Larimichthys polyactis*) after the 1950s. There were, however, increases by the 1990s in the catches of smaller species with lower trophic levels including Japanese anchovy (*Engraulis japonicus*), Gazami crab (*Portunus trituberculatus*), southern rough shrimp (*Trachypenaeus curvirostris*), yellowfin sole (*Lamada aspera*) and golden threadfin (*Nemipterus virgatus*).

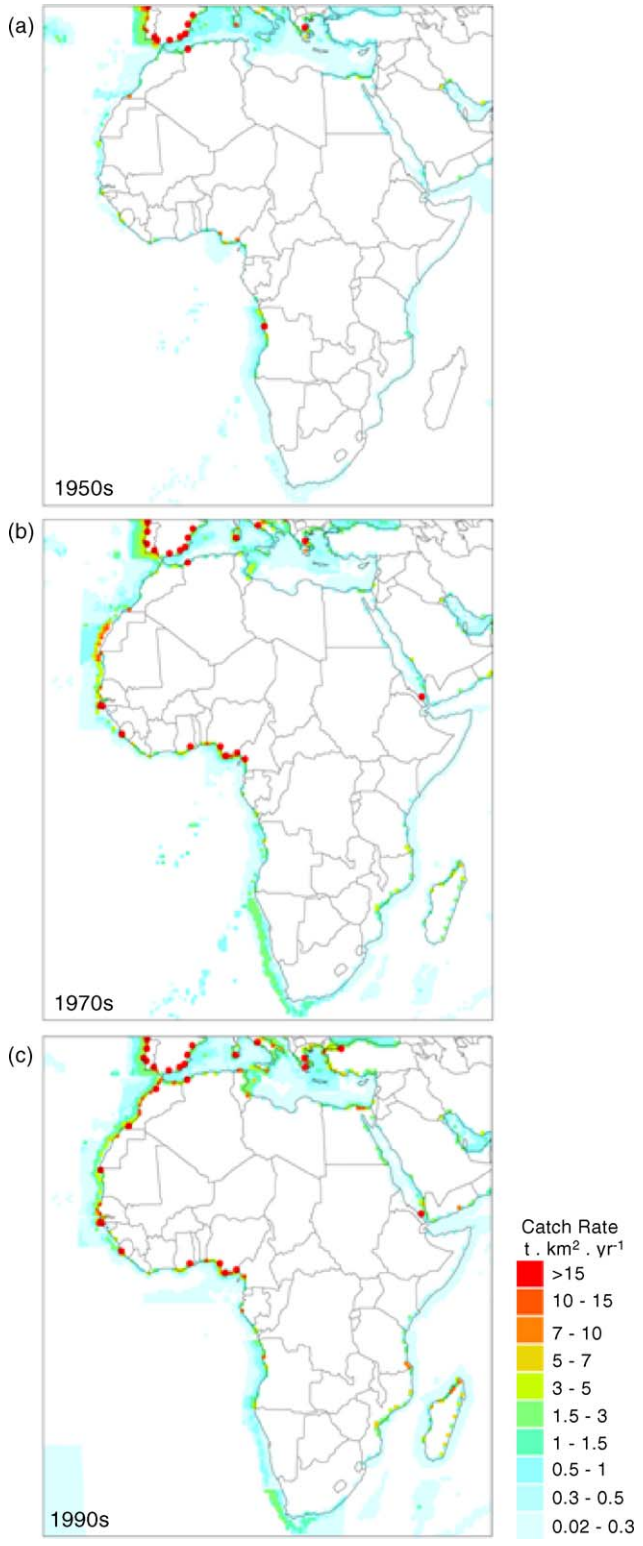

Fig. 4. Maps of catch rate (tonnes km^2 year^{-1}) associated with bottom trawl from Africa for the (a) 1950s, (b) 1970s and (c) 1990s.

In the South China Sea, extending to the Arabian Sea and the west coast of India, there were increases after the 1950s in the trawl catches of anchovies (*Stolephorus* spp.), giant tiger prawn (*Penaeus monodon*) (though some of the latter

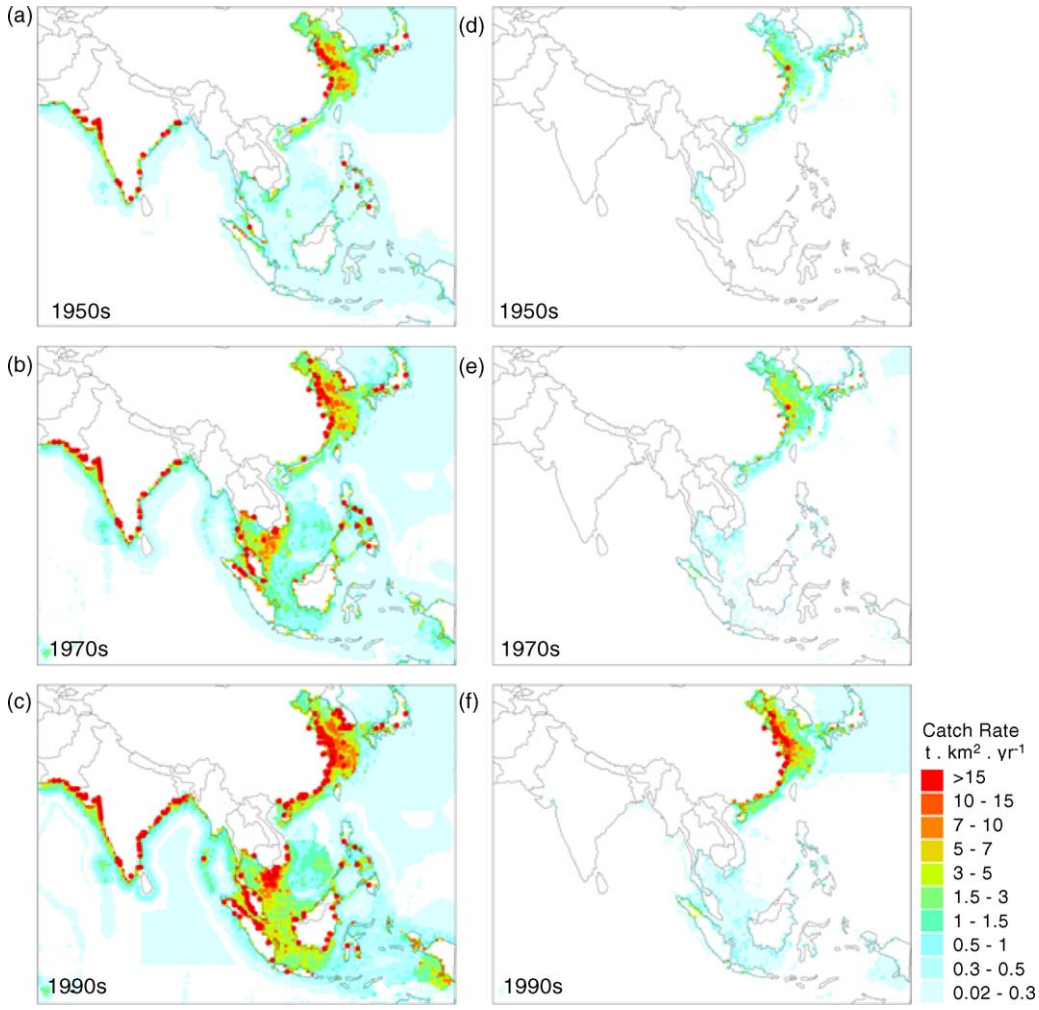

Fig. 5. Maps of catch rate (tonnes km^2 year^{-1}) associated with bottom trawl (a–c) and dredge gears (d–f) from Asia for the 1950s, 1970s and 1990s.

could be misreported aquaculture production). There were also increased bottom trawl catches along the coast of India of sea catfishes (Ariidae) and the southern rough shrimp, while shrimps from the family Crangonidae peaked in the 1970s. Trawled catches of some unidentified penaeid shrimp decreased in this area in the 1990s. Though the expansion appears to have peaked along the west coast of India by the 1970s, the coast of China showed a continued expansion of reported catch rates, as did those of Thailand, Malaysia and Indonesia.

Dredging was less important in this region but was important in inshore areas of the Sea of Japan and the East China Sea. Though catch of dredged Japanese carpet shell (*Ruditapes philippinarum*) peaked in the 1970s, others like the Japanese scallop (*Patinopecten yessoensis*) and ark clams (*Arca*) continued to increase. Further south in the South China Sea, dredged catches of brown mussel (*Perna viridis*) peaked in the 1970s, the short-necked clams (*Paphia*) peaked in the 1980s, while Anadara clams (*Anadara*) continued to increase after the 1950s.

3.2. Proportion of catch using trawl or dredge gear

The expansion of bottom trawl gear as the dominant gear associated with coastal fisheries catch in many areas of the world is evident in Fig. 6. This figure shows the proportion of all catch that is taken by bottom trawl. Even in the 1950s, for many areas of the world, this gear accounted for more than 40% of all reported catches. The association increased decade by decade with concentrations of trawling increasing in many locations. By the 1970s, trawl fisheries for American plaice (*H. platessoides*) along the west coast of Greenland and the Grand Banks of Newfoundland, marbled rockcod (*Notothenia rossii*) along the coast of Antarctica and the Weddell Sea, Japanese anchovy (*E. japonicus*) in Asia, and prawns, such as banana prawn (*Penaeus merguiensis*), along the north coast of Australia dominated fisheries by all other gears. This expansion process continued, and by the 1990s, trawl fisheries for blue grenadier (*Macruronus novaezelandiae*) around New Zealand and for the Argentine short-fin squid along the coast of Argentina dominated fisheries using other gears.

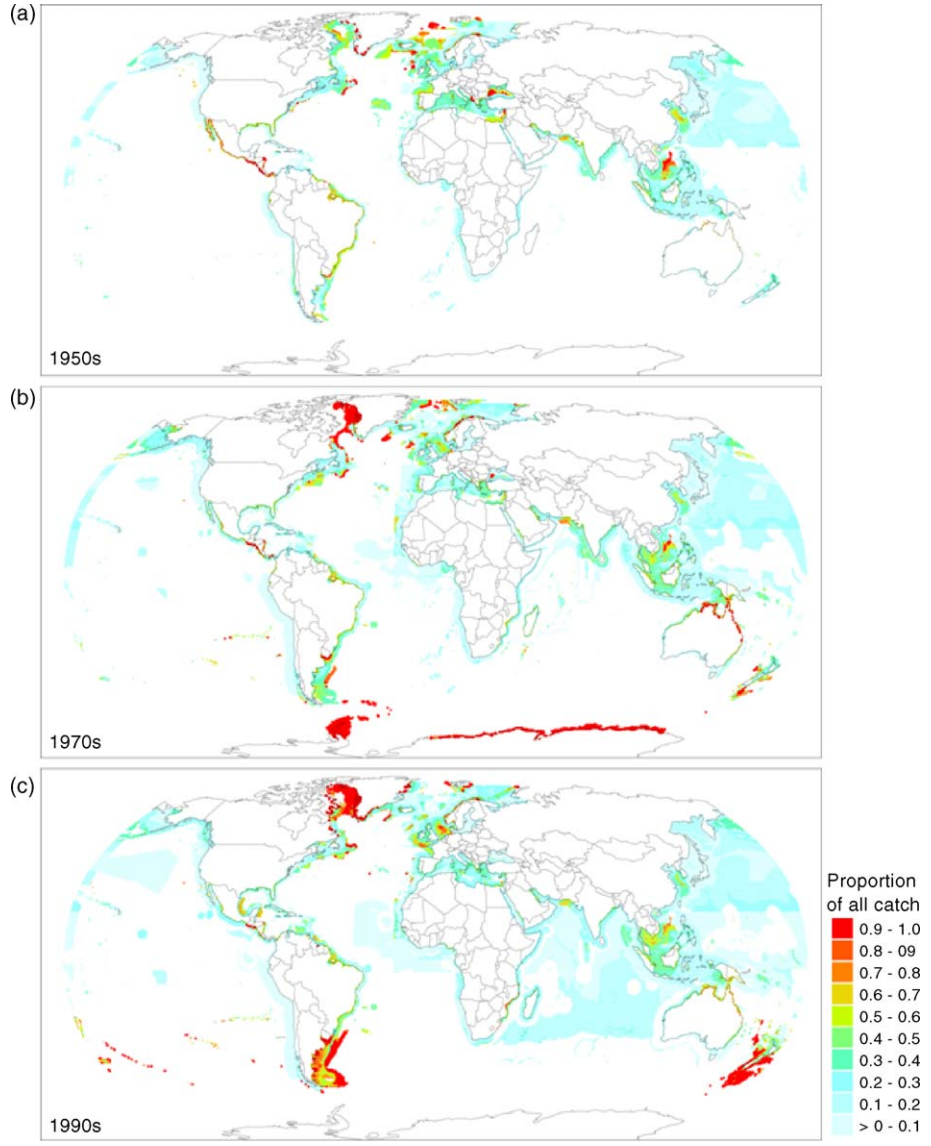

Fig. 6. Map of the proportion of all reported catch associated with bottom trawl gear (excludes dredges) for the (a) 1950s, (b) 1970s and (c) 1990s.

4. Conclusions

This type of detailed spatial information (Watson et al., this volume) will be instrumental in investigating the changes in the impacts of fishing gears such as bottom trawl and dredging on marine habitats and communities. There is considerable fear for deep-water corals and other communities in the path of the expansion of trawling. With the continued expansion of fishing gears into deeper waters and remote areas, this type of analysis will be extremely valuable to inform policy development and to help develop future management options. Considerable debate continues on how best to limit destructive fishing activities on the high seas where national, and even regional bodies have little power to intercede. With the expansion of deep-water trawling, and with the increased use of offshore seamount sites there is a greater need to monitor changes in fishing activities and their impacts.

In order to make information about global fishing patterns widely available, the SAUP has created a website that makes much of the data referred to here available (Watson et al., 2005). It is hoped that this will inform the debate on the effects of fishing on the marine environment in general and on the impacts of trawling specifically.

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