

An Assessment of Fishery Yields from the East China Sea Ecosystem

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Introduction

The East China Sea (ECS) (Fig. 1) supports some of the most important fisheries and stocks of the People's Republic of China (PRC) which are exploited by fishing fleets based in Zhejiang, Fujian, Jianxu, and Shanghai

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ABSTRACT—A first assessment of important East China Sea fisheries was carried out using data from 1956 to 1993. Two different data sets were available: 1) catch and effort data taken from landings and boat registrations and 2) catch and effort data from skipper's logs taken at sea. The two sets provided similar trends in CPUE over the study period. Stocks of high value, low volume species have been fished heavily and now produce very low landings or have been depleted (e.g. small and large yellow croaker). Some high volume and low value species have also been heavily fished (e.g. green filefish) while others (e.g. hairtail) are still producing high landings. Surplus production models were fitted to seven stocks. All showed considerable fluctuations in landings around MSY. The green filefish stock had an estimated MSY of around 160,000 t/yr at an effort of 2,500,000 kw and was depleted by a combination of excessive effort (around 4,000,000 kw in 1993) and marked fluctuations in landings (up to 70,000 t/yr above or below MSY). A sustainable policy for managing ECS fisheries should address the effects of both effort and environmental variation.

Provinces. PRC landings were 1,228,638 t (44.2% of total ECS landings), 1,042,233 t (37.5%), 379,403 t (13.6%), and 131,476 t (4.7%), respectively, for these four provinces, and totalled 2,781,750 t in 1992. The ECS landings also represented 27.8% of total PRC marine landings (9,336,927 t in 1992; China Ministry of Agriculture, 1993).

Foreign landings in the ECS are not monitored. Recent estimates suggest that approximately 900,000 t/yr were landed in Taiwan, 400,000 t/yr in the Republic of Korea, and 200,000 t/yr in Japan by overseas fishing vessels operating in the ECS for a total foreign catch of 1,500,000 t/yr in the early 1990's.¹ Total ECS landings in 1992 were therefore about 4,200,000 t of which about 65% were landed by boats based in China. Although adequate data on foreign landings and effort are not available, it is important to carry out an assessment of the ECS landings and fisheries to identify a sustainable management policy for the area and its fisheries.

Methods and Data

Two data sets were available: 1) annual landings and effort data from fisheries statistics and 2) total catch, effort, and CPUE data from the offshore ECS Fishing Fleet logbooks.

Annual Landings and Effort Data

Annual landings and effort data are compiled by local, district, and Provincial Fisheries Management Bureaus (FMB's) and collated by the East China Sea Fisheries Management Bureau in Shanghai for the entire ECS. Effort is

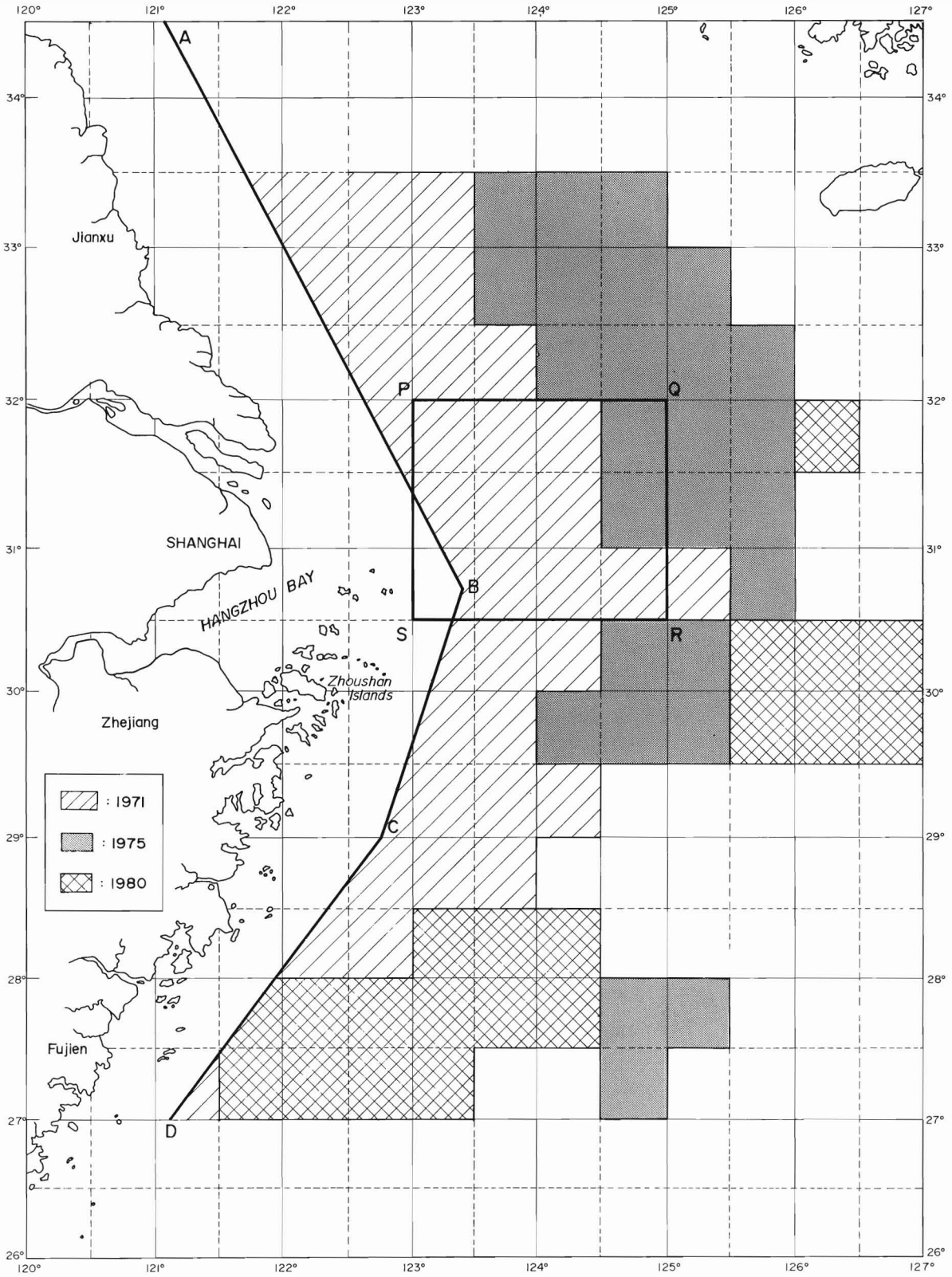
estimated from boat registration files and is measured in kilowatts. Effort estimates do not take into account the possibility that registered boats are unused, but it is thought that any biases will tend to be constant so that effort trends will be correctly estimated.

Until 1986, all fish landed were transported to large state-owned and managed fish processing plants where they were weighed and the species composition of the landings was recorded; data were reported to the FMB's. From about 1987 onward, a policy of economic liberalization was introduced, and fishermen were required to declare only the total value of landings by species. The volume of the landings was estimated at local FMB's by combining total value of the landings with price data. Total landings and effort data are made available about 12–18 months in arrears for the ECS as a whole. Landings data are only available by Province. Segregation of effort and landings data by smaller units is not possible at this time. Data on landings are available for the stocks listed in Table 1.

Table 1. — East China Sea fish stocks¹ for which landings are available.

Common name	Scientific name
Large yellow croaker	<i>Pseudosciaena crocea</i>
Small yellow croaker	<i>Pseudosciaena polyactis</i>
Edible jellyfish	<i>Rhopilema esculenta</i>
Cuttlefish	<i>Sepiella mandroni</i>
Green filefish	<i>Navodon septentrionalis</i>
Hairtail	<i>Trichiurus haumela</i>
Mackerel and scad	<i>Scomber japonicus</i> and <i>Decapterus maruadsi</i>
Spanish mackerel	<i>Scomberomorus</i> sp.
Pomfrets	<i>Pampus argenteus</i> , <i>P. cinereus</i> , <i>P. sinensis</i>
Chinese herring	<i>Ilisha elongata</i>
Shrimp and crabs	>99% palaemonids and portunids

¹ In addition, data are available for a wide variety of low-valued, high-volume species grouped together as "other species" as defined in the text.



The three species of pomfrets may reasonably be treated as a unit stock, as may all of the others excepting mackerel and scad (7) and shrimp and crabs (11) (Table 1), which are multispecies stocks. No records are available of their varying species composition.

No data are available on the allocation of effort between stocks, which are fished by means of a wide variety of pelagic, semipelagic, and demersal gears. To allow a first assessment of important ECS stocks, the relation between landings for the above stocks and total ECS effort was studied using various Shaeffer (1957), Pella and Tomlinson (1969), and Fox (1970) models, fitted with CLIMPROD (FAO, 1994) and POPDYN (Hall, 1986). This procedure arbitrarily assumes that a constant proportion of total ECS effort was allocated to each stock from 1956 to 1993. This assumption will be violated when a stock is driven to extinction (<5% of peak landings). The assumption will also be erroneous during the first few years of a fishery when a new stock is attracting effort, but in practice this was not a problem as data for most stocks were only collected for periods during which the stock produced landings >5% of peak landings; extrapolations were carried out where necessary.

Total Catch, Effort, and CPUE Data

From 1971 to 1982, data on total effort and CPUE were collected manually for the offshore fishing fleet (operating east of line ABCD, Fig. 1) by the East

◀ Figure 1. — The East China Sea: line ABCD separates the Coastal Management Zone (to the west), in which trawling is prohibited for all species (except beam trawling for shrimp), and the offshore area (east of ABCD). Small onshore boats (>25 GT and <125 GT) operate primarily in the onshore area (west of ABCD) while the fleets of larger (150–650 GT) boats operate in the offshore zone only (east of ABCD). Fisheries assessment and management in both offshore and onshore areas are the shared responsibility of the East China Sea Fisheries Research Institute and the East China Sea Fisheries Management Bureau, and of the Zhejiang Provincial Fisheries Research Institute and the Zhejiang Fisheries Management Bureau. Area PQRS is typical of all similar areas adjacent to and east of line ABCD.

China Sea Fisheries Research Institute, through skippers' log books, by half-degree squares. Data were computed annually. Using these data it was possible to:

- 1) Determine the spread of effort from the inshore area towards the east into the ECS,
- 2) Estimate total effort, catch per unit effort (CPUE), and fishing intensity by half-degree square, and
- 3) Estimate mean annual CPUE for the whole offshore ECS fishery only, allowing comparison with estimates of the CPUE for the whole ECS from fisheries statistics data collated by the East China Sea Fisheries Research Bureau (see previous section on annual landings and effort data).

Results

ECS Fishing Gear Distribution

A wide variety of gears are used for fishing in the ECS (Fig. 2) where inshore fishing (mostly by boats >25 GT and <125 GT) is reserved for small gear and set net fishing. Offshore fishing is usually reserved for large-scale purse seining and trawling (usually 150–650 GT boats).

Expansion of the ECS Fishing Area, 1971–82

Figure 1 shows the movement of effort offshore from 1971 to 1980 in the ECS. By 1982, the last year for which the half-degree square data are available, effort had moved still further offshore. Prior to 1965 the ECS fishery was entirely coastal (i.e. west of ABCD, Fig. 1); by 1971 a substantial offshore area (51,000 n.mi.²) had been occupied, and by 1982 most of the ECS out to long. 127° (97,000 n.mi.²) was fished, albeit only lightly in the far eastern area. Table 2 shows in more detail how effort expanded and fishing intensity changed from 1974 to 1980. Fishing intensity was much higher in the western part of the offshore area PQRS (Fig. 1, characteristic of areas east of and adjacent to line ABCD), than in the ECS as a whole. Effort in this area also increased at a much higher rate (×6.73) than in the ECS as a whole (×2.12).

Table 2. — Changes in ECS fishing strategy, 1974–82 (see Figure 2 for areas studied)

Year	Data for entire ECS		PQRS data only
	Total effort (h/yr)	Fishing intensity (h/n.mi. ²)	Fishing intensity (h/n.mi. ²)
1974	123,279	1.90	2.20
1975	142,273	1.94	3.53
1976	204,498	2.84	6.00
1980	386,943	4.03	15.42
Ratio ¹	3.14:1	2.12:1	6.73:1

¹ Ratio for 1989:1974.

Calibration of CPUE

CPUE was estimated independently for the whole ECS from fisheries statistics recorded in the aforementioned data set 1 (annual landings and effort data), with CPUE measured in t/kw, and from data set 2 (CPUE data) recorded in skipper's logbooks during fishing, with CPUE in mean t/h of fishing for 6 years (1971, 1974, 1975–76, 1980, 1982). The least squares regression of CPUE estimated in t/kw (for the whole ECS from fisheries statistics) on CPUE estimated in t/h (for the offshore ECS only, east of line ABCD, Fig. 1) was significant ($r = 0.962$, $p = 0.002$); the intercept was not significantly different from 0 ($p < 0.05$). From 1971 to 1982, the offshore fishery caught mainly green filefish, mackerel and scad, and hairtail, whereas the whole ECS landings included these species and other large important stocks such as shrimp and crab, large yellow croaker, "other species,"² pomfret, and cuttlefish, taken mainly to the west of line ABCD (Fig. 1). The significant correlation of CPUE's suggests that trends in CPUE are similar for all stocks, and supports the simplifications needed to assess the ECS fish stocks.

Changes in Landings

ECS landings may be divided into 1) small volume and relatively high value "old" species fished since 1956, 2) high volume, relatively low value "new" species fished heavily mainly from around 1965 onwards, and 3) a variety of very low value "other" species used for aquaculture feed, reduction to fish meal, and only occasionally for human con-

² See following "Changes in Landings" section for the definition of this term.

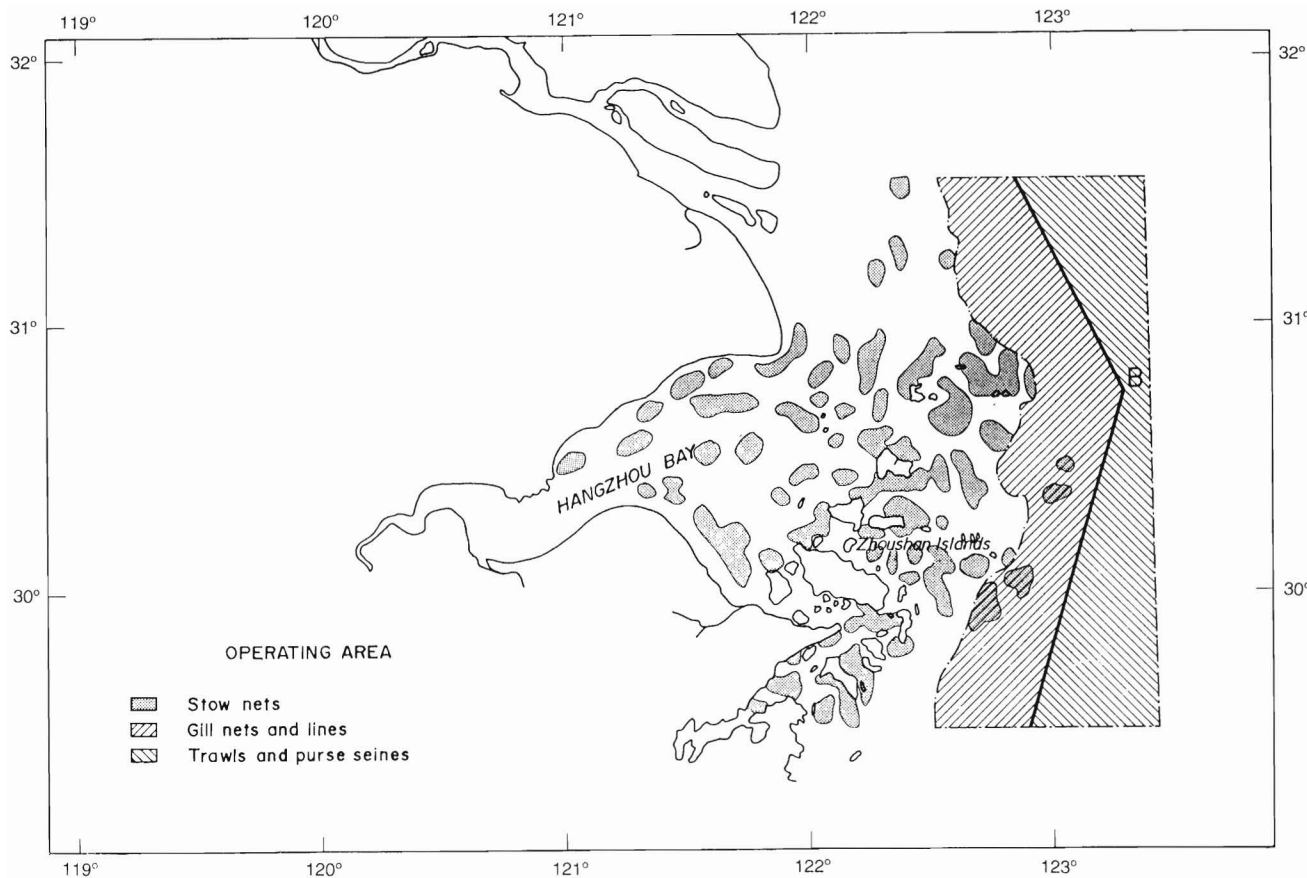


Figure 2. — Distribution of marine fishing gear in the ECS near Hangzhou Bay. Point B is also shown in Figure 1. The offshore fleet uses mostly trawls and purse seines. The inshore fleets use smaller boats and more artisanal, small-scale, gear.

sumption. The volume of “old” species landed fell from >300,000 t in 1956 to about 50,000 t in 1992, while the volume of “new” species rose from 250,000 t in 1956 to >1,000,000 t in 1992 (Fig. 3). Landings of all old species except Chinese herring fell markedly (Fig. 4); landings of three new species increased markedly (hairtail, 100,000–650,000 t/yr; shrimp and crab, 132,000–550,000 t/yr; mackerel and scad, <200–300,000 t/yr; from 1956 to 1993, respectively; Fig. 5). Three new fisheries (pomfrets, Spanish mackerel, and green filefish) were established in the 1970’s, while the mackerel and scad stock was more heavily fished. Of the 11 stocks for which data are available, five showed a marked long-term fall in landings. Large yellow croaker, small yellow croaker, jellyfish, cuttlefish, and green filefish were fished so heavily that the stocks were all reduced to commercial

insignificance by 1990. Data for cuttlefish (Fig. 4) do not show this clearly because *S. mandroni* (the main species providing >95% of the cuttlefish landings) was fished in inshore and western ECS waters, but was replaced by various offshore species from about 1985 onwards. The proportion of *S. mandroni* in the landings was not monitored regularly, but it is known to have fallen to very low levels (<10%) by 1993.

Surplus Production Modelling

Results of surplus production modelling are shown for eight different stocks (Fig. 6, 7; Table 3), most of which showed decreasing landings at higher effort levels. The green filefish stock (Fig. 6) was commercially extinguished in the early 1990’s when landings fell to about 3,000 t/yr and effort exceeded 4,000,000 kw. Landings of yellow filefish, *Thamocomus modestus*,

Table 3. — Results¹ of surplus production modelling of important ECS stocks.

Species	MSY (t)	F _{opt} (kw)	R ² (%)
Large yellow croaker	120,000	500,000	79
Small yellow croaker	40,000	300,000	68
Jellyfish	25,000	600,000	56
Cuttlefish	50,000	500,000	84
Green filefish	160,000	2,500,000	57
Pomfrets	50,000	3,500,000	61
Hairtail	420,000	2,000,000	71
Chinese herring	20,000	50,000	68

¹ MSY = maximum sustainable yield, nearest 5,000 t/yr; F_{opt} = Effort needed to harvest MSY, nearest 50,000 kw.

increased from traces (<1%) prior to about 1990 to 30,000–40,000 t in 1993 as this offshore stock was fished to replace the lost green filefish landings. Green filefish reach 35 cm total length (TL), and in the mid 1980’s the modal size of fish landed was about 25 cm TL; yellow filefish are smaller (up to 20 cm TL, modal size about 15 cm TL), and are less valuable. Only the pomfrets

stock supported increasing landings for the effort range studied. Hairtail landings showed a decreasing trend with increasing effort until about 1990 (effort >3,000,000 kw). Models could not be fitted for mackerel and scad, Spanish mackerel, and shrimp and crab because these stocks show continuously increasing landings (Fig. 5).

Discussion

Effects of Increasing Effort

Total ECS landings show a continuously increasing trend, but five important stocks (with combined peak landings of about 650,000 t/yr) have been fished to commercial extinction from about 1979 to 1990, while only three important stocks show an increasing trend. Of these, shrimp and crab are a multispecies multigear stock, with (according to anecdotal reports) a sharp increase in number of species fished, with several new types of gear, especially in the Zhoushan Islands in the last 5 years. This stock is probably similar to ECS fisheries as a whole, with overfished species being replaced as effort increases, by new and previously unfished, or markedly underfished, species. Because data are lacking it is not possible to assess how this stock will react to future effort increases.

The mackerel and scad stock is more homogeneous but the proportion of the species in the landings is not known and may have changed in response to increasing effort. Only the promfrets stock shows stable landings, while only the Spanish mackerel stock (and some components of the multispecies shrimp and crab stock) may not be fully fished. Increasing landings of the "other species" stock offers the possibility of maintaining landings for human consumption in spite of the generally decreasing trends in landings for important fisheries (but only if methods for generally processing fish currently rejected as food for human consumption can be identified and applied at an industrial scale as was done for filefish in the 1970's, stimulating development of the fishery).

Detailed trophic studies of ECS fish stocks have not yet been completed, but

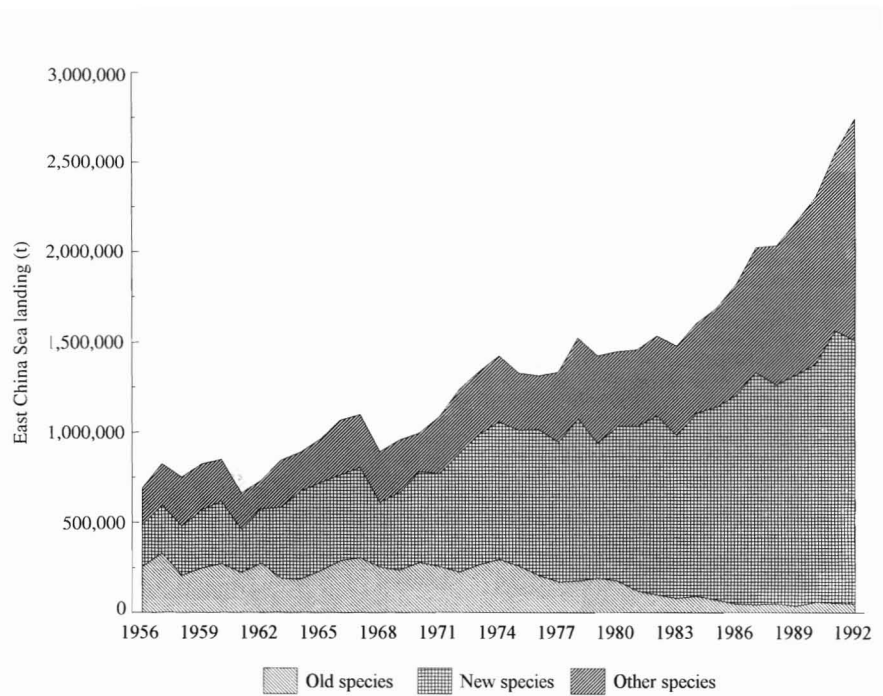


Figure 3. — East China Sea landings separated into "old," "new," and "other" species.

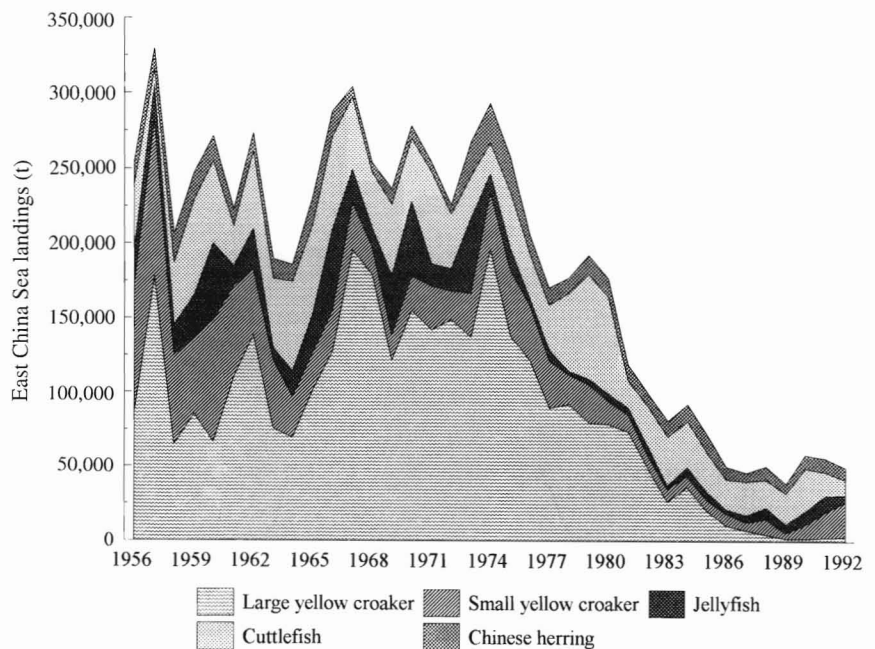


Figure 4. — Landings of "old," relatively highly priced, species.

large and small yellow croaker are known to be secondary predators, and have been replaced in the landings by primary predators (e.g. hairtail and, until recently, green filefish).

Projection of total ECS effort, based on observed effort expansion from 1956 to 1993, suggests that by 2013, total effort will have increased from about 4,000,000 kw to around 14,000,000 kw.

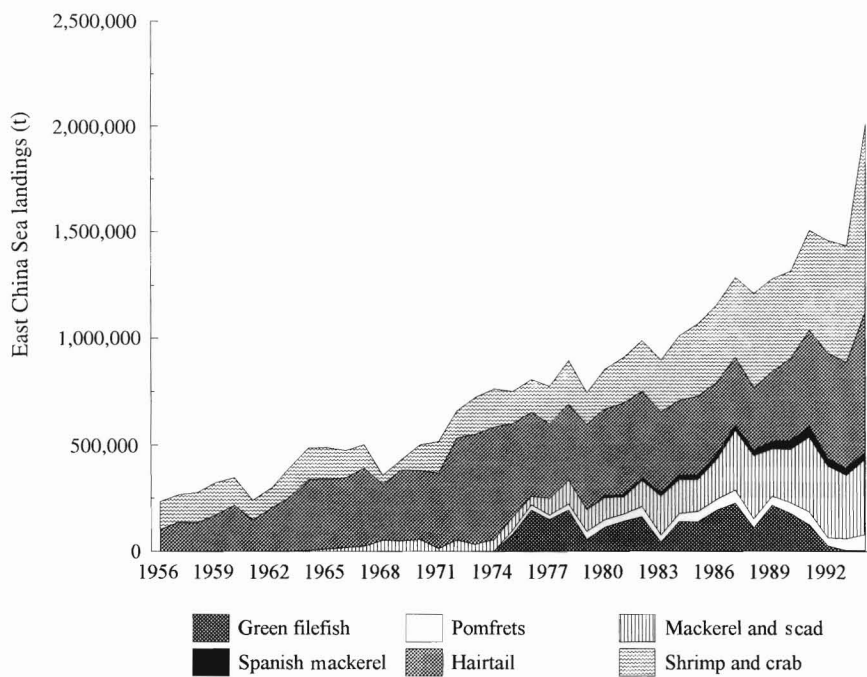


Figure 5. — Landings of “new,” relatively low priced, species.

It is very unlikely that this rate of effort expansion is sustainable: either an effort limitation policy will be devised and implemented and will lead to a sustainable level of harvest for some of the remaining stocks, or effort will eventually be reduced as a response to falling catch rates and profitability, with consequent economic losses in the fishing sector as a whole when this eventually occurs.

Fluctuations in Landings

Figures 5–7 all show that sustainable short-term fluctuations in landings may occur around a generally sustainable level of landings. In the case of green filefish, landings fluctuated by >70,000 t annually around an MSY of 160,000 t (Fig. 6). These fluctuations were probably caused by changes in environmental factors. This instability, combined with rapidly expanding effort (about 25% from 1988 to 1993) may have contributed to the commercial extinction of the green filefish stock. On the other

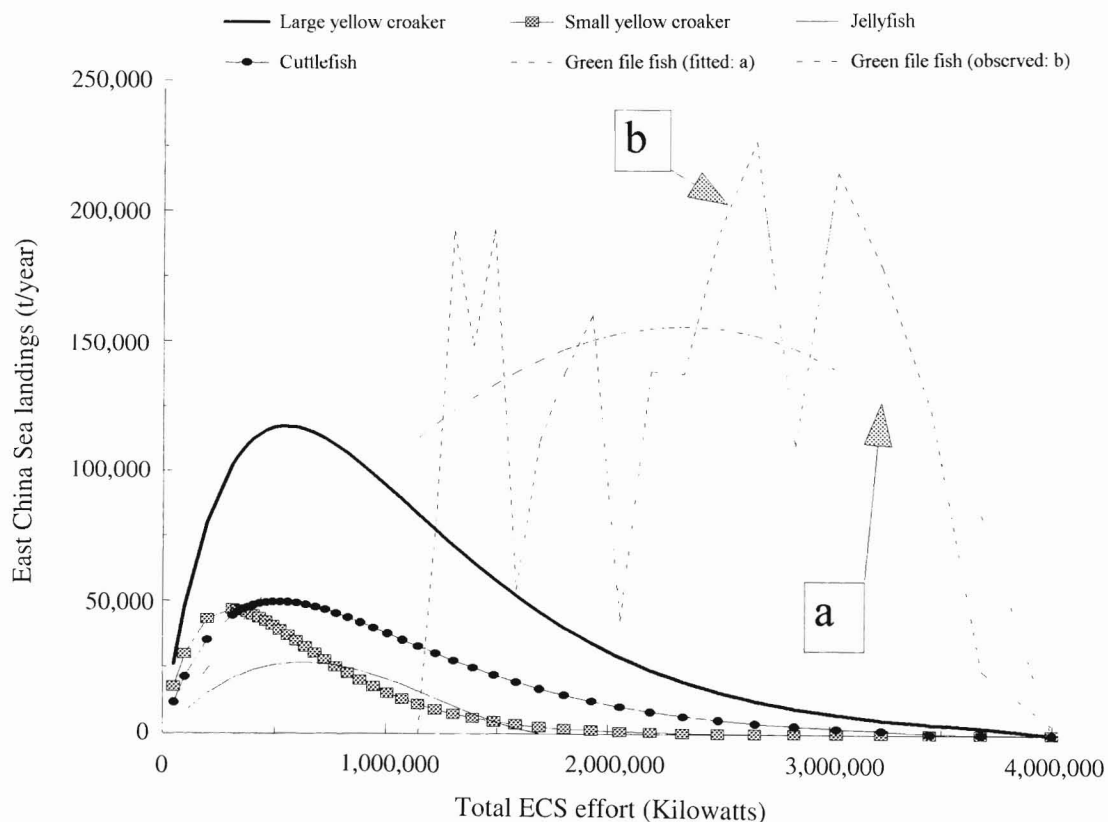


Figure 6. — Surplus production models for five stocks that have showed decreasing landings.

hand, hairtail landings (Fig. 7) increased in the early 1990's in spite of a decreasing trend over the previous decade, but recent landings were dominated by immature 1-year-old fish. Landings of small yellow croaker showed a sharp increase from <3,500 t in 1989 to >23,000 t in 1992 (Fig. 4), but were dominated by 1–2 year old fish 12–15 cm TL, instead of the larger (20 cm TL) older (3–5 year olds) that previously dominated the landings. Minimum size at maturity for this species has decreased from 14–15 cm TL in the 1970's to around 11–12 cm TL in the 1990's, consistent with heavy overfishing. Increases in landings of hairtail and large yellow croaker in the 1990's may also have been caused by environmental variation. This possibility causes concern: when the environmental influence is reversed, landings of hairtail may fall

below the level shown by the fitted curve (Fig. 7), while landings of small yellow croaker may return to levels characteristic of the late 1980's. Even well established fisheries such as hairtail are now vulnerable to overfishing, while any increase in the landings of overfished species is likely to be temporary. A sustainable exploitation policy for the ECS fisheries should address the effects of both environmental variation and increasing effort.

Acknowledgments

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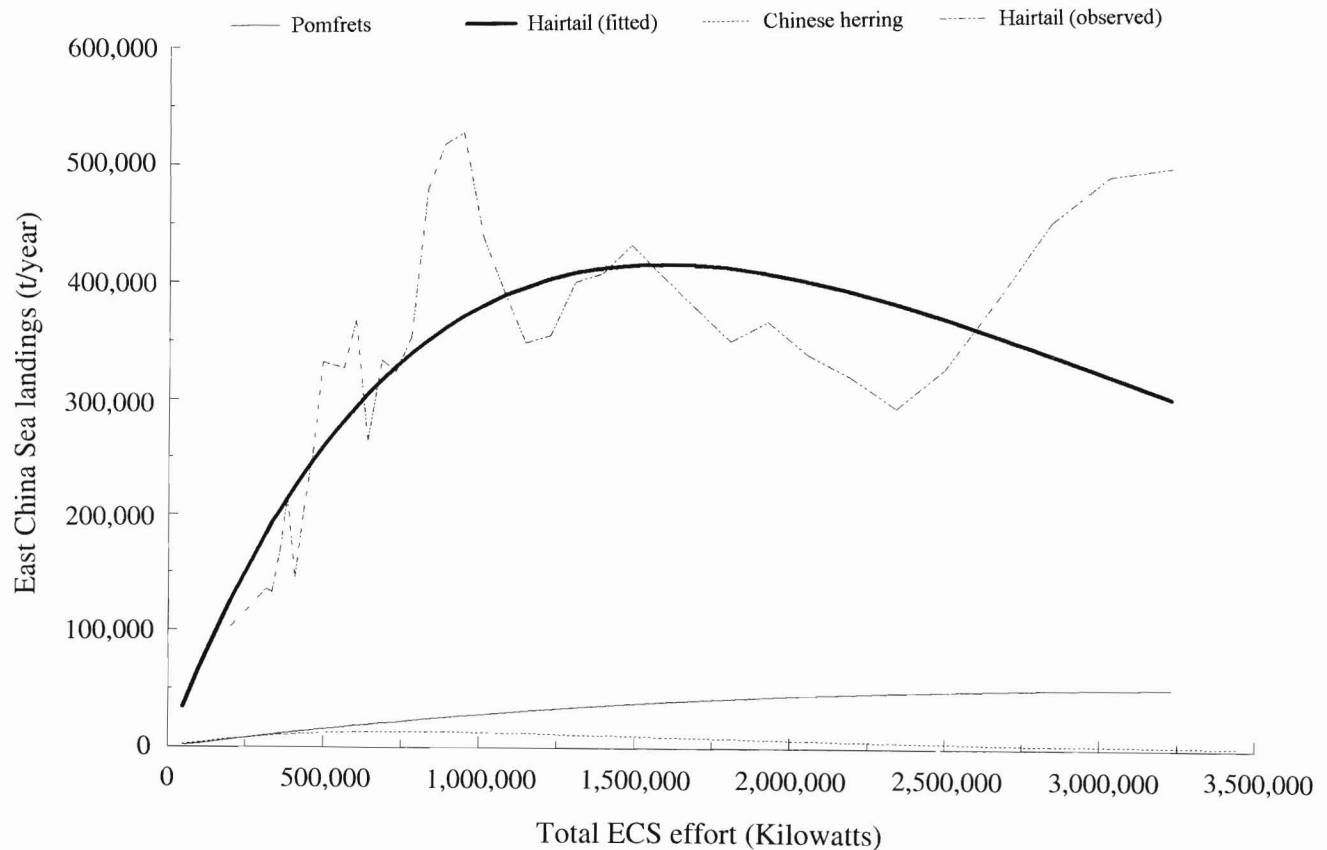


Figure 7. — Surplus production models for three species showing increasing (hairtail, Chinese herring) and sustained (pomfrets) landings.