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The Marine Fisheries of China: Development and Reported Catches

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ABSTRACT

This document presents two interrelated studies on the marine fisheries of the People's Republic of China, both emphasizing, if in different ways, the magnitude of the catches reported throughout the 1990s.

The first study, by Lillian Pang and Daniel Pauly, titled "Chinese Marine Capture Fisheries from 1950 to the late 1990s: the Hopes, the Plans, and the Data," reviews the history and development of Chinese marine fisheries since 1950, notably the extremely strong increase of reported catches from the mid-1980s on. The case is then made, based on the design of the statistical reporting system, and the professional motivation structure of local fisheries officials, that over-reporting is likely to be the cause for much of the nominal catch increase. Supporting evidence is provided by similar over-reporting in other food-producing sectors, by various other fisheries studies (notably of catch per effort trends), the stressed state of Chinese coastal ecosystems, and the proclamation, by China's Central Government, of a zero-growth policy designed to undermine local over-reporting and to restructure the fisheries sector.

The second study, by Reg Watson, titled "Spatial Allocation of Fisheries Landings from FAO Statistical Areas 61 and 71" describes a rule-based, computer-intensive algorithm developed by the author and associates to map the world's fisheries catches in ½ degree cells. The resulting global map, which suggests the Chinese shelf and adjacent waters to be as nearly as productive as the Peruvian coastal upwelling system, was broadly reproduced by a General Additive Model that used depth and primary production as predictor variables. The catches reported from Chinese marine waters explained a large fraction of the differences between observed and predicted values, strongly suggesting that current Chinese nominal catches are greatly over-reported.

These two studies thus confirm each other, and provide strong evidence that indeed, Chinese national statistics over-report marine catches from Chinese waters. The internal adjustments that correcting for the underlying deficiency of the statistical reporting system will require are not investigated, and nor are the food policy issues implied by these findings. It is clear, however, that these issues are serious, for both China and the rest of the world, thus explaining, if need be, the critical tone of our studies. It is hoped that the Chinese authorities, international bodies, concerned scientists and others will find harmonious ways to resolve these issues.

DIRECTOR'S FOREWORD

How much fish has been caught? This is the most fundamental question for all concerned with fisheries: fishers, managers, researchers, the public and the income tax authorities. Like most such simple but widespread items, there is never an exact answer, but because of the fundamental importance of catch data, vast amounts of time and effort are expended in sampling, counting, weighing, monitoring, filling out forms and databases, analyzing and indeed arguing over the results. Under-reporting of catch, through unreported unmandated and illegal catches is a serious and world-wide problem[i]. In this report, the reverse situation, in which catches are over-reported, is described. Using the wrong figures affects the accuracy not only of stock assessment, but also the evaluation of the impacts of fishing on aquatic ecosystems and how they might be mitigated.

As a nation, the People's Republic of China takes one of the largest catches of fish in the world and hence the accuracy if its data can greatly affect the interpretation put upon any trends in the world figures.

This report contains the calculations and back ground material for a paper to be published in Nature in fall 2001[ii]. It consists of two parts. First, Ms Lillian Pang and Dr Daniel Pauly detail the social and political background against which massive over-reporting of fish catch has occurred in China. Second, Dr Reg Watson applies a spatial catch allocation algorithm to Chinese waters in order to estimate expected catch amounts. His work highlights anomalies in the 1990s of as much as 10 tonnes/km^2 /year when compared to reported amounts for Chinese waters. Taken together these two pieces of work establish the case for large over-reporting of catches. The paper published in Nature expands the statistical model for estimating annual catches and improves on these estimates. The implication of this finding for the world fish catch is that in fact the total has probably been falling for over a decade.

Had it been detected, this signal of decline in the world fish catch would likely have alerted us to the impact of serious fishery depletions almost a decade ago. In fact the lack of change in the total world fish catch seems to have contributed to complacency about the status of world fisheries, with, until very recently, only a few voices being raised, often arguing for a serious problem despite the stable world total masking serious serial depletion[iii]. But in fact, then, this analysis means that the fisheries situation is much worse than we had thought, and has been so for longer than we had thought, underscoring the need for radical change in the way that fisheries go about their business.

The Fisheries Centre at the University of British Columbia supports research that first clarifies, and then finds ways to mitigate, the impacts of fisheries catches on aquatic ecosystems. Only with such insight of how whole aquatic ecosystems function can management policies aim to reconcile the extraction of living resources for food with the conservation of biodiversity, with the maintenance of ecosystem services, with amenity and with other multiple uses of aquatic ecosystems. Indeed, the present dire state of marine ecosystems and their fisheries around the globe signals a pressing need for what may be termed the "ecosystem imperative". Correct values for catches are hence essential for this kind of analysis.

Although ecosystem agendas of this kind have recently become embodied in the legislative goals of many nations, and are an integral part of the FAO *Code of Conduct for Responsible Fisheries,* in practice there have been few attempts to work out how it might actually be done. In sponsoring the *Sea Around Us* project, the Pew Charitable Trusts of Philadelphia, USA, have devoted a significant amount of funding to a project that aims to address this question. The research team[iv] of senior scientists, postdoctoral research assistants, graduate students, consultants and support staff commenced work in late 1999. Members of this team have been excited and challenged by the unprecedented scope of the research work. Most of the methods used to tackle the problem are new[v] (see Pauly et al. 2000), and many of the measures developed by the team have been translated into the revolutionary new mapping system used in this report.

This report is the latest in a series of *Fisheries Centre Research Reports* published by the UBC Fisheries Centre. A full list is shown on our web site at http:/fisheries.ubc.ca, and the series is fully abstracted in the *Aquatic Sciences and Fisheries Abstracts*. The Research Report series aims to focus on broad multidisciplinary problems in fisheries management, to provide a synoptic overview of the foundations and themes of current research, to report on research work-in-progress, and to identify the next steps and ways that research may be improved. *Fisheries Centre Research Reports* are distributed to all project or workshop participants. Further copies are available on request for a modest cost-recovery charge. Please contact the Fisheries Centre by mail, fax or e-mail to 'office@fisheries.ubc.ca'.

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References and Notes

[i] Pitcher, T.J. and Watson, R. (2002) "Estimating Illegal and Unreported Catches From Marine Ecosystems: A Basis For Change." Fish and Fisheries *(in press)*.
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[iii] Pitcher T.J. (2001) "Fisheries Managed to Rebuild Ecosystems: Reconstructing the Past to Salvage The Future." Ecological Applications 11(2): 601-617; Pauly, D. (1996) "One hundred million tonnes of fish and fisheries research." Fisheries Research 25: 25-38.
[iv] A list of team members may be found in Annex A of Zeller, D., Watson, R. and Pauly, D. (Editors). (2001) Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort, and National/Regional Data Sets. Fisheries Centre Research Reports 9(3).
[v] Pauly, D. and Pitcher, T.J. (2000) "Assessment and Mitigation of Fisheries Impacts on Marine Ecosystems: A Multidisciplinary Approach for Basin-Scale Inferences, Applied to the North Atlantic." Pages 1–12 in Pauly, D. and Pitcher T.J. (eds) Methods for assessing the impact of fisheries on marine ecosystems of the North Atlantic. Fisheries Centre Research Reports 8(2): 195pp

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LIST OF EXHIBITS

1. PART I

CHINESE MARINE CAPTURE FISHERIES FOR 1950 TO THE LATE 1990S: THE HOPES, THE PLANS AND THE DATA

by L. Pang and D. Pauly

1.1. Summary and conclusions

This contribution reviews the development of Chinese marine fisheries and fleet structure since the founding of the People's Republic of China ('China,' excluding Hong Kong, Macao, and Taiwan) in 1949, up to the present, with emphasis on the type and quality of underlying statistical information, especially on landings. Our main purpose is to provide a basis for evaluating the credibility of reported nominal catches, with particular emphasis on total marine landing increases from the mid 1980s to the late 1990s, and thereby to complement the analysis of spatially disaggregated Chinese fisheries catch statistics presented by R. Watson in Part II of this volume.

Our main conclusion, derived from several independent, but converging lines of evidence is that the exponential increase of Chinese marine fisheries landings from the mid-1980s to the late 1990s was largely based on over-reporting of convenient figures by local officials. Indeed, over-reporting of production statistics has been a persistent problem in China, affecting a number of sectors, not only fisheries. The Chinese government's latest response to this, a 'zero growth' policy, serves to help in making local officials aware of the need to report on qualitative, rather than quantitative changes in the performance of the fisheries. In the meantime, however, the true level of China's fisheries catches will have to be inferred, if approximately, through comparison with catches from other parts of the world, and the correction factors emerging from this used to pinpoint further the administrative mechanisms which have led to the inflated catch estimates for the 1980s and 1990s.

1.2. Introduction

This contribution reviews the development of the Chinese marine fisheries since the founding of the People's Republic of China ('China', excluding Hong Kong, Macao, and Taiwan; Fig. 1) in 1949, up to the year 2000, with emphasis on the type and reliability of the statistical information these fisheries generated.

This study was prompted by the growing suspicion, among fisheries scientists and managers, both in China and abroad (FAO/FI 1999), that the reports of strongly increasing landings for the period from the mid-1980s to the late 1990s may have been inflated, and do not reflect actual landings, nor the productive capacity of the Chinese continental shelf and adjacent waters.

Contrary to many accounts of Chinese 'fisheries' (e.g., Zhu 1980), this report does not cover China's large aquaculture/mariculture industries, nor China's inland (freshwater) fisheries. Likewise, we will discuss only casually the biology, ecology and distribution of major exploited species, as this has been recently done by Chen (1999), based on as much recent data as seem to be available. Further, we do not differentiate between catches and landings (though we use mainly the latter term), as discarding of by-catch does not appear to be a problem in China. On the other hand, we do differentiate between 'nominal landings' (i.e., official landing figures) and 'real' landings, the latter being unknown, and the whole point of this contribution.

Note, finally, that we use numbered endnotes for citations to material originally in Chinese, here transcribed through the Pinyin system, and to some pertinent materials available on-line (notably translations of official documents), while standard references, citing author(s) and year, are used for all other bibliographic material.

1.3. Historical Overview of Chinese Marine Capture Fisheries

The Chinese marine capture fisheries experienced considerable growth since the founding of the People's Republic of China, in 1949. However, this growth was irregular, due to a series of political crises, and the ensuing recoveries. The major steps in this uneven development are: (a) Postwar Recovery (1949-1952); (b) First 5-Year Plan (1953-1957); (c) Second 5-Year Plan/Great Leap Forward (1958-1962); (d) Three-Year Re-Adjustment Period (1963-1966); (e) Cultural Revolution and Aftermath (1966 - 1978); and (f) Return to Normalcy and Growth (1978-present). However, the official Chinese fisheries statistics, as submitted to FAO, reflect the changes and upheavals that went along with these events only imperfectly, if at all (Fig. 2).

Figure 1. Chinese coastal provinces and territories. The adjacent shelf area (down to 200 m depth) is about 374, 000 km² (Chen 1999). Note that bottom trawling is banned within the inshore closure

Few records are available from the Postwar Recovery Period. Overall landings for this period appeared to have increased rapidly, starting from a base of about 0.6 million t in 1950 and reaching one million t in 1952,[1] most of it caught by non-motorized coastal vessels (Sarhage and Lundbeck 1992, p. 214; see also Table 1).

The growth momentum established during the postwar recovery period continued through the First 5-Year Plan, nominal landings increasing to about 1.7 million t in 1955.[2] However, Sarhage and Lundbeck (1992, p. 214) note that, "early statistics were rather inaccurate," suggesting, "it is possible that the catches before 1958 were higher than indicated."

Be it as it may, the established trends of increases in fishing effort and landings did not continue in the following period: what was to be the Second 5-Year Plan turned into the Great Leap Forward, itself ending in a catastrophic decline of production in literally all sectors of the Chinese economy, leading to widespread famines accentuated by a series of droughts and other calamities (Hunter and Sexton 1999). Official statistics from this period reflect this as stagnating landings, continuing during the subsequent Three-Year Re-adjustment Period (see, e.g., Fig. 113 in Sarhage and Lundbeck, 1992). Throughout the 1960s, nominal landings remained around 2 million t and Chinese fishers targeted relatively large and valuable demersal and benthopelagic species, such as large and small yellow croakers, flounder and other flatfish, pollock and cuttlefish.[3] Nominal fisheries catches did increase during the Cultural Revolution and its Aftermath, but rather slowly. This is not a surprise, given the turmoil prevailing during the Cultural Revolution (Hunter and Sexton 1999; Lippit 2000), also known as "ten years of disasters." Indeed, various fisheries were closed during this period, to prevent victims of the Cultural Revolution, and/or even disillusioned fish workers, to use fishing vessels to leave the country.[4]

By the late 1970s, the economically important species targeted during the previous period had been largely depleted (see below for the example of large yellow croaker), and species such as filefishes, and herring, which had been spurned earlier, became the target of directed fisheries, and contributing increasingly to total landings.[5]

However, overall economic growth started to pick up as successive reforms were launched, the first of these, promulgated in 1978, being devoted to the agricultural and fisheries sectors (Blecher 2000).

In its first stage (1978-1984), this reform abolished the People's Commune system that had been in place since 1958, and replaced it with a 'household contract responsibility' system that linked remuneration to output. However, nominal landings grew only 1.2%, from 3.5 million tons in 1976 to 3.9 million tons in 1985.[4] Indeed, this period bracketed a net decline in nominal catches, from about 1978 to the early 1980s (Fig. 2). A government report of 1979 on the state of the country's fisheries pointed out that the expansion of bottom trawling and stake nets had depleted the resources, and induced the collapse of several species.[6] That same report called for a stabilization of overall fishing effort at current levels, the replacement of trawling by gillnetting and other fixed gear, etc. Given the manifest decline of China's own coastal resources, this report also suggested distant water fishing as outlet for its excess fishing capacity, and as source of fish. The conservation measures proposed in that report were not implemented, but the expansion into distant water fishing was (Mathew 1999).

In March 1985, China sent its first Distant Water Fleet (DWF) to West Africa. The West African countries in which China's DWF has been operating, thus "turning foreign aid into commercial benefits." are Gabon, Gambia, Guinée, Guinea-Bissau, Mauritania, Morocco, Senegal and Sierra-Leone. China however, never became an important player in that part of the world, where DWF catches were earlier dominated by countries from the former Soviet block, and now by countries from the European Union (see Bonfil et al. 1998). Other countries in which the Chinese DWF has been operating include Argentina (squids), Malaysia, Indonesia (major spp. not available), the Philippines, Marshall Islands and Mauritius (tuna), New Zealand (squids), Pakistan (demersal fishes), Iran, Sri Lanka, Columbia (tuna), Peru, Palau (tuna, since 1987), Russia (demersals, incl. pollock), Thailand (spp. n.a.), and Yemen (squids). Moreover, high sea fishing fleet operate in the North Pacific (squids), the Indian Ocean and Central Western Atlantic (tuna, see below).

In 1981, another government report on 'outstanding fishery problems' identified overcapacity as the overriding issue, and called for suppression of capacity growth through measures such as diverting the larger motor boats to offshore fishing, lowering inshore catch target level, and transferring surplus fishing vessel crew to fish processing and aquaculture, etc.[7] In 1983, the government issued another statement calling for a stop to catch increases (see below for a

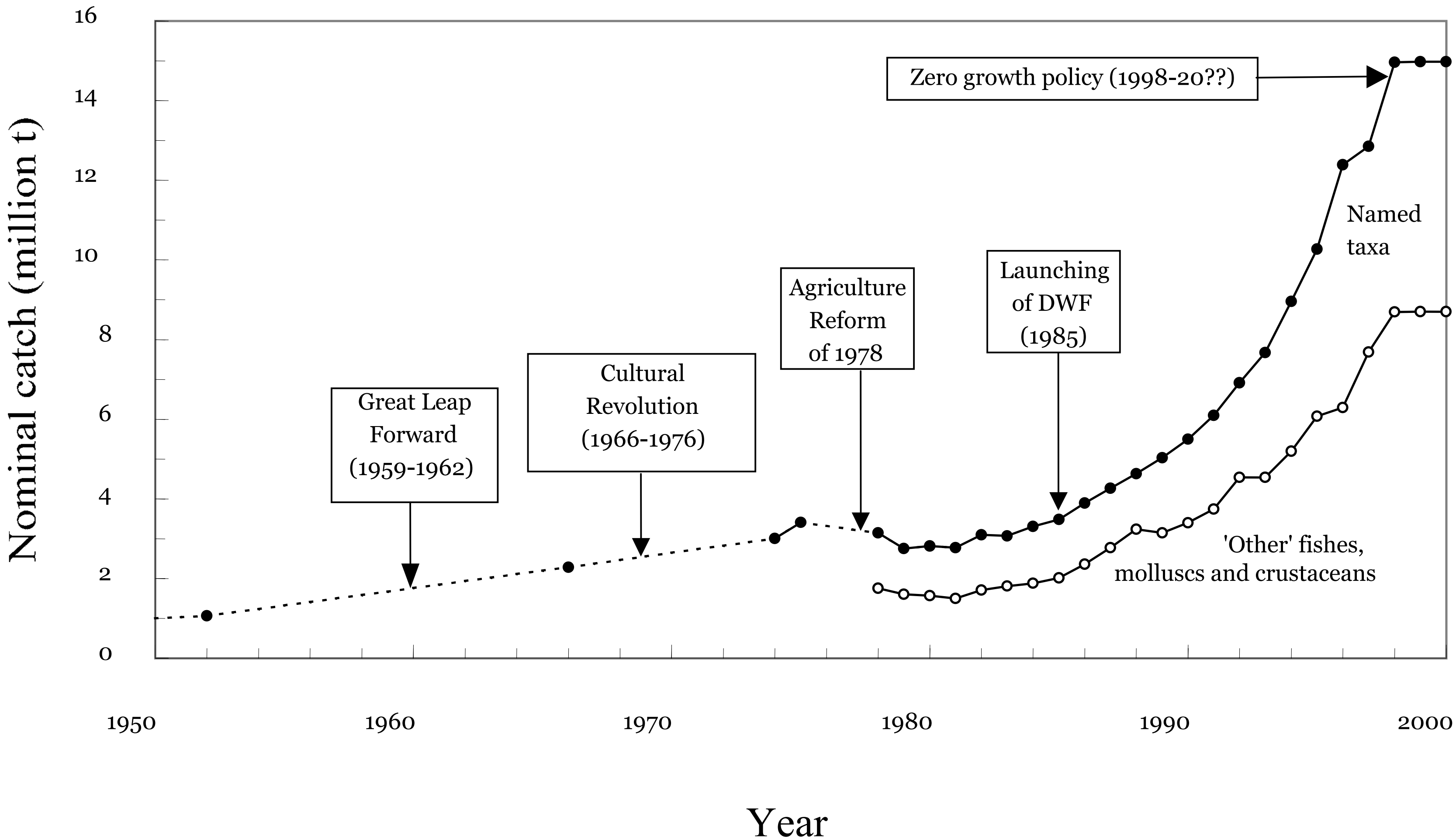

Figure 2. Timeline of key events for Chinese fisheries, 1950-2000 (based on data in Tables 3 and 5, and narrative in the text).

reprise of this), stricter control over the increase of fishing boat numbers, protection and increase of inshore resources through artificial restocking, the development of offshore fishing, and speeding up the development of a DWF.

These various reports and ineffectual calls to action are not mentioned here because they led to the intended interventions, but on the contrary, because they did not lead to anything except for the development of a Chinese DWF. Thus, they provide a basis for understanding the next phase in a gradual loss of control, culminating in semi-anarchic developments within the 'mass fishery' sector, and national landing statistics that ended up grossly overestimating catches.

Between 1985-1992, the agriculture reform entered a second stage, marked by the elimination of the state monopoly of purchase and marketing of agricultural products, and the gradual re-emergence of a now dominant strong private sector (Table 2). The relaxation of price control over fisheries products in 1985 and China's Fishery Act of 1986 had a strong impact on fishing effort and catches (i.e., they continued to increase, see Table 3), but seemingly not on catch/effort ('CPUE'), which, incredibly enough, remained relatively stable throughout the entire period (Fig. 4). Although China's marine and fisheries research institutes became involved more than previously with issues of fisheries development (Anon 1980), analysis of commercial fisheries catch data never became part of their mission (a problem prevailing in many countries), and this manifest problem with the credibility of the statistical reporting system was therefore not addressed.

However, in 1987, a first serious attempt to control effort was initiated by the central government. Aimed only at limiting aggregate horsepower by fishing zone, it was referred to as 'single control' (see below for 'double control' measures). The control targets were never met and by mid-1990s, the status of the coastal resources was perceived to be bleak enough to require the central government to impose measures it considered draconian. Thus, beginning in 1995, an annual summer moratorium system was placed on boats operating in the Yellow Sea and East China Seas. In 1997, as part of the Ninth Five Year Plan (1996-2000), a 'double control' policy was announced, which aimed at limiting both the number of boats and their power (hence the name). In support of that policy, i.e., in an effort to better control inshore effort, the Ministry of Agriculture also had fishing permits reissued in all coastal provinces and cities. As well, the Ministry called for further 'acceleration of fishery development through structural adjustment,' i.e., shift of fishing effort from inshore to offshore, expansion of the post-harvest sector, etc.). Moreover, the Ministry's emphasized the role of China's DWF as a (subsidized) priority industry,[8] crucial for implementing the country's "sustainable development strategy.' Consequently, on November 7, 1997, the Chinese Ministry of Finance and the State Taxation Administration announced that, in addition to the various tax incentives under the Eighth Nine-Year Plan (1991-1995), all domestically funded enterprises engaged in distant-water fishing would be exempted from income tax.[9] Moreover, since 2000, the fisheries enterprises based on Hainan (see Fig. 1) are actively encouraged to fish in the Spratleys, and provided fuel subsidies and state guarantees against the risk of loss at sea and vessel confiscation in this contested area of the South China Sea (Valencia 1978), similar to the U.S. refunding costs incurred to those of its tuna vessels that stray into the EEZ of various countries along the coast of the Eastern Pacific. The first payments occurred in early 2001 (before the Chinese New Year).

Both the 'single control' and 'double control' measures failed and inshore fishing capacity continued to grow. In 1998 and each of the subsequent year, the summer moratorium, which one may describe as 'too little, too late,' was extended both in time and space, including a large area of the South China Sea (north of 12° N), while trawling in banned in Bohai Sea all year round. In 1998, China also opted for an unprecedented 'zero growth' policy for setting annual marine catch targets. This policy stipulates that all levels of government and fishery administrative departments in each coastal province, are to take appropriate measures, based on local conditions, to guarantee the achievement in 1999, of zero growth in marine catch, which changed the previous practice of aiming toward ever increasing catches. (Note that this previous practice was usually expressed in form of 'guiding targets' by top leaders, then turned into 'local targets' by lower-level administrators). The zero growth policy continued in the year 2000, with the expected result that the official catch for 1999 and 2000 are almost exactly equal to that for 1998 (see Table 3), a theme to which we shall return in the section on 'the struggle against over-reporting.'

In 1999, the Ministry of Agriculture issued new fishery structural adjustment guidelines, again emphasizing strict control of fishing effort, and aiming for catch reductions.[10] The measures designed to reduce effort included:

Table 1. Growth of the Chinese fishing fleet, 1952-1999, based on official statistics[a] (all units * 1000; note interrupted time scale; kW and GRT are aggregated figures). These values are likely to underestimate true effort in the 'mass fishery' (see text).

	Motorized boats		**Non-motorized boats**	
Year	**N**	**kW**	**N**	**GRT**
1952	0.3	24	121.4	657.0
1957	1.5	76	135.2	733.0
1962	5.1	316	123.1	610.0
1965	7.5	458	129.4	570.0
1970	13.9	719	128.2	571.0
1975	29.2	-	-	-
1978	39.3	-	126.0	393.0
1979	42.8	2,150	120.0	363.0
1980	49.8	2,419	123.3	350.0
1981	60.9	2,627	118.5	330.0
1982	79.8	2,871	115.0	274.0
1983	95.9	3,064	103.6	248.0
1984	112.1	3,271	102.0	219.0
1985	132.8	3,639	93.8	196.0
1986	164.4	4,185	74.8	160.0
1987	196.3	4,832	76.3	145.0
1988	217.5	5,566	71.0	121.0
1989	234.1	6,293	66.5	107.0
1990	244.2	6,797	76.4	103.0
1991	242.7	7,242	64.8	91.0
1992	244.2	7,831	72.8	90.0
1993	250.1	8,107	46.3	68.4
1994	259.3	8,394	43.5	60.7
1995	274.0	9,801	40.8	65.8
1996	280.4	10,755	-	-
1997	282.5	11,219	-	-
1998	283.2	11,801	-	-
1999	280.0	12,181	-	-

a) Based on data from China Sustainable Development Information Network-Ocean (http://sdinfo.coi.gov.cn) and State Oceanic Information Network (http://www.coi.gov.cn)

(a) A stop on permissions to build new fishing vessels (except for distant water fishing purposes);

(b) A 'comprehensive clear up of illegal boats';

(c) A prohibition on the introduction of foreign boats to fish in the Chinese EEZ;

(d) The gradual establishment of a mandated vessel retirement system; and

(e) The strict prohibition for non-fishing laborers to take jobs in marine fisheries.

In the second half of 2000 [the "Year of Fishery Quality" - as opposed to mere 'quantity'], as part of their effort to control inshore fishing effort, the Chinese authorities carried out a first-ever national census of marine fishing vessels (see below for some choice results). Finally, on December 1, 2000, a revised Chinese Fishery Act went into effect, which, among other things, increases punishment for illegal fishing (incl. use of destructive methods such as explosives), and lays the legal foundation for a quota management system.

In parallel to these developments, nominal landing figures continued until 1998 the stratospheric climb initiated in the mid 1980s (see Fig. 2), reaching such improbably high values that questions as to their credibility began to be raised openly. This is the main topic of this report, but it will be addressed after we briefly discuss the structure of the fishing fleet, to illustrate yet another aspect of the loss of control alluded to above.

1.4. Structure and growth of the fishing fleets

1.4.1 The domestic fleets

Sarhage and Lundbeck (1992), referring to the late 1980s, provide a good starting point for describing the Chinese fishing fleet:

> "It is difficult to estimate the number of fishing vessels. A very large number of small sampans and sailing junks, possibly more than 400,000 are used for this purpose. Motorization started during the 1920s, and today the number of motorized ships is estimated at 157,000. Most of these vessels are, however, small and only suitable for operations in inshore or inland waters. A high-sea fishery began only in 1985 and is now carried out with more than 50 larger stern trawlers."

According to the recently completed national marine fishing boat census, China's three fisheries administrative zones (Bohai & Yellow Seas, East China Sea, South China Sea) currently boast a total of 244,300 registered motor fishing boats, totaling 5.41 millions GRT, with a total power of over 12 million kW.[11] This may make China the country with the highest number of marine fishing boats in the world. However most of them are small, as noted in the above quote. Thus, for example, while Shandong Province has 40,000 marine fishing boats, 90% of these are powered by motors under 44 HP.[12]

Presently, three official documents are required for engaging in fishing activities along the Chinese coast:

1. A fishing vessel inspection document;
2. A fishing vessel registration document; and
3. A fishing permit.

According to results of the national boat census, as many as 28% of the boats lack all three required documents and 21% lack at least one of them. Of all the problematic boats, 72% are small boats less than 12 meters long, including 15,600 light boats or rafts, of which many, operating in inshore nurseries, are reported to utilize destructive fishing techniques, including explosives. Similarly, the East China Sea Zone census report,[13] covering Jiangsu Province, Shanghai City, Zhejiang Province, and Fujian Province, notes that statistics for small-size boats in that zone are incomplete, and that the actual power of the motor boats' main engines is usually higher than in the boats' registration papers. The same source indicates that only 34% of the 117,000 marine fishing boats have all three licenses. Also, the overwhelming majority of the light boats, sampan and rafts operate without license.

Similarly, in the South China Sea Zone, about 50% of 78,000 fishing boats lacked at least some documents and 23% lacked all.[14] Of the problematic vessels, 90% were small motorboats with engines of less than 59 HP, i.e., light boats, sampans or rafts, many of them working as gillnetters.

It must be realized, however, that this large number of vessels is not the result of a deliberate policy by the central government. In contemporary China, state-run enterprises contribute only 10% of nominal landings, and an even smaller fraction of boat numbers [Also, they tend to operate at "tremendous losses" (Mathew 1999)]. Rather, the uncontrolled growth of the so-

Table 2. Stucture of the Chinese fishing fleet in 1995 (motorized boats only) by boat type, size and ownershipa. The data (from China Fisheries Network (http://www.china-fishery.online.sh.cn) are arranged by province, from the northeast to the southwest (see Fig. 1).

Number of catching boats											
	Private sector					**State-Owned**					
HP	> 600	200-600	61-199	21-60	< 20	> 600	200-600	61-199	21-60	< 20	All boats
Mean kW	555	204	89	26	8	558	250	95	37	9	
Mean GRT	262	99	41	12	4	334	117	49	14	3	
Province											
Liaoning	166	39	1,547	8,859	19,837	102	9	99	131	74	30,863
Hebei	14	110	1,462	1,968	5,283	14	1	19	2	0	8,873
Tianjin	14	15	236	393	271	14	0	0	0	0	943
Shandong	128	708	2,541	8,103	33,892	103	67	160	104	708	46,514
Jiangsu	57	780	2,064	6,751	10,603	55	94	39	11	2	20,456
Shanghai	125	71	354	57	56	125	42	7	0	0	837
Zhejiang	281	6,471	12,760	4,918	15,615	141	25	19	3	0	40,233
Fujian	39	2,663	4,528	6,682	38,562	14	9	2	10	37	52,546
Guangdong	388	3,059	6,167	9,548	31,653	71	14	13	6	113	51,032
Guangxi	37	865	1,004	1,319	7,222	19	22	5	0	5	10,498
Hainan	17	299	1,794	2,908	7,502	6	6	14	0	5	12,551
TOTAL	1,100	15,080	32,910	51,506	170,496	664	289	377	267	944	273,633

Number of carrier boats											
	Private sector					**State-Owned**					
HP	> 600	200-600	61-199	21-60	< 20	> 600	200-600	61-199	21-60	< 20	All boats
Mean kW	578	205				601	244				
Mean GRT	292	99				361	117				
Province											
Liaoning	216	60	-	-	-	142	27	-	-	-	445
Hebei	15	118	-	-	-	15	9	-	-	-	157
Tianjin	18	19	-	-	-	16	1	-	-	-	54
Shandong	160	827	-	-	-	126	101	-	-	-	1,214
Jiangsu	62	832	-	-	-	60	104	-	-	-	1,058
Shanghai	139	76	-	-	-	139	47	-	-	-	401
Zhejiang	312	6,801	-	-	-	259	99	-	-	-	7,471
Fujian	43	2,728	-	-	-	17	12	-	-	-	2,800
Guangdong	409	3,077	-	-	-	81	22	-	-	-	3,589
Guangxi	37	869	-	-	-	19	22	-	-	-	947
Hainan	21	303	-	-	-	12	10	-	-	-	346
TOTAL	1,432	15,710	-	-	-	886	454	-	-	-	18,482

-called 'mass fisheries' is the result of an inability to enforce legislation and regulations on the ground, whether they deal with safety issues, diversion into the fisheries of local resources from other sectors, or the related issue of local authorities encouraging the growth of local fleets, a theme to which we shall return when discussing the accuracy of the landing statistics.

The explosive growth of the number of small crafts since 1985 is the result of two factors, both acting simultaneously. The first of these is the 1985 relaxation of price controls over fishery products, which made many forms of fishing profitable that earlier had not been, and thus tempted many to try their luck fishing. The other factor, occurring in the same period, is the enormous mass migration of farmers and farm workers to coastal areas (Mathew 1999). This exodus itself had two causes. One is simultaneously economic and cultural, and is tied to the fact that, in China, as in most other developing countries, the cities offer more economic prospects and culturally richer lives than the countryside. The other driving force behind this mass migration is ecological: between 1985 and the early 1990s, China lost over 5 million hectares of farmland, especially in Eastern China and in the hinterland of various coastal provinces,[15] with the trend continuing unabated into the mid 1990s (Smil 2000), and beyond (Anon. 2000).

Since 1985, the number of fishery workers in China has increased by six million, of which about 2 million are engaged in fishing itself.[16] Hence, the increase in the number of new, small boats operating inshore using gear considered destructive by authorities, or even by traditional fishers. Here, we have a clear-cut case of what Pauly (1997) described as 'Malthusian overfishing.'

Currently less than 50% of the boats that are operating along the Chinese coast have been inspected with regards to their safety features.[17] As a result, a large fraction of the marine accidents along the Chinese coast involves boats built without permit.[18] In the wake of an increased death toll in 1999, the Chinese Ministry of Agriculture, in January 2000, issued an urgent notice to authorities at all administrative levels to step up inspection of fishing boats, to stop allowing modification of steel vessels over 20 years old and of wooden vessels over 15 years (if the modifications are designed to enable them to engage in distant water fishing), to stop licensing imported vessels that are over 20 years old, and to tighten licensing and management of ship inspection personnel.

Clearly, the Fishery Act of 1986, which strongly promoted fishery development, is outdated in that it cannot deal with the new problems that have surfaced after a decade and a half of deepened economic reform. Notably, the Fishery Act does not enable China to meet its new responsibilities as a signatory to recent international treaties, conventions and agreements, notably the United Nations Convention on the Law of the Sea, and FAO's Code of Conduct for Responsible Fisheries. Moreover, the Act is widely perceived as too lenient, and its articles too vague to guide enforcement acting against those who contravene its various articles.

What may be called 'local protectionism' has also played a role in creating the present uncontrolled situation with regard to the operation of fishing vessels, especially the small ones. In many areas, local officials have granted fishing or boat construction permits to applicants who, had the regulations been implemented, would have been found not to qualify, in order to collect fees to supplement their own incomes, and/or finance the institutions they work for. In other cases, local officials have intentionally overlooked the status of vessels lacking licenses, as their own political careers benefit from reports of high local 'production.' We shall document this as we later return to this theme, which also explains numerous anomalies in nominal landing statistics.

Another aspect of lost of control over the fisheries is that local fishery law enforcement authorities are chronically short of funds, and generally lack the means to carry out their responsibilities. Thus, for example, according to the director of the Fishery Superintendence Bureau of Jiangsu Province,[19] there are only four law enforcement vessels at the provincial level, totaling 940 GRT, and 30 vessels at city or county level, all poorly equipped and under-motorized – this for a province with a nominal catch of over 500,000 t. Not only are the enforcement vessels slower than the fishing boats they are supposed to supervise, but also, they lack the operating funds required to sustain their normal operations.

1.4.2. The distant-water fleets

In was only in 1985 that China started fishing outside of the Chinese Exclusive Economic Zone (EEZ), with high hopes for diversified, lucrative activities. However, the distant water fisheries never succeeded in overcoming the so-called 'two-90% syndrome,[20] which deals with the fact that 90% percent of the distant-water landings come from bottom trawling operations and that 90% of the fish is taken from other nations' EEZs through payment of access fees. Or put differently: so far, China has not really managed to deploy a modern high sea fleet concentrating on large pelagic fishes and other resources in international waters. Rather, what China did, in effect, was to deploy part of its coastal fleet along foreign coastlines. Thus, 95% of the Chinese distant-water fleet consists of small vessels capable of operating only in waters with depths less than 200 m, i.e., on continental shelves. Moreover, 90% of the larger boats designed for high sea fishing are second-hand vessels over 18 years old, and thus prone to malfunction and requiring frequent repairs.[21]

The Chinese government and researchers have realized that the importation of second-hand boats cannot provide a lasting technological basis for the distant water fleet. However, financing is major obstacles to self-reliance in this area, as vessels suited for tuna fishing on the high seas are tremendously expensive. Moreover, Chinese shipyards do not presently master the construction of modern long liners and seiners with speed, deck machinery and freezing capacities suitable for internationally competitive tuna fishing operations.

Still, in 2000, Chinese tuna catches were of the order of 29,800 t, representing an increase of 54% over 1999.[22] China has since 1994 participated in multinational negotiations on the management of Central and Western Pacific tuna, and became a member of the International Commission for the Conservation of Atlantic Tuna in 1996, and of the Indian Ocean Tuna Commission in 1998. With regard to these bodies, China follows the classical tactic of catching as much as possible, in order to secure as high quota as possible in future multinational negotiations, the plan being for China to double or triple in the next few years its present 1% share of the global tuna catch.[23]

The other major type of oceanic resources targeted by the Chinese distant-water fleet are squids. The fishery began in 1990 in the Sea of Japan, and grew rapidly. Restricted by the EEZ of Japan and Russia, Chinese squid boats in the Northwest Pacific must operate mainly between 150° E and 158° E.[24] Many of the Chinese squid fishing boats are converted small demersal trawlers, which lack year-round sea-going capability. Until a fleet of larger squid boats capable of year-round operation is built, the Chinese deep-sea squid fleet will remain unable to alternate between the fishing grounds in the North and the South Pacific, as done by the Korean and Japanese squid fishing fleets.

Since 1996, Chinese companies have been paying access fees to New Zealand and Argentina to fish for squids in their EEZs. In 2000, China reportedly caught 330,500 t of squids, an increase of 48,400 t over 1999.[25] By late February 2001, China had sent 93 squid boats to the Southwest Atlantic, where the current daily catch per boat is in the range of 3-10 t, lower than during the corresponding period of 2000.[26]

In January 1997, the Chinese State Council approved the Ministry of Agriculture's call for further expansion of China's DWF as an important component of the Ninth Five-Year Plan (1996-2000), committing itself to treating it as a priority industry and to provide it with special support.[27] Added to the various taxation incentives under the Eighth Five-Year Plan (1991-1995), on November 7, 1997, the Department of Finance and the State Taxation Bureau announced exemption of income tax for all domestically funded enterprises engaged in distant-water fishing.[28]

Overall, by 1998, China had over 1,200 distant-water fishing vessels and 27,000 fishery workers in West Africa, North Pacific, Southwest Pacific, South Asia, and Southeast Asia, catching over 900,000 t of fish valued at US$ 5 billion.[29] In 2000, the DWF increased to over 1,700 units operating on the high seas and in waters of over 30 countries and regions under bilateral agreements. However, their aggregated nominal catch was 865,200, less than in1998 and 1999.[30]

1.5. Nominal catches and their composition

1.5.1. Tonnage, by year and province

This contribution deals with the reliability of Chinese landing statistics. However, before presenting our arguments, we must present at least a subset of these data, to provide a background for the subsequent discussion.

Table 3 presents nominal landings by fishing zone for the period 1952 to 2000. Note the rapid growth from the mid 1980s to the mid/late 1990s, and essentially identical values for 1998, 1999 and 2000, a first result of the Chinese government's 'zero growth' policy discussed further below.

Table 4 presents nominal landings by province, some ecological characteristics of the fish caught and the gear types for the year 1995, representative of the period of concern here, during which nominal landings increased at phenomenal rates. One noteworthy aspect of this table is that it tacitly includes some catches

Table 3. Nominal Chinese marine landings (1000 t) by fishing zone, 1950 –2000[a]

Year	Bohai Sea	Yellow Sea	East China Sea	South China Sea	Other Areas[b]	TOTAL
1950	-	-	-	-	-	595
1952	-	-	-	-	-	1,060
1955	-	-	-	-	-	1,720
1965	-	-	-	-	-	2,120
1966	-	-	-	-	-	2,283
1974	-	-	-	-	-	3,006
1975	-	-	-	-	-	3,406
1978	-	-	-	-	-	3,145
1979	322	604	1,342	486	-	2,773
1980	294	515	1,415	552	37	2,813
1981	285	468	1,491	529	1	2,774
1982	286	573	1,594	623	23	3,099
1983	289	623	1,468	681	11	3,072
1984	317	611	1,645	725	7	3,305
1985	375	619	1,690	777	24	3,485
1986	390	653	1,801	960	92	3,896
1987	418	773	1,932	1,153	105	4,381
1988	465	850	1,919	1,276	123	4,633
1989	488	940	1,987	1,472	149	5,036
1990	516	1,086	2,073	1,615	219	5,509
1991	588	1,170	2,178	1,788	372	6,096
1992	810	1,208	2,311	2,068	515	6,912
1993	858	1,320	2,642	2,241	612	7,673
1994	905	1,487	3,275	2,601	691	8,959
1995	954	1,706	4,378	2,377	853	10,268
1996	1,077	1,984	4,338	2,880	2,211	12,490
1997	1,291	3,352	5,000	3,136	1,075	13,854
1998	-	-	-	-	-	14,967
1999	-	-	-	-	-	14,976
2000	-	-	-	-	-	14,775

[a]Note interrupted time scale (see Fig. 2 for interpolations). Based on data from China Fisheries Science and Technology Information Network (http://www.cafs.ac.cn), China Fisheries Network (http://www.china-fishery.online.sh.cn), State Oceanic Information Network (http://www.coi.gov.cn), China Agriculture Information Network (http://www.agri.gov.cn), and China Fisheries Information Network (http://www.ifishery.com). Small differences between data in this table and their original sources are due to rounding errors;

[b]'Other areas' is an ill-defined category which does not appear to include the DWF. Used here to balance zonal and total catches.

Table 4. Nominal landings by province and gear type in 1995 (1000 t). Based on data from China Fisheries Network (http://www.china-fishery.online.sh.cn)

Prov. \ Area	Bohai Sea	Yellow Sea	East China Sea	South China Sea	Other areas	ALL AREAS	Inshore %	Pelagic %	Trawl %	Seine %	Drift/ gillnet %	Fixed gears %	Long. lining %	Others %
Liaoning	397	409	28	0	79	911	83	36	29	3	22	26	3	16
Hebei	155	1	1	0	4	160	97	37	3	0	46	34	2	15
Tianjin	18	0	0	0	6	24	76	28	20	0	26	14	5	35
Shandong	376	900	236	0	106	1,618	79	40	49	2	13	22	1	13
Jiansu	8	372	182	0	6	567	7	40	26	0	8	50	0	15
Shanghai	0	25	60	0	77	162	43	67	79	16	0	1	4	0
Zhejiang	0	0	2,347	0	123	2,470	34	66	64	4	5	21	2	3
Fujian	0	0	1,524	45	51	1,620	59	25	45	10	9	24	3	9
Guangdong	0	0	0	1,494	120	1,614	78	30	62	8	16	1	8	4
Guangxi	0	0	0	498	1	498	88	35	84	1	3	4	2	6
Hainan	0	0	0	341	0	341	82	47	10	11	54	8	11	7
DWF	0	0	0	0	283	283	0	0	100	0	0	0	0	0
TOTAL	954	1,706	4,378	2,377	852	10,268	63	41	52	5	12	19	3	8

assigned to provinces, but taken from fishing grounds not adjacent to these provinces' coastal waters. This is due to most provinces having their own offshore and/or distant water fleet. Here, however, we use 'DWF' to refer only to the national distant water fleet, the China National Fishing Corporation. We do not return to this theme as these fleets do not contribute much to China's overall catches, notwithstanding the attention and subsidies they receive from various levels of governments.

Table 5 is more instructive, as it indicates that the bulk of the landings belong to the 'other' category ('other fishes,' 'other crustaceans,' etc.). Table 6 documents this problem on a province basis, while Fig. 2 emphasizes its temporal aspect. As might be seen, the large differences in level of taxonomic aggregation among provinces still leads, at the national level, to about 60% of the catch being allocated, every year, to the 'other' category (Fig. 2). In many countries, a large fraction of 'other' fishes and invertebrates is usually an indication of data tampering, since it is easier to fabricate unspecified than species-specific landing data. In the case of China, however, the explanation may be than (a) the State Statistical Bureau (SSB) requires its local offices to report only on a small number of species, the rest being of the 60% of landings assigned to the 'other' category, and (b) Chinese consumers, who generally prefer freshwater over marine fishes, have only a few favorites among marine species, most contributing to the 40% of the landings that are assigned to low-level taxa. [One of these favorite incidentally is (golden colored) large yellow croaker, which can fetch prices of up to 100 US $ per kg (Mathew 1999).

1.5.2. Species and size composition

The waters along the Chinese coast, and offshore to the limits of the Chinese EEZ are rather species-rich, due to the country ranging from a center of tropical fish biodiversity in the South to temperate waters peopled by completely different assemblages in the North (Richardson 1846). Overall, FishBase reports 659 species of marine (fin-)fishes from Chinese waters (Froese and Pauly 2000). However, not all of these species are equally important, and some species, such as the belt- or cutlassfish *Trichiurus lepturus* and the large yellow croaker *Pseudosciaena crosea*, have long dominated the demersal catches, though they are now far less abundant. This uneven contribution by different species is accentuated by statistics which poorly differentiate between fish (and invertebrate) taxa, the bulk of the landings being lumped into the 'other' category (see Tables 5 and 6, and Watson, this volume).

As in other areas of the world, the strong fishing pressure to which the Chinese marine fisheries resources are subjected appears to have led to massive changes in catch composition, reflective – at least in part – of changes in the structure of the underlying ecosystems. That the contribution to the nominal landings of traditional species such as cutlass fish (*T. lepturus*) and large yellow croaker (*P. crosea*) should have declined is not surprising: after all, overall landings have increased, and some of this increase is certainly due to previously underexploited species (including jellyfish, see Table 5) now having become the target of new fisheries. However, as these new species overwhelmingly consist of small pelagics such as the anchovy *Engraulis japonicus*, and small invertebrates, it is obvious that we are here confronted with yet another instance of what Pauly et al. (1998) have called 'fishing down marine food webs,' wherein large slow-growing, long-lived species with high trophic levels (TL), i.e., predators such as *P. crosea,* are replaced in the ecosystems and in the catches by small, short-lived species with low TL, i.e., by forage fish and invertebrates (see, e.g., Tong et al. 2000 for the case of the Bohai Sea).

This effect is documented here by Fig. 3A, presenting TL trends in Chinese nominal landings (as reported to FAO for Statistical area 61, i.e., the Northwest Pacific), and estimated from data in FishBase 2000 (Froese and Pauly 2000), based on the approach in Pauly et al. (1998). The trend line consists of two segments: the first, from 1950 to 1969, is completely flat, reflecting an unchanging composition of the landings (not a realistic feature, thus implying problems with the underlying data), and a second period of variable, but generally declining mean TL, indicating a transition toward fishes and invertebrates generally low in their respective food webs. This is confirmed by Fig. 3B, which presents similar trend of mean maximum size, i.e., mean maximum length of the species in the landings, weighted by their catch. [Divide this by 3 to obtain approximate mean length in the catch]. Note that the precise definitions of these lengths is of little import here: what matters is that they are declining, in spite of the crudeness of the underlying catch data, thus indicating lack of sustainability (Pauly et al. 2001).

Moreover, this between-species effect is strengthened by a related within-species effect, due to size reduction of the mean size of carnivores, which also reduces their trophic level (Pauly et al. 2001). For instance, the average length of cutlassfish declined from 21.5 cm in 1959 to 17.1 cm in 1981 and 15.6 cm in 1999, with less than 1% of the landed individuals over 2

Table 5. Composition (in %) of nominal landings by species (groups), 1978-1996 (1000 t). Based on data from China Fisheries Science and Technology Information Network (http://www.cafs.ac.cn) and State Oceanic Information Network (http://www.coi.gov.cn).

Landed group[a]\ Year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Pseudosciaena crosea	2.61	2.57	2.64	2.48	1.64	0.94	1.04	0.62	0.36	0.31	0.30	0.29	0.35	0.31	0.39	0.47	0.78	0.66	0.72
Larimichthys polyactis	0.67	1.13	1.10	1.08	0.86	0.80	0.51	0.74	0.42	0.36	0.40	0.26	0.34	0.59	0.68	1.04	1.17	1.50	2.29
Trichiurus lepturus	10.76	13.71	12.68	15.44	13.72	12.49	11.41	10.94	8.54	7.19	6.04	6.31	7.02	7.04	6.69	8.44	9.94	10.22	9.66
Scomber japomicus	3.14	3.51	2.58	2.29	2.98	4.26	3.14	2.22	2.78	3.03	3.98	3.52	2.78	3.06	2.62	3.63	3.80	3.65	3.37
Decapterus maruadsi	4.70	2.85	4.94	4.27	4.93	5.89	5.07	5.58	5.01	6.29	4.14	4.85	5.47	5.29	4.22	3.47	4.88	5.06	5.48
Filefishes	8.62	3.29	4.94	6.47	7.40	3.81	8.21	6.50	8.98	7.42	4.34	5.94	4.75	3.60	1.70	1.28	2.22	1.20	1.89
Engraulis japonicus	-	-	-	-	-	-	-	-	-	-	-	40.00	54.00	113.00	193.00	557.00	439.00	489.00	671.00
Pomfrets	0.86	1.35	1.32	1.30	1.59	1.27	1.39	1.60	1.49	1.66	1.06	6.31	7.02	7.04	6.69	-	-	-	-
Ilisha elongata	0.33	0.47	0.46	0.46	0.36	0.39	0.43	0.41	0.42	0.26	0.25	1.08	1.17	1.20	0.79	-	-	-	-
Scomberomorus niphonius	0.45	1.32	1.57	1.49	1.70	1.71	1.90	2.17	1.98	1.81	2.06	0.24	0.32	0.39	0.32	-	-	-	-
Clupea pallasii	0.61	1.22	1.17	1.08	0.64	0.58	0.23	0.07	0.13	0.24	0.17	-	-	-	-	-	-	-	-
Other fish	36.66	37.83	35.73	33.91	34.09	35.63	32.07	31.90	33.49	33.38	35.44	28.65	29.68	28.75	29.53	45.98	44.40	45.96	43.09
Total finfish	69.40	69.29	69.15	70.27	69.89	67.72	65.40	62.69	63.63	61.96	58.17	58.05	59.68	58.69	55.71	71.70	72.17	73.05	72.53
Penaeid shrimps	1.06	1.69	1.10	0.90	0.47	0.80	0.89	1.74	2.36	3.41	4.19	3.20	3.15	3.21	2.64	-	-	-	-
***Acetes* spp.**	5.42	3.07	4.08	4.80	4.45	4.64	4.77	4.98	3.68	2.95	3.15	3.29	2.98	2.73	2.46	-	-	-	-
***Trachypenaeus* spp.**	0.33	0.35	0.46	0.09	0.36	0.66	0.66	2.03	2.92	1.97	2.29	1.12	1.38	1.15	1.09	-	-	-	-
Other crustaceans	7.23	7.72	7.24	7.15	7.79	7.46	8.72	8.08	6.90	7.53	8.25	8.41	7.59	7.93	7.53	-	-	-	-
Total crustaceans	14.08	12.80	12.92	12.93	13.05	13.57	15.06	16.82	15.88	15.89	17.05	16.02	15.11	15.03	13.71	17.11	18.31	17.02	17.27
Cuttlefish	1.72	2.82	2.46	0.90	1.39	1.46	1.37	1.26	1.05	1.09	1.21	0.86	0.97	0.87	0.74	-	-	-	-
Mussels	2.67	2.07	1.96	2.97	2.98	3.15	3.47	3.07	4.44	5.71	7.10	7.44	7.00	6.27	5.80	-	-	-	-
Scallops	-	0.00	0.00	0.06	0.03	0.06	0.10	0.19	0.50	0.80	2.01	1.96	2.07	2.38	3.64	-	-	-	-
Other molluscs	4.78	4.77	5.22	5.29	5.82	6.94	6.89	8.01	9.15	9.72	9.79	10.60	10.73	10.45	11.81	-	-	-	-
Total molluscs[b]	9.18	9.66	9.61	9.19	10.21	11.64	11.84	12.53	15.15	17.31	20.11	20.85	20.78	19.97	22.00	9.26	8.07	8.13	7.68
Jellyfish	0.11	0.41	0.28	0.56	0.50	0.30	0.94	1.45	0.40	1.08	0.53	0.53	0.55	1.21	2.46	1.77	1.28	1.69	2.39
Algae	7.23	7.84	8.04	7.05	6.35	6.77	6.77	6.50	4.94	3.78	4.14	4.55	3.88	5.10	6.11	0.16	0.17	0.11	0.14

a) Filefishes include *Thamnaconus* and *Tripodichthys blochii;* pomfrets include *Pampus argenteus, Ephippus orbis,* and *Parastromateus niger*.
b) Note that shelled mollusc weights were originally expressed as 'meat weight' (=1/2.5 total wet weight).

Table 6. Nominal landings by species (groups) and province in 1995 (1000 t). Based on data from China Fisheries Network (http://www.china-fishery.online.sh.cn).

Species \ Province	Liaoning	Hebei	Tianjin	Shangdong	Jiangsu	Shanghai	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	DWF	TOTAL
Pseudosciaena crosea	5.8	0.0	1.1	7.4	0.4	0.0	8.1	15.1	25.2	0.0	3.9	0.0	67.0
Larimichthys polyactis	6.3	0.9	0.0	66.4	40.6	1.7	33.6	0.0	0.0	0.0	3.5	0.0	153.0
Trichiurus lepturus	6.9	0.1	3.0	50.1	143.0	4.5	579.9	121.9	90.7	8.9	30.7	0.0	1,039.7
Ilisha elongata	0.1	0.0	0.0	0.7	1.9	0.0	9.9	6.3	24.1	2.5	1.1	0.0	46.6
S. niphonius	5.8	0.5	0.0	88.1	50.1	0.2	25.0	21.9	41.9	20.9	17.2	0.0	271.6
Pomfrets	1.5	0.1	0.1	22.3	29.8	0.9	76.1	27.3	36.9	4.3	9.8	0.0	209.0
Snappers	1.6	0.0	0.0	0.6	0.1	0.0	1.7	3.8	36.7	6.7	7.4	0.0	58.6
Scomber japonicus	50.0	0.4	0.0	77.5	38.7	24.9	80.3	38.9	42.6	14.0	6.7	0.0	374.0
Decapterus maruadsi	0.0	0.0	0.0	0.0	0.0	0.2	9.5	211.4	218.0	69.0	7.1	0.0	515.2
Engraulis japonicus	66.4	0.3	0.0	354.7	4.9	0.0	9.4	18.3	26.8	3.2	5.0	0.0	489.1
Sardinops melanostictus	1.3	0.1	0.0	5.2	0.3	0.2	0.3	0.0	43.9	5.0	2.1	0.0	58.4
Clupea pallasii	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	2.3
Muraenesox cinereus	0.2	0.0	0.0	3.0	1.0	0.2	48.9	54.8	28.6	3.4	14.7	0.0	154.9
Groupers	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3	8.2	3.3	9.0	0.0	23.0
Liza haematocheila	3.1	10.7	0.3	14.1	0.0	0.0	1.2	0.0	22.9	17.9	1.3	0.0	71.4
Nemipterus virgatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	104.2	72.9	47.5	0.0	224.6
Filefishes	0.5	0.0	0.0	6.6	3.6	6.8	16.9	19.2	42.0	18.9	7.8	0.0	122.4
Total finfish	477.7	73.0	13.2	1,111.6	332.6	133.6	1,651.6	1,323.5	1,363.4	388.0	295.7	272.0	7,436.0
Penaeus spp.	0.7	1.3	0.4	2.0	0.2	0.0	2.6	7.6	15.5	10.5	2.3	0.0	43.0
Trachypenaeus ssp.	12.2	1.0	0.1	54.4	9.3	0.0	16.5	31.5	19.8	5.7	1.3	0.0	151.7
Acetes chinensis	68.5	18.5	1.4	65.2	19.2	10.0	115.6	27.6	27.9	30.5	5.9	0.0	390.4
Portunus ssp.	6.7	2.9	0.2	15.5	36.7	8.1	78.3	45.4	38.8	9.5	1.2	0.0	243.5
Scylla serrata	5.5	0.0	0.0	0.3	0.0	0.0	1.4	4.5	10.7	1.2	1.5	0.0	25.2
Total crustaceans	214.3	0.1	6.6	284.5	102.8	18.2	656.0	1,175.0	147.3	59.5	0.0	0.0	2,664.3
Sepia esculenta	14.8	0.9	1.3	11.8	3.1	0.1	80.9	57.4	23.3	14.6	5.5	0.0	213.8
Other molluscs	146.8	23.0	2.9	3.6	86.0	6.8	73.4	45.0	43.2	30.2	14.0	-	476.1
Total molluscs	161.5	23.9	4.2	15.3	89.2	6.9	154.3	102.4	66.5	44.8	19.6	1.3	689.9
Jellyfish	47.3	5.5	0.1	59.9	35.6	0.4	5.1	4.4	7.7	3.8	2.1	0.0	171.9
Misc. marine products	9.5	3.8	0.0	8.4	6.8	2.7	2.0	14.2	25.7	2.1	6.6	7.9	89.7
Algae	1.1	0.0	0.0	0.4	0.0	0.0	1.1	0.4	3.6	0.0	4.1	0.0	10.6
TOTAL CATCH	911.5	160.1	24.1	1,618.1	567.1	161.8	2,470.2	1,620.0	1,614.2	498.2	340.6	282.6	10,268.4

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years. This is similar for large yellow croaker, whose mean length in landings was 21.4 cm in 1959, about 20 cm in 1981, and 15.4 cm in 1999, also with less than 1% of the landed individuals over 2 years.[31] This effect is not accounted for in Fig. 3A and 3B; if it were, this would accentuate the downward trends displayed therein.

One problem with using a declining trend of mean trophic levels of landings as evidence of the increasing ecosystem impact of a given fishery is that moving down the food web may be the result of a deliberate choice, for which justification may be found in an increased demand, as occurs in China. After all, biological production does tend to increase by a factor of about ten as one moves down one trophic level in typical marine ecosystems (Pauly and Christensen 1995). Thus, one could argue that a fair evaluation of the impacts of a fishery should not be based on an index which simply decline as the fishery moves down the food web of a particular ecosystem. Rather, such index should decline only when catches do not increase as expected. Thus, we also present here a time series of an index enabling us to assess whether the Chinese marine fisheries are balanced (FIB) in ecological terms (Pauly et al. 2000a). The FIB index is defined, for any year i in a series by

$$FIB = \log (\Sigma Y_i * 10^{TL_i} / \Sigma Y_o * 10^{TL_o}) \qquad \ldots 1)$$

where Y_{ij} is the catch of species (group) j, TL_j its trophic level in the catch, Y_{oj} the catch at the start of the series and TL_{oj} the mean trophic level in the catch at the start of the series. [Note that the FIB index, as defined here, assumes a 10% transfer efficiency between trophic levels, a mean value applying to a wide range of marine ecosystems (Pauly and Christensen 1995)].

Figure 3C shows that the FIB index for China has increased since 1950, which implies (a) a geographic expansion; or (b) excessive catch estimates (see Pauly et al. 1998, 2000a, 2001, for more details on the interrelationships between catches and trophic levels). As the data underlying this analysis originate, in principle at last, only from FAO area 61, only the limited catches (of squid and pollock, see section on DWF) from fishing grounds East and Northeast of the Chinese shelf could have contributed to item (a); hence we conclude that (b) applies, i.e., that the FIB index confirms the suspicion of over-reporting.

Most of the small fishes presently caught by the Chinese coastal fisheries, i.e., fishes that grow to small size, and the juveniles of large species, are now used for fish meal, which feeds a rapidly expanding demand from the aquaculture sector (both freshwater and marine), a trend which may, in the long term, compromise net food fish supply to Chinese consumers (Naylor et al. 2000), but not followed upon here.

While some fisheries management techniques, such as seasonal closures, have been attested in China as early as 2000 B.C. (Mathew 1999), only a few stock assessments of individual species, using contemporary concepts in fish population dynamics, i.e., reaching beyond yield per recruit analyses, appear to have been conducted on Chinese marine fishes. One of these few studies, published in English, is that of Huang and Walters (1983). Its main result, pertaining to the East China Sea stock of large yellow croaker, *Pseudosciaena crosea* (Richardson, 1846), was that the fishing effort levels prevailing in the late 1970s had already led to a massive reduction of the biomass of this long-lived, coastal and hence highly vulnerable fish, and that its yield would decrease upon further effort increases. Chen (1999) confirms this:

> "In the 1960s and 1970s, fishing season and fishing grounds were very distinct but became weaker because after the 1970s the stock size had been in continuous decline."

However, as fishing effort increased, nominal catches of *P. crosea* from the East China Sea rebounded from a low in the mid 1980s, then engaged in a steady climb (see Table 3.1 in Chen 1999), suggesting the assessment to have been erroneous, or the statistics from the mid-1980s to be questionable. [The earliest stocking program for *P. crosea* was initiated in 1997, too late to explain the reported high catches (about 80,000 t) of this species in the mid 1990s (see Table 6). Had the catches of the late 1990s been the result of a stocking program, this would have made it one of the rare success stories in a field where failures abound].

1.6. Chinese fisheries statistics

Although there is a huge literature on the economic history of China, it must be realized that:

> "Any discussion of the outcome of various attempts to quantify China's economic experience must, out of caution, begin with a health warning concerning their ability to reflect accurately the contemporary economic reality. There was no systematic compilation of statistics, either government

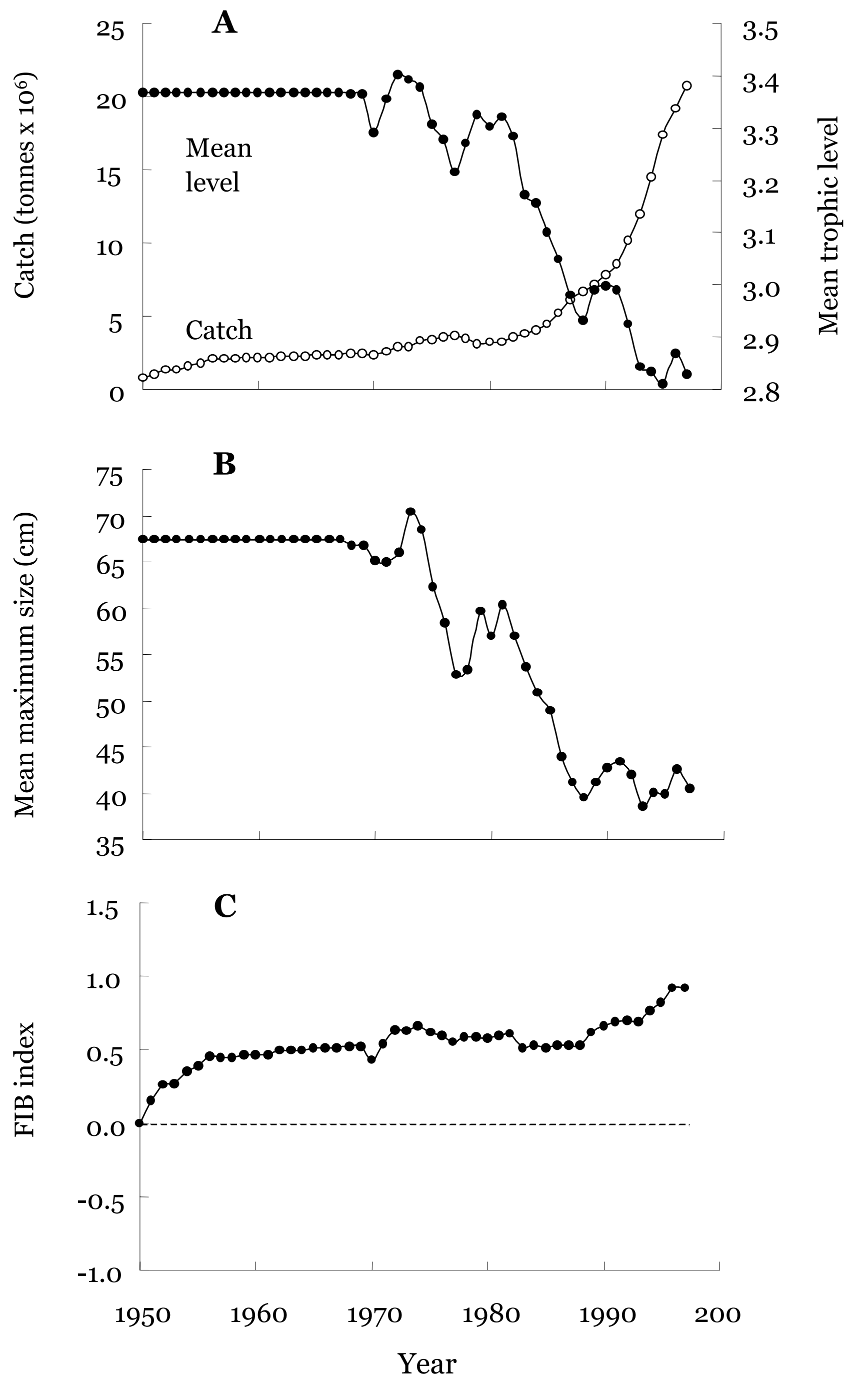

Figure 3. Ecosystem status indicators for Chinese marine waters (FAO Area 61), adapted from Fishbase 2000 (Froese and Pauly 2000).

A Nominal catch (from FAO) and mean trophic level of catch;
B Mean maximum length of species in the catch;
C FIB index, whose increasing value suggests that catches since the mid-1980s are too high, given their trophic level (see text).

> or private, for output or income prior to the 1950s" (Richardson 1999, p. 25).

The Chinese State Statistical Bureau (SSB; then known as National Bureau of Statistics), established in 1952, thus fulfilled a real need. And indeed, from the early 1950s to the late 1970s, official Chinese statistics played a key operational role in the economic and political spheres. However, it is important to realize that statistics were not only put to what may be seen as their 'natural' use, as an economic tool for monitoring the (planned) economy, but also as a propaganda device, i.e., for motivating and mobilizing the Chinese people in the building of a socialist society. Thus, only trusted cadres, usually communist party members, were involved in collecting and interpreting statistical information.

Thus, as noted by Banister (1987), the Chinese government, since the very inception of the SSB, failed to introduce the principle of independence between statistical reporting and political control of the economy. She predicted that the choice of communist cadres and local political leaders as the persons primarily responsible for collecting statistical information would eventually lead, as indeed happened, to massive data manipulation. Another economist, Robert F. Dernberger,[32] made similar comments on the Chinese official statistical system:

> "One of the most important hypotheses of information theory tells us that such a system will not produce a very accurate set of statistics, i.e., the statistics should be completely independent from the individual collecting them, who should be neutral as to what those statistics say, and the ultimate users should be unknown to those who collect the statistics. Just as with the principle of free markets, no individual should have any influence over the final outcome. The production units at the lowest level have departments or assigned workers to collect the statistics for that unit and these statistics are then packaged and reported to their superiors at a higher level. Obviously, those doing the collecting are not neutral to what the statistics report and they know full well who will be using them and for what purpose [...] The State Statistical Bureau begins to aggregate statistics that are collected and kept at the county level, a rather high level of aggregation even before the State Statistical Bureau begins to aggregate these statistics even further as they are passed up through each successive level of the bureaucratic hierarchy for reporting, i.e., to the Prefecture, the Province, and then the State level. This process of aggregation for the purpose of reporting provincial level totals and national level totals, of course, might result in offsetting differences from the truth being reported by lower levels. Yet, the deviations from the truth would tend to all run in the same direction, i.e., the reasons for under-reporting or over-reporting affecting all local units alike, causing the totals reported by higher levels to aggregate these deviations from the truth."

Indeed, during Chairman Mao's Great Leap Forward, in the late 1950s, zealots criticized the Chinese statistical system for showing wide gaps between the plans and the realities. Chang (1991, Chapter 12) gives a riveting eyewitness account of how various statistics were adjusted to show great success, even as the economy slid into disaster (see also Lippit 2000). Subsequently, the State Statistical Bureau (SSB) was able to enjoy a short period of autonomy before its staff were accused of 'revisionism,' and their institution utterly destroyed during the Cultural Revolution.

During the decade spanned by the Cultural Revolution, Chinese intellectuals and professionals (including statisticians) were sent to 're-educate themselves' in the countryside. As well, large amounts of statistical data were burned. It is only in the late 1970s and early 1980s that the SSB began slowly to recover and to rebuild its hierarchy of provincial, prefecture, and county level bureaus and offices.

This rebuilding process accelerated in the mid 1980s, after China passed, in 1984, a Statistics Act providing a legal basis for a system of national statistics. This gave the SSB and its provincial branches responsibility for collecting all kinds of statistics, making it possible to standardize information gathering, monitor quality, and introduce modern methods of sampling and data processing. This Act also explicitly forbids political interference with the statistical data, especially the common habit of local or regional cadres to revise production data upward, and unpleasant statistics downward.

The primary function of SSB staff is to provide timely statistical information to economic and political decision makers. To meet this goal, the SSB has tried, since its revival in the late 1970s, to enable its lower-level offices to check on the statistics being collected within the various production units. The Bureau has also attempted to impose uniform standards and forms for the reporting of statistics throughout China. But throughout the last two decades, statistical misreporting has continued to be widespread. Indeed, misreporting is considered to have become increasingly serious in the past two decades (Kwong, 1997, and see below).

A major problem involves what Albert Keidel, senior economist with the World Bank, describes as the 'tension' between target figures and reported results: "By emphasizing economic goals, the government invites inaccuracies."[33] In effect, and until recently, local officials were rewarded for reporting inflated production data, because production data were a key criterion for evaluating the performance of the local government and party officials, and of their departments. Thus, local officials had a strong incentive to report significant gains in agricultural and fishery development because promotions were closely tied to local increases in gross production figures. Conversely, local officials have no incentives to truthfully report falling or even stagnating landings. This theme is elaborated upon in the Section on 'the struggle against over-reporting,' but may be introduced here by a few examples.

The 1996 Chinese poultry production figure was found seriously over-reported after it was compared with the result of China's first national agricultural survey, conducted in 1997. Over-reporting has been officially admitted and the 1996 poultry output figures have since been retroactively corrected[34].

A nationwide statistics law enforcement check carried out in 1997 uncovered 60,000 cases of violation, with 57% involving misreporting and/or tampering with data.[35] According to the Deputy Director of the SSB, aggregate data from provinces, cities and counties were more problematic than macroeconomic figures and over-reporting was most serious with the production figures from township and village enterprises (TVEs). Moreover, most of the false reporting had the explicit support of local government officials.[36]

In Summer 2000, the Director of the SSB, Mr Zhu Zhixin pointed out what he perceived as three deficiencies in current Chinese statistical work:

1) Government leaders and high ranking civil servants are complaining that the SSB often fails to provide timely statistics, and that the statistics compiled and presented are not useful for development planning;
2) The public is aware of the discrepancies between optimistic statistics and the reality they experience daily, while the statistics also fail the academic and business communities;
3) Foreign researchers and businesspeople have the impression that all Chinese statistics are unreliable.

These deficiencies undermine both the national and international academic research needed for sound policy development, as well as the government's policy of encouraging foreign investments.

Similarly, at the year 2000 annual meeting of the Chinese People's Political Consultative Conference (CPPCC), which runs annually in Beijing in parallel with the annual session of Chinese National People's Congress, Li Lijun, a CPPCC member from Hunan Province, called for stern action against statistical frauds and for a reform of the official assessment system:

> "Fraudulent statistics have become a serious problem in some areas and government departments at all levels. Every year 40,000-60,000 cases come to light involving fraudulent statistics. Such frauds not only affect the country's economy by jeopardizing economic planning and policy-making, but also tarnish the government's image and encourage corruption. To stop such fraud, we must enhance the legal awareness of officials at all levels and strengthen the responsibility system. Major officials should be held responsible for violating the Statistics Act. Furthermore, research and survey techniques should be improved to increase statistical accuracy. Due to outdated statistical methods and poor supervision, the statistics submitted by local governments include serious fabrications. Statistical research methods such as sampling, therefore, should be improved and survey processes be made transparent. Also, supervision by the press should be allowed and reform must be carried out to improve the official assessment and promotion system. Economic statistics should not be the sole standard for the assessment of official. Finally, there is a lack of laws to prosecute offenders for minor violations. Pertinent regulations should be promptly made to guarantee punishment of violating officials."[37]

This topic also appeared at a press conference marking the occasion of the publication of the Statistical Communiqué of the People's Republic of China, February 26, 1999. There, a reporter asked raised the issue of the quality of statistics, pointing to informal reports stating that the production of meat and aquatic (fisheries) products had been overestimated by 40% (see also FAO/FI, 1999; and endnote 36). In his response, the then Director of the SSB, Mr. Liu Hong, did not reject the 40% figure, but rather admitted that over-reporting, and the 'watery component' of statistics (the Chinese equivalent to 'airy' statistics, i.e., statistics that do not hold water) existed, due to some local officials' attempts to obtain positive performance evaluations. He went on to explain that inaccurate statistics on meat production were also caused by limited staff in rural statistical offices, where a certain amount of estimates were obtained through inferences that may be seen as problematic.[38] Unfortunately, Mr. Liu Hong did not comment specifically on the accuracy of fishery statistics.

His successor, Mr. Zhu Zhixin conceded in 2000 that China does not have a sound statistical system, and he called on the creation of an innovative system that would take fully into account the multiple interests of the State and local governments. He suggested that a number of parallel statistical systems might have to coexist for a while, which would then gradually be united into one uniform system.

One important aspect of a reformed system would be to introduce, for fisheries as well, the sampling surveys used for complementing and assessing the reliability of agricultural statistics, and which has led to the discovery of serious over-estimates in meat and poultry statistics (see above). Until this sampling survey approach is also applied to fisheries statistics, they will continue to be based on report forms filled out by officials from the fisheries sector itself.

On the other hand, a reform is being carried out to improve the assessment and promotion system of government officials, and particularly to ensure that reports of positive economic statistics should not be the sole standard for the evaluation of their performance. This brings us to the crux of the matter.

1.7. The struggle against over-reporting

The instances mentioned above of catch over-reporting and other kinds of statistical fraud need to be put in the broader societal context. That context is corruption. Some forms of this phenomenon are universal: they are one of the many results of the tension between private (or family) interest and the public good. In the West, corruption often involves the political elite, e.g., via the funding of politicians' campaigns by individuals expecting various benefits for themselves or their companies (e.g., contracts, regulatory and tax adjustments, etc.). Examples are the case of a former German Chancellor, of most members of the Italian cabinet (until the 'Clean Hand' anti-corruption crusade of the mid-1990), of successive mayors of Paris in the 1980s and 1990s, or the continued revelations around the issue of 'campaign reform' in the USA. In China, over-reporting is considered to be a form of fraud, itself a form of corruption.

In Imperial China, the system of delegating state function such as tax collection and law enforcement to semi-private provincial and/or local entities bred a profound abhorrence of corruption, or '*tanwu*', well expressed by the two characters used to write that word, literally 'greed' and 'dirt.' This abhorrence also applies to the corrupt individual, government or society, for which '*fuhua*' or '*fubai*' are used, the former meaning 'rotten', or 'decomposed', the latter 'rot', and 'non-performance' (Kwong 1997, p. 3).

Indeed, corruption, and the perception of corruption have been major political factors throughout the two millennia of Chinese imperial history: dynasties, usually launched by energetic reformers, lasted only as long as they could control the effects on the populace of the inevitable corruption of its officials. Consequently, there were great hopes that the Republic founded in 1911 would rid the country of the corruption that contributed to the downfall of the late Qing dynasty; as is well known, this did not happen. However, the founding of the People's Republic of China does appear to have led to a reduction of the staggering level of official corruption that characterized the period from 1911-1949 (Kwong 1997), although there are some who are willing to contest this (see, e.g., Groombridge 1998).

In 1952, a strict Statute on Corruption was issued which provided detailed definitions of activities which the Communist Party and State apparatus would not tolerate. And just as 'insider trading' is an actively suppressed crime in some Western countries, but tolerated in others, the Statute included some offences that would not necessarily be considered corruption in the West. Kwong (1997, p. 14-15) describes this as follows:

> "*Pianqu*, or *zapian* (fraud), is the intentional perversion of truth for the purpose of inducing another to part with his/her personal belongings. *Taoqu*, a term that appeared in the 1952 statute, has similar meaning, but is no longer popular.

> Chinese officials had great powers and would simply demand what they wanted from their subordinates or charges, who were ignorant of their rights, *but these same official would have to file misleading or false reports misrepresenting themselves or their organizational achievements to obtain materials or recompenses they were not entitled to from their superiors*." (Our emphasis.)

The 1952 Statute was strengthened, in 1957, by a Regulation on Reward and Punishment of State Administrative Personnel, which warned state employees against corruption in general (*tonwu*), but also specifically against false reporting and lying to their superiors (Regulation 4). As Kwong (1997, p. 17) emphasized:

> "the actions covered by Regulation 4 were similar to fraud even though individuals might not get something substantive for their personal use – in the socialist system, many officials submitted false reports so as to remain in the good book of their supervisors."

Interestingly, these regulations did not discuss smuggling, or financial speculation, presumably because these activities, rampant at the end of the Qing dynasty and in the ensuing Republic, had ceased to be important in the mid 1950s.

In the section of her book devoted to 'Pervasive Gray Corruption,' Kwong (1997) provides a definition of the term 'gray' (or administrative) corruption, distinct from legal/criminal corruption. Thus she writes:

> "Officials engaged in false reporting, bribery, misuse of public funds, defrauding the government and other misdemeanors for their own interest and that of their organizations. Many more of these examples fall into the administrative definition of corruption than the legal one, and can be categorized as gray rather than black corruption [....]. What sets China, and indeed other socialist countries, apart from the capitalist West is not any basic difference in the nature of corrupt activities but the salience and peculiar form some of these activities have taken due to unique socialist structural arrangements. A brief comparison of corruption in China and the capitalist West will highlight this point. First, Chinese socialist state officials fabricated reports to please their superiors. In the West's more democratic society, administrators feel much less compunction about catering to the demand and interest of their superiors. Because of the different ownership structure, many such reports would be of no interest to Western governments. If submitted, the authors would be reprimanded for fabrication, and not accused of corruption."

It may have been expected that with the gradual dismantling of the planned economy in China, and the establishment of a market economy, gray corruption as defined here have declined, just as smuggling and speculation declined following the founding of the People' Republic of China. In fact, the opposite happened: all forms of corruption, including gray corruption increased following the 1978 onset of reforms, and the excesses that outraged the populace in the 1980s (Gong 1994) have been matched by the even more outlandish excesses of the 1990s (Huang 2001). Indeed, the increase of corruption is worrying the Communist Party and the Government, which have cracked down – notably with death penalties – on well-connected gangs, notably in the richer coastal provinces.

A related problem is local patriotism, or 'mountaintopism' (*shantouzhuyi*), 'departmentalism' (*benweizhuyi*), or various forms of parochialism (*difangzhuyi*), i.e.,

> "the pursuit by managers of the unit's interest to the detriment of the collective interest. People who engaged in organizational corruption based on false reporting, bribery, extortion [...] could console themselves that they were doing it for their organizations and not for themselves" (Kwong 1997, p. 71).

As Shapiro (2001), a naturalized Chinese and member of the Chinese People's Consultative conference points out:

> "The duel goes on: 'You have your *zhen ce* (measures), we have our *dui ce* (counter-measures),' is a popular saying. The local governments do everything they can to ignore or get around national orders which they consider to be to their disadvantage. In some cases, local governments will even falsify reports to Beijing, to assure compliance when in fact there is none. This has become an extremely serious problem in achieving national legal standards, with no immediate solution in sight."

In fact, competition, e.g., for water resources, or reduction of the tax burden from the capital has always been strong among Chinese provinces (Hendrischke 1999), and similarly for counties within provinces (Jacobs 1999). Such competition can reach all the way to the smallest production units, which is not surprising, given that between-firm competition ('socialist competition,' encouraged by Lenin in the Soviet Union in the early 1920s) always was a strong component of Chinese socialism. Also, many small, reportedly 'collective' township and village enterprise (TVEs) are in fact privately owned (Chai 1998, p. 182; see also Fewsmith 2000, Mood 2000 and Wilson 2000), and can be expected to compete in a more or less open market.

In the meantime, the statistics thus generated continue to serve a multitude of partly contradictory purposes, many still related to their use in local competition and for propaganda. Anon. (1999) puts it as follows:

> "With gradual perfection of the Chinese market economy system, fishery statistical data not only serve the state plan (sic!) program, macro control and adjustment, but also serve the society and the mass fishery production and management units. [...] The special statistical institutions and statisticians work for the aggregate statistical survey at ministerial, provincial, municipal, county and township level in terms of professional affairs and are responsible for the superior departments and the local governments."

This multiplicity of tasks, a serious case of 'mission drift,' combined with the coupling of personal career advancement with reports of increased production from local enterprises, has provided a strong incentive for local government officials to continue over-reporting of landings from the local fisheries 'production and management units' under their purview. Two features of official Chinese fisheries statistics support this:

1. Incompatibilities between different types of information;
2. The regularity of the annual landings increases since the mid 1980s, suggestive of steady exponential growth.

An example of item (1) is the continued increase, since the mid 1980s, of the reported landings of large long-lived species (such as large yellow croaker *Pseudosciaena crosea*) that were already severely overfished in the 1970s, when overall effort was much smaller, and perhaps more importantly the lack of decline since the early 1980s, of nominal catch/effort ('CPUE') in the Yellow/Bohai Seas, East China and South China Sea fisheries, despite two- to five-fold increases in fishing effort (Fig. 4). Such stability of catch/effort implies either of the following:

a. That the resource base is barely impacted by fishing;
b. That the stocks are 'hyperstable' (Hilborn and Walters 1992), i.e., that they are experiencing a range collapse as they are fished down, largely unnoticed because the fisheries operates at the core of the stocks' ranges;
c. That the fisheries are constantly expanding, and depletes one stock after the other (sequential overfishing), the expansion being both geographic and ecological, i.e., the fisheries move down the food web;
d. That the apparent increases of nominal catch did not really occur, and that catch/effort did in fact decrease.

It can safely be assumed that (a) and (b) do not apply to the situation prevailing here, because Fig. 4 indicates a strong decline of catch/effort from the 1960s to the 1980s. Rather, while we concede that (c) is occurring as well (see above), we consider Fig. 4 to provide strong evidence of landing records having been doctored such as to suggest that increase of effort (new boats) led to more or less proportional increases of landings. Such linear coupling of effort with landings is often, if wrongly assumed by bureaucrats the world over, and it is therefore not surprising in the case of China.

[Two staff members of the South China Sea Bureau of Fishery and Fishing Port Superintendence, Ministry of Agriculture, have recently analyzed historical fishery data from the South China Sea. Their results briefly recalled below confirm the above re-interpretation of the catch/effort data in Chen (1999):

Due to use of the large number of wooden sailing boats in the earlier period of Chinese fishery development, they first converted the number of these boats into horsepower (7 wooden boats = 1 motorized boat of 29.4 kW or 40 HP). They found that catch/effort first rose, from 1.31 t/kW in 1953 to 2.3 t/kW in 1959, dropped to 0.69 t/kW in 1981, then gradually increased, reaching 1.06 t/kW in the late 1990s. Given that the power of the fishing boats in the area (Guangdong, Guangxi, and Hainan provinces) has increased dramatically over the years from only 4 motored boats with a total power of 595 kW to 74,175 motored boats with a total power of over 3 million kW, an increase of catch/effort goes against all that is known about the impact of fisheries on the resources they exploit. The researchers then examined the catch/effort of a number of trawlers from Dongguan City, Guangdong, which had been monitored, and noted that their catch/effort had

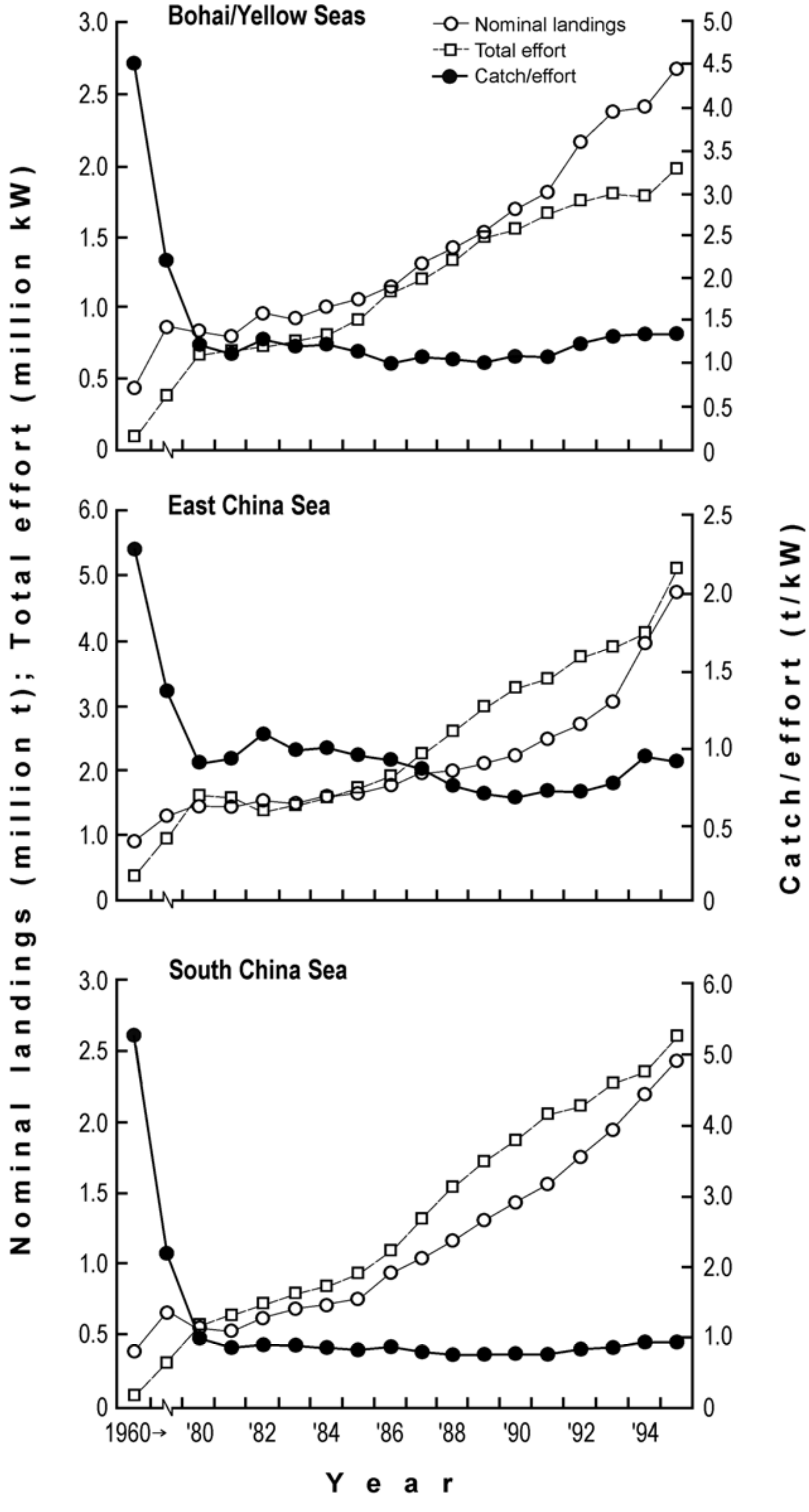

Figure 4. Trends of nominal catches, effort and catch/effort ('CPUE'), 1960-1995 (from Chen 1999). Note unrealistic constancy of catch/effort from 1980 to 1995 [Also note break of x-scale between 1970s and 1980]

dropped from 792 kg/kW in 1986, 616 kg/kW in 1991, and 369 kg/kW in 1998, far different from what the nominal catch statistics imply. Therefore, they came to the conclusion that the published statistics for nominal catches in the South China Sea are higher than actual catches,the over-reporting rate being in the order of 30-40 %.[39]]

Another example of incompatibility (item 1 above) is provided by FAO/FI (1999), wherein staff of FAO's Fishery Information, Data and Statistics Unit noted the discrepancy between Chinese marine fisheries landing and household fish consumption data, which imply an increase of per caput fish supply that has not been observed on the ground, even if exports and the increasing fish meal production are taken into account.

Above item (2), i.e., the suspicious regularity of the increases in nominal landings is shared with several of China's neighbors, where for several decades, year-to-year landing increases are manufactured in the capital, by multiplying the previous annual figure with some, often constant percentage. [This can be checked by plotting, for various Southeast Asian countries, log(landings) versus year, which generates straight lines, nicely parallel for various landings taxa and ecological groupings].

However, we believe that in the Chinese case, the landings increases were not generated centrally. Rather, we think that they were the results of relatively small adjustments, at successive administrative levels, by a vast number of independent, but similarly motivated local bureaucrats, just as described in the longer quote above by R.F. Dernberger. A large number of such independent, local 'adjustments,' which would tend to add small, normally distributed fractions [though truncated at the lower end] to an initial value, are all that is needed, via the Central Limit Theorem, to generate large, but similar (annual percent) increases when the data are aggregated at higher administrative levels. This is consistent with:

- The demonstrated over-reporting of production in the livestock and poultry industries, where the motivation for officials to over-report local output is similar to that in fisheries (see above);
- The spatial analysis of Chinese fisheries landings in Watson (this volume);
- Continued dependence of local enterprises on the whims of local officials (Shapiro 2001; Huang 2001); and
- Lack of effective mechanisms and/or interests countering over-reporting *at the local level*.

That the Chinese government is aware of these problems, and has tacitly acknowledged massive over-reporting of fisheries landings is evident from its establishment of a 'zero growth policy,' which explicitly states that landings must cease increasing above the 1998 level.

The 'zero growth' policy of the Chinese government is at first sight disconcerting: what can be obtained by insisting that catches cannot/will not increase, if not a straight, flat series of catches over time (see Fig. 2 for the period 1998-2000), different from, but in its own way as fanciful as the exponential increases of the 1980s and 1990s?

The point is that the government's insistence that catches may not increase (except for the DWFs) removes all reasons for local officials to over-report catches from their villages, townships or counties, thus uncoupling their performance evaluation from production figures. This, on the other hand (and this is an explicit goal of the zero-growth policy), should encourage or force them to report on qualitative changes in the fishery, e.g., on success in phasing out illegal and excess inshore vessels, shifting deck crew into post-harvest jobs, further developing the DWFs and recreational fishing, etc. As well, the policy is intended to pave the way for 'progressive' provincial leaders willing to break with the old 'tonnage' ideology. The drastic zero-growth policy, strange as it may look to Western fisheries scientists, appears to be not only appropriate given the conditions prevailing in the Chinese fisheries sector, but also a necessary first step towards sustainability in inshore waters.

This may be illustrated through the example of Daishan, a coastal county in Zhejian Province, where competitions for the biggest catches were held among fishing villages, for 14 years, from 1985-1999.[40] While the villages competed to win the title of 'Ten Thousand Tonnes Village,' the townships in which they were located competed to be that with the highest number of such villages in their jurisdiction. As it can be easily imagined, these competitions resulted in dramatic increases in the number of fishing boats in the area and rapid depletion of adjacent fisheries resources. The competition was abolished only in 1999, in response to the government's call for zero growth.

In a sense, the zero growth policy, which breaks with the past (statistics), is therefore similar to the break which, in the 1980s, saw China admit, first to itself, then to the world, that its national aquaculture statistics, then based on unwarranted extrapolations from a few models farms, were wildly exaggerated.

There is a good, additional reason for such break: the deplorable state of the Chinese coastal environment and its ecosystems are rapidly nearing the point at which they will become unable to support productive activities - our next and last topic.

1.8. China's coastal environment

Liu and Chen (2000) writing on "the present status of Chinese fishery" assert that:

> "thanks to the intensified effort of protecting offshore fisheries resources, extension of the rest period of fishing and expansion of extent of fishing prohibition, the stock numbers offshore has seen an obvious rise again, and the output of marine fishing reach 14.97 million tons, 8.0% from that in the previous year."

We cite this not only because this provides a good example of scientists using alleged landing increases to expound at international meeting on the wisdom of governmental management decisions (here: a recently introduced 2-3 month seasonal closure for coastal gear), but to illustrate how optimistic assessment of this sort can coexist, in Chinese accounts, with the perception, albeit dim, of a much gloomier reality. Thus, Li and Chen (2000) conclude the above cited abstract with the concession that:

> "Although great efforts have been made by the coastal provinces (municipalities and autonomous regions), to control the sewage discharged into the sea, the pollution of the near shore water is still serious and the overall quality of the marine environment tends to be deteriorated and the open-sea waters is also being threatened. The task for the sustained development of marine resources has a long way to go."

And indeed it does: China is probably one of the countries of the world with the most serious pollution problems (Mirsky 2001, Shapiro 2001; Smil 2001) both with regards to the terrestrial and the marine environments.

Chen (1999) gives a brief review of coastal pollution along Chinese coastlines, with emphasis on the Northeast, where studies have been more intensive, and where the damage appears to be worse. He lists numerous sources and examples of pollution (point sources or through rivers, i.e., involving discharges from the hinterland), notably raw sewage from cities and other human settlements and pig farms, industrial products (oils and other organic chemical, including pesticides, heavy metals, etc.) and effluents from mariculture industry (disease organisms, harmful algal blooms).

Here are a few new examples, most adapted from Anon (2000):

- The frequency, duration and offshore extent of red tides have been increasing since 1990,[41] and they have reportedly caused 120 million US$ worth of losses to the fishing industry in the Bohai, Yellow and South China Seas in the Spring of 1999, and may be one of the reason for the drastic decline of landings of commercial algae (see Table 5);
- Fishers in Hebei province filed suit in November 2000, claiming that wastewater from upstream paper mills in Henan Province had killed 3 million US $ worth of the fish they usually target;
- A 1999 study conducted by a team from the Georgia Institute of Technology estimated that reduced sunlight due to sooty air may be depressing agricultural yields by 5-30 % over 70 % of China [leaving open the question whether this would impact coastal primary production as well];
- Erosion causes the loss of about 5 billion t of topsoil per year, washing away nutrients equivalent to 54 million t of chemical fertilizer, twice the annual Chinese production of this product [this leaving open the question whether the topsoil reduces coastal fertility (by increasing turbidity, as does airborne soot, see above) or increases it (because of the nitrogen and other nutrients it contains)].

Making sense of such disparate information is difficult. One generality may be that in most cases, probably including China, marine ecosystems are impacted more strongly by fishing than by pollution, while the converse applies inland.

However, while this may be true in relative terms, the absolute damage to coastal marine resources may be considerable. As no integrative meta-analysis is available from the marine environment, we present in Table 7 a number of estimates of the percent of the annual Chinese Gross Domestic Product (GDP) that is lost through pollution, if only to indicate the orders of magnitudes that are involved here.

The estimates in Table 7 were based on a variety of methods, ranging from contingent valuation (i.e., 'willingness to pay') for the World Bank study, to detailed analysis of the economic impacts of premature deaths due to increases of respiratory illnesses for some other studies. Consequently, there has been a lively debate about appropriate methodologies, with emphasis on methods that work in data-sparse situations, or rather in a situation "abounding in dubious statistics and unverifiable claims and peopled by masses of uncooperative bureaucrats prone to treat any unflattering statistics as a deep state secret." (Smil 1998).

One interesting aspect of Table 7 is the consistently high values of the estimates of damage to China's environment, which range from 5.4 to 13.9% of GDP, although pertaining only to terrestrial (incl. freshwater) resources. [Note that this argument holds even if the Chinese GDP, given the statistical problems alluded to above, were much larger, or much smaller than assumed by the authors of the studies in Table 7; also it holds irrespective of one's stand on GDP as an 'ecologically adequate' measures of the size of the economy in either developed or developing countries].

One implication is that the massive destruction of China's natural resources (forests, freshwater, agricultural land, clean air, etc.) is such that, jointly with the (relatively small) population growth rate, it largely offsets the growth of the overall economy.

Another implication is that it becomes even more difficult to believe that China, of all major fishing nations in the world, should be able to keep increasing its coastal fisheries landings in the face of massive coastal pollution (including detritus from ubiquitous mariculture operations), and the consequent destruction of coastal nurseries. In other countries, including some of China's immediate neighbors, lower levels of pollution (and lower of excess fishing effort) have led to stagnating or even decreasing catches.

Table 7. Estimates of damage to the Chinese economy (expressed as % of Gross Domestic Product) resulting from air, water and other forms of pollution, and from damage to China's environment (excl. marine waters).

Year	Air	Water	Other	Environm.	GDP Sum of %	Source
1983	2.2	4.5	0.0	8.9	15.6	Guo & Zhang (1990)
1985	n/a	n/a	n/a	12.5	12.5	Jin Jianming (1994)
1990	0.9	0.7	0.5	5.4	7.5	Smil (1996)
1992	2.5	2.0	0.0	n/a	4.5	Sun (1997)
1992	2.4	1.5	0.2	13.9	18.0	Smi & Mao (1998)
1993	1.4	1.6	0.2	6.9	10.0	Zheng & Xu 1997)
1993	1.1	0.9	0.8	6.9	9.7	Xu Songling (1998)
1995	7.1	0.6	n/a	n/a	7.7	World Bank (1997)

1.9. Discussion

Accurate monitoring of and reports on economic performance indicators appear to have been a problem besetting the People's Republic of China since its very beginning, in 1949. The two key reasons for these are both related to China's governance structure. They are:

a. Lack of political autonomy for the statistical reporting system and the recurrent, overt politization of that system; and

b. A positive correlation between performance evaluation of local bureaucrats and their reporting of production figures matching predicted increases in national or provincial plans.

China dealt with item (a) by professionalizing its statistics collection system, i.e., it moved away from its earlier reliance on politically trusted cadres. However, as successive crises in the

European, particularly British, agriculture production systems illustrate (e.g., bovine spongiform encephalopathy, salmonella in poultry, persistent pollutants in farmed salmon), it is extremely difficult for governments to set up independent 'watchdog' agencies, capable of questioning the production-oriented policies of their various ministries (Rubery 2001).

The situation is even more difficult regarding item (b). During the first three decades of the People's Republic of China, strong ethical standards were imposed from the top down, through dedicated communist party members and cadres, which together with the absence of opportunities for misdeeds, appear to have limited various forms of corruption, including that form of 'gray corruption' leading to over-reporting (i.e., over-reporting, during the early decades of the People Republic of China may have been more commonly the result of political zealotry than of naked personal gains). The economic reforms introduced in 1978, which explicitly encouraged people to "get rich," and which questioned the ethical basis of earlier policies, had the unforeseen side-effects of an explosion of corruption cases in the 1980s and 1990s, and increased poverty among segments of the farmer populations in the hinterland. Massive coastal migration and the related growth of uncontrolled 'mass fisheries' offered rich pickings and increased opportunities for over-reporting to corrupt local official. China's assessment and promotion system for officials (=civil servants) overemphasizes production output figures and in effect, provides incentives for statistical misreporting. This is facilitated by imperfect setup of the statistical system itself, and the fact that, as stipulated in a circular of 1985 jointly issued by the Ministry of Finance and the SSB on 'Transferring Statistical Operating Expenditures to Higher [Administrative] Levels,' the operational budget of the local offices of the SSB are appropriated at the local level.

This, combined with competition between production units, townships and even provinces, led to a massive inflation of landing reports. One irrefutable line of internal evidence is the nearly constant catch per effort reported since the early 1980 for all three major regions (Bohai & Yellow Seas, East China Sea, and South China Sea), even though nominal effort during this period has increased by factors of 2 to 6, and catch per effort had earlier (in the 1960s) been reported as declining. The central government's 'zero growth' policy is in itself evidence, as well, that the nominal catch reports had lost their anchor in reality.

Another, more indirect line of evidence, is provided by the extremely high levels of environmental pollution and degradation prevailing in China, which has been estimated to reduce the Chinese Gross Domestic Product by 5-15%. Other countries, less impacted by pollution and environmental degradation, have experienced stagnating or even decreasing landings from their coastal waters, mainly due to impacts on inshore fish nurseries.

China's central government appears to be quite aware of the serious over-reporting problem discussed here, and its response, the 'zero growth' policy explained above, may succeed in solving it. However, this is does not resolve the issue of what the actual catches from the Chinese coastal fisheries actually are.

For this, we propose that 'external' landings estimates should be generated, using a comparative approach consisting of the following elements:

1. Using detailed and more reliable landing statistics from neighboring countries to interpolate the approximate composition of the large fraction of the Chinese catch allocated to 'other fishes;'
2. Using the composition in (1), fish depth and latitudinal distribution data in FishBase (Froese and Pauly 2000), global primary production data from the European Union's Joint Research Center, in Ispra, Italy, and other sources to allocate taxa to those areas of the Chinese EEZ over which they were likely caught;
3. Compare the catch distribution in (ii) with the global map of catch distribution recently derived in the context of work by the *Sea Around Us* project (see Pauly and Pitcher, 2000, and Pauly et al. 2000b); and
4. Estimate, through a General Linear Model, from (3), the likely landings in the Chinese EEZ.

Watson (this volume) presents an implementation of (1)-(4). These results fully confirm the main point of the present report, i.e., that official Chinese landings from the mid 1980s to the late 1990s were seriously over-reported. We hope that this will contribute to a re-evaluation of China's official marine landing statistics.

2. PART II

SPATIAL ALLOCATION OF FISHERIES LANDINGS FROM FAO STATISTICAL AREAS 61 AND 71

by R. Watson

2.1 Summary and conclusions

The fisheries landing statistics of FAO statistical areas 61 and 71 for the 1990s were examined using a rule-based procedure. A large part of landings from these areas were reported by the People's Republic of China, and much of this was identified as 'miscellaneous' fishes, crustaceans or molluscs. These statistics were disaggregated into lower taxonomic groups, based on landings reported by China and two of its nearest neighbors. The disaggregated landing reports for each statistical area were then allocated to 30-minute by 30-minute spatial cells based on spatial databases of known taxon distributions and national fishing access. The former database was compiled, in consultation with experts, based on ocean depth, primary productivity, coral reef presence, and other factors. The later database included considerations of global maritime boundaries, fishing access arrangements and permanent ice cover. Each landing record was accumulated proportionally in each of the ocean's spatial cells, producing maps of global landings for a number of marine groups. Landing records for which there was no spatial cells common between the reporting FAO statistical area, the distribution for the taxon reported, and the reporting nation's fishing access rights were logged, and used to identify reporting problems.

A general additive model was used to examine the relationship between the spatially disaggregated landing records and major oceanographic factors. Landing rates within spatial cells were predicted by the log of cells' average depth and primary productivity. The predicted landing rates were compared to those based on landings reported to FAO. Maps of the reported, predicted, and differences in landing rates are included, and these demonstrate that some locations within FAO 61 and 71, in particular the coast of China, have reported landings which are not consistent with the global model. Specifically, there were large areas within the Chinese EEZ with landing rates of 10 t km^{-2} year^{-1} or higher than those predicted by the model. Possible explanations for the predicted differences in landing rates and landings are discussed. The most likely explanation is gross over-reporting of landings within area 61 by China.

2.2 Introduction

Official statistics of fisheries landings are provided to FAO annually by member countries. These are reported for a range of species and aggregated taxa for each of FAO's statistical areas. There has been concern for several years that some reports provided for statistical areas 61 and 71 have indicated levels of fish landings that are not consistent with global patterns (Pang and Pauly, this volume). Despite differences in fleet size and fishing intensity, it is now widely held that the majority of the world's fisheries are taking most of the sustainable production of marine ecosystems, and this production is related through the food webs to underlying factors controlling primary production (Pauly and Christensen 1995). It therefore seems unlikely that some regions can produce considerably higher fisheries landings than comparable areas elsewhere regardless of the magnitude of fishing fleets employed.

Investigation of likely landing levels requires fisheries statistics on finer spatial and taxonomic scales than typically reported to FAO. It is common for reporting countries to break down the major portion of their statistics to the genus or species level of identification. This level of description is highly desirable if knowledge of the fish's distribution and habitat requirements is to aid the spatial disaggregation of statistics. Unfortunately, some countries provide the majority of their fisheries statistics by highly aggregated categories such as 'miscellaneous marine fishes'.

A two-stage process is therefore required. The first is to disaggregate the reported statistics into taxa of lower levels, such as families, genus or species. This process allows to proceed with the second stage, wherein aspects of the fish's biology and known distribution are combined with what is known of the reporting country's access to fishing areas to produce a fine-scale spatial disaggregation of the reported landings. This process builds global maps of annual landing rates as each country's landing records are processed. Using these maps, statistical models relating landing rates to known oceanographic parameters such as depth and primary productivity allow anomalies to be identified.

Highly anomalous landings rates can then be reviewed with reporting nations for clarification.

2.3 Methods

2.3.1. Spatial Resolution and Spatial Cell Size

The process described in this report seeks to disaggregate landings from FAO's statistical areas to smaller units that can be used in a statistical model using oceanographic parameters. To facilitate this, spatial units of ½ degree latitude by ½ degree longitude were used. These will be referred to as 'spatial cells'. The choice of this size was a balance between larger cells that would average many depths and other characteristics, and provide only a crude model of distribution, and a finer structure that would require intensive computing power and data of a scale not widely available. Over the world's seas and oceans the selected cell size requires a matrix with approximately 180,000 cells.

2.3.2. Data Sources

2.3.2.1. Fisheries Landings

The fisheries data used was supplied by FAO. For all but annual tuna and billfish landings FAO's FishStat+ (www.fao.org/fi/statist/FISOFT/FISHPLUS.asp) was consulted. Landings of tuna and billfish were taken from FAO's Atlas of Tuna and Billfish Statistics (http://www.fao.org/fi/atlas/tunabill/english/home.htm). The totals were used unaltered. A process of taxa disaggregation (described below) was used, however, to enable the use of published distributional and biological information in the spatial disaggregation process. Only records of fishes and marine invertebrates were used in the analysis, i.e., data on marine mammals and algae were not considered. The statistical data used were only 'official' reported landings, i.e., they do not include discarding, nor do they make any attempt to correct for unreported, misreported catches or other errors.

2.3.2.2. Fish Taxonomy, Biology and Distribution

FishBase (www.fishbase.org) provided excellent information on fish taxonomy, their biology and distribution. This provided a framework for our databases and assisted with the process of spatial disaggregation by providing actual distributions or information on the limits to the distribution of many fish taxa. SpeciesDAB (Coppolla et al. 1994, and see below) supplied similar information for many invertebrate taxa.

2.3.2.3. Depth

Sea-floor elevations data were taken from the ETOPO5 dataset available on the U.S. National Geophysical Data Center's 'Global Relief' CD (www.ngdc.noaa.gov/products/ngdc_products.html) that provides elevation in 5-minute intervals for all points on earth. Elevations below sea level (depths) were averaged for each spatial cell used in our database.

2.3.2.4. Primary Productivity

Global primary productivity data (in g C m^{-2} $year^{-1}$) were provided by the Joint Research Centre (JRC), of the European Commission Space Applications Institute (SAI) Marine Environment Unit (ME), in Ispra, Italy. (See www.me.sai.jrc.it/me-website/contents/shared_utilities/frames/index_windows.htm). The data set was developed using the Behrenfeld and Falkowski (1997) model, which includes (US) NOAA's satellite data on sea temperatures, chlorophyll *a* levels and light irradiance. The data set was available on a spatial scale of approximately 0.176 degree and was averaged into ½ degree spatial cells. The time period averaged was for readings taken during 1999, and was taken to represent a basic climatology of primary productivity.

2.3.2.5. Coral Reefs

Global modeled data (from Kleypas et al. 1999) on the presence or absence of coral reefs was made available from Reefbase (www.reefbase.org/) on a 5-minute resolution. This was accumulated into our ½ degree spatial cells to provide a spatial reef coverage index, used to disaggregate landings of species whose life-history requires the presence of coral reefs.

2.3.2.6. Seamounts

The gazetteer provided on the U.S. National Geophysical Data Center's 'Global Relief' CD (www.ngdc.noaa.gov/products/ngdc_products.html) was used to count the number of known seamounts in each of our ½ degree global spatial cells. These were used to provide the basis for the distribution of taxa known to occur only on, or in the proximity of seamounts.

2.3.2.7. Permanent Ice Coverage

Data from the U.S. National Snow and Ice Data Centre, Boulder, Colorado (nsidc.org/index.html) were obtained which provided monthly limits of sea ice coverage. These were used to identify spatial cells unavailable for fishing due to (nearly) permanent ice coverage.

2.3.2.8. Exclusive Economic Zone

Boundaries of exclusive economic zones (EEZ) and declared fishing zones for fishing nations were taken from the Global Maritime Boundaries CD, which uses existing claims and the United Nations' Law of the Sea's rules to delineate these zones even though many are still technically or legally unresolved (Veridian, 2000; www.maritimeboundaries.com/main.htm).

2.3.2.9. Fishing Agreements

A database of fisheries agreements between nations, FARISIS (FAO, 1998) was kindly made available by FAO. The utility of the information therein was enhanced by importing it to Microsoft Access database, a process that required parsing the exported text file using a Microsoft Visual Basic program. This database allows the fishing agreements between nations to be listed so that the rules of fishing access required in the spatial disaggregation process could reflect current or historical arrangements.

2.3.3. Taxonomic Disaggregation

Taxonomically highly aggregated landings statistics are problematic for any analysis including spatial modeling. Some countries report the majority of their landings under the 'miscellaneous marine fishes', 'miscellaneous marine crustaceans' and 'miscellaneous marine molluscs' categories (Table 8). Some of these countries combine a large, highly aggregated catch fraction with large reported landings. China tops the list of these countries in term in the total tonnage it reports in this format. According to FAO statistics China has reported approximately 113 million tons of marine landings this way since 1950, nearly three times as much as any other nation.

Because statistics supplied by China to FAO contribute such a large part of the landings reported from areas 61 and 71 (34% since 1990), it was necessary to disaggregate these landings based on the more detailed records from neighboring areas, presumed to have similar catch compositions). Taiwan and South Korea (T&SK) were used for this; North Korea (i.e., the Democratic Peoples' Republic of Korea) was not, as it provides even less taxonomic detail than China (Table 8).

Disaggregation of landing records was performed separately for each broad category (fishes, crustaceans and others, mainly molluscs). Within each category the percent of the total landings that was assigned to the 'miscellaneous' category was assigned to more specific taxa based on the breakdown of landings reported by T&SK. This procedure was performed independently for each statistical reporting year.

For example, in 1998 China reported 27% of its total landings as 'miscellaneous marine fishes'. This same year, the average proportion of total landings reported by T&SK for the same group of aggregated taxa was only 10%. Therefore, initially the procedure assigned 17% (the difference) of the Chinese 'miscellaneous marine fish' landing statistics to fish taxa identified at more specific levels than as 'miscellaneous' in the Chinese statistics or in those of T&SK. This difference was assigned step-wise in small fractions using a rule-based approach. The rules were that:

- China's proportion of landings assigned to any identified taxon can never be reduced, regardless of what T&SK reported;
- The fraction of the difference remaining being assigned to a taxon during each iteration was in proportion to the difference between the proportion reported by China and that reported by T&SK;
- All taxonomic levels were considered equally, i.e., fish families were treated the same as fish genera or species; and
- All taxa reported by T&SK could be used for reporting Chinese landings even if a taxon was not specifically reported in official Chinese landings statistics (but could be presumed to be a hidden portion of the 'miscellaneous' category).

In our example, this process continued until the additional 17% of 'miscellaneous' fish fraction reported by China but not by T&SK was assigned to explicit fish taxa.

Once this first stage was completed, the remaining proportion of Chinese landings still identified as 'miscellaneous marine fishes' were

Table 8. Countries reporting landings in taxonomically highly aggregated groups based on totals from FAO statistics from 1950 to 1998 inclusive. Listed are the top 20 countries (or territories) ranked by the total tonnage (million t) reported as 'miscellaneous marine fishes', 'miscellaneous marine crustaceans' or 'miscellaneous marine molluscs' (all abbreviated as MM). The overall mean over the same period is also shown.

Country	Marine Total (million t)	MM Fishes (million t)	MM Crustacea (million t)	MM Molluscs (million t)	MM Fishes (%)	MM Crustacea (%)	MM Molluscs (%)	MM Total (%)	MM Total (million t)
China	200.0	74.4	16.5	22.2	37.2	8.2	11.1	56.6	113.1
Korea D.P.R.	36.1	35.4	0.3	0.0	98.1	0.7	0.0	98.8	35.7
Thailand	68.2	32.2	0.0	0.1	47.2	0.0	0.2	47.3	32.3
Japan	375.2	21.6	0.3	0.0	5.8	0.1	0.0	5.8	21.9
Viet Nam	24.0	19.1	0.0	0.6	79.5	0.0	2.6	82.1	19.7
Myanmar	18.3	18.1	0.0	0.0	98.9	0.0	0.0	98.9	18.1
Indonesia	64.1	10.3	0.1	0.0	16.0	0.1	0.0	16.1	10.3
Former USSR	209.9	8.1	0.1	0.6	3.9	0.1	0.3	4.2	8.8
India	67.5	7.7	0.6	0.1	11.5	0.8	0.1	12.4	8.4
Malaysia	26.1	7.7	0.2	0.0	29.3	0.7	0.1	30.0	7.9
Mexico	31.2	6.6	0.0	0.1	21.0	0.0	0.2	21.2	6.6
Korea Rep.	68.0	5.7	0.0	0.3	8.4	0.0	0.4	8.9	6.1
Bangladesh	6.3	4.4	0.3	0.0	69.6	4.1	0.0	73.7	4.6
Brazil	21.9	4.3	0.0	0.2	19.6	0.1	0.7	20.4	4.5
Taiwan	29.5	4.2	0.0	0.1	14.1	0.0	0.3	14.4	4.3
Spain	56.0	3.4	0.2	0.2	6.0	0.3	0.4	6.7	3.8
Italy	16.9	3.0	0.1	0.3	18.0	0.8	2.0	20.8	3.5
USA	171.0	3.3	0.0	0.2	1.9	0.0	0.1	2.0	3.4
Iran	4.0	3.0	0.0	0.0	75.6	0.0	0.3	76.0	3.0
Hong Kong	6.4	2.4	0.0	0.1	37.5	0.0	2.0	39.5	2.5
MEAN	-	-	-	-	19.6	0.3	0.3	20.3	1.2

assigned to explicit fish taxa within the Chinese statistics in proportion to their presence at that stage. Thus, all fish landings were assigned to taxa more informative than the 'miscellaneous' segment.

The same procedure was used for crustaceans, and for all remaining unidentified fractions (mostly molluscs). Note that this procedure did not alter, for any year, the overall total landings for China, nor the total for each broad category (fishes, crustaceans, and others); also note that the 'taxonomically disaggregated' landing records resulting from this procedure were used only for the spatial disaggregation detailed below, not to generate alternative landing statistics for China.

2.3.4. Taxa Distribution

The process of spatial disaggregation of fisheries statistics required a database of the global distribution of all taxa reported to FAO. For each taxon, the proportion of the world's known distribution was mapped to the spatial cells represented in the database. This information is provided in two ways.

The first and preferred method was to use maps of distributions prepared by experts. Many excellent texts such as Muus and Dahlstrøm (1974), Scarratt (1982) and Cohen et al. (1990) provide global distributional maps that augment the extensive set of distributions available from FAO (Anon, 2001). Some were provided to us as geographical information systems (GIS) compatible files. Most distributions, however, were available only as photocopies and had to be scanned, re-projected and otherwise processed before they could be added to our database. Most sources produce distributional maps using knowledge of fisheries landings, museum collections and generalized depth and temperature ranges of the exploitable ages and life history stages. What is here referred to here as 'depth' is the depth of water over which the species can be taken rather than the depth in the water column the species is taken from. The reason for this is to allow generalizations using a global bathymetry. This definition means that there are no depth limits for taxa such as 'large pelagic fishes', as these species may be found over the deepest parts of the world's oceans. If depth limits for a taxon were these were used in conjunction with distributional maps to restrict the distribution to a subset of the ocean's spatial cells when the spatial database record was created. Thus, individual spatial cells included in broad distributional areas on maps were not included if they were outside the known depth range for the taxa.

The database describing the distribution of marine taxa is not simply presence/absence for each spatial cell but rather the proportion of the world's distribution to be found in that cell. Moreover, it was assumed that areas of the world that had a greater general primary productivity level would on average support greater populations of most marine fauna. Thus, the spatial primary productivity data mentioned above were used to apportion the distribution of each taxon among the cells that fell within its distributional limits.

Other methods were used when distributional maps were not available. The first was used exclusively for taxa identified at the genus level, which were assumed to cover the sum of all areas covered by their component species, as available in our database. When no such distributions were available, tabular limits to distribution (for depth, and/or latitude and FAO Statistical Area) were used, as for other taxonomic levels. One excellent source for the required tabular data (i.e., information on the biology and distribution of fishes) is FishBase (Froese and Pauly 2000), which includes contributions from numerous experts, and which covers the world ocean. FAO's SPECIESDAB (Coppola et al., 1994) is also an excellent source of tabular information on range of fishes and marine invertebrates, notably their presence/absence in the 18 marine FAO statistical areas.

When tabular limits were used to construct distributions, the maximum and minimum depths were used as more than absolute limits: based on numerous published information (see e.g., Alverson et al. 1964, Pauly and Chua 1994), it was assumed that the maximum abundance occurred at depths approximately 1/3 of the way between the minimum and maximum depths, and a triangular distribution was used to construct the proportions of the distribution found at each intervening depth. In a similar way the maximum distribution of taxa with latitudinal limits was taken to occur at a midpoint in the range with a triangular distribution assumed.

These tentative distributional ranges, based on known depth or latitude limits were reviewed when presence/absence by FAO statistical data was available. That is, if a species had a wide distribution described by a range of depths and latitudes but was never known to occur in FAO statistical area 21 then its distribution in our database would reflect this known limit, and spatial cells within FAO 21 were removed from its range.

Therefore, the limits of the final distribution of taxa for which maps were did not previously exist reflect depth, latitude, and presence/absence by FAO statistical area, while the relative abundance with these limits reflect depth, latitudinal range, and primary productivity. A number of experts have reviewed these distributions, and where appropriated, their input was used to adjust the parameters underlying questionable distributions.

2.3.5. Fishing Access

Each of the ocean's spatial cells was assigned to a country if the center of that cell occurred within the boundaries of the EEZ of that country, as defined by the Global Maritime Boundaries database (Veridan, 2000). Cell that were not assigned to any country's EEZ were considered to be on the high seas, and accessible by fleets of all countries.

Rules were developed to allow fishing access to the EEZ cells of one country by another. Initially only the country itself was allowed to access the cells assigned to its own EEZ and this was modified as more information became available on that country's fishing practices and access rights. 'Guilds' of fishing countries were defined, based on the assumption of mutual access to the EEZ cells of any country within the guild by another country in the guild. Such arrangement (albeit with many specific limitations) exists between fishing vessels of the European Union and elsewhere. There are also many examples where countries with historical ties (former colonies or territories) allow fishing access to another countries. On a case-by-case basis, in consultation with national experts, the database of fishing access that is used in the spatial disaggregation process was extended by granting 'permission' to allow access to the spatial cells defining the EEZ of one country by other countries.

The fishing access database was further enhanced by consulting with the FAO's FARISIS database (FAO 1998), which records fishing agreements and allows non-historical and distant-water fishing access rights to be included.

2.3.6. Spatial Disaggregation

Using landing records that were taxonomically disaggregated where necessary, a rule-based process was used to spatially disaggregate the landings statistics from their original FAO large statistical areas to a subset of much smaller spatial cells within that area (Fig. 5).

The official landings records for all countries fishing within the reporting year as determined by FAO statistics (A in Fig. 5) are processed as a set of database records by first disaggregating the statistics for large generalized group into records at lower taxonomic levels (B in Fig. 5 – described above). These records were then processed individually though the spatial disaggregation process (C in Fig. 5, detailed in Fig. 6).

Each taxon represented in a landings record was looked up in the database of taxonomic spatial distributions (produced by the methods described above). This yielded a subset of the spatial cells of the worlds oceans and the proportion of the world's distribution that had been estimated for each cell. The country reporting (fishing) is used with the database of fishing access (described above) which records which spatial cells are available for that country to fish in (including the EEZ of other countries for which arrangements exist). The FAO area that the statistic is reported for was used to provide a third set of spatial cells, i.e., those within the statistical area from which a landing was reported. These sets of spatial cells are then compared and if there is no overlapping cells the landing is not allocated and an 'error report' is logged (Fig. 6). Otherwise, the reported landing is assigned among overlapping cells in proportion to their areas. Thus, landing rates (t km^{-2} $year^{-1}$) are accumulated in each cell as each record is processed.

Logging allocation errors has proven very instructive in reviewing whether species distributions and countries' fishing access ranges were consistent with landings records. Indeed, this process allows for constant improvement of the underlying databases. At present, there are approximately 5% of global landings that cannot be mapped to a set of spatial cells for lack of overlap between the distribution of the various taxa, the reporting countries' fishing access, and the FAO statistical area from which the landing was reported. Some of these errors will be eliminated when access arrangements for fishing countries and taxa distributions have been fully reviewed by experts. This process has already required a shift from predominately depth-determined species distributions, which do not always allow landings in statistical areas where they are frequently reported (often these problems have been confirmed by experts on the fisheries in question). Sometimes errors originate

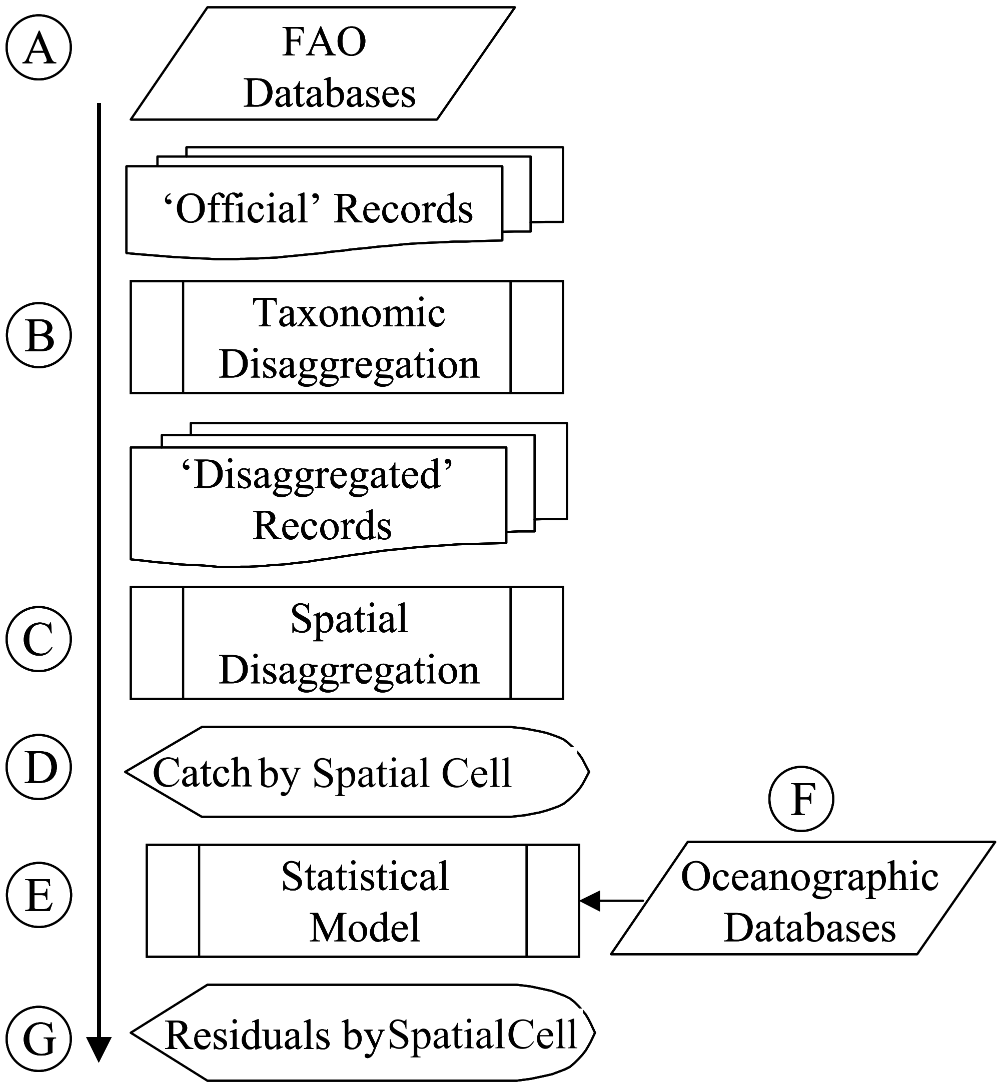

Figure 5. Schematic diagram of the processing procedures used to produce landing rate maps.

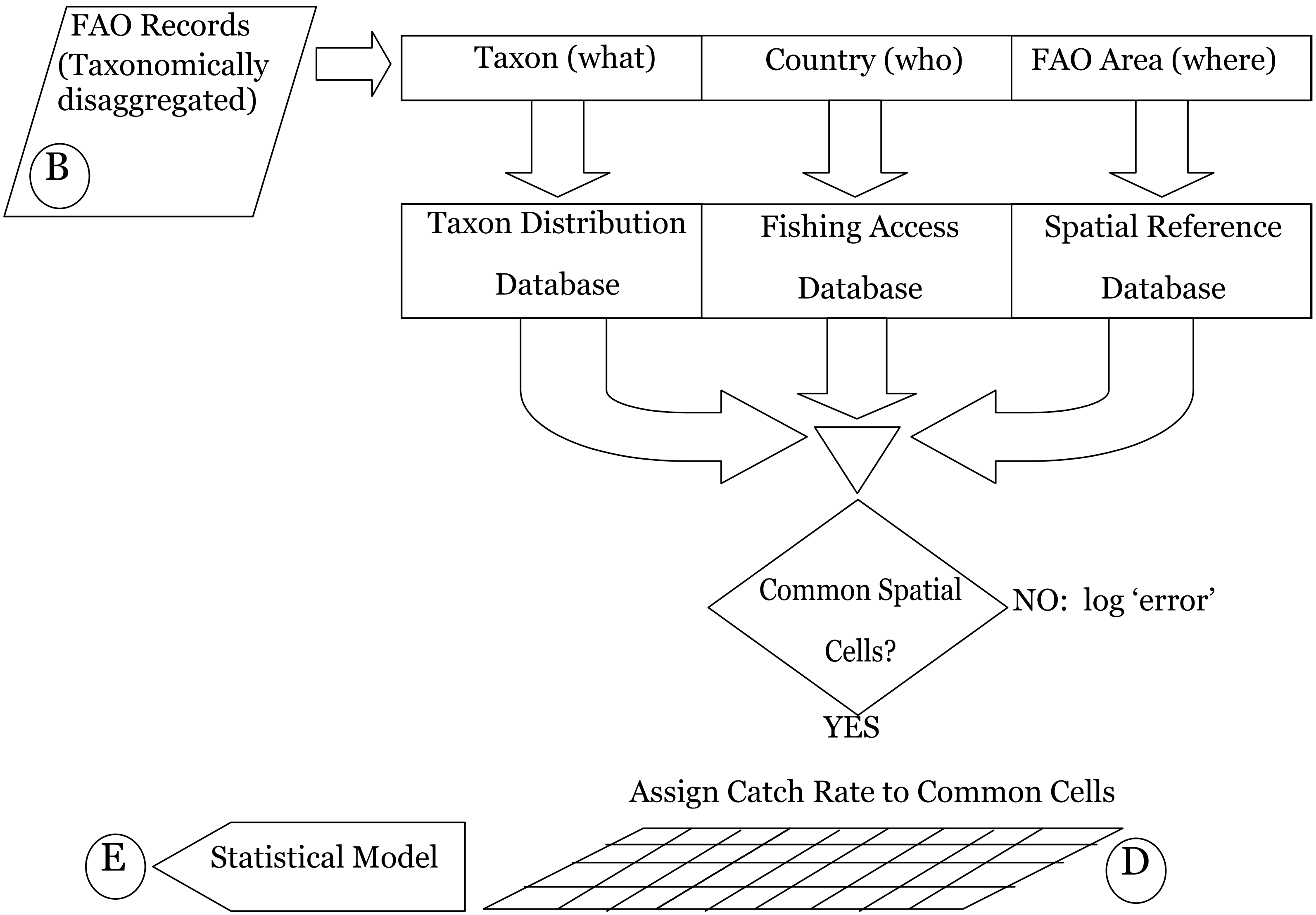

Figure 6. Schematic diagram of the spatial disaggregation process.

because countries do not report landings for all FAO areas they fish in, but simply report all the landings for their major fishing areas, or report distant-water landings from closer fishing areas. In the case of China, reports to FAO do not attribute catches to statistical areas. FAO staff must attribute what catch they can to areas outside of statistical area 61 (within which China's EEZ is located) and assign the rest by default to area 61.

Still, we have achieved overlap (between the species' distribution, the countries' fishing access, and the FAO area the landings were reported from) for about 95% of the world's marine landings, with each of our spatial cells allocated a proportion of these landings depending of their area (cells nearer the poles are smaller than those on the equator). In this way, a grid map of landing rates is build up as each landing record is processed (D in Fig. 6). Though each record is processed for the taxonomic level it is reported at (after disaggregation), the results are gathered and reported in 12 major groups for the purposes of this contribution. These groups are: anchovies, herrings (defined as non-anchovy Clupeiformes), perches (taxa in Perciformes), tuna and billfish, cods, salmons/smelts, flatfishes, scorpionfishes (Scorpaeniformes), sharks and rays, crustaceans, molluscs, and 'others'. This report only deals with the aggregate total of these 12 groups.

2.3.7. Statistical Analysis

The result of the spatial disaggregation was a database for each year providing the landing rate (t km^{-2} $year^{-1}$) of each of 12 major groups of marine organisms for each of the global spatial cells (including the total of all groups combined). This database was merged with databases of oceanographic factors such as average depth and primary productivity so that a statistical model describing the distribution of annual landing rates could be developed (E in Fig. 5). Annual landing distributions for 1990 to 1998 were averaged, and this dataset representative of the 1990s was used in subsequent modeling and mapping.

A general additive model (GAM) was developed using the S-Plus 2000 software by examining which oceanographic factors best predicted the pattern of global landings rates produced by the spatial disaggregation process (E in Fig. 5). A range of factors and their interactive terms were considered. After examining the model fits and the patterns of residuals, a simple model relating landing rate, C (t km^{-2} $year^{-1}$) to primary productivity rate, p (g C m^{-2} $year^{-1}$), and the log of average depth, $\log(d)$ (m), and their interaction, i was chosen:

$$C \approx p + \log(d) + i \qquad \text{... 2)}$$

2.3.8. Landing Rate Predictions

A statistical model was used to predict the average 1990s landing rates for all reporting groups combined, for each spatial cell, given its primary productivity and depth. Predicted landing rates were truncated at zero (necessary for some cells in low productivity oceanic areas). The cells' predicted landings were expressed as a proportion of the sum of global landings, and multiplied by the reported total of annual landings. This rescaling produced predicted landing rates for each spatial cell with the same average global total of landings as reported for the period, i.e., it corrected for 95%, rather than 100% of the global catch having been spatially disaggregated. Thus, the GAM was not used explicitly to predict global landings from oceanographic parameters, but rather the distribution of landing rates amongst the spatial cells contributing to the reported total landings. The difference in the landing rates resulting from the spatial disaggregation of current statistics and the rescaled predictions based on primary productivity and average depth were mapped. Predicted changes to the landings of statistical areas 61 and 71 were calculated by using the landing rates that the GAM predicted for cells in these areas.

2.4. Results

2.4.1. Taxonomic Disaggregation

The results of the taxonomic disaggregation are shown in Table 9. The example shown is for an average of the 1990s, for which the Chinese landings reported to FAO averaged 53% reported only to the three major 'miscellaneous' groups, 7% identified to family and 39% identified to the species or genus level. After the disaggregation there were no landings left in the miscellaneous category, 2% at the order or class level, 9% at the family and 89% identified to species or genus. The large increase in the latter category allowed specific biological and distributional information to be used to greatly increase the precision of the subsequent spatial disaggregation process.

Table 9. Mean reported landings for China for the 1990s, broken down by for each taxon (at the level of description supplied to FAO) with the proportion of the total. The proportional breakdown for China's neighbours, Taiwan and South Korea, is shown for comparison and because it was used in the taxonomic disaggregation that resulted in the column labeled 'Adj. proportion China'. Taxa with zero reported landings were left blank (Group 1=finfish; Group 2=crustaceans; Group 3=molluscs).

Group	Taxa	English Name	Proportion China	Proportion Neighbours	Adj. proportion China
1	-	Miscellaneous marine fishes	34.81	8.68	-
1	*Trichiurus lepturus*	Largehead hairtail	8.73	4.54	8.73
1	*Engraulis japonicus*	Japanese anchovy	5.09	9.76	8.63
1	*Decapterus*	Scad	4.92	0.62	4.92
1	*Scomber japonicus*	Chub mackerel	3.34	10.32	8.46
1	Polynemidae	Threadfins	2.83	-	2.83
1	*Scomberomorus niphonius*	Japanese Spanish mackerel	2.62	1.18	2.62
1	*Cantherhines*	Filefishes	2.53	0.05	2.53
1	Stromateidae	Butterfishes	1.63	0.53	1.63
1	*Theragra chalcogramma*	Alaska Pollack	1.39	10.95	8.42
1	*Larimichthys polyactis*	Yellow croaker	1.23	1.40	1.59
1	*Muraenesox cinereus*	Daggertooth pike conger	1.02	0.35	1.04
1	*Nemipterus virgatus*	Golden threadfin bream	0.87	0.30	1.04
1	*Sardinops melanostictus*	Japanese pilchard	0.77	1.65	1.53
1	Sparidae	Porgies	0.65	0.48	0.65
1	Mugilidae	Grey mullets	0.64	-	0.64
1	*Pseudosciaena crosea*	Large yellow croaker	0.54	0.85	0.82
1	*Ilisha elongata*	Elongate ilisha	0.45	0.02	0.45
1	*Epinephelus spp.*	Groupers	0.25	0.11	0.25
1	Sciaenidae	Drums or croakers	0.11	3.07	2.34
1	Scombridae	Mackerels, tunas, bonitos	0.08	0.09	0.10
1	*Clupea pallasii*	Pacific herring	0.05	0.34	0.26
1	Elasmobranchii	Sharks and rays	-	0.38	0.30
1	Rajiformes	Skates and rays	-	0.37	0.28
1	Clupeiformes	Herrings	-	0.28	0.22
1	Salmoniformes	Salmons, pikes and smelts	-	0.05	0.04
1	Pleuronectiformes	Flatfishes	-	0.01	0.01
1	Ariidae	Sea catfishes	-	0.01	0.01
1	Lophiidae	Goosefishes	-	0.33	0.25
1	Exocoetidae	Flyingfishes	-	0.04	0.03
1	Scorpaenidae	Scorpionfishes or rockfishes	-	0.26	0.20
1	Serranidae	Sea basses: groupers and fairy basslets	-	0.03	0.02

Group	Taxa	English Name	Proportion China	Proportion Neighbours	Adj. proportion China
1	Sillaginidae	Smelt-whitings	-	0.06	0.04
1	Malacanthidae	Tilefishes	-	0.05	0.04
1	Lutjanidae	Snappers	-	0.19	0.15
1	Mullidae	Goatfishes	-	0.00	0.00
1	Gobiidae	Gobies	-	0.11	0.08
1	Istiophoridae	Billfishes	-	0.00	0.00
1	Cynoglossidae	Tonguefishes	-	0.10	0.08
1	*Sphyraena*	Barracudas	-	0.04	0.03
1	*Caranx*	Jacks	-	0.42	0.32
1	*Scomberomorus*	Spanish mackerels	-	0.09	0.07
1	*Seriola*	Amberjacks	-	0.23	0.16
1	*Upeneus*	Mullets	-	0.02	0.02
1	*Auxis*	Goatfishes	-	0.14	0.10
1	*Coryphaena hippurus*	Common dolphinfish	-	0.45	0.34
1	*Istiophorus platypterus*	Indo-Pacific sailfish	-	0.12	0.09
1	*Chanos chanos*	Milkfish	-	0.00	0.00
1	*Acanthocybium solandri*	Wahoo	-	-	-
1	*Euthynnus affinis*	Kawakawa	-	0.08	0.06
1	*Katsuwonus pelamis*	Skipjack tuna	-	0.18	0.14
1	*Scomberomorus commerson*	Narrow-barred Spanish mackerel	-	0.17	0.13
1	*Scomberomorus guttatus*	Indo-Pacific king mackerel	-	0.05	0.04
1	*Thunnus alalunga*	Albacore	-	0.56	0.43
1	*Thunnus albacares*	Yellowfin tuna	-	0.73	0.60
1	*Thunnus obesus*	Bigeye tuna	-	0.06	0.05
1	*Thunnus thynnus thynnus*	Northern bluefin tuna	-	0.03	0.02
1	*Thunnus tonggol*	Longtail tuna	-	0.59	0.47
1	*Makaira indica*	Black marlin	-	0.04	0.03
1	*Makaira mazara*	Indo-Pacific blue marlin	-	0.15	0.11
1	*Tetrapturus audax*	Striped marlin	-	0.02	0.01
1	*Xiphias gladius*	Swordfish	-	0.04	0.03
1	*Conger myriaster*	Western North Pacific conger	-	0.95	0.73
1	*Cololabis saira*	Pacific saury	-	2.56	1.93
1	*Hyporhamphus sajori*	Japanese halfbeak	-	0.07	0.05
1	*Gadus macrocephalus*	Pacific cod	-	0.19	0.14
1	*Eleutheronema tetradactylum*	Fourfinger threadfin	-	0.29	0.22
1	*Lates calcarifer*	Barramundi	-	0.00	0.00
1	*Priacanthus macracanthus*	Red bigeye	-	0.22	0.16
1	*Trachurus japonicus*	Japanese jack mackerel	-	1.19	0.89

Group	Taxa	English Name	Proportion China	Proportion Neighbours	Adj. proportion China
1	*Decapterus russelli*	Indian scad	-	0.19	0.13
1	*Megalaspis cordyla*	Torpedo scad	-	0.04	0.03
1	*Mene maculata*	Moonfish	-	0.19	0.15
1	*Nibea mitsukurii*	Nibe croaker	-	0.09	0.07
1	*Pennahia argentata*	Silver croaker	-	0.31	0.23
1	*Arctoscopus japonicus*	Sailfin sandfish	-	0.13	0.10
1	*Hypoptychus dybowskii*	Korean sandeel	-	0.37	0.28
1	*Pampus argenteus*	Silver pomfret	-	0.54	0.42
1	*Psenopsis anomala*	Melon seed	-	0.33	0.25
1	*Sebastes alutus*	Pacific ocean perch	-	0.00	0.00
1	*Chelidonichthys kumu*	Bluefin gurnard	-	0.00	0.00
1	*Pleurogrammus azonus*	Okhostk atka mackerel	-	0.21	0.16
1	*Stephanolepis cirrhifer*	Thread-sail filefish	-	1.80	1.36
1	*Mugil cephalus*	Flathead mullet	-	0.29	0.22
1	*Atrobucca nibe*	Longfin kob	-	0.05	0.04
1	*Platycephalus indicus*	Bartail flathead	-	0.15	0.11
1	*Ruvettus pretiosus*	Oilfish	-	0.17	0.13
1	*Saurida undosquamis*	Brushtooth lizardfish	-	0.01	0.01
1	*Paralichthys olivaceus*	Bastard halibut	-	0.10	0.07
1	*Etrumeus teres*	Round herring	-	0.08	0.06
1	*Spratelloides gracilis*	Silverstriped round herring	-	0.03	0.02
1	*Sardinella zunasi*	Japanese sardinella	-	0.49	0.37
1	*Clupanodon thrissa*	Chinese gizzard shad	-	0.40	0.29
1	*Decapterus maruadsi*	Japanese scad	-	0.27	0.19
1	*Parastromateus niger*	Black pomfret	-	0.18	0.13
1	*Rachycentron canadum*	Cobia	-	0.03	0.02
1	*Lateolabrax japonicus*	Japanese seaperch	-	0.07	0.05
1	*Chirocentrus dorab*	Dorab wolf-herring	-	0.00	0.00
1	*Pagrus auratus*	Squirefish	-	0.11	0.08
1	*Saurida tumbil*	Greater lizardfish	-	0.25	0.19
1	*Acanthopagrus schlegeli*	Black porgy	-	0.01	0.01
1	*Pseudopleuronectes herzensteini*	Littlemouth flounder	-	0.71	0.52
1	*Takifugu porphyreus*	Purple puffer	-	0.32	0.24
2	-	Miscellaneous marine crustaceans	7.93	0.00	-
2	*Acetes japonicus*	Akiami paste shrimp	3.56	0.92	4.36
2	*Portunus trituberculatus*	Gazami crab	2.12	0.76	2.57
2	*Trachypenaeus curvirostris*	Southern rough shrimp	1.47	0.11	1.79
2	*Penaeus chinensis*	Fleshy prawn	0.49	0.06	0.59

Group	Taxa	English Name	Proportion China	Proportion Neighbours	Adj. proportion China
2	*Portunus pelagicus*	Blue swimming crab	0.27	0.10	0.33
2	Decapoda	Decapoda	-	2.07	2.55
2	Brachyura	Marine crabs nei	-	2.34	2.88
2	*Paralithodes*	King crabs	-	0.00	0.00
2	*Metapenaeus*	*Metapenaeus* shrimps nei	-	0.06	0.07
2	*Penaeus monodon*	Giant tiger prawn	-	0.01	0.01
2	*Scylla serrata*	Indo-Pacific swamp crab	-	0.02	0.03
2	*Penaeus japonicus*	Kuruma prawn	-	0.21	0.26
2	*Panulirus longipes*	Longlegged spiny lobster	-	0.00	0.00
2	*Penaeus penicillatus*	Redtail prawn	-	0.13	0.16
2	*Metapenaeus joyneri*	Shiba shrimp	-	0.19	0.24
3	-	Miscellaneous marine molluscs	10.38	0.48	-
3	Sepiidae, Sepiolidae	Cuttlefish,bobtail squids nei	1.50	0.76	1.53
3	*Strongylocentrotus*	Sea urchins nei	0.00	0.00	0.00
3	-	Sea-urchins and other echinoderms	-	0.15	0.09
3	Cephalopoda	Cephalopods nei	-	0.12	0.08
3	Bivalvia	Clams nei	-	1.16	0.73
3	Gastropoda	Gastropods nei	-	0.24	0.15
3	Octopodidae	Octopuses, etc. nei	-	0.78	0.48
3	Mytilidae	Sea mussels nei	-	0.25	0.16
3	Cardiidae	Cockles nei	-	0.18	0.11
3	*Loligo*	Common squids nei	-	0.83	0.52
3	*Haliotis*	Abalones nei	-	0.01	0.01
3	*Arca*	Ark clams nei	-	0.04	0.02
3	*Anadara granosa*	Blood cockle	-	0.11	0.07
3	*Mactra sachalinensis*	Hen clam	-	0.27	0.18
3	*Turbo cornutus*	Horned turban	-	0.33	0.21
3	*Ruditapes philippinarum*	Japanese carpet shell	-	0.73	0.46
3	*Todarodes pacificus*	Japanese flying squid	-	9.16	5.66
3	*Meretrix lusoria*	Japanese hard clam	-	0.12	0.07
3	*Stichopus japonicus*	Japanese sea cucumber	-	0.09	0.06
3	*Mytilus coruscus*	Korean mussel	-	0.17	0.11
3	*Crassostrea gigas*	Pacific cupped oyster	-	0.82	0.52
3	Loliginidae, Ommastrephidae	Various squids nei	-	1.05	0.67
3	*Pecten yessoensis*	Yesso scallop	-	0.01	0.00

2.4.2. Current Spatial Allocation

The taxonomic and spatial disaggregation produced landing rate estimates for each of the global spatial cells. These results showed large areas of the world's oceans with landing rates from 0 to 0.2 t km^{-2} year^{-1} (Fig. 7) and the global average including oceanic areas was 0.22 t km^{-2} year^{-1}. There were areas, however, primarily along the coast of China, where reported landing rates were in excess of 10 t km^{-2} year^{-1}. Though these unusually high landing rates were in areas of relatively high primary productivity, they were, nevertheless very unusual as they combined very high landing rates with an extensive area (approximately 367,500 km^{-2}). The area with the unusual landing rate was predominately within the EEZ of China (based on Pang and Pauly, this volume, our spatial disaggregation access rules assumed only China could fish in these areas). Therefore, these landing rates originated with landings statistics reported to FAO by China. Globally only 0.3% of the area of the world's oceans had landing rates higher than 10 t km^{-2} year^{-1}, and 30.6% of this area occurred within the EEZ of China. Other areas with high landing rates typically had exceptionally high primary production rates, such as along the Peruvian coast where permanent, strong upwelling plumes support fisheries on species low in the food web, mainly the anchoveta *Engraulis ringens* (Pauly et al. 1989; Faure and Cury 1998).

2.4.3. Predicted Spatial Allocation

Predicted landing rates for each spatial cell based on primary productivity and the log of average depth (assuming the same total of global landings as 'officially' reported) are mapped in Fig. 8. The most obvious difference between the landing rates in this figure and those in the map of the landing rates based on the spatial disaggregation process (Fig. 7) is the great reduction in the landing rates in the cells along the coast of China, with most this area having predicted landing rates of 2 to 5 t km^{-2} year^{-1}, much less than the many values of 10 t km^{-2} year^{-1} or greater implied by the reported landings.

2.4.4. Predicted Differences in Landing Rates and Landings

Mapping the difference in the landing rates of spatial cell resulting from the spatial disaggregation process and those predicted by the statistical model produced Fig. 9. Clearly there were many areas where the differences were quite small (2 t km^{-2} year^{-1} or less) and this would be expected as the total global landings were scaled to the same reported global total. Within statistical areas 61 and 71 there were a few locations such as along the Gulf of Carpentaria in northern Australia where a greater landing rate was predicted than was reported (based on spatial disaggregation).

There were, however, some more obvious differences in landing rates. The dominant feature of Fig. 9 is the large area, along the coast of China, where reductions in landing rate of 10 t km^{-2} year^{-1} or more were predicted by the GAM. Overall, only 0.16% of the area of the world's oceans was predicted to be over-reported to this extent, and of this, 19% was within the EEZ of China. This indicates that the landings predicted for China (which has its EEZ in this area) are much greater than would be predicted based on a global model of primary productivity and depth.

Using the landing rates predicted by the GAM, the average landings for the 1990s for areas 61 and 71 would be reduced by 48% to 8 and 6.8 million t respectively. The average annual Chinese landings for the 1990s in areas 61 and 71 would be reduced overall by 64% to 2.7 million t.

2.5. Discussion

The basis for the analysis presented here is to try and predict what fisheries landings and annual landing rates would be expected from areas of the world's oceans. The best predictive model found so far was one using underlying primary productivity and depth. Based on this there were significant areas where observed landing rates were very different from the predicted values.

It is widely accepted that reported landings usually underestimate the catch of marine species. In many fisheries there is significant discarding of catch before it is landed (Watson et al. 2000). In many circumstances, particularly where quotas exist, not all catch is declared. Catch may also be misidentified, or misreported from another statistical area. Methods exist to estimate these reporting problems (Pitcher and Watson, 2000). It is rare that there is concern that reported landings may overestimate actual landings.

The model reported here was developed to estimate the spatial distribution of catch rates globally, and not to estimate the actual landings made by any specific nation. The rescaling of model-predicted catch rates to the 'official' global

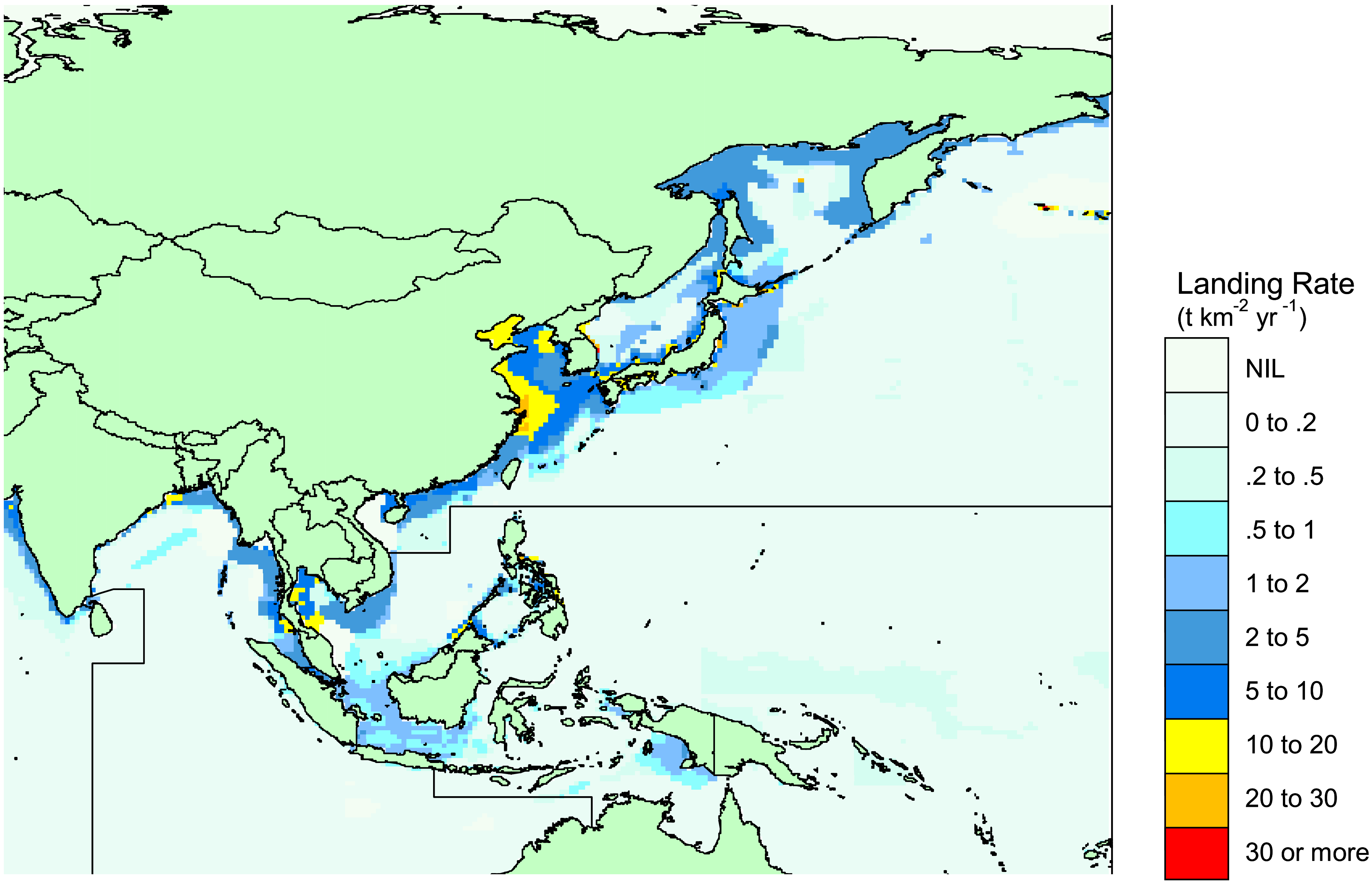

Figure 7. Map of reported mean landing rates in Northeast and Southeast Asia (t km^{-2}year^{-1}) of all species combined for the 1990s resulting from taxonomic and spatial disaggregation of FAO's fisheries landing records.

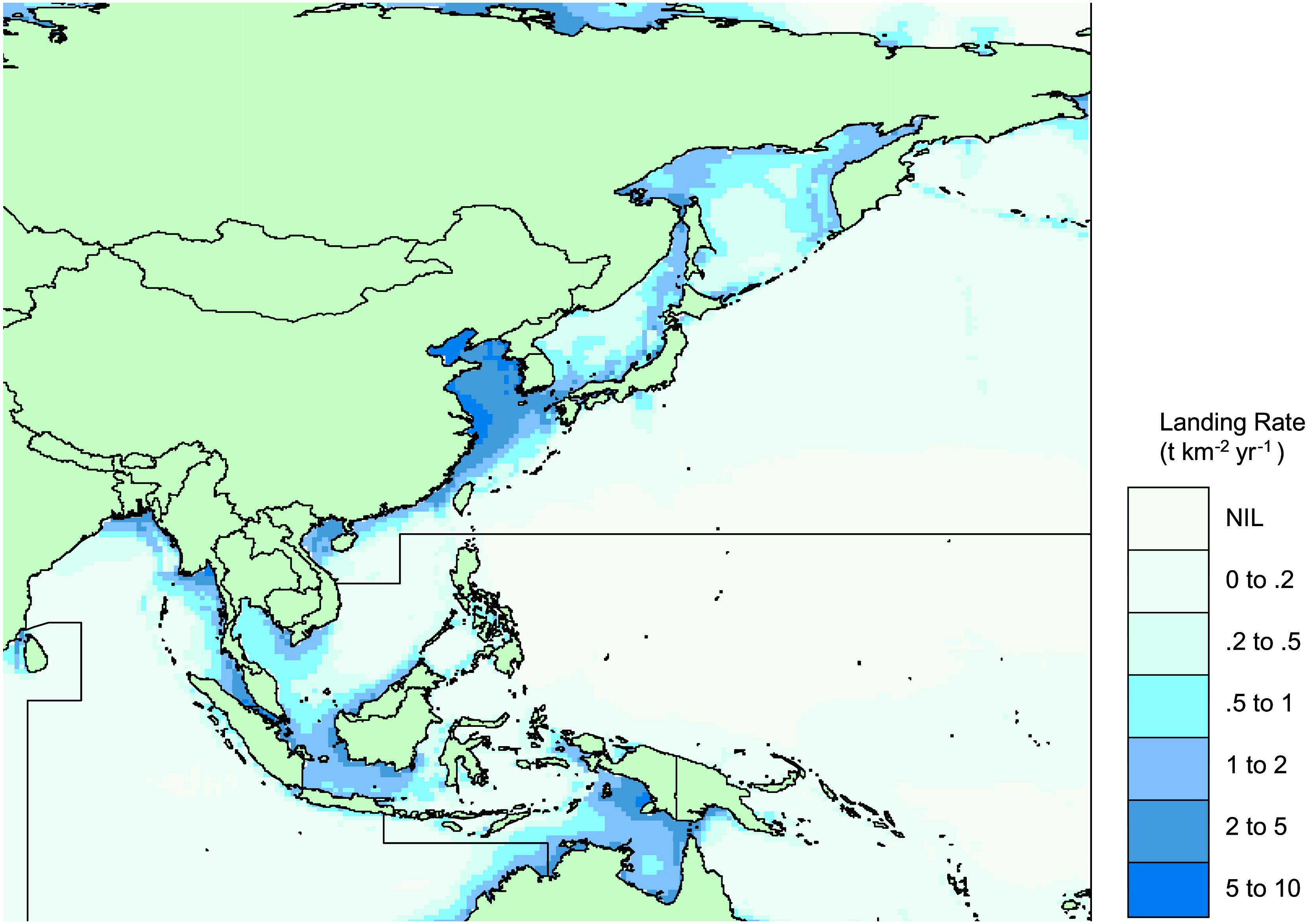

Figure 8. Map of mean landing rates in Northeast and Southeast Asia (t km^{-2}year^{-1}) of all species combined for the 1990s predicted by primary productivity and depth in a global general additive statistical model

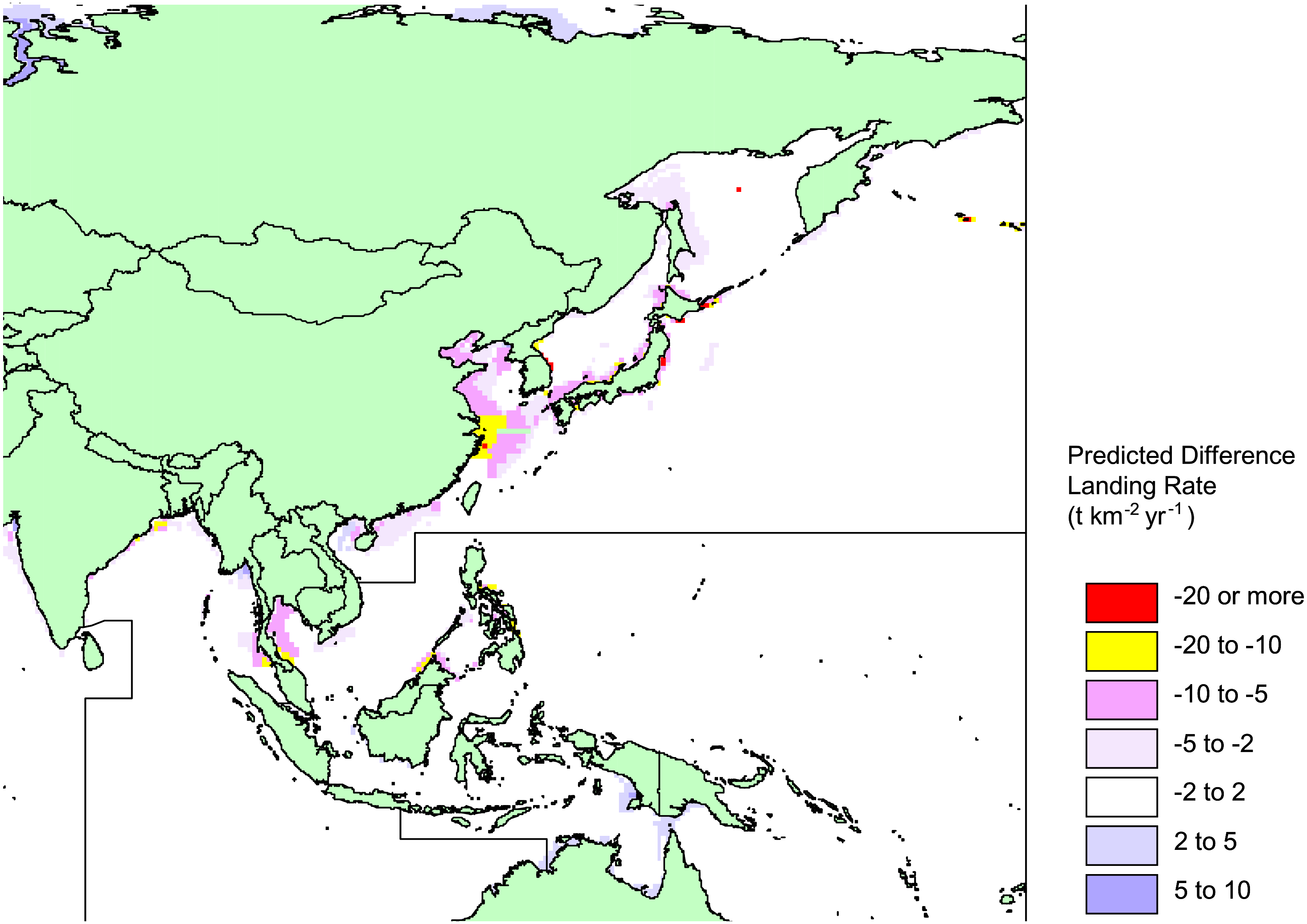

Figure 9. Map of mean predicted change in landing rates (t $km^{-2}year^{-1}$) of all species combined for the 1990s predicted by primary productivity and depth in a global general additive statistical model

total of landings precludes any accurate estimates of what a specific country's landings should actually be, as the actual global total may be considerably different than the total currently accepted (indications are that it is actually higher due to underreporting by many countries). This model does, however, clearly indicate that there are abnormally high catch rates reported for coastal China, originating from Chinese reported landings. Although this is not the only place in the world's oceans where this difference exists, it is the most extensive, and it dominates the statistics from FAO areas 61 and 71.

Regardless of exact predictions, the conclusion must be, therefore, that landings reported from coastal areas of China are much greater than would be predicted. If the underlying primary productivity of this area does not explain the high landing rates, then perhaps aspects of the Chinese fleet may suggest other reasons. Smith (1999) examined the global fleets of vessels over 100 tons and found that though the statistics for the Chinese fleet were somewhat problematic (China is not well represented in Lloyd's database), what evidence there was suggested a huge fleet: with substantial increases through the 1990s. There is, however, evidence that the majority of this huge fleet is of low horsepower and do not have the same fishing capacity of European vessels of the same size. Pang and Pauly (2001) also examined Chinese vessel statistics and found a large (though not well enumerated) fleet of relatively small tonnage vessels that were mostly suitable for coastal waters. Despite the unavailability of accurate statistics describing the Chinese fleet, it seems quite unlikely that the enhanced landing rates reported from this region could be explained by fleet capacity alone.

Another explanation for the unexpectedly high landings reported from Chinese waters in FAO statistical areas 61 and 71 may be the misreporting of landings made by distant-water fleets. Chinese distant-water fleets (DWF) were reported to fish as far away as Morocco but to discharge their catches at Chinese home ports (Bonfil et al., 1998). If these landings were reported from the statistical area of the home port (area 61) rather than from the area where the catch was taken, this would increase landings reported to area 61 (and similarly for area 71). In this way, fish landings supported by primary productivity in other areas of the world may account for the high landing figures reported. However, as shown by Pang and Pauly (this volume), the catches of Chinese DWF are not large enough to account for the large residuals of the GAM described above.

If greater fish catches are being taken from the Chinese coast than almost anywhere else in the world's oceans, through whatever means, it would suggest that these catches are not sustainable. In fact, Chen et al. (1997) found that several stocks in the East China Sea have declined significantly over the last 20 years. Aggregate levels of fisheries landings were sustained only through the increase in take of relatively newly fished and low value species. They suggested that presently, certain environmental conditions may be sustaining high fish catches for some stocks, but that without these conditions, these stocks may be endangered. The unusual apparent productivity of Chinese coastal waters is also not consistent with a global analysis performed by Caddy et al. (1998), who observed that while there had been a rise in global catches over the last decades, there had in fact been a slowing of growth or even decline in recent years (late 1990s). Pang and Pauly (2001) cite examples of declining stocks in Chinese coastal waters, without these declines being reflected in reported landings, which, from 1985 to 1998, invariably increased.

The continued high levels of Chinese landings seem very problematic given the failure of global statistical models to predict them based on well-founded factors such as primary productivity and depth. While global fisheries catches stagnates or declines in most areas, China's nominal catches increased, contributing 1.5 % per year more to the world catch since 1989, up to the present, staggering figure of 19 % of world's fisheries landings – this from an EEZ that includes only 1.4% of the world's shelf area. The most tenable hypothesis for this unusual trend is that for some time, reports of Chinese landings have overstated actual landings for these areas, as suggested by Pang and Pauly (this volume). Such inaccuracies can have serious consequences for China to manage its fisheries sector, and for international efforts to monitor the state of global fisheries.

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