People's Republic of China

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The Fishery

China has the largest fishery in the world. The total production was 5.1 million t in 2005, of which 28.5% was from marine captures. Catches from marine capture fisheries reported by the UN Food and Agriculture Organization (FAO) increased from 3.1 million t in 1980 to a maximum of 17.2 million t in 1998 and 1999 (Table 21, Fig. 30A and B). Catches in 2002 declined about 4% from the 1999 levels. China's marine capture fisheries have accounted for about 18% of the world catch in recent years (Table 21, Fig. 31) of which marine fish make up the largest group in the catch (Fig. 32). Much of the catch is reported in species aggregates, such as marine fishes (nei), or scads (nei). Scads include, for example, *Trachurus japonicus*, *Decapterus maruadsi*, *Septipinna taty*, and *Sardinella zunasi*. Some of the key species in the Yellow Sea are listed in Table 22 and represent about 17 to 20% of the catch over the past few decades.

Aquaculture is the major supplier of seafood in China. Production of seafood from aquaculture just exceeded wild production in 1985 and by 2003 was 1.4 times larger than the wild catch. Marine aquaculture consists mostly of shrimp, molluscs, and aquatic plants, with fish representing about 2.5% of the approximately 20.9 million t of marine aquaculture production in 2003. A common food for cultured fish is the bycatch in marine fisheries. In 2003, marine fish production was 519,000 t, and was expected to increase substantially. China is also one of the world's major importers of fish meal and, increasingly, more seafood for domestic consumption.

Major Coastal Fishing Areas

The major coastal fishing areas are in the Bohai Sea, the Yellow Sea, and the East China Sea (Fig. 33). The Yellow/Bohai Sea is bordered by China, Democratic People's Republic of Korea and Republic of Korea, and is located at latitudes of 32°–41°N, and longitudes of 118°–126°30′E. A border line, separating the Yellow Sea from the East China Sea, is commonly drawn from the mouth of the Yangtze River to Jeju Do. The Yellow Sea large marine ecosystem, as internationally defined, also includes the Bohai Sea. Major rivers discharging directly into the Yellow/Bohai Sea include the Han, Datung, Yalu, Huanghe and Sheyang, from the middle region to the north, and the Yangtze River in the south. The Yellow Sea annually receives more than 1.6 billion t of sediments from the rivers (Valencia, 1988). It covers an area of about 460,000 km^2 and has a geologically unique bottom. The seafloor has an average depth of about 40 m, a maximum depth of 140 m north of Jeju Do, and slopes gently from the Chinese continent, and more rapidly from the Korean Peninsula to a north–south trend of bathymetric contour. There is a depression with smooth terrain in the central part of the Yellow Sea which is an important overwintering ground for many fish species. The Bohai Sea and the shallow waters along the coast in the Yellow Sea are important spawning grounds for most species distributed in the Yellow Sea. The Bohai, Yellow and East China seas are marginal seas of the Pacific Ocean bounded by the Korean Peninsula and China. The Yellow Sea is a semi-enclosed shelf sea with distinct bathymetry, hydrography, productivity, and trophically dependent populations. Shallow, but rich in nutrients and resources, the sea is most favourable for coastal and offshore fisheries, and has had well-developed multi-species and multi-national fisheries. However, over the past several decades, many changes in productivity, biomass yields, species composition and shift in dominance have occurred. Overexploitation is the principal reason for the changing state of the ecosystem, but natural environmental perturbation should be considered an important driving force causing changes in the species composition and biomass yields, at least for pelagic species and shellfish.

The Yellow Sea is one of the most intensively fished areas in the world. China has increased the total annual catch from about 0.5 million t in the 1950s and 1960s to around 1.5 million t in recent years. Four provinces and one municipality, including Lioaning, Hebei, Shandong, Jiangsu, and Tianjin are along the Chinese coast in the Yellow Sea.

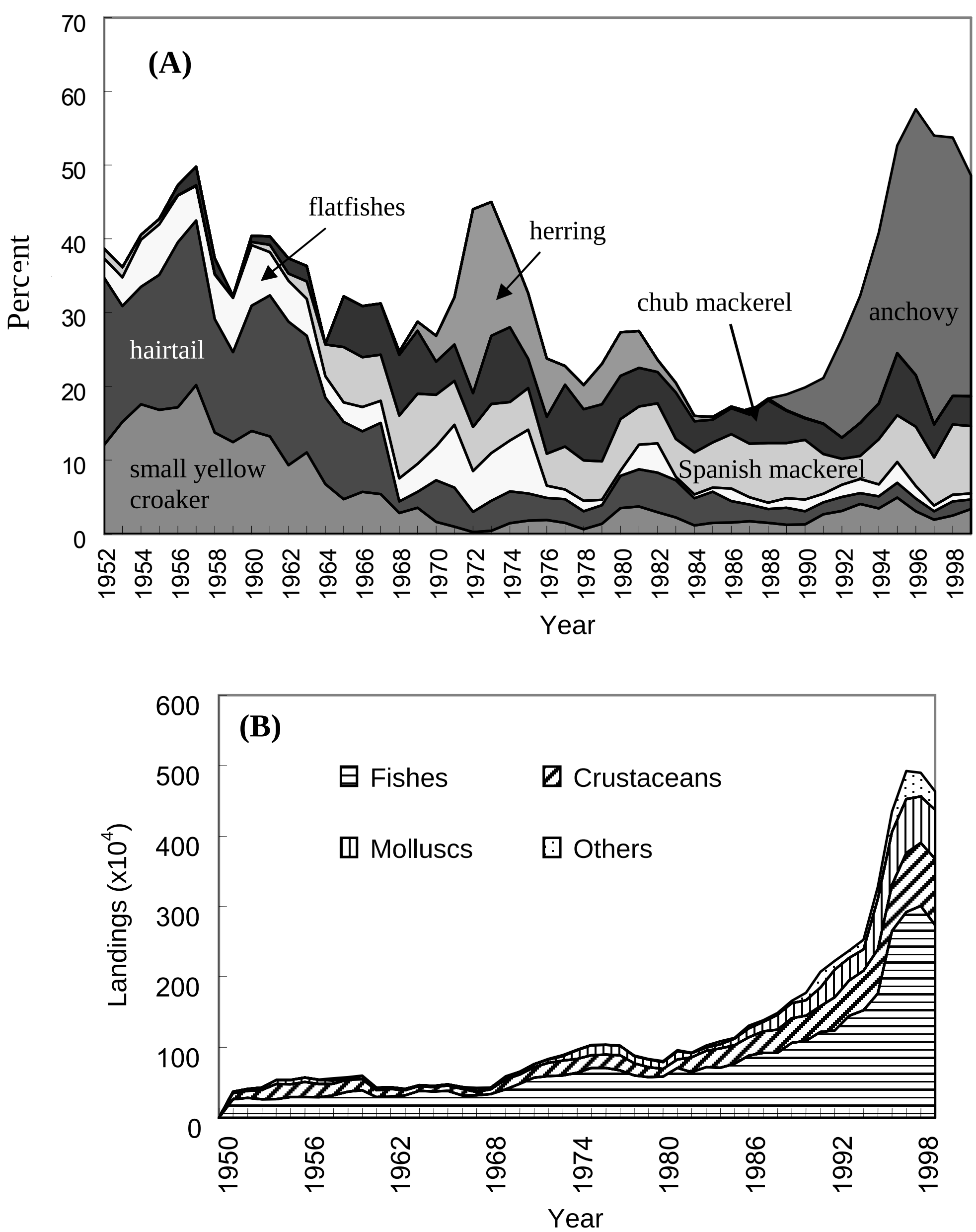

Fig. 30 (A) Proportion of major species in total fish landings from northern China; (B) total landings from northern China. Some of the catches were from the East China Sea.

Table 21 Catch (in millions of t) for the world, China, and the world, excluding China, from 1950 to 2002 (FAO, 2003).

Year	World catch	China catch	World catch – China catch
1950	18.697	0.880	17.817
1951	21.147	1.249	19.897
1952	22.947	1.558	21.389
1953	23.399	1.723	21.676
1954	25.348	2.032	23.316
1955	26.737	2.206	24.531
1956	28.405	2.369	26.036
1957	28.542	2.042	26.500
1958	29.137	2.091	27.046
1959	31.517	2.134	29.383
1960	33.852	2.215	31.637
1961	37.645	2.396	35.249
1962	40.974	2.539	38.435
1963	42.026	2.491	39.535
1964	46.621	2.466	44.154
1965	47.603	2.530	45.073
1966	51.467	2.504	48.963
1967	54.798	2.509	52.289
1968	58.092	2.626	55.467
1969	56.570	2.553	54.017
1970	62.767	2.490	60.277
1971	62.857	2.704	60.153
1972	58.541	3.009	55.533
1973	59.000	3.099	55.901
1974	62.292	3.385	58.908
1975	61.810	3.497	58.313
1976	65.214	3.597	61.616
1977	63.778	3.623	60.155
1978	65.934	3.416	62.519
1979	66.421	3.042	63.378
1980	67.185	3.139	64.045
1981	69.408	3.135	66.272
1982	71.114	3.490	67.624
1983	71.060	3.645	67.415
1984	76.671	3.918	72.754
1985	78.236	4.178	75.057
1986	83.725	4.759	78.965
1987	84.321	5.378	78.942
1988	87.796	5.749	82.047
1989	88.312	6.165	82.147
1990	84.778	6.654	78.123
1991	83.723	7.372	76.351
1992	85.198	8.323	76.875
1993	86.562	9.351	77.210
1994	92.094	10.867	81.227
1995	92.396	12.563	79.834
1996	93.862	14.182	79.679
1997	94.314	15.722	78.592
1998	87.687	17.230	70.457
1999	93.790	17.240	76.550
2000	95.516	16.987	78.528
2001	92.785	16.529	76.346
2002	93.212	16.553	76.659

The Yellow Sea contains an abundance of living marine resources. There are about 300 fish species, 41 crustaceans, and 20 cephalopods, but only around 50 species are represented in the fishery. Warm-water species dominate, accounting for 46.7%, with temperate water species making up 44.7%. Only a few cold water water species are found in the area. Tang *et al.* (2003) provide a detailed account of the changes in the major fisheries resources in the Bohai Sea (Table 22).

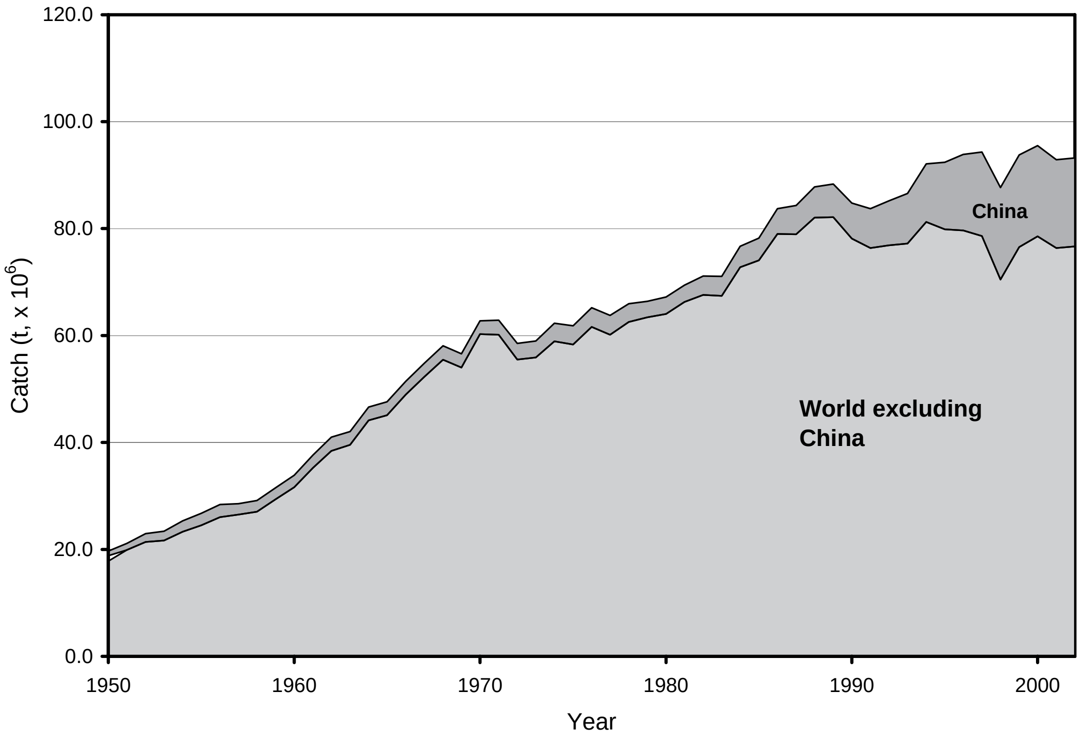

Fig. 31 Total catch (in millions of t) for China, and the world, excluding China, in capture fisheries from 1950 to 2002 (FAO data).

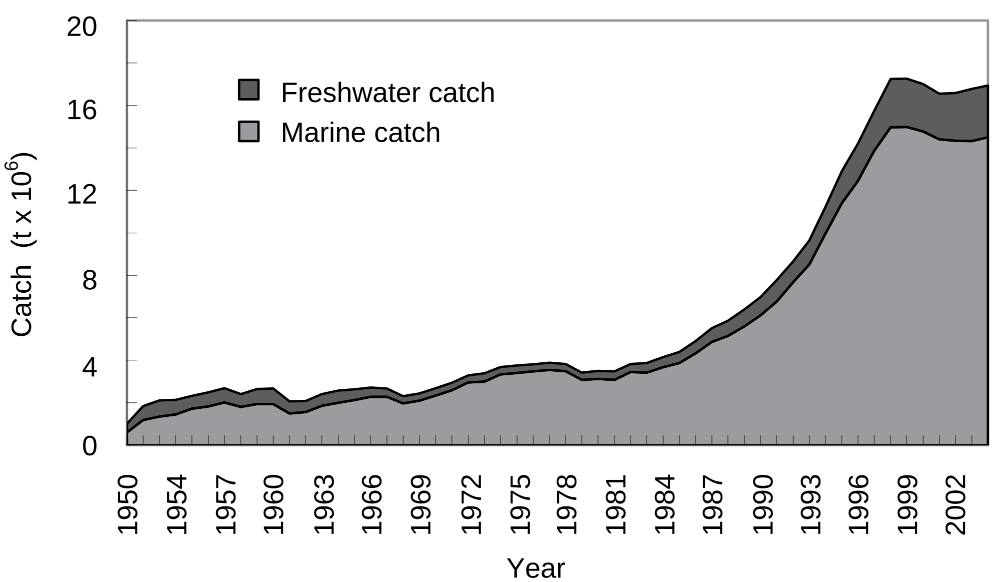

Fig. 32 Contributions of marine and freshwater catches to the total Chinese capture fishery.

Table 22 Major species and their percentages in biomass (weighted from May, August and October) of fisheries resources, by year, in the Bohai Sea (modified from Tang *et al.*, 2003).

Species	**%**
1959	
Small yellow croaker *Pseudosciaena polyactis*	29.5
Largehead hairtail *Trichiurus haumela*	29.3
Peneaid shrimp *Penaeus chinesis*	14.6
Half-fin anchovy *Setipinna taty*	4.7
Skate *Roja porosa*	4.4
1959 Total Marine Catch	82.5
1982	
Half-fin anchovy *Setipinna taty*	20.3
Squid *Loligo beak*	10.7
Blue crab *Portunus trituberculatus*	10.3
Anchovy *Engraulis japonicus*	7.7
Small yellow croaker *Pseudosciaena polyactis*	5.6
Spanish mackerel *Scomberomorus niphonius*	4.3
Mantis shrimp *Oratosquilla oratoria*	4.1
Seabass *Lateolabrax japonicus*	3.3
Skate *Roja porosa*	3.0
Yellow drum *Nibea albiflora*	2.7
Scaled sardine *Harengula zunasi*	2.5
Pomfret *Stromateoides argenteus*	1.8
White croaker *Argyrosomus argentatus*	1.6
Bighead croaker *Collichthys niveatus*	1.4
Southern rough shrimp *Trachypenaeus curvirostris*	1.4
Cuttlefish *Sepiella maindroni*	1.4
1982 Total Marine Catch	82.1
1992–1993	
Anchovy *Engraulis japonicus*	35.1
Half-fin anchovy *Setipinna taty*	10.1
Gizzard shad *Clupanodon punctatus*	8.2
Small yellow croaker *Pseudosciaena polyactis*	7.2
Mantis shrimp *Oratosquilla oratoria*	6.1
Squid *Loligo beak*	5.9
Blue crab *Portunus trituberculatus*	3.6
Seabass *Lateolabrax japonicus*	3.4
Rednose anchovy *Thrissa kammalensis*	3.3
Skate *Roja porosa*	3.2
1992–1993 Total Marine Catch	82.5
1998	
Gizzard shad *Clupanodon punctatus*	24.0
Half-fin anchovy *Setipinna taty*	18.1
Pomfret *Stromateoides argenteus*	11.1
Spanish mackerel *Scomberomorus niphonius*	8.5
Mantis shrimp *Oratosquilla oratoria*	5.7
Blue crab *Portunus trituberculatus*	4.8
Rednose anchovy *Thrissa kammalensis*	4.8
Small yellow croaker *Pseudosciaena polyactis*	4.0
1998 Total Marine Catch	81.0

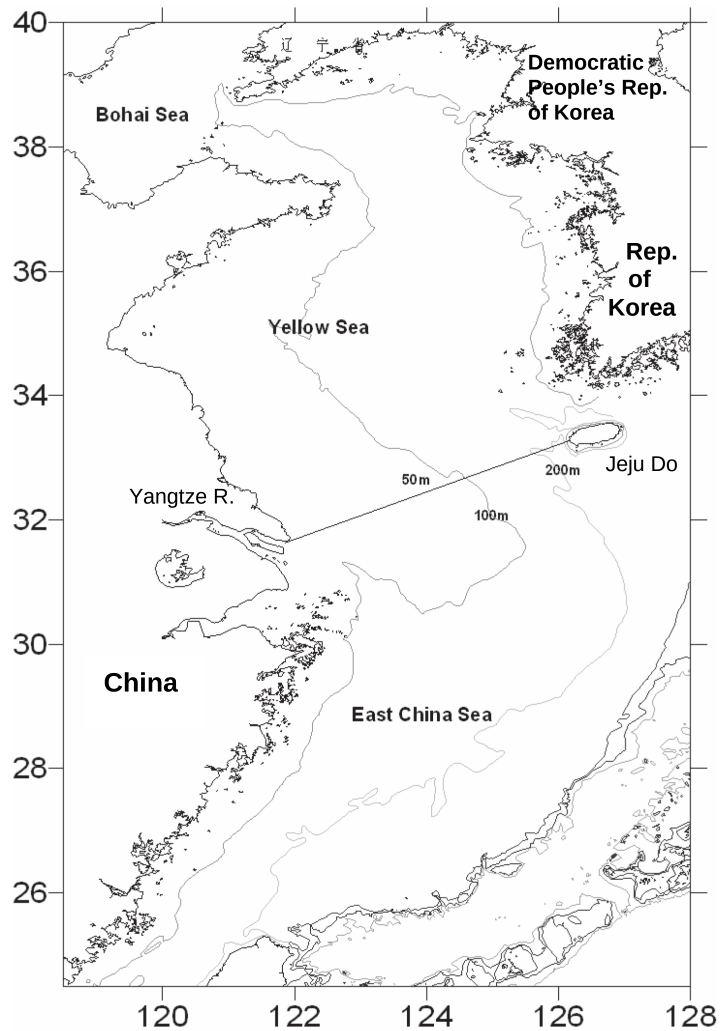

Fig. 33 Map of East China, Yellow and Bohai seas. Line between the Yangtze River and Jeju Do denotes the division between the Yellow Sea and East China Sea.

Climate

The climate system of the Yellow Sea and East China Sea is strongly affected by processes in the Northwest Pacific Subtropical High system through the Kuroshio Current and the land climate system. The Asian monsoon is dominant in the summer, and the northern cold air system is important in the winter months. Therefore, the long-term variation in the East China Sea and the Yellow Sea is complex. Both seas share the same climate system. Air temperature over the area has followed a warming trend since 1956. A negative temperature anomaly period occurred from 1956 to 1987, followed by a positive anomaly until 1998. Since 1998, it appears that there is a negative temperature anomaly. Wang *et al.* (1998) considered that air temperature patterns differ from large-scale global patterns because of the influence of climate over the land. There was a warming of the Yellow Sea sea surface from 1989 until 2000, when a cooling period began. In general, there has been a warming trend since 1968, with an increase in sea surface temperature of 0.27°C per decade and 0.12°C per decade at 50 m depth. In the East China Sea there has been a decadal pattern in the coastal sea surface temperatures. In general, the 1960s were cool, the 1970s warm, the 1980s cool, and the 1990s warm, with a maximum occurring around 1998. Temperature increases in coastal areas were larger than in offshore areas.

Key Species in the Fishery

Small yellow croaker (*Pseudosciaena polyactis*)

Biology

Small yellow croaker is warm-temperature bottom fish that is distributed in the Bohai Sea, Yellow Sea and East China Sea (Zhao *et al.,* 1990). Three geographical stocks, the northern stock, the Lüsi stock, and East China Sea stock, are recognized (Liu, 1990). The northern stock migrates seasonally between the central southern Yellow Sea during winter and northern part of the Yellow Sea and Bohai Sea from spring to autumn. The Lüsi stock is the largest and is distributed in the southern Yellow Sea. It migrates seasonally, often only short distances, mainly between shallow and deep waters in the southern Yellow Sea. The East China Sea stock only migrates in the East China Sea waters.

In the Yellow Sea small yellow croaker mainly over-winter in water depths of 60 to 80 m. Water temperatures range from 8° to 15°C and salinity varies from 33 to 34 psu. Spawning grounds are usually in the estuaries where the salinity is affected by river runoff. Small yellow croakers start their spawning migration from the wintering grounds in March, and spawn in the shallow coastal waters of 10 to 20 m depth from April to May, mostly along the Chinese coastal waters. In the 1950s and 1960s, about 0.5 to 3% of 1-year-old fish were mature and most fish matured at 2 years. However, most fish have matured at 1 year since the mid-1970s. The fecundity of small yellow croaker is from 32,000 to 72,000 eggs per fish at age 2 to 4 years and from 83,000 to 125,000 eggs per fish at age 5 to 9 years. Population parameters of small yellow croaker in the northern area during April surveys from 1955 to 1998 are presented in Table 23.

Small yellow croaker is a slow growing species with a long life span, and a maximum recorded age of 23 years (Liu, 1990). The northern stock in the waters off northern Shandong Peninsula in spring is comprised of fish migrating into the spawning grounds of the Bohai Sea from the wintering grounds of the central Yellow Sea. This population has been traditionally fished by fishermen from northern China in April. During the late 1950s, the length composition in catches ranged from 19.7 to 21.9 cm in mean body length and 150 to 199 g in mean body weight, and consisted mainly of age groups from 2 to 5 years. Fish below 16 cm in body length, being mostly immature, occupied only a small proportion of the spawners in the 1950s. From 1955 to 1957 this proportion was only 1.0 to 3.9%, increasing slightly in 1958 and 1959 because of the great exploitation pressure in 1957. Consequently, the proportion of young fish increased in the spawning population after 1957 (Liu, 1960). Meanwhile, fish over 20 cm body length accounted for 51.2 to 85.8% of the population. Therefore, the older fish, which could repeat spawning, became the major source of spawners, indicating that the stock was not out of equilibrium. After about three decades of heavy exploitation, the population structure changed. Compared to the 1950s, the fish size of the northern area stock in the 1980s was smaller, only 15.1 to 16.6 cm in mean body length and 59 to 80 g in mean body weight (Table 23). The smallest mean fish size in the 1980s occurred in 1985, and increased slightly in 1986. During the surveys of the 1980s, the number of small yellow croaker below 16 cm body length accounted for 54.3 to 76.5%, and those larger than 20 cm accounted for 8.5 to 17.2% of the catch. This trend was almost opposite to the situation observed in the 1950s. Only 8.5% over 20 cm, 15% in the range of 17 to 19 cm, and the rest below 16 cm in body length were found in the catch of 1985. Thus, only a minor proportion of the stock may be able to spawn more than once before being caught.

The mean length of the spawning population of the Lüsi stock in spring is shown in Table 24. During the 1950s and 1960s, the mean length of the stock ranged from 20.0 to 24.4 cm, with a corresponding mean body weight of 140 to 318 g and mean age of 3.8 to 6.3 years, older than observed for the northern stock. In the 1970s, the number of older fish decreased with a corresponding increase in fishing intensity, which affected the whole structure of the stock. Mean body length declined to 17.9 cm with a mean body weight of 102 g and a mean age of 2.4 years. In the 1980s, the structure of the spawning population continued to change. Fish in the catches of the Lüsi stock in the main distribution area averaged only 14.7 cm in length, 55 g in body weight and had a mean age just exceeding 1 year. The catch in 1985 had a mean length of only 12.7 cm and 35 g in mean body weight, increasing in 1986, but then decreasing to the smallest values ever recorded in 1987 and 1988 (Table 24). The Lüsi spawning stock in the spring was comprised of mainly 1- to 2-year-old fish, of which the 1-year-olds were dominant. Older fish were rarely caught in the 1980s. Therefore, in recent years the spring fishery has been highly dependent on recruiting year classes.

Fishery

The population which was distributed in the wintering grounds (far from shore) was rarely fished in the 1950s because of small-sized fishing boats and rough seas. However, with improvements to fishing vessels and gear technology, fishermen can now fish in all areas of the Yellow Sea year round, so that small yellow croaker is also fished/exploited heavily during the winter months.

Small yellow croaker in the Yellow and Bohai seas were mainly exploited by China, Japan and Korea in the 1950s and 1960s. Since the 1980s, this species has been fished mainly by China and Korea. In China, small yellow croaker are caught mostly by the three northernmost provinces (Shandong, Liaoning and Hebei) and one municipality (Tianjin), and some catches are also taken by the Jiangsu province and Shanghai in the mid-eastern part of China.

Figure 34 shows the fluctuation in catch of small yellow croaker by northern China from 1950 to 1998 (Jin, 1996a,b). This catch might be slightly different from the actual catch from the Yellow and Bohai Seas due to the incomplete statistics, but it reflects the variation in catch of small yellow croaker in the Yellow and Bohai Seas during this period. The yield of small yellow croaker increased nearly linearly in the 1950s, and tended to decline in the 1960s, reaching the lowest level in 1972. Since then, the catch has varied with several small peaks, but increased continuously in the 1990s, perhaps indicating a trend of increased productivity.

During the 1960s, the total fishing power of northern China, as reflected by the increased horse power of motor boats, expanded by more than three times. Motorboat horsepower in the 1970s and 1980s increased 10 times and 24.5 times, respectively, compared to the 1950s. Although the fishing effort cannot be proportionately allocated to small yellow croaker, the fishing pressure has undoubtedly risen considerably.

Table 23 Size composition and mean body length, weight and major age groups of small yellow croaker in the north area northern Yellow Sea in spring from 1955 to 1998 (Jin, 1996a).

Year	$\bar{L}$ (cm)	$\bar{W}$ (g)	Main age group (yrs)	Percentage of length group by number		
				≤ 160	170–190	≥ 190
1955	21.9	199	3–5	1.0	13.2	85.8
1956	21.7	191	2–5	2.4	22.2	75.4
1957	20.8	163	2–4	3.9	35.4	60.7
1958	19.7	157	2–3	14.9	33.9	51.2
1959	19.8	150	2–4	17.7	27.6	53.9
1985	15.1	59	1–2	76.5	15.0	8.5
1986	16.6	80	1–2	54.3	28.7	17.0
1988	16.5	78	1–2	54.5	28.3	17.2
1998	12.3	28	1	100	0	0

Table 24 The mean body length, weight and age of the pre-spawning population (spring) of small yellow croaker in the southern Yellow Sea from the 1950s to 1980s (Jin, 1996a).

Year	1950s	1960s	1970s	1980s	1980	1985	1986	1987	1988
$\bar{L}$ (cm)	22.1	22.7	17.9	14.7	16.4	12.7	15.9	12.1	12.3
$\bar{W}$ (g)	203	218	102	55	77	35	70	30	31
$\bar{t}$ (yr)	5.3	5.2	2.4	1.2	1.5	0.8	1.4	0.6	0.7

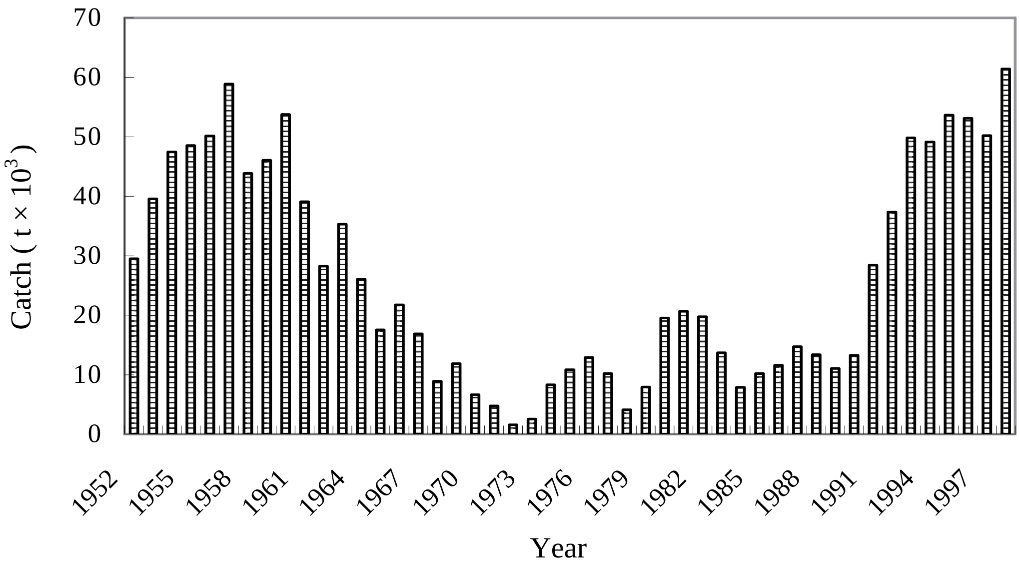

Fig. 34 Variations in catch of small yellow croaker from northern China from 1950 to 1998.

The proportion of small yellow croaker in the catches of marine fishes in northern China varied from 14.0% in the 1950s to 7.6% in the 1960s, 1.2% in the 1970s, and 2% in the 1980s. The proportion increased in the 1990s, indicating that the species productivity may have started to improve.

Ocean and climate effects

Small yellow croaker is a bottom fish that also spawns on the bottom. Kim *et al.* (1997) showed that cold temperatures at 75 m depth were associated with reduced productivity and weak year classes. From 1989 through to 2000, there was a warming period in the Yellow Sea, after which a cooling period began. It is difficult to assess the impact of ocean and climate changes in the species. Small yellow croaker is a migratory fish with a wide temperature range, and abundance data are obtained from the fishery which depends on fishing effort.

There was no indication of major environmental changes in the Yellow Sea in the 1980s when catches declined to one-sixth of those in the 1960s (Tang, 1993), which suggests that the decreases resulted from excessive fishing. Despite these drops and very high fishing effort, there was a recovery of the catch in the 1990s, suggesting that trends in the ocean environment were associated with the increased abundance.

Anchovy (*Engraulis japonicus*)

Biology

Anchovy is a small inshore pelagic species that is widely distributed in the Bohai Sea, Yellow Sea, and East China Sea. There may be at least two stocks in these areas: Yellow Sea and Bohai Sea stock and East China Sea stock (Zhu and Iversen, 1990). Anchovy migrate seasonally with changes of sea surface temperature. The optimum temperature ranges from 10° to 13°C, and the anchovy is not usually found in waters below 7°C (Iversen *et al.*, 1993). In November and December, the densest areas of distribution are in the northern and central parts of the Yellow Sea. During winter anchovy migrate to the southeastern region of the Yellow Sea and northern part of the East China Sea. In spring, as water temperatures increase and anchovy gonads develop, the fish migrate into shallow coastal waters for spawning, and then disperse for feeding, moving into deeper southern waters. After November, there are very few anchovy left in the Bohai Sea. Dense schools are observed in the southeastern Yellow Sea and northern East China Sea. Anchovy also migrate diurnally, depending on the light and water temperatures. They usually appear in dense schools near the bottom during the daytime, and remain scattered in the upper to surface layers at night.

Spawning areas are in the nearshore waters and bays along the Chinese coast. The three major spawning areas are: bays in the Bohai Sea, nearshore waters off the southern tip of the Shandong Peninsula, and off the Zhejiang (East China Sea) coast (Zhang, 1983; Zhu and Iversen, 1990). The age of anchovy at first maturity is 1 year. Fecundity ranges from 600 to 13,600 eggs per female.

According to the surveys by the R/V *Bei Dou* from 1984 to 1988 (Zhu and Iversen, 1990), the spawning season of anchovy is from May to October. The peak spawning period is from mid-May to late June, with the optimum spawning temperatures from 14° to 18°C in the Yellow Sea. One- to 2-year-old fish dominate the spawning stock. Ovulation can be of the multi-peak or continual type, within a year, *i.e.*, ovulation occurs as the eggs ripen, without an obvious resting stage in between (Li, 1987).

There are some feeding differences between juveniles (0 age group) and adults. The diet of juvenile anchovy is dominated by copepoda (55% by weight; Chen, 1978; Zhu, 1991). As the anchovy grow, the dominant prey gradually shifts to the arrow worm *Sagitta crassa*, copepod *Calanus pacificus*, amphipod *Themisto gracilipes*, euphasiid *Euphausia pacifica*, and some algae.

The length of anchovy at hatching ranges from 2.6 to 2.9 mm (Zhao *et al.*, 1990). Zhang (1983) reported that the body length was 3.2 mm after hatching, and at a body length of 18.5 mm (length at metamorphosis), it becomes an adult. Five months after spawning, the length reaches 60 to 90 mm. The growth rate is higher for the 1-year-old group, and is reduced with age (Zhu and Iversen, 1990). The maximum life span is about 4 years (Iverson *et al.*, 1993). Anchovy are prey for 30 to 40 important higher trophic level species (Tang and Ye, 1990).

Fishery

Anchovy used to be an undesired species for the Chinese fishery because of its low market value. In the past, only post-larvae and juveniles were used by some coastal artisan fishermen for dried food. In the 1960s, the catch was very small, about 750 to 1000 t in the northern Yellow Sea. In recent years, a dramatic increase in biomass occurred in the Yellow Sea and northern East China Sea. The stock seemed to be stable and was estimated by acoustic surveys to be about 2.5 to 4.2 million t (Zhu and Iversen, 1990) from 1985 to 1995. A potential annual catch was on the order of 0.5 million t (Iversen *et al.*, 1993). In 1989, a pair-trawler anchovy fishery started and expanded quickly into a large-scale, year-round fishery in the mid-1990s. Since then, there has been a rapid decline and by 2001–2002, the abundance was less than 10% of its peak level in 1993, which was estimated to be 4,120,000 t (Zhao *et al.*, 2003).

The annual anchovy catch in China varied between 30,000 and 190,000 t between 1989 and 1992. It rapidly increased to 600,000 t in 1996, more than 1 million t in 1997 and 1998, and has decreased thereafter (Fig. 35). Intense fishing, increasing yearly by 20 to 83% in catch in the Yellow Sea before 1999, must have affected the spawning stock because the fishery has shown a considerable increase in the proportion of 1-year-old fish. More than 90% of the catch from the Yellow Sea was recruitment from the spring of 1998, and acoustic surveys show that the stock is now almost collapsed (Jin *et al.*, 2001).

Climate and ocean effects

There is evidence that the abundances of Japanese anchovy and Japanese sardine follow opposite trends. This indicates that ocean conditions are responsible for the shifts in trends from one species to another. Kim (1992) proposed that the distribution of anchovy eggs and larvae in June is related to the ocean conditions in the eastern waters off Korea. Ocean conditions that favour the transportation of anchovy eggs and larvae into productive coastal areas in the summer also favour anchovy survival and growth.

Spanish mackerel (*Scomberomorus niphonius*)

Biology

Spanish mackerel are widely distributed in the northwestern Pacific Ocean. They are abundant in the Bohai, Yellow, and East China seas. The species undergoes long-distance seasonal migration. There are two wintering stocks, one in the southeastern Yellow Sea, and the other located offshore of the East China Sea (28°00′–31°20′N, 123°40′–125°30′E). The stock in the East China Sea spawns from April to May, mainly in the coastal waters between Fujian (southeast China) and the Shandong Peninsula. The other stock spawns from May to June in the Bohai Sea and the northern Yellow Sea (Wei, 1991). After spawning, Spanish mackerel feed in

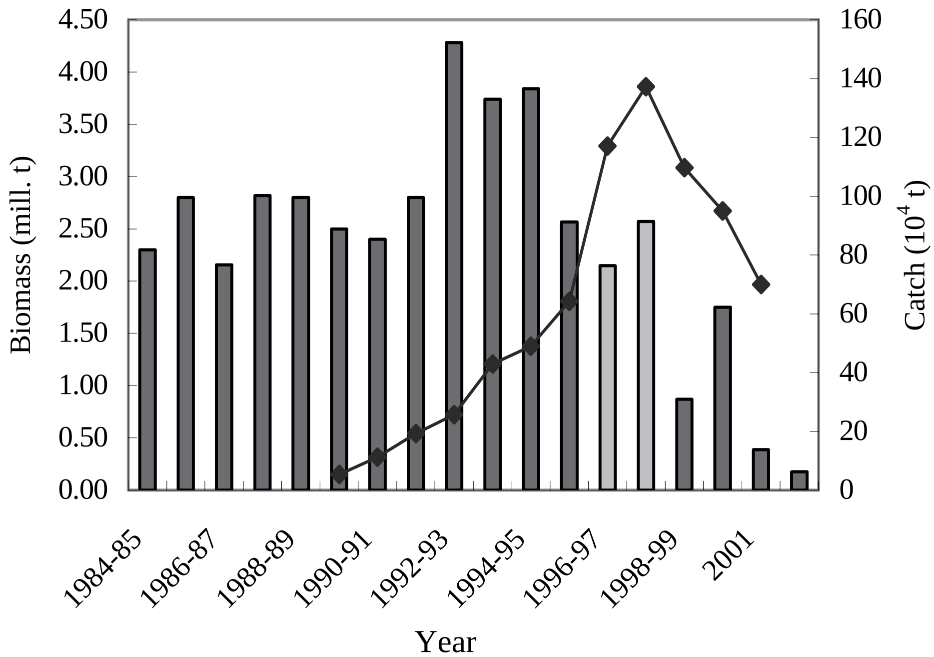

Fig. 35 Yearly variations of Japanese anchovy biomass (bars) and landings (line). Biomasses in 1997 and 1998 were estimated by virtual population analysis (VPA); catches in 2000 and 2001 were estimated.

coastal waters. The distribution of this species is strongly influenced by water temperature. They migrate southward with decreasing temperatures. In November, they are distributed mainly in the central and southern Yellow Sea and in December, return to their wintering grounds.

Spanish mackerel mature at 1 to 2 years in the Yellow and Bohai seas. They spawn mostly in the bays of the Bohai Sea, although some spawn along the coast of Shandong Peninsula. The major spawning season is from May to June, depending on the water temperature. Spawning occurs at a depth of 15 to 30 m. The water temperature of the spawning areas differs greatly between the northern and southern waters, ranging from 9° to 13° C in the Bohai Sea and 11° to 20°C in the southern East China Sea, whereas the salinity is similar throughout, ranging from 28 to 31 psu (Zhang, 1983; Wei, 1991). Fecundity is about 280,000 to 1.1 million eggs per female.

Spanish mackerel are believed to have strong piscivorous habits. Small pelagic fish, such as Japanese anchovy and sardines, account for about 90% of the total weight of their stomach contents (Tang and Ye, 1990). Japanese anchovy make up the larger portion and have been referred to as "food of Spanish mackerel" by Chinese fishermen. The size of prey increases with the growth of Spanish mackerel, but the prey composition does not vary significantly.

At hatching Spanish mackerel measure from 4.3 to 5.0 mm in fork length (Zhao *et al.*, 1990). Their growth rate is the fastest recorded among pelagic fishes in the Yellow and Bohai seas. Ocean age 0 fish can reach 25 to 30 cm in fork length and weigh 200 to 400 g at the time of spawning. Females grow faster than males, with an average increase in length of 26.1%, compared with 21.9% for males in the second year after spawning (Wei, 1991).

Fishery

Spanish mackerel are the largest fishable pelagic fish in the Yellow and Bohai seas. In autumn, there is no obviously dominant length group, as fork length can range from 20 to 54 cm. Ocean age 0 fish account for 99.7% of the catch. Mean lengths have decreased since the mid-1960s, indicating an increased proportion of young fish. Age 1 fish accounted for only 1 to 7% during the period from 1952 to 1969, increased to 10–27% in the 1970s, and further increased to about 36–56% in the beginning of the 1980s (Wei, 1991).

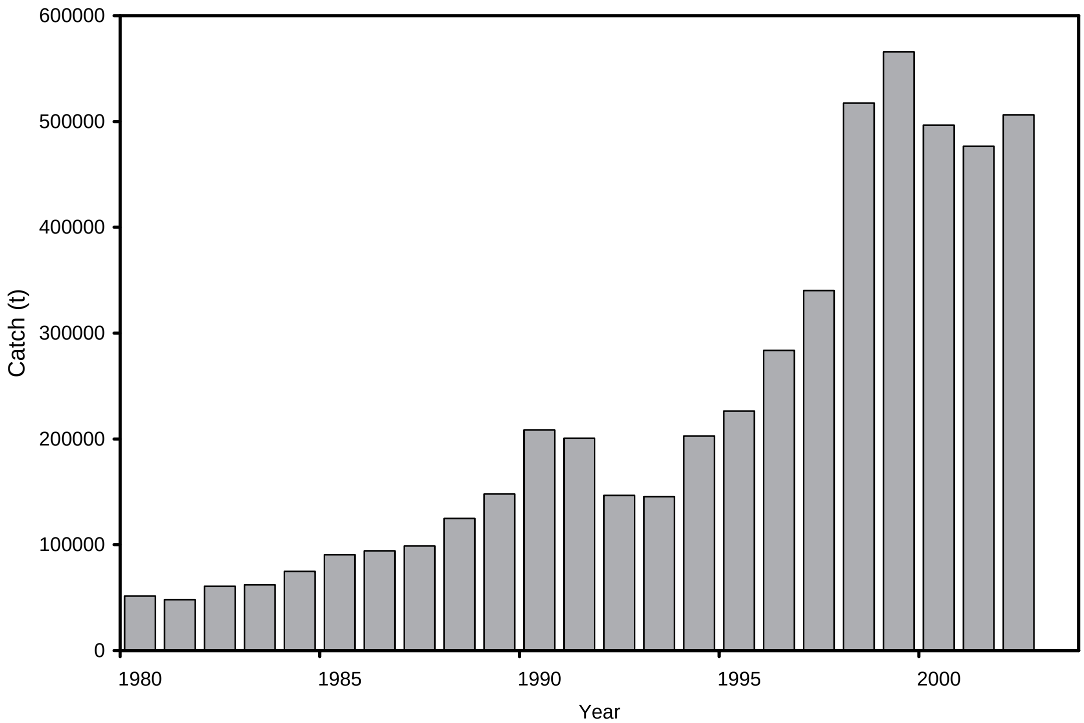

Fig. 36 Chinese catch (t) of Spanish mackerel from 1980 to 2002 (FAO, 2003).

Spanish mackerel are caught mainly by gillnet in China, and are a bycatch in other fisheries. The annual catch increased rapidly in the 1960s and ranged from 20,000 to 40,000 t. Two-year-old fish dominated the catch (about 75%), and the total mortality was about 65% (Wei, 1991). By the mid-1970s, the catch was taken mainly from the spawning stock in spring. Thereafter, the increase in fishing effort and the large quantity of age 0 fish caught by trawlers in autumn have resulted in a decline of spring catch. Total catches from northern China fisheries have continuously increased in recent years, reaching more than 500,000 t (Fig. 36). Since the mid-1990s, the catches have occurred mainly in the autumn, following the summer fishing closure.

Climate and ocean effects

It is difficult to identify a relationship between climate, the ocean, and productivity because of the lack of time series data.

Pacific herring (*Clupea pallasii*)

Biology

Pacific herring is a local stock that only inhabits the central to northern regions of the Yellow Sea (north of 34°N; Ye *et al.*, 1980). There was a small stock found in the 1950s which became widely distributed in the Yellow Sea from the late 1960s onward. The wintering ground is in the central, deep water of the Yellow Sea. In February the adult population migrates toward coastal waters off the Shandong Peninsula for spawning, and then moves into the central and northern Yellow Sea for feeding. In winter the stock is distributed mainly in the central part of the Yellow Sea (Tang, 1991).

Spawning begins in February in very shallow waters (3 to 7 m) along the coast and bays around the Shandong Peninsula, with a small group of herring spawning on the banks in the northern Yellow Sea and off western Korea. The main spawning season is from March to April. Water temperatures of 0° to 5°C and salinity around 30 psu are required for spawning (Zhang, 1983). The eggs stick together and adhere to reefs, algae, and other substances (Tang, 1980). Hatching time decreases with increased temperature, from about 12–14 days at 5.5°–10°C to 7–8 days at 15°–20°C (Jiang and Chen, 1981; Zhang, 1983). According to observations on artificial hatching and embryonic development of Yellow Sea herring (Jiang and Chen, 1981), the body length of newly hatched larvae ranges from 5.2 to 6.8 mm. After 4 to 5 days, they reach 7.2 to 7.8 mm, and after 12 to 13 days, attain a length of 9.9 to 11.2 mm. The growth rate is fastest during summer, accounting for 43% of the total yearly growth, and decreases during autumn (Tang, 1991).

The feeding period is mainly from April to August, and *Euphausia pacifica* constitutes more than 99% of the total stomach contents by weight in Pacific herring in the Yellow Sea (Wei and Jiang, 1992). During the rest of the year they feed little or not at all.

During the spring survey in 1986, the fork length of the spawning stock of Yellow Sea herring ranged from 13 to 30 cm, with a mean length of 20.8 cm. There were two peaks in the length distribution, one at 18–19 cm and one at 23–24 cm, which accounted for 38.8% and 30.9% of 1- and 2-year-old fish, respectively. However, when the stock was very abundant during the period from 1970 to 1974, the mean age of the catch was 2.5 years and the fork length and body weight averaged 22.8 cm and 134 g, respectively. Fish 4 years old and older accounted for 15.6%, and decreased to 1.5% in the period from 1975 to 1982 (Liu, 1990). This demonstrates that the spawning stock at present depends mainly on the 2-year-old age group. In autumn, the length composition of herring was dominated by the 21–22 cm group, accounting for 67.2% by number, and 9.3% of the catch was age 0 fish.

Fishery

The Yellow Sea herring fishery has experienced two peaks in history (around 1900 and 1938), followed by a period of little or no catch (Tang, 1993). Since 1967, many demersal stocks in the Yellow Sea have been overfished or depleted. Recovery and outburst of the Yellow Sea herring seems to be associated with the depletion of other stocks. The catch of Yellow Sea herring increased rapidly to a peak (more than 180,000 t) in 1972, and decreased sharply thereafter. Tang (1981, 1993) demonstrated that although the fluctuations in recruitment of the Yellow Sea herring have been very large and have had a direct effect on the fishable stock, there is no strong relationship between spawning stock and recruitment. Environmental conditions, such as rainfall, wind, and daylight, are major factors affecting the fluctuations in recruitment, and long-term changes in biomass may be correlated with a 36-year cycle of the wetness oscillation in eastern China (Tang, 1993). Undoubtedly, high fishing pressure speeds up the depletion. During a period of declining stock size, the spawning stock must be kept above the biologically safe level. The abundance of adult fish is currently reduced to a very low level, and there is no longer a fishery of this stock in the Yellow Sea.

Climate and ocean effects

Tang (1981, 1987, 1995) found that there was no strong relationship between the size of the spawning stock and subsequent recruitment. Similar observations have been made for other Pacific herring populations. It was observed that rainfall, wind, and daylight affect recruitment. There is also a relationship between periods of abundance and a 36-year cycle of dryness and wetness which is associated with the Southern Oscillation. The trends in Pacific herring catch ae also similar to catches of chub mackerel (Tang, 1995), indicating that ocean conditions affecting Pacific herring recruitment may occur in trends. It is believed (Ye, 1985) that environmental conditions have an important influence on the long-term productivity of chub mackerel.

Pacific herring abundances tend to be controlled by predation and productivity, the so-called “wasp-waist” relationship. If there is abundant food for larval herring, there may be strong year classes. If favourable ocean conditions also produce predators of herring, then the abundances are smaller. Recognizing that these effects may occur, it is also important to recognize that overfishing is an important cause of the collapse of herring in the Yellow Sea.

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