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Ecoprofile rays and skates on the Dutch continental shelf and North Sea

ECOPROFILE RAYS AND SKATES

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Foreword/Voorwoord

This ecoprofile was written to be used in the project Water System Orientation (WSV), and was commissioned by the North Sea Directorate and the National Institute for Coastal and Marine Management (RIKZ), both of the Directorate-General of Public Works and Water Management.

Dit ecoprofiel werd geschreven in het kader van de Watersysteem Verkenningen (WSV), in opdracht van Directie Noordzee en het Rijksinstituut voor Kust en Zee (Rijkswaterstaat).

Summary

Several species of rays and skates were common in Dutch territorial waters at the beginning of the century and there was a directed fisheries on these species. During the 1930's a decline in landings was seen and shortly after the Second World War there were few rays left on the Dutch continental shelf. At the present time only two species of ray are caught in Dutch waters (the starry ray, *Raja radiata*, and the stingray, *Dasyatis pastinaca*), neither are commercially important. The starry ray has replaced the thornback ray (*R. clavata*) as the most abundant species. Although total mortality (natural + fisheries) on adult rays is above the theoretical replacement level for a number of species, the same species are still present off the British coast. This area is possibly a source of individuals for other parts of the North Sea. It is as yet unclear which stage in the development (i.e. survival of adults, eggs or juveniles) is the one limiting the recolonisation of Dutch coastal waters by the endemic species.

Schematic comparison of the relative distribution of ray species on the Dutch continental shelf between a reference situation (1900-1909) and the present day (1993-1994). Areas defined by Directorate-General of Public Works and Water Management (Rijkswaterstaat), see Figure 8. Symbols represent the following: 0 = outside area of distribution; ++ = abundant; + = present; (+) = present in very low numbers; - = absent; ? = unknown (as yet).

	<i>R. batis</i> skate (vleet)	<i>R. clavata</i> thornback ray (stekelrog)	<i>R. montagui</i> spotted ray (gladde rog)	<i>R. radiata</i> starry ray (sterrog)	<i>D. pastinaca</i> stingray (pijlstaartrog)
	REF/NOW	REF/NOW	REF/NOW	REF/NOW	REF/NOW
Eems/Dollard	0/0	0/0	0/0	0/0	0/0
Wadden Sea - east	0/0	+/-	0/0	0/0	?/-
Wadden Sea - west	0/0	+/-	0/0	0/0	++/-
Oosterschelde	0/0	+/-	0/0	0/0	+/+
Westerschelde	0/0	+/-	0/0	0/0	+/-
Grevelingen	0/0	??	0/0	0/0	??
Coastal waters	+/-	++/-	++/-	0/0	+/+
North Sea - south	+/-	++/(+)	++/(+)	+/+	+/+
North Sea - central	+/-	+/(+)	+/(+)	+/++	0/0
Remarks	commercial absent	commercial amoeba species	limited commercial value	non- commercial scavenger	non- commercial

The areas are dealt with separately.

Wadden Sea

At the beginning of the century (1900-1920) there was a lively ray fisheries in the Wadden Sea and northern Zuiderzee, consisting of thornback and stingrays, caught in lobster nets, standing nets and trawls. The post-war years were especially provident (1919-1920) but this was short-lived and a decline was seen in the 1930's. It was generally thought that the demise of the thornback ray in the Wadden Sea in the 1930's and again after the second world war was due to over fishing in the southern North Sea during these periods (Bergman, 1989). No rays have been caught in the Wadden Sea since 1966, when 13 kg were landed, and it is probable that rays were scarce from the mid-1950's onwards (Bergman, 1989; Vooijs *et al.*, 1990).

Coastal waters and southern estuaries

The ray fisheries in the estuaries was composed primarily of thornback rays (90%) and stingrays (10%), although spotted and blonde rays were caught in the coastal waters. The estuaries in Zeeland were more important for thornback and stingrays than those in South Holland or the Wadden Sea, except following the First World War when record landings were registered from the Wadden Sea. The fisheries occurred in the spring and summer, after which the rays migrated to deeper water (thornbacks) or back south (stingrays). The decline in ray abundance occurred later here than in the Wadden Sea. Thornback rays were common until the 1960's and were there was a commercial fisheries until this time, however, between 1979 and 1985 no thornbacks were caught in commercial fykes. Stingrays are still caught regularly in the Eastern Schelde delta, although they are much less frequent than before the Second World War. Spotted and (occasionally) blonde rays were also caught off the Dutch coast, after World War II, but are now very rare visitors.

North Sea

North Sea - Dutch continental shelf

Survey data show decline in numbers and species composition of rays. No rays were found in the German Bight and north of the Dutch Wadden islands in 1993, while at the beginning of the century this was a well-known ray and skate fishing ground (Hoogendijk, 1893; Bergman, 1989). From the descriptions of Hoogendijk (1893) and Redeke (in Bergman, 1989) of the skate and ray fisheries at the end of the last century it is apparent that special ray and skate fishing trips were carried out, but the fish were not valued for consumption on the Dutch market and the thornbacks were exported to Belgium. Hoogendijk (1893) complained that very few people actually ate the common skate, despite its exquisite taste!

North Sea - International waters

Fisheries statistics from the entire North Sea show periods of declining catches, following periods of recovery during the two world wars. After the second World War landings data was divided into southern, central and northern North Sea. Landings from the southern North Sea started declining in 1947 and again in the early 1960's, although a slight increase has been seen in the past 15 years, possibly as a result of increased fishing effort. A comparison of survey data from 1906-1909 and 1993 shows a

decline in numbers and distribution of thornbacks and the disappearance of the common skate which used to be present throughout most of the North Sea. The starry ray, *Raja radiata*, is now the most common species throughout the North Sea, with the exception of southern and coastal areas. This is probably the southern limit of its' distribution. Although there appear to be fewer rays present in the southern North Sea, the coast of Britain has remained a stronghold for species such as the thornback and spotted rays.

Samenvatting

Tijdens de eerste decennia van deze eeuw waren roggen en vleten talrijk op het Nederlands Continentaal Plat. Er bestond een gerichte visserij op de rog en het vlees werd als voedsel gewaardeerd. Tijdens de jaren 30 werd een achteruitgang geconstateerd en kort na de tweede wereld oorlog werden roggen in het zuidelijk Noordzee als zeldzaam beschouwd. In de huidige situatie zijn slechts twee (niet commerciële) soorten regelmatig gevangen op het Nederlands Continentaal Plat, dit zijn de sterrog (*Raja radiata*) en de pijlstaartrog (*Dasyatis pastinaca*). De sterrog heeft de stekelrog (*R. clavata*) vervangen als de meest talrijke soort in de Noordzee. De totale sterfte (natuurlijk + visserij) op volwassen individuen van een aantal roggen soorten gaat boven de theoretische maximum voor het voortbestaan van de soorten in de Noordzee. Toch komen deze soorten bij de kust van Engeland nog voor en dit gebied vervult misschien een functie als bron voor individuen elders in de Noordzee. Het is nog onduidelijk of het de sterfte van volwassenen is, of van het ei of juveniele stadium, die de beperkende factor is voor het herkoloniseren van het Nederlands Continentale Plat door de inheemse roggensoorten.

Onderstaand schema geeft een overzicht van de relatieve verspreiding en talrijkheid van roggensoorten op het Nederlands Continentaal Plat tussen het begin van deze eeuw (1900-1909 = REF) en nu (1993 = 'NOW'). De gebieden zijn door Rijkswaterstaat gedefinieerd (Figuur 8). Symbolen geven het volgende weer: 0 = buiten verspreidingsgebied; ++ = talrijk; + = aanwezig; (+) = aanwezig in lage aantallen; - = afwezig; ? = onbekend (tot nu toe).

	<i>R. batis</i> skate (vleet)	<i>R. clavata</i> thornback ray (stekel- rog)	<i>R. montagui</i> spotted ray (gladde rog)	<i>R. radiata</i> starry ray (sterrog)	<i>D. pastinaca</i> stingray (pijlstaartrog)
	REF/NOW	REF/NOW	REF/NOW	REF/NOW	REF/NOW
Eems/Dollard	0/0	0/0	0/0	0/0	0/0
Wadden Sea - east	0/0	+/-	0/0	0/0	?/-
Wadden Sea - west	0/0	+/-	0/0	0/0	++/-
Oosterschelde	0/0	+/-	0/0	0/0	+/+
Westerschelde	0/0	+/-	0/0	0/0	+/-
Grevelingen	0/0	?/?	0/0	0/0	?/?
Coastal waters	+/-	++/-	++/-	0/0	+/+
North Sea - south	+/-	++/(+)	++/(+)	+/+	+/+
North Sea - central	+/-	+/(+)	+/(+)	+/++	0/0
Remarks	commercial absent	commercial amoebic species	limited commercial value	non- commercial scavenger	non- commercial

De veranderingen in de verschillende gebieden worden apart beschreven

Waddenzee

Tijdens het begin van de eeuw (1900-1920) bestond er in de Waddenzee en noordelijke Zuiderzee een belangrijke visserij op stekel- en pijlstaartrog. Er werd veel gevangen, vooral na de eerste wereld oorlog, maar tijdens de jaren 30 werd een achteruitgang geconstateerd. Deze achteruitgang en de afname in aanlandingen na de tweede wereld oorlog worden toegeschreven aan intensieve visserij in de zuidelijk Noordzee (Bergman, 1989). Sinds 1966 zijn er geen roggen meer gevangen in de Waddenzee en het is waarschijnlijk dat vanaf de jaren 50 deze soorten zeldzaam zijn geworden (Bergman, 1989; Vooijs *et al.*, 1990).

Kustwateren en zuidelijke estuaria

In deze wateren werden voornamelijk stekelroggen (90%) en pijlstaartroggen (10%) gevangen, alhoewel gladde en blonde roggen ook tot de vangst konden behoren. De Zeeuwse estuaria waren belangrijker dan die in Zuid Holland of de Waddenzee. De visserij vond voornamelijk plaats gedurende de lente en zomer, waarna de roggen naar diepere water migreerde of terug naar het zuiden (pijlstaartroggen). De achteruitgang in aantallen voltrok zich later hier dan in de Waddenzee. Tot de jaren 60 was er een visserij op stekelrog, maar tussen 1979 en 1985 werden geen roggen gevangen door beroepsvisserij. Pijlstaartroggen worden nog steeds in de Oosterschelde gevangen, alhoewel in lagere aantallen dan voor de tweede wereld oorlog. Gladde en blonde roggen werden kort na die oorlog gevangen, maar zijn nu zeldzaam geworden.

Noordzee

Noordzee - Nederlands Continentaal Plat

Uit onderzoeksdata blijkt dat tussen het begin van de eeuw en begin jaren 90 er een achteruitgang in aantallen en soortenrijkdom van roggen heeft plaatsgevonden. *Raja radiata* (sterrog) heeft de stekelrog (*R. clavata*) vervangen als de meest algemene soort. Ondanks de achteruitgang blijft de engelse kust een haven voor soorten als de stekel- en gladde rog. Gebieden ten noorden van de Wadden eilanden en de Duitse bocht waren vroeger belangrijk rog visgronden (Hoogendijk, 1893; Bergman, 1989) maar hier worden tegenwoordig weinig roggen gevangen.

Noordzee - Internationale wateren

Visserijstatistieken van 1903-1993 van alle roggen en vleten gevangen in de Noordzee laten een wisselend beeld zien. Hoge vangsten in de jaren 20 en 30 en eind jaren 40 werden afgewisseld met lage vangsten tijdens de twee wereld oorlogen en sinds eind jaren 40 is er een afname te zien. Dit voltrok zich het eerst in de zuidelijke Noordzee in 1947 en weer in begin jaren 60. In de afgelopen 15 jaar is een lichte stijging te zien in de aanlandingen van rog en vleet, waarschijnlijk als gevolg van de verhoogde visserijinspanning. Uit onderzoeksdata blijkt dat de stekelrog uit de oostelijke noordzee is verdwenen en dat de vleet nauwelijks meer in de Noordzee wordt gevangen. De sterrog (*Raja radiata*) is de meest algemene en talrijke soort in de Noordzee, behalve in de zuidelijke wateren en kustzone.

Contents

1	Introduction 11
2	Reference situation 13
2.1	Dutch Continental Shelf 13
	2.1.1 Wadden Sea and "Zuiderzee" 13
	2.1.2 Coastal waters and southern estuaries 16
	2.1.3 North Sea 18
2.2	North Sea - International waters 23
	2.2.1 Fisheries Statistics 1903-1983 23
	2.2.2 Survey data 1906-1909 24
3	Present situation 27
3.1	Dutch Continental Shelf 27
	3.1.1 <i>Dasyatis pastinaca</i> - Stingrays 27
	3.1.2 <i>Raja radiata</i> - Starry rays 27
3.2	North Sea 32
	3.2.1 Landing data 32
	3.2.2 Survey data 32
4	Long-term trends 35
4.1	Fisheries Statistics 1903-1993 35
	4.1.1 ICES data - North Sea: all countries 35
	4.1.2 ICES data 1903-1983 - North Sea: Netherlands 35
	4.1.3 Dutch trawlers - North Sea 35
4.2	Data from ICES International Bottom Trawl Surveys: 1970-1993 36
4.3	'Wodan' & 'Huxley' survey data (1906-1909) vs. IBTS survey data (1993) 37
4.4	Data from the RIVO transect programme and Sole Net Survey 39
	4.4.1 RIVO transect programme: 1950-1960 & 1965-1967 39
	4.4.2 RIVO Sole Net Survey: 1969-1994 39
4.5	NIOZ register of rare fish species 41
5	Autecology 47
5.1	Reproductive strategies 47
	5.1.1 Rajid species 48
	5.1.2 <i>Dasyatis pastinaca</i> 49
5.2	Growth 49
5.3	Food and Feeding Habits 52
5.4	Migration and distribution 53
5.5	Abiotic parameters 54
6	Anthropogenic effects 55
6.1	Fisheries 55
	6.1.1 Exploitation 55

	6.1.2 Harvestable biomass	57
	6.1.3 Discards	58
6.2	Habitat changes	58
6.3	Contaminants	58
6.4	Eutrophication	60
7	Recommendations	61
8	Amoeba values	63
9	References	65

Appendix I 73

Appendix II 75

1 Introduction

Rays and skates belong to the class Chondrichthyes, the cartilaginous fish, together with the sharks and ratfish. Chondrichthyes have a simple, internal skeleton, composed of cartilage and without bony fin rays. There are two subclasses: Elasmobranchii which includes the rays, skates and sharks (97% of species); and the much smaller sub-class Holocephalii which includes the chimaeras and ratfish (3% of species) (Compagno, 1990).

Rays are derived from sharks and have a dorso-ventrally flattened form in which the pectoral fins are expanded forwards and fused with the head. Mouth and gill openings are situated ventrally and a spiraculum is present on the dorsal side to enable the expulsion of water after passage over the gills. Sexual dimorphism is apparent by all cartilaginous fish. The males have mixopterygia or claspers, cartilaginous appendages which are inserted into the cloaca of the female to implant the spermatophores (Richards *et al.*, 1963). There is internal fertilisation, rays and skates laying hard capsules which contain fertilised eggs whilst stingrays and electric rays are viviparous, bearing live young in the summer months. Elasmobranchs (rays, skates and sharks) are long-lived and produce relatively few, well-developed eggs or young, and generally have a high age at maturity (Holden, 1973; Fahy, 1989; Hoenig & Gruber, 1990).

There are nearly 500 ray and skate species world-wide, including skates (Rajiformes; 44% of all species) stingrays (Myliobatiformes; 35%), guitarfishes (Rhinobatiformes; 11%) and electric rays (Torpediniformes; 9%) (Compagno, 1990). The remaining 1% comprises the sawfishes (Pristiformes).

Skates and stingrays are demersal and are commonly found in shallow waters but also to extreme depths; one *Bathyraja* species is found up to 3000 m deep. The genus *Raja* (skates) has 23 species in the Northeast Atlantic, of which nine are present in the North Sea. As well as the skate species, one stingray species, *Dasyatis pastinaca*, is also found in the North Sea in the summer months and occurs along the coast and in the estuaries of Zeeland and South Holland, as far north as the Wadden islands. Two electric ray species (*Torpedo* sp.) are also occasionally found in the North Sea. See Appendix I for an overview of the species found on the Dutch continental shelf.

The ray species most typical to Dutch waters is the thornback ray, *Raja clavata*. This species is the one most commonly landed for consumption, both in the past and at the present time. Both *R. batis* and *R. montagui* are also landed for consumption, when available, although the former species is very rare in the North Sea and the latter is only occasionally caught within the Dutch fishing limits. In the Dutch commercial fisheries rays are taken as by-catch and most are exported to other European countries. Nearly 700 metric tonnes of rays were landed in 1994, probably at

least 90% of these were thornbacks. This is the highest amount landed since the 1930's and follows an upward trend, initiated in the late 1960's. The most abundant species in the North Sea is the starry ray, *R. radiata*, which is not landed for consumption in Europe. There is no commercial fisheries for the stingrays at the present time, although there was in the past. For example, this species was a valued bycatch of the standing net fishery for thornback rays in the Wadden Sea up to the 1930's. The stingray is a popular target for anglers in the Oosterschelde.

Rays occupy the same spatial niche as other demersal fish species such as flatfish. There is interspecific competition for food (crustaceans) and large rays prey on flatfish and other demersal fish species (e.g. sand eels). However, it is unlikely that rays have a detrimental impact on the species mentioned because their relative abundance is so low. In 1986 rays and skates represented 2.7% of the total biomass of fish in the North Sea and 11.7% of all flatfish (Daan *et al.*, 1990). Mean values between 1977 and 1986 were 3.2% and 12.5%, respectively (Daan *et al.*, 1990).

The thornback ray (stekelrog) has been chosen as the species to be used for further management scenarios (amoeba, Water Management Plan 4). Although this species is no longer abundant off the Dutch coast, it was the most common species in the first half of the century and had a high commercial value. Most of the (fisheries) data for the reference situation concerns this species.

This ecoprofile is an update of one made by Bergman (1989). Information from the previous study is included in this report, with acknowledgement to the author. The division and naming of geographical areas dealt with in this report follow the nomenclature of the Directorate-General of Public Works and Water Management as shown in Figure 8.

2 Reference situation

2.1 Dutch Continental Shelf

2.1.1 Wadden Sea and Zuiderzee

At the beginning of the century (1900-1930) there was a lively ray fisheries in the Wadden Sea and northern Zuiderzee, consisting of thornback and stingrays, caught in lobster nets, standing nets and trawls (Bergman, 1989). The post-war years (1919-1920) were especially provident (Table 1) and Redeke (1922, in Bergman, 1989) has described the thornback ray as being abundant on the sand flats and in the sea grass fields of the Wadden Sea in spring and early summer. This abundance was short-lived and a decline was seen in the 1930's, which has generally been attributed to over fishing in the southern North Sea (Zijlstra, 1978; Beumkes, personal communication; both in Bergman, 1989). Few rays were caught in the northern Zuiderzee after the turn of the century (1907-1909), although the situation beforehand is unknown (Redeke, 1910a, in Bergman, 1989) and in the southern part only incidental catches have been described (Redeke, 1922; Colijn *et al.*, 1932; both in Bergman, 1989). No rays were found in the former Zuiderzee once this had been dammed in by a long dike stretching across the northern part between North Holland and Friesland (Afsluitdijk; Havinga, 1954, in Bergman, 1989). Stingrays were caught for their liver oil, which was a cure-all, and were apparently so plentiful that fishermen carried a special hatchet with which to remove the spine from their tails. Juveniles were treated in this way before being released and the chance of the fisherman being wounded at a later date was minimised (Beumkes, personal communication, in Bergman, 1989).

The fisheries in the Wadden Sea and the estuaries of Zeeland and South Holland from 1911-1920 are described in ministerial Annual Reports (Anonymous, 1914; 1915a; 1915b; 1917; 1918a; 1918b; 1919; 1920a; 1920b; 1921). Total catches are shown in Figure 1 and Tables 1 and 4. Rays were caught in the Wadden Sea between March/April and July, with a peak in May (Figure 2). This occurred primarily in standing nets, although trawls and lines were also used and rays were also caught in shrimp nets and herring fykes (Anonymous, 1914; 1915a; 1915b; 1917; 1918a; 1918b; 1919; 1920a; 1920b; 1921; van Ginkel, 1993). Before 1912 the catches landed in Den Helder were included in the North Sea fisheries statistics and the Wadden Sea statistics were not complete for all fish markets around the Wadden Sea until 1916, and varying returns were seen (Table 1). In Zoutkamp (eastern Wadden Sea) the catches steadily declined from 1910 onwards, whilst those in Den Helder increased, especially after the war (Table 1).

Figure 1.

A: Annual landings from coastal fisheries.
 B: Annual landings from Wadden Sea fisheries.

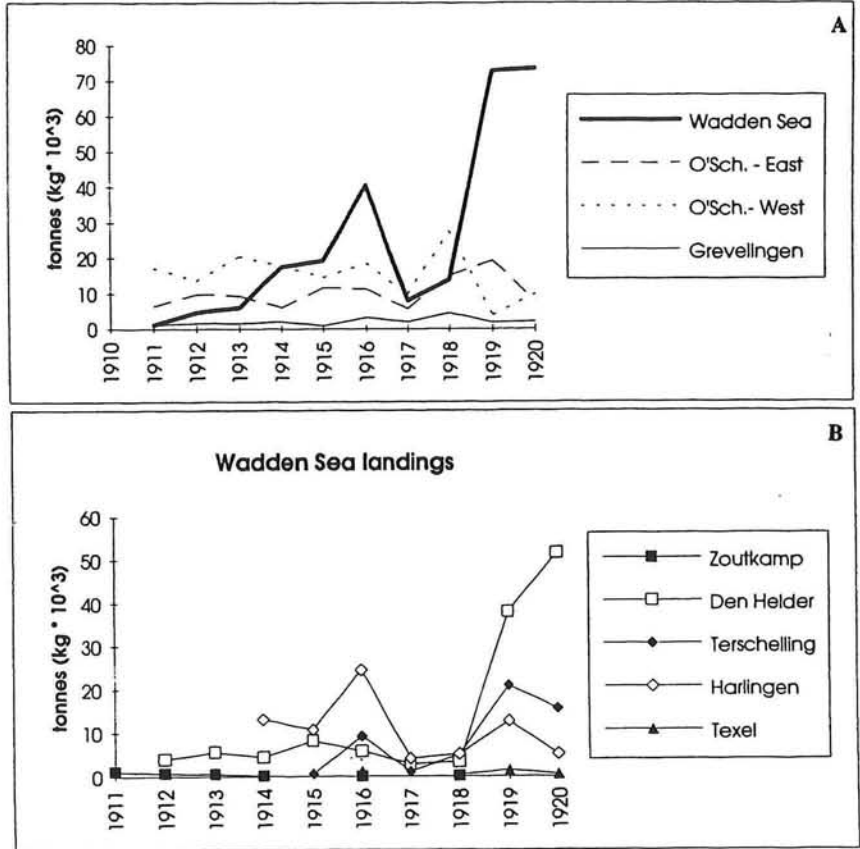


Figure 2.

Fisheries in the Wadden Sea by fishermen from Texel, around 1890. The black bar represents the period in which a particular fisheries occurred. Ray fisheries ('rog') occurred between March/April and July. Figure from Ginkel (1993).

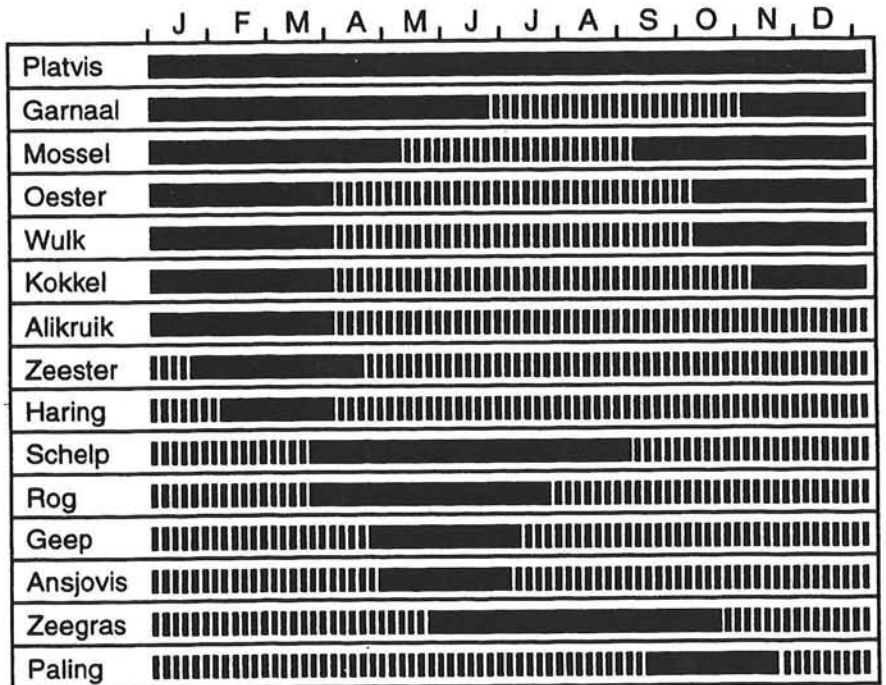


Table 1.

Annual landings of rays from fisheries in the Wadden Sea at various fish markets.

The fisheries occurred throughout the entire period, but the catches were, unfortunately, not always registered.

Values in metric tonnes (Anonymous 1994; 1915a; 1915b; 1917; 1918; 1918b; 1919; 1920a; 1920b; 1921).

	Zoutkamp	Den Helder	Terschelling	Harlingen	Texel	van Ewijcksluis	Wieringen-West
1911	1.14						
1912	0.71	3.95					
1913	0.47	5.49					
1914	0.11	4.38		13.02			
1915		8.11	0.49	10.70			
1916	0.01	5.74	9.22	24.44	1.12		
1917		2.79	1.06	4.09			
1918	0.11	3.30	4.98	5.13	0.38	0.01	
1919		37.91	20.81	12.68	1.41		
1920		51.55	15.61	5.09	0.45		0.44

Thornback rays were caught as by-catch in the German shrimp fisheries and between 1954 and 1960 a number of juveniles of about 20 cm were registered, but these are the only data available for the eastern (German) Wadden Sea (Meijer-Waarden & Tiewes, 1965; Tiewes, 1971; all in Bergman, 1989; Tiewes, 1983).

No rays were caught after 1967 during sampling surveys carried out between 1960 and 1973 in the Wadden Sea (Postuma & Rauck, 1978, in Bergman, 1989). The relative abundance of rays (expressed as % of total flatfish) declined from 1965 onwards, see Table 2.

Table 2.

Total landings of rays (*Raja clavata*) in kg from the Dutch Wadden Sea. Postuma & Rauck, 1978. nd = no data.

	1948	1960	1961	1962	1963	1964	1965	1966	1967-1973
Rays	34	35	81	121	nd	31	14	13	0
Total Flatfish		207019	289618	208464	102534	79659	147876	177135	753512
% of Total		0.017	0.028	0.058		0.039	0.009	0.007	0

Adult stingray individuals were rare off the coast at Den Helder following World War II and catches of stingrays in the Wadden Sea were low from 1962 onwards. This is reflected in the catches of this species in the fyke net, placed at the entrance to the western Wadden Sea (Marsdiep), close to Texel (Table 3).

Table 3.
Numbers of stingrays (*Dasyatis pastinaca*) caught annually in the NIOZ fyke close to Texel, in North Holland (NIOZ archive). Average effort was 100 days per year.

Years	Stingray-numbers
1960-1965	7
1965-1970	3
1970-1975	3
1975-1980	0
1980-1985	1
1985-1990	1
1990-1995	0

2.1.2 Coastal waters and southern estuaries

At the beginning of the century standing nets and beam trawls were used to catch rays in the estuaries of South Holland and Zeeland. The thornback ray was the dominant species, although nearly 10% of the catches were the stingray *Dasyatis pastinaca* and spotted (*R. montagui*) and blonde (*R. brachyura*) rays were also caught in the coastal waters (Bergman, 1989). The estuaries in Zeeland were more important for thornback and stingrays than those in South Holland or the Wadden Sea, except in 1916 and following World War I when record landings were registered from the Wadden Sea (Tables 4 & 5). The fisheries occurred in the spring and summer, after which the rays migrated to deeper water (thornbacks, *R. clavata*) or migrated southwards (stingrays, *D. pastinaca*) (Anonymous, 1927, in Bergman, 1989). The decline in ray abundance occurred later here than in the Wadden Sea. Thornback rays were common until the 1960's and there was a commercial fisheries until this time. However, during a fish survey, carried out between 1979 and 1985, no thornbacks were caught in fykes (Philippart & Meijer, 1982; Meijer, 1984; 1986; all in Bergman, 1989). In 1945-1948 the numbers of adult stingrays decreased in the Oosterschelde, whilst at the same time large numbers of juveniles were still caught. The entire coastal fleet only landed a few tens of livers per week at the fish market in Vlissingen in 1947 (NIOZ archives, in Bergman, 1989). Stingrays were caught in up to 10% of the fykes and weirs during a survey between 1979 and 1985 in the Oosterschelde, primarily in June and August and mostly in the eastern part of the estuary (Meijer & Philippart, 1982; Meijer, 1984; 1986; all in Bergman, 1989). In the late 1940's the stingray was acknowledged to be a rare summer visitor to the Grevelingen and between 1979 and 1985 this species was not caught in the experimental fykes, although it was occasionally seen by commercial fishermen (Philippart & Meijer, 1982; Meijer, 1986; both in Bergman, 1989). Spotted and (occasionally) blonde rays were also caught off the Dutch coast, we know this for certain following the second world war, but they are now very rare visitors.

The majority of the rays caught in the western Oosterschelde came from lobster fishermen (80% in 1913), with only 16% from standing nets, set specifically for rays and skates. Weirs were a popular fishing method in the eastern Oosterschelde and Grevelingen. Shrimp fishermen in the Westerschelde regularly caught rays, but unfortunately rarely registered the catches. There are only two years of landing data (1917 and 1918). The rays were caught between March and August/September, with a peak in May/June.

Table 4.

Total annual landings of thornback rays from the Wadden Sea and estuaries. Values in metric tonnes (Anonymous 1914; 1915a; 1915b; 1917; 1918a; 1918b; 1919; 1920a; 1920b; 1921).

	Wadden Sea	Oosterschelde-East	Oosterschelde West	Westerschelde	Grevelingen
1911	1.14	6.39	17.10		1.07
1912	4.66	9.84	13.70		1.58
1913	5.97	9.25	20.40		1.43
1914	17.51	5.91	17.76		1.96
1915	19.29	11.62	14.57		0.86
1916	40.52	11.28	18.51		3.13
1917	7.94	5.60	9.81	0.15	1.94
1918	13.90	15.02	27.60	0.75	4.47
1919	72.80	19.34	3.75		1.76
1920	73.49	7.91	9.87		2.02

Table 5.

Total numbers of rays caught (*R. clavata* 90%; *Dasyatis pastinaca* 10%) in the period 1925-1927 in the estuaries of South Holland and Zeeland (Anonymous, 1926; 1927; 1928).

	Westerschelde	Oosterschelde	Grevelingen
1925	-	7300	1000
1926	0	7400	250
1927	0	3500	750

Although the stingray appeared to decline in numbers, this species is still caught regularly in the eastern part of the Oosterschelde (Meijer & Philippart, 1982; Meijer, 1984; 1986; all in Bergman, 1989; Meijer, 1989). Also see Table 9 and Figure 7.

Table 6.

Landings of (sting)rays from the delta area (Visserijnieuws). Data expressed in metric tonnes.

Year	S. Holland estuaries	Zeeland estuaries	Estuaries in both areas
1946			15
1947		19	
1948		34	
1963		2	
1964		5	
1965		4	
1966		7	
1967	0.1	14	

The annual catch of rays in Dutch coastal waters was taken between April and August, after which the rays were not abundant in the Dutch estuarine waters, see Table 7 (Bergman, 1989). In 1947 a total of 18851 kg was caught, as compared to 33389 kg in 1948 (Visserijnieuws, 1948; 1949).

Table 7.

Landings of rays in Dutch coastal waters in 1948. Values expressed in kg (Visserijnieuws, 1949).

	Dollard and Eems	Lauwers-zee	Wadden Sea	S. Holland estuaries	Zeeland estuaries
Februari	-	-	-	-	-
April	-	-	-	-	3098
May	-	-	11	6868	
June	-	-	20	-	2474
July	-	-	4	-	873
August	-	-	-	19	289
Total	-	-	35	19	13602

2.1.3 North Sea

A directed ray fisheries was not developed until the 20th century and was initially done by trawls (sleepnetten) and long lines (beug). Long-lining was short-lived and by 1935 was no longer economical (Bergman, 1989). Monthly landing data are available from the fish markets at IJmuiden, Den Helder and Harlingen from around the turn of the century (Figures 3 & 4).

These statistics show that most rays and skates were caught in the winter and early spring off the central Dutch coast (IJmuiden) and in May to August/September off the northern coast of Holland and possibly also in the Wadden Sea (Den Helder and Harlingen) (Figure 3), although data shown in Figure 2 suggest that the fishing season stretched from April to July in the latter area.

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Figure 3.
Relative monthly landings of *Raja spec.* at
three fish markets in 1900.

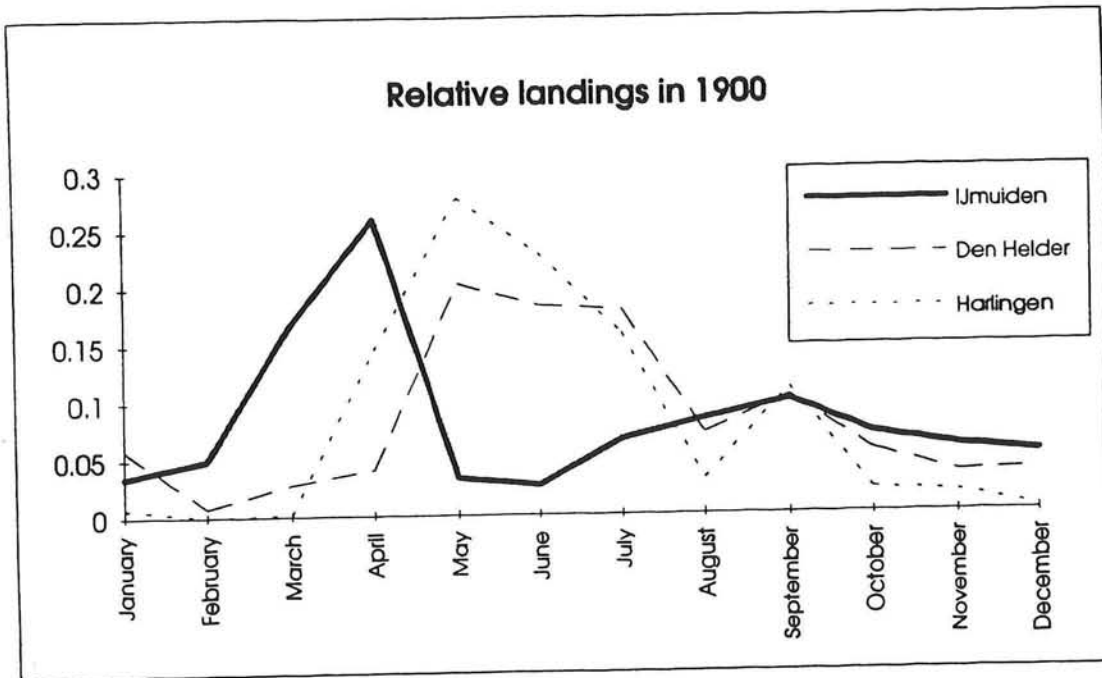
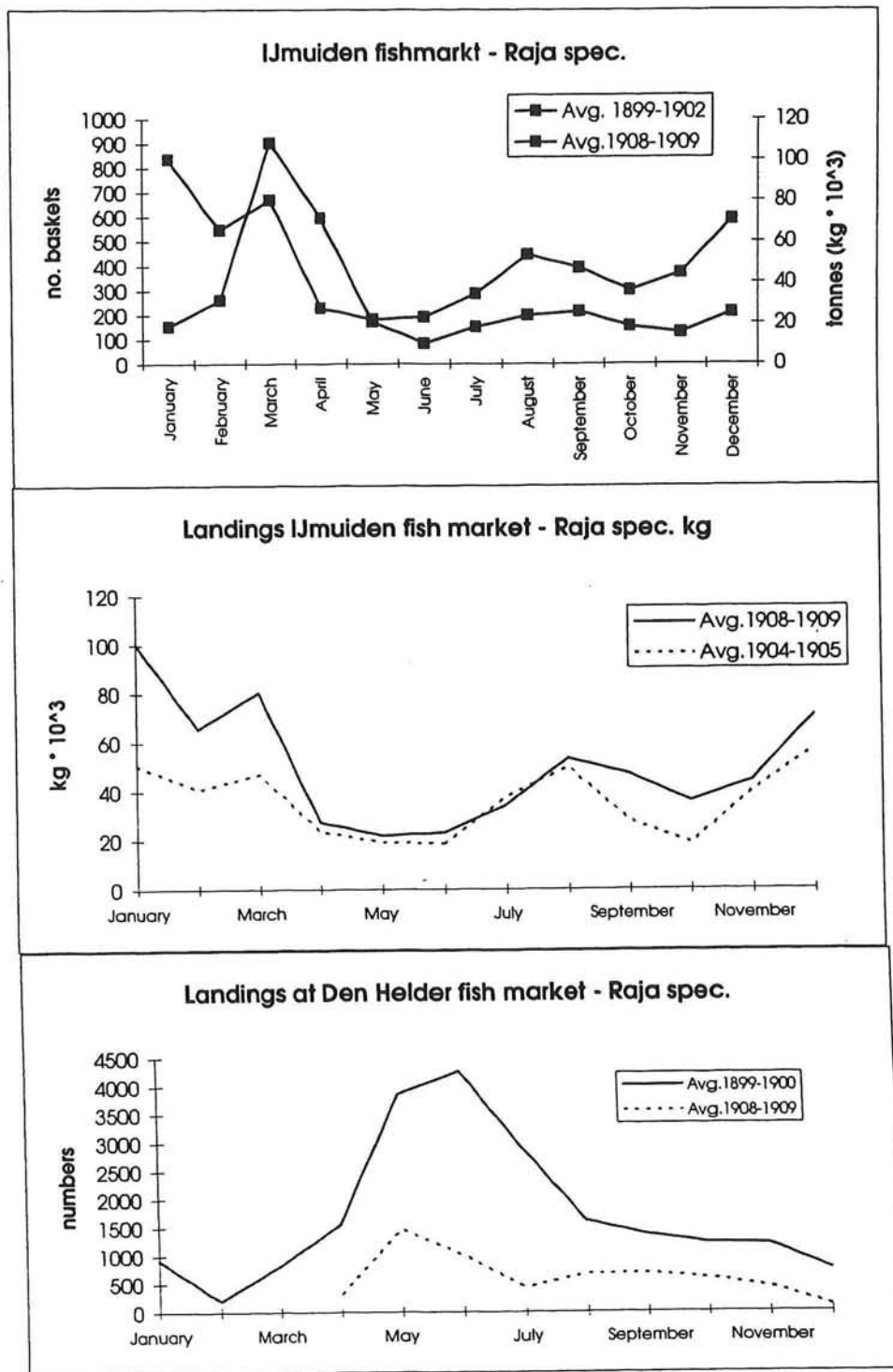


Figure 4.
 Monthly statistics of numbers and biomass of *Raja spec.* at the fishmarkets in IJmuiden and Den Helder at the turn of the century.



The seasonal trend seen at IJmuiden was probably due to the fact that the fish migrated to deeper (and cooler) waters in the summer months and that they had a higher chance of avoiding the net in the relatively clearer waters. If the majority of the fishing effort remained in the coastal zone, then fewer fish would be caught in the summer than in the winter. It is probable that the fishermen from Den Helder and Harlingen fished in relatively deeper waters (the coast shelves more steeply in the north of Holland) as well as in the Wadden Sea. These would both lead to higher catches. Most of the descriptions of the fisheries consider *Raja clavata* to be the prime species caught.

There was a decrease in landings at Den Helder between 1899-1900 and 1908-1909 (Figure 4C). This was especially apparent in the winter and early spring (December-April). In 1908 and 1909 no rays were caught between January and March (a time when the numbers in previous years were lower anyway). No details on length frequency are available so it is unknown if these were juveniles/mating adults etc.

The thornback ray was considered a common and abundant species (Redeke, 1910a, in Bergman, 1989) and the fishing grounds were the sandy areas Northwest of Helgoland, the small Fisher Bank and the Jutland bank, deeper than 40 m. This species was caught all year round, and in the coastal areas in spring and summer (Tesch & de Veen, 1933; Redeke, 1935; Wheeler, 1969; van Roon, 1975; all in Bergman, 1989), coinciding with lower landings from the North Sea between May and October (Redeke, 1910a, in Bergman, 1989). Redeke (1910b, in Bergman, 1989) observed that the rays caught on fishing trips in the period 1902-1911 were between 20 and 50 cm (juveniles). The amount of thornback rays caught annually in the period 1907-1909 was the same (630 tonnes) as that of whiting, haddock, cod and small plaice. In 1929-1930 the landings of all skates and rays was about 600 tonnes, of which about 30% were the common skate (*Raja batis*) (Visserijnieuws, 1932). See also Figure 6. This species was not common in the southern North Sea (Redeke, 1935, in Bergman, 1989) and was never caught in the coastal waters. Skates caught in the North Sea between 1902 and 1911 were 20-60 cm in length and the largest of these were caught close to the Dogger Bank (Redeke, 1910b, in Bergman, 1989). An annual average of 42 tonnes (trawlers) and 80 tonnes ('beugers') of skates were caught between 1907 and 1909. Peaks in landings were seen in March-June in the years 1909-1910 and 1934-1939 (NIOZ archives, in Bergman, 1989).

Fisheries on stingrays (*Dasyatis pastinaca*) occurred between May and September and the individuals were 60-70 cm long in the period studied, which was 1933-1940 (Redeke, 1935, in Bergman, 1989; Vooijs, *et al.*, 1990).

In 1948, shortly after the second World War, research was initiated at the Netherlands Institute for Sea Research (NIOZ) to determine the migration of various ray species (NIOZ archives; Boer, 1972). It appears that the spotted (*Raja montagui*) and blonde (*R. brachyura*) rays were most abundant in the winter months (Dec.-Jan) and in April off the coast near Den Helder. It was thought that these probably represented rays migrating

southwards (Dec.-Jan.), respectively northwards (April) to avoid the low water temperatures occurring in winter. This was also borne out by the fact that the highest catches of spotted and thornback (*R. clavata*) rays off the Belgian coast occurred in March-April. However, in the 25 years before 1948 (since 1923) there were no large catches of large rays in the seas between the Netherlands and Great Britain in April/May or later, and it was the thought that the rays returned to the Channel in April (Kristensen, NIOZ, personal communication). Kristensen described these species as southern species. However, there is a letter in the archives from B.B.Rae in Aberdeen dated 31st March 1952, describing *R. naevus*, *R. brachyura* and *R. montagui* as native to Scottish waters, living and breeding there. The latter two species were found as far north as the Shetlands. However, this does not have to conflict with the description of southern (Kristensen) or Lusitanian (Yang, 1982b) species as it is possible that they use the Gulf Stream to arrive in Scotland.

The fact that detailed research was done into the migratory behaviour of the spotted, blonde and thornback rays in the post-war years, suggests that these species were abundant in Dutch waters and were commercially important. This coincides with a peak in the landings of all ray and skate species in this period, following the reduced fishing effort between 1940 and 1945 (Figure 14).

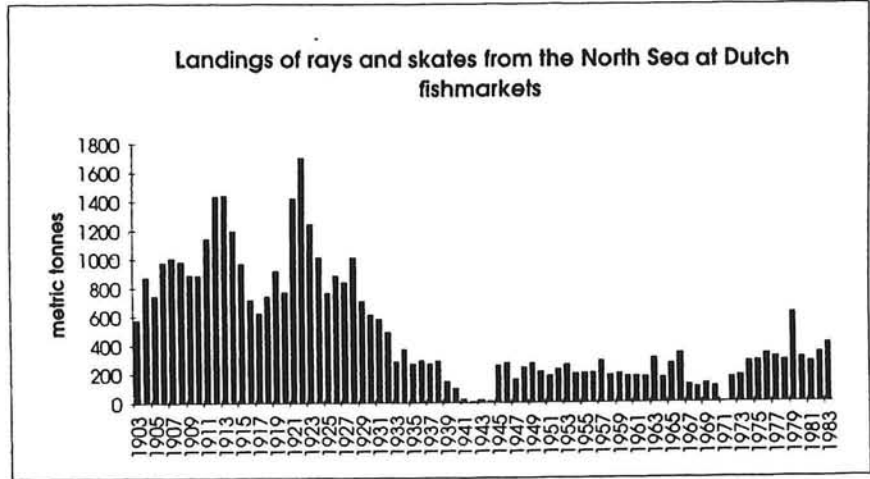
In his description of the fish fauna of the North Sea Sahrhage (1964, in Bergman, 1989) described the thornback ray as rare and occurring South-east of the Orkneys, on the Oyster Grounds and on the White Bank. The common skate represented only 7% of all the skates and rays caught and were caught north and west of the co-ordinates 54° N and 3° E. The individuals were 0.25 - 1.5 m in length. The starry ray (*Raja radiata*) was the most common species, being found north and west of the co-ordinates 55° N and 4° E.

2.2 North Sea - International waters

2.2.1 Fisheries Statistics 1903-1983

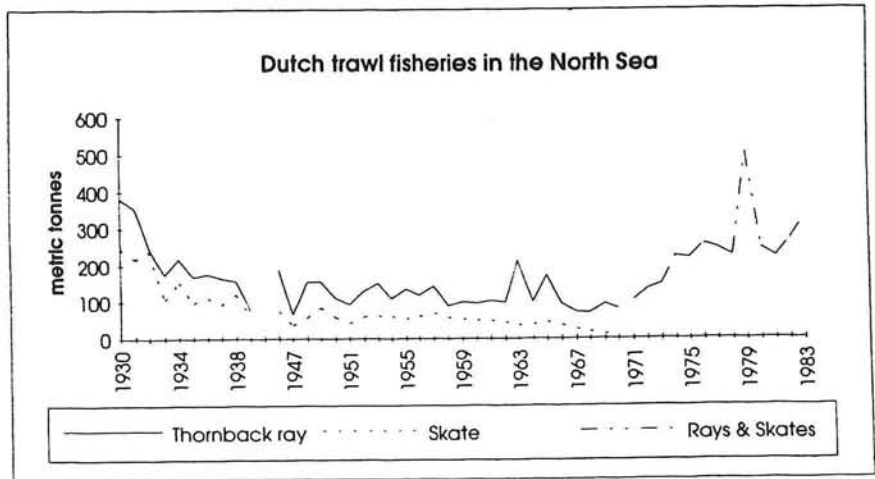
Landings of all rays and skates at Dutch fish markets were between 575 and 1006 metric tonnes just after the turn of the century (Figure 5 and Appendix II). A peak was reached in 1922, after which the landings declined.

Figure 5.
Landing statistics from all Dutch fish markets as reported to the International Council the Exploration of the Sea (ICES) 1903-1983 (ICES Bulletin Statistique, 1904-1984).



In 1930 Dutch trawlers landed more than 625 tonnes of rays and skates, of which common skates represented nearly 40% (Figure 6 and Appendix II). This percentage declined steadily until less than 10% in 1970, after which the species was not registered separately (Figure 6 and Appendix II).

Figure 6.
Landing statistics from the Dutch trawl fisheries 1930-1983 (Visserijnieuws, 1931-1984).



2.2.2 Survey data 1906-1909

Survey data from Dutch and British research vessels give some insight into the distribution and abundance of six *Raja* species. Data are available from between 1906 and 1909 for the Dutch vessel 'Wodan' and between 1906 and 1908 for the British vessel 'Huxley' (Figure 7 and Table 8).

Table 8.

Average catch per haul: Wodan 1906-1909 (all quarters) & Huxley 1906-1908 (all quarters). Data from RIVO, Rijnsdorp, personal communication.

Area	<i>R.radiata</i>	<i>R.brachyura</i>	<i>R.montagui</i>	<i>R.batis</i>	<i>R.naevus</i>	<i>R.clavata</i>
1 Southern	0	0.05	0.21	0.19	0	2.73
2 Dogger	0.96	0	0.01	0.17	0.01	1.79
3 German Bight	0.11	0	0	0.29	0	1.06
4 Central	5.89	0	0.03	1.00	0.12	0.15
5 Coast S. Bight	0	0	0.05	0	0	1.49
6 Coast G. Bight	0.02	0	0	0.06	0	1.21
7 Coast Scotland	0.02	0.04	1.48	0.48	0	3.02
8 Coast GB	0	0.56	1.83	0.94	0	26.56

The thornback ray was numerically the most important species and was relatively the most abundant in all areas studied, with the exception of the central North Sea (area 4), where the starry ray was the most abundant. Rays were most abundant off the south-east coast of England (area 8), primarily because the thornback ray was so abundant in this area. The differences between the situation described by this data set and that seen in 1993 are discussed in Chapter 4 (Long-term trends).

Figure 7.
Average catch per haul from the research vessels 'Huxley' and 'Wodan' from 1906-1909.

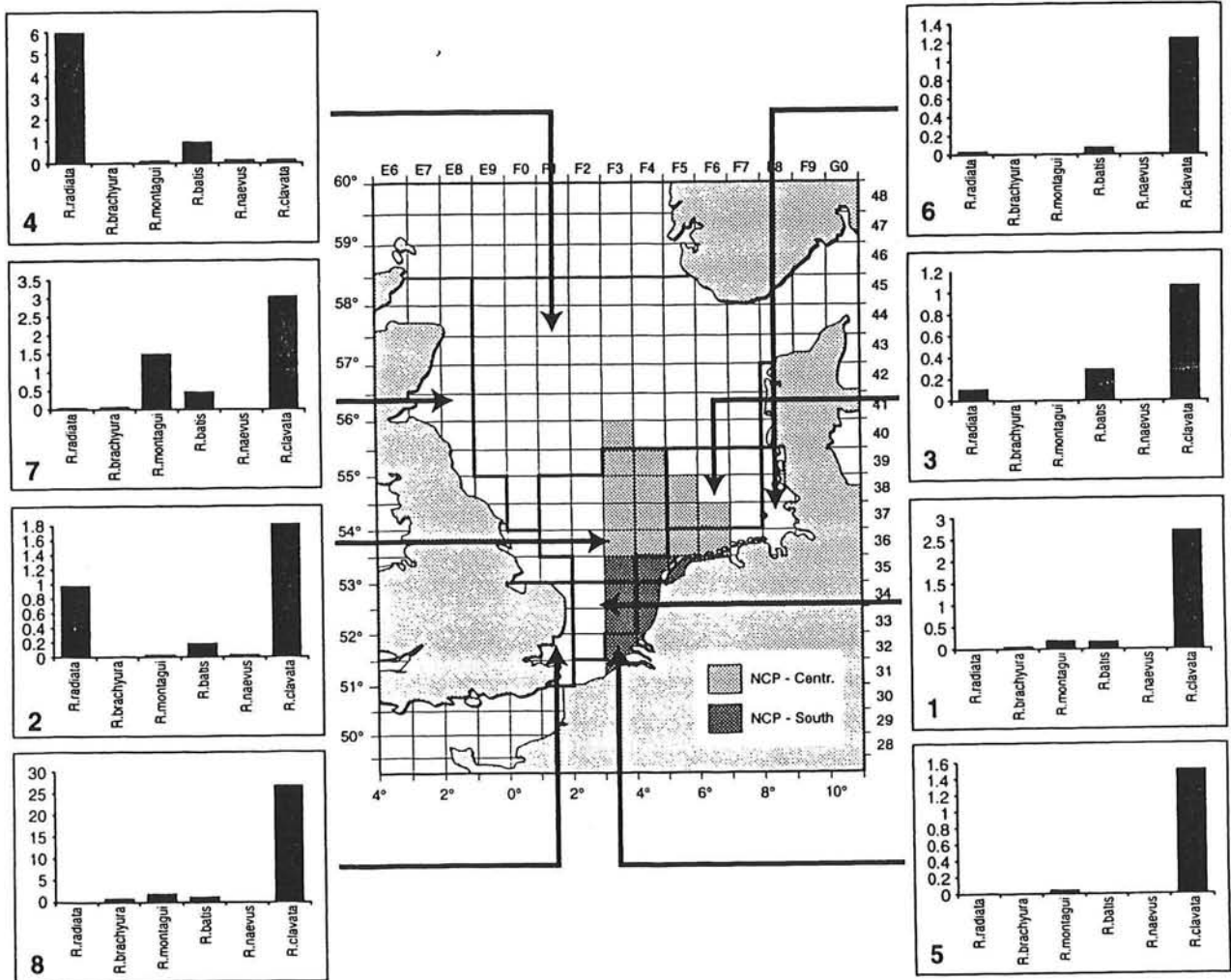
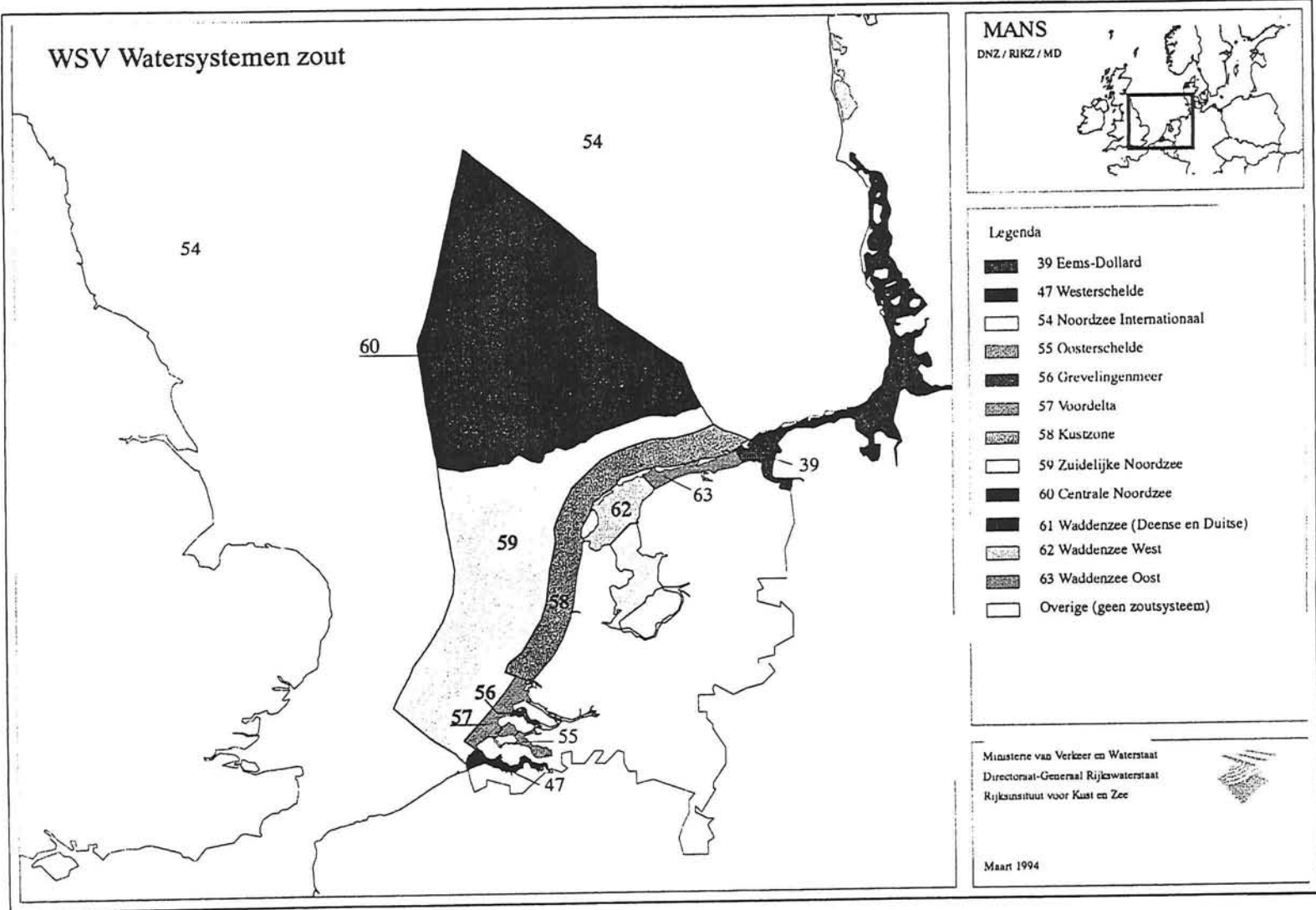


Figure 8.

Kaart, de zoute watersystemen



3 Present situation

3.1 Dutch Continental Shelf

No rays have been caught in the Wadden Sea since 1966, when 13 kg were landed, and it is probable that rays were scarce from the mid-1950's onwards (Vooijs *et al.*, 1990; Witte, personal communication).

The only species still caught regularly on the Dutch continental shelf are the stingray (*Dasyatis pastinaca*), which is caught in the Oosterschelde and the starry ray (*Raja radiata*), which is caught in the central North Sea (as defined by the Directorate-General of Public Works and Water Management (Rijkswaterstaat) see Figure 8). Other species are caught sporadically (*R. clavata*, *R. montagui* and *R. naevus*), or not at all (*R. batis*).

3.1.1 *Dasyatis pastinaca* - Stingrays

Stingrays are still caught regularly in the Oosterschelde, although they are much less frequent than before World War II. Fyke catches in the Oosterschelde have been carried out and analyzed by Bureau Waardenburg. The pattern of catches is shown in Table 9. See Figure 9 for the areas mentioned.

3.1.2 *Raja radiata* - Starry rays

The central North Sea part of the Dutch continental shelf represents the southern limit of the distribution of the starry ray, *Raja radiata* (Figure 10). As such numbers are low but have remained relatively stable over the past 20 years. *R. clavata* and *R. montagui* were also occasionally caught on the Dutch continental shelf (Figures 11 & 12).

Table 9.

Fyke catches of stingrays, *Dasyatis pastinaca*, in the Oosterschelde. From Bureau Waardenburg (Meijer, 1989).

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Schelphoek						1	1	1	4		7
Zierikzee		1	1			1					3
Zandkreek					2		4	1			7
Speelmansplaat	7	8	8	4	6	7	4	2	7	11	64
Bergen op Zoom	9	6	5	6	14	12	10	13	7		82
Oesterdam									3		
Total	16	15	14	10	22	25	15	17	21	11	166

Figure 9.

Sampling stations for the fish survey carries out by Bureau Waardenburg in the Oosterschelde (1979-1988). Figure from Zeehengelsport February 1992 and Meijer (1989).

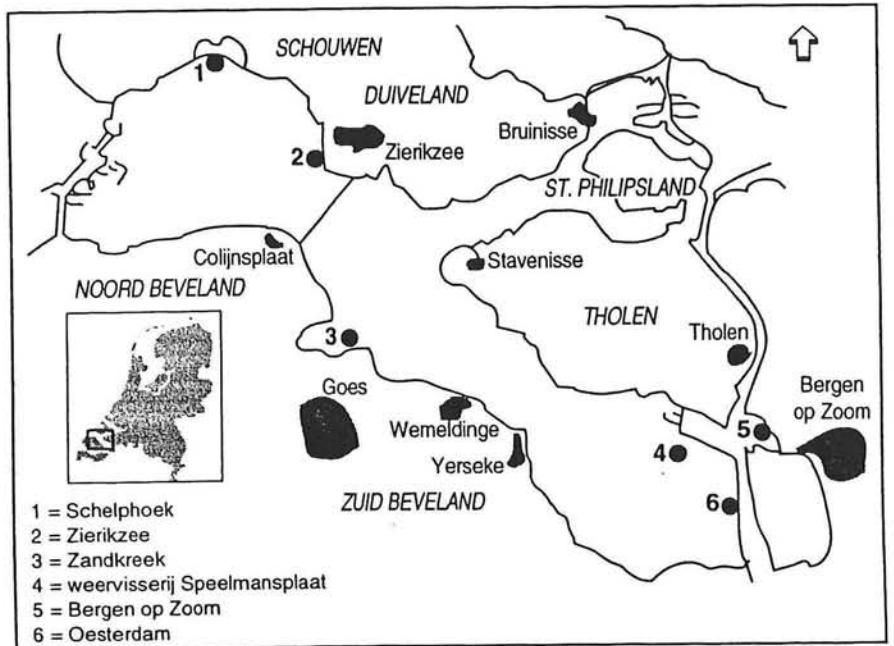


Figure 10.
Distribution and abundance of the starry ray, *Raja radiata*, in the North Sea. Data from the ICES International Bottom Trawl Survey, 1974-1993.

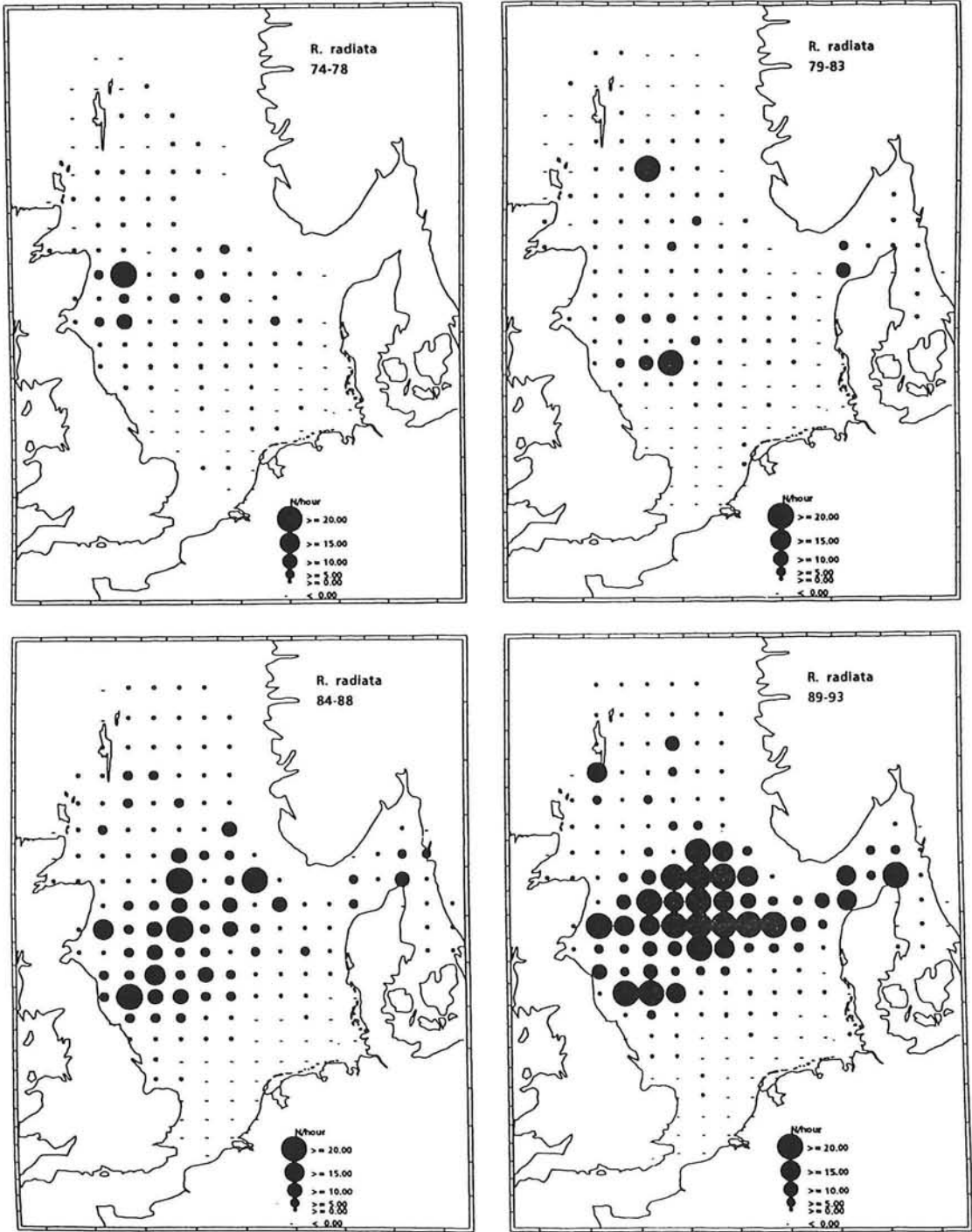


Figure 11.

Distribution and abundance of the thorn-back ray, *Raja clavata*, in the North Sea.
Data from the ICES International Bottom Trawl Survey, 1974-1993.

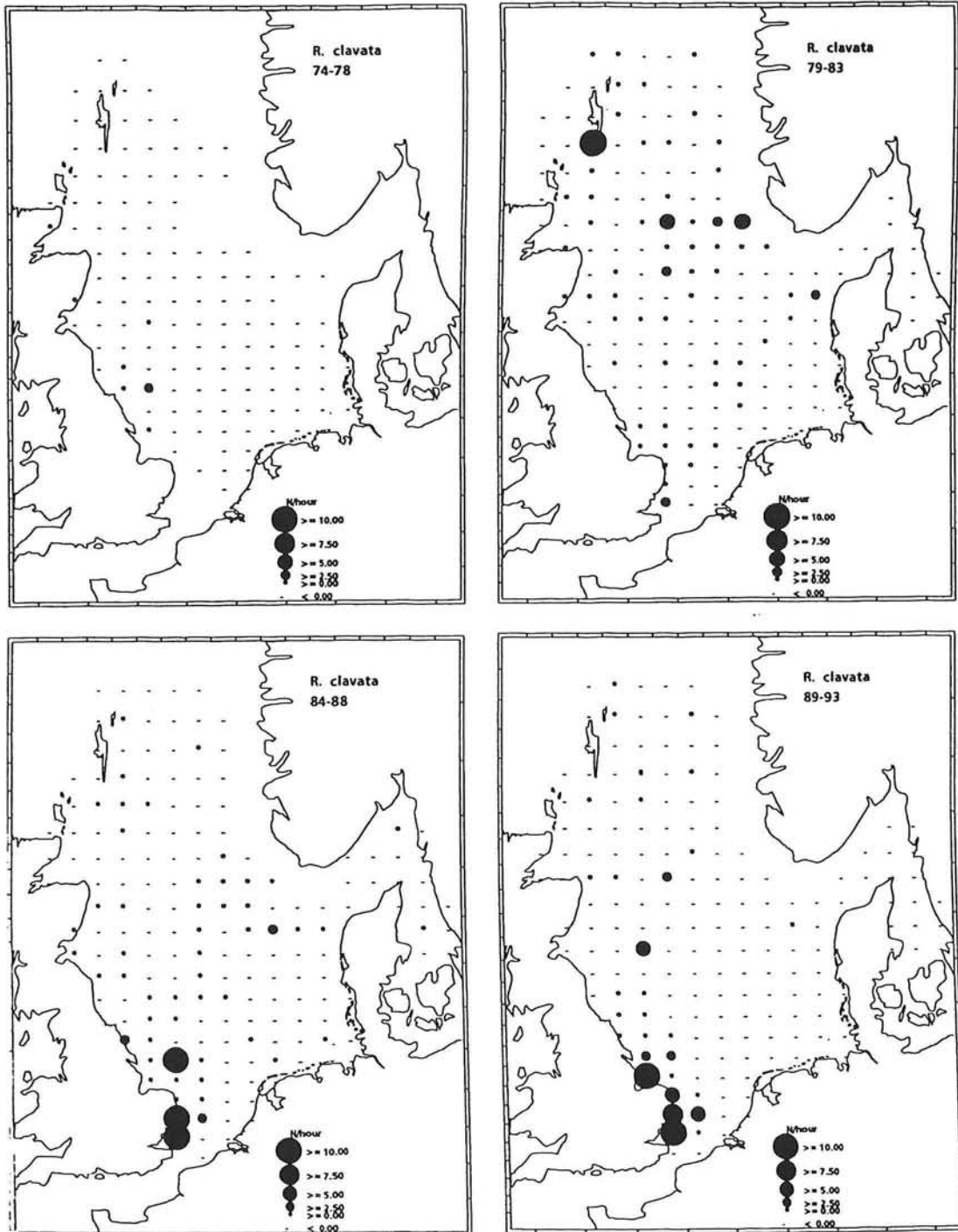
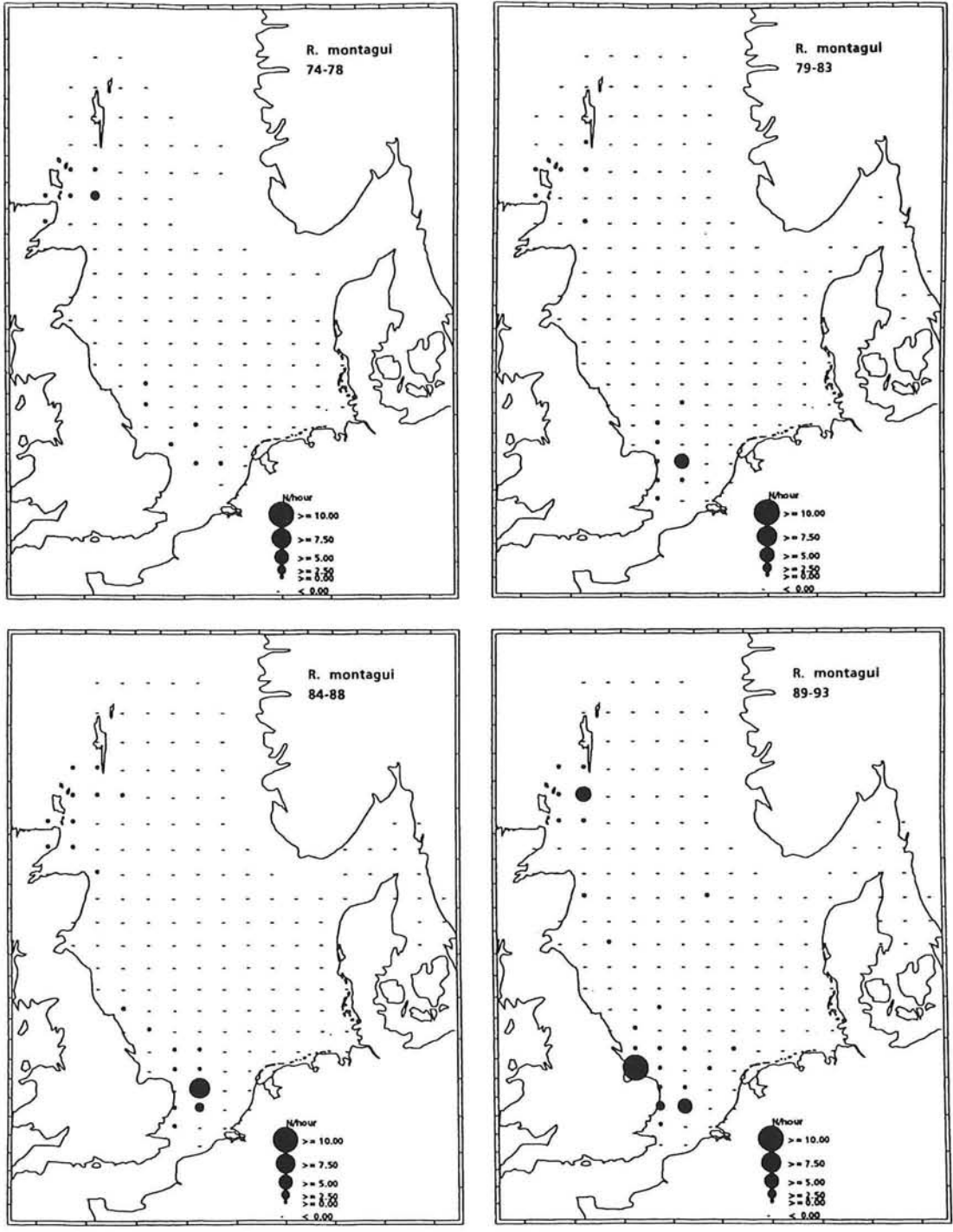


Figure 12.
Distribution and abundance of the spotted
ray, *Raja montagui*, in the North Sea.
Data from the ICES International Bottom
Trawl Survey, 1974-1993.



3.2 North Sea

3.2.1 Landing data

The total amount of rays and skates handled at Dutch fish markets in 1994 was 675,450 kg (personal communication, Produktschap Vis). This is 65% higher than the last official statistics, published in 1983 in the ICES Fisheries Statistics and is comparable to landings from 1929/1930 (Appendix II).

3.2.2 Survey data

IBTS survey data (for description of survey see Chapter 4) show that *R. radiata* is the most abundant species in the North Sea and that the centre of the population falls in the central North Sea (Figures 10 & 13 and Table 10). A comparison with 1906-1909 shows that distribution of the population of *R. clavata* has shifted from being centred in the southern North Sea to the area off the east coast of Britain and in the Thames estuary (Figures 7, 11 and 13).

Figure 13.

Average catch per hour from research vessels collaborating in the ICES International Bottom Trawl Survey (IBTS), 1993.

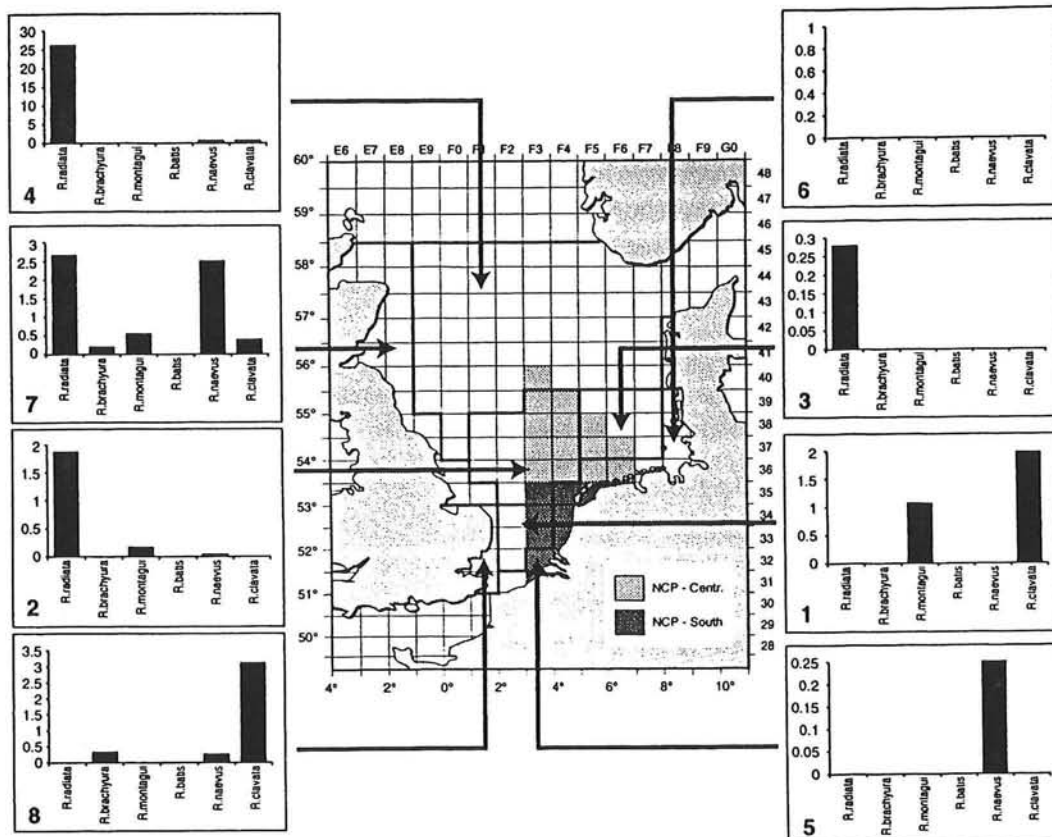


Table 10.

Average catch per hour: IBTS 1993.

Area	<i>R. radiata</i>	<i>R. brachyura</i>	<i>R. montagui</i>	<i>R. batis</i>	<i>R. naevus</i>	<i>R. clavata</i>
1 Southern	0	0	1.1	0	0	2
2 Dogger	1.85	0	0.19	0	0.06	0
3 German Bight	0.28	0	0	0	0	0
4 Central	26.14	0	0	0	0.52	0.54
5 Coast S. Bight	0	0	0	0	0.25	0
6 Coast German Bight	0	0	0	0	0	0
7 Coast Scotland	2.64	0.17	0.5	0	2.44	0.33
8 Coast GB	0	0.33	0	0	0.33	3.17

Several estimates of ray and skate biomass for the period 1977 to 1988 have been made, based on data from the English Groundfish Survey (Yang, 1982a; Daan *et al.*, 1990; Sparholt, 1990a; Sparholt & Vinther, 1991). The biomass was estimated at 300 to 600 thousand tons, constituting ca. 3 to 6% of the total biomass of North Sea fish. The average over this period was nearly 400 thousand tons (Table 11).

Table 11.

Total biomass in thousand tonnes estimated from English Groundfish Surveys 1977-1986, according to methods developed by Sparholt (1987). From Daan *et al.*, 1990.

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	Mean
<i>R. batis</i>		4.8	5.4	0.5				6.2	0.5	4.9	2.2
<i>R. brachyura</i>								0.3			0
<i>R. circularis</i>	19.4				0.3			3.9		1.5	2.5
<i>R. clavata</i>	11.7	6.5	6.3	6.1	3.0	48.3	15.9	6.1		12.3	11.6
<i>R. fullonica</i>	15.7			1.9	7.4						2.5
<i>R. oxyrinchus</i>								3.7		8.5	1.2
<i>R. montagui</i>	18.4	1.3	0.3		5.1	47.9	2.8	7.6	5.0	73.0	16.1
<i>R. naevus</i>	64.1	102.8	42.5	12.7	77.7	54.6	33.0	17.9	21.4	28.6	45.5
<i>R. radiata</i>	428.5	272.4	275.1	227.1	433.8	514.3	241.4	288.9	155.2	247.8	308.4
<i>Total</i>	557.8	387.8	329.6	248.3	527.3	665.1	293.1	334.6	182.1	376.6	390.2

The starry ray *Raja radiata*, which occurs throughout the North Sea, was the dominant species. *R. radiata* is not a commercially important species and the estimated biomasses as noted above were consequently higher than was indicated by commercial landings (Sparholt & Vinther, 1991). Sparholt and Vinther (1991) stated that the biomasses calculated by Yang (1982a), Sparholt (1990a) and Daan *et al.* (1990) for *Raja radiata* (and presumably the other species) are probably an overestimate. These authors recalculated the biomass of *Raja radiata* to be approximately 100 thousand tons (Sparholt & Vinther, 1991). The mean annual commercial catch of rays and skates for the period 1983-84 was 5 thousand tons, about 1.6% of the total biomass as estimated by Sparholt (Sparholt, 1990a).

4 Long-term trends

4.1 Fisheries Statistics 1903-1993

4.1.1 ICES data - North Sea: all countries

Catch data from member countries of the International Council for the Exploration of the Sea (ICES) have been collected since 1903 and published in the ICES Fisheries Statistics (formerly Bulletin Statistique des Pêches Maritimes). The data represent the nominal commercial catch reported to the ICES by the national statistical offices of its member countries. Data collected on rays and skates are presented as one group. Up to and including the second World War the data were collected for the entire North Sea (area IV). Since then the data was divided into southern, central and northern North Sea (areas IVc, IVb and IVa, respectively).

The fluctuations in landings can be seen in Figure 14. Before World War I the landings from the entire North Sea were relatively stable. In the 1930's landings of rays and skates dropped and it was only after a period of limited exploitation during the Second World War that they increased. After the war landings decreased in the southern North Sea and decreased again around 1963. Landings from the central North Sea dropped around 1955, coinciding with a sharp increase from the northern North Sea. Landings dropped in both northern and central areas at the end of the 1960's. Since the early 1970's landings from all areas have remained more or less the same.

4.1.2 ICES data 1903-1983 - North Sea: Netherlands

Comparison of landings from all countries (Figure 14) and the Netherlands alone (Figure 6) shows that the ray and skate fisheries in Holland did not pick up again after the second World War to the extent that it did in the other countries. Landings in Holland remained at a relatively low level until a low in the late 1960's/early 1970's, after which landings increased, a trend which appears to be going on until the present day (1994). This was not reflected in landings from the central and southern North Sea for all countries until the late 1980's and is possibly an indication of an increase in effort or fished area, rather than an increase in the abundance of rays (Figure 14).

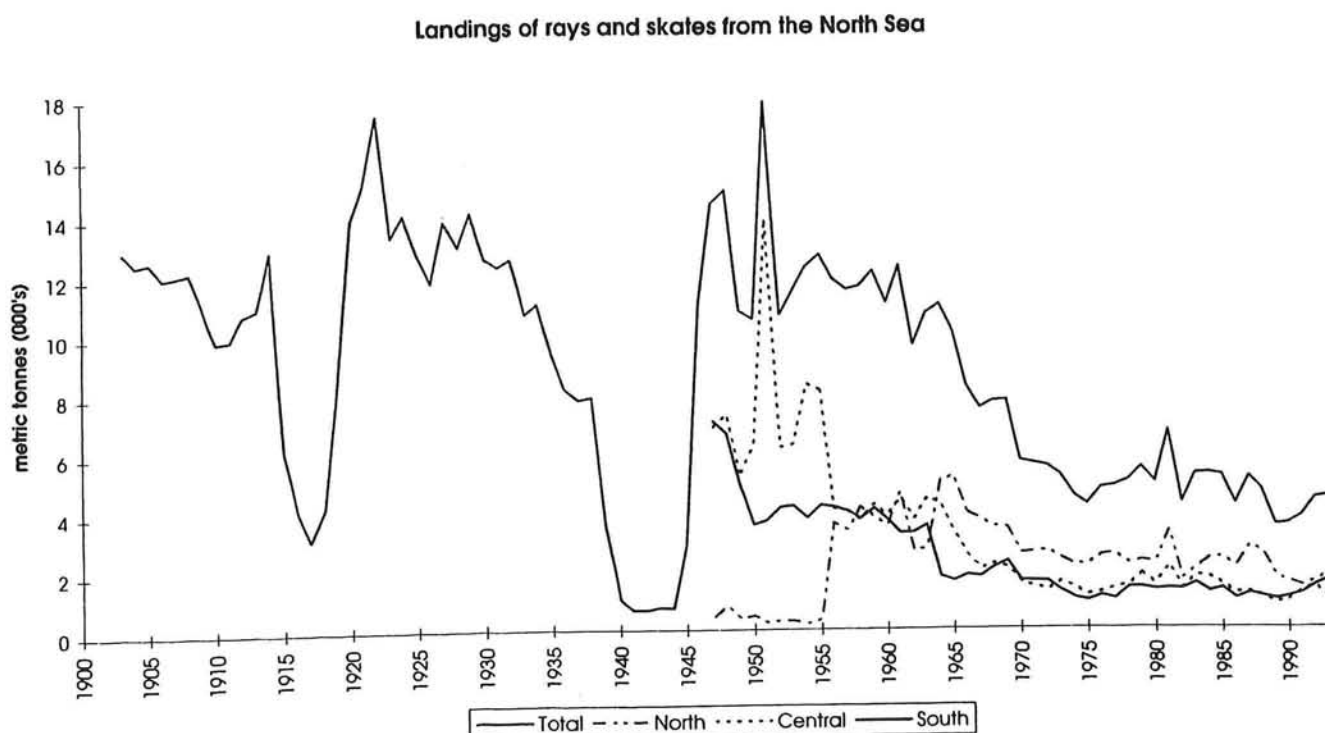
4.1.3 Dutch trawlers - North Sea

Landing data from the Dutch trawler fisheries have been published between 1903 and 1983 (Figure 6 and Appendix II). Between 1930 and 1970 skates (*Raja batis*) and rays (primarily *R. clavata*) were distinguished separately. However, considering the steep decline in skates it is probable that after this date few skates were caught by Dutch trawlers. Since approx. 1971 the total landings of rays and skates have increased (Figures

5 & 6). The present landings of nearly 700 metric tonnes are comparable to those in the late 1920's. These figures are the landings in Dutch harbours, but do not necessarily represent the abundance of rays on the Dutch Continental Shelf, as they may be caught outside the Dutch fishing limits, by both Dutch and foreign vessels.

Figure 14.

Landings data of *Raja spec.* from the North Sea from all countries, as reported to the ICES (ICES Bulletin Statistique, 1904-1987; ICES Fisheries Statistics, 1988; unpublished ICES data, 1989-1993).



4.2 Data from ICES International Bottom Trawl Surveys: 1970-1993

Since 1974 the whole North Sea, the Skagerrak and the Kattegat have been surveyed annually in February. The survey was initially called the International Young Fish Survey (IYFS) but has been renamed the International Bottom Trawl Survey (IBTS). Data was collected by ICES member countries per ICES statistical rectangle, each measuring 30 * 30 nautical miles. Details of the survey are published in the Atlas of North Sea Fishes (Knijn *et al.*, 1993). The data are stored in a database at the Netherlands Institute for Fisheries Research in IJmuiden. Rays and skates were identified to species level. The data are presented as average catch/hour per year for the entire North Sea and as average catch/hour per statistical rectangle for four five year periods (1974-1978, 1979-1983, 1984-1988 and 1989-1993).

Data on nine *Raja* species was collected during the IBTS. In Figure 15 the average catch per hour for all the quadrants sampled in the North Sea is plotted against time for seven of the species. The graphs are arranged in order of abundance. Two species are not shown: *R. circularis* (6 individuals caught) and *R. undulata* (3 individuals caught). Two species from southern waters were also caught in the North Sea. Nine stingrays (*Dasyatis pastinaca*) were caught in 1992 Northeast of the Shetlands, and four electric rays (*Torpedo marmorata*) were caught in 1975, due east from the Shetlands. Distribution data for three species have been plotted for the periods: 1974-1978, 1979-1983, 1984-1988 and 1989-1993 (Figures 10-12).

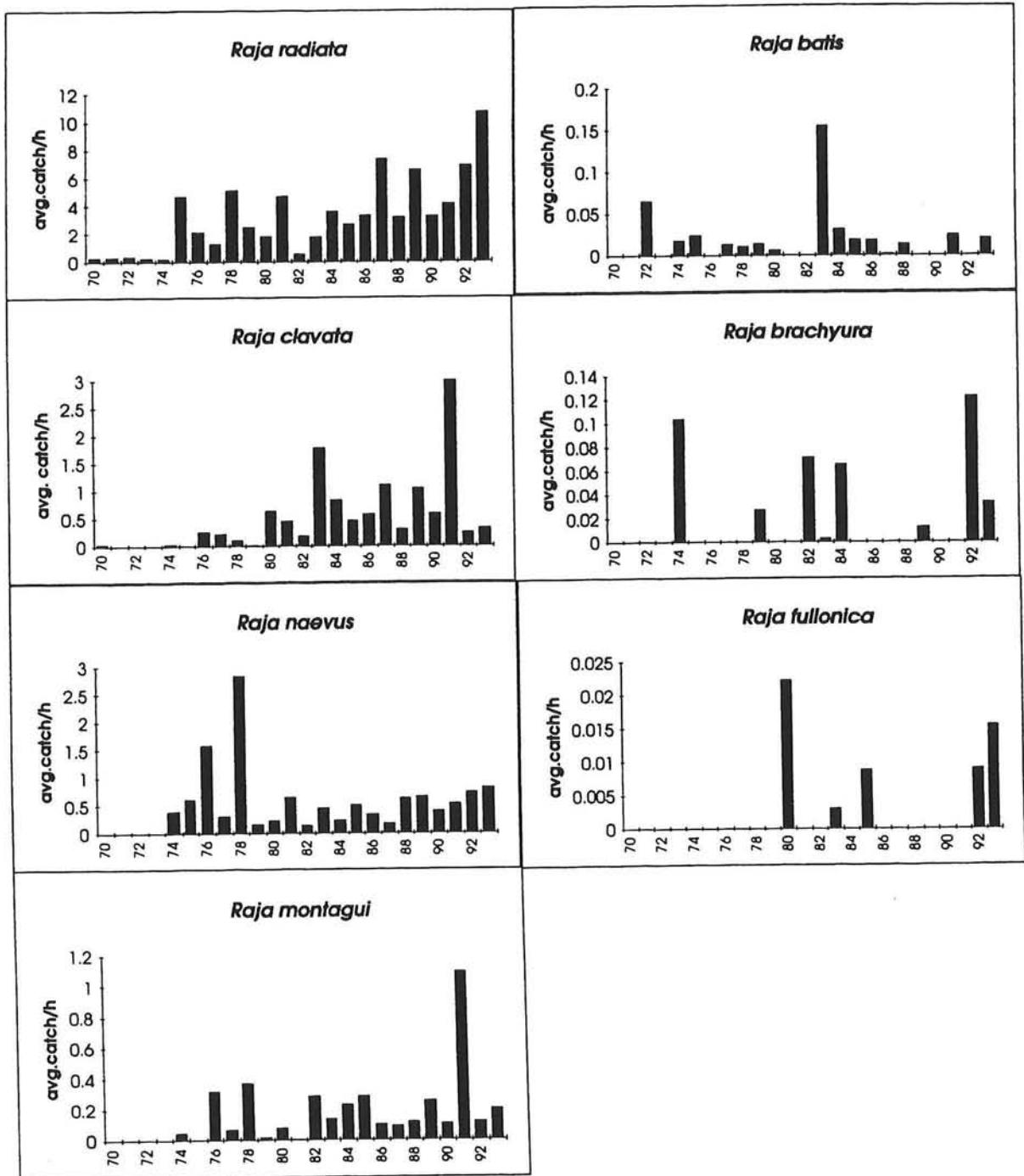
The starry ray (*R. radiata*) was the most abundant and appears to increase in abundance with time. Starry rays were caught further north and fewer were caught in the southern North Sea during the period studied. Numbers of *R. clavata*, the thornback ray, fluctuated but showed a record catch in quadrant 32F1 in 1991. The distribution of this species has decreased since the period 1979-1983. *R. naevus*, the cuckoo ray, was caught in relatively large numbers until 1978, after which the catches dropped. A slight increase can be seen in the past six years, coinciding with an increase in distribution. This species was caught further south and Southeast in the period 1989-1993 than beforehand. The catches of the spotted ray (*R. montagui*) remained relatively stable from the early 1980's onwards. There were two areas of distribution, one off the east coast of Britain and one around the Orkneys. In the period 1989-1993 several spotted rays were caught between these two areas.

4.3 'Wodan' & 'Huxley' survey data (1906-1909) vs. IBTS survey data (1993)

A comparison between survey data from the beginning of the century (1906-1909) and the present day (1993) shows that there have been shifts in abundance and distribution of species (Figures 7 & 13). However, even in the past, there were relatively more rays off the British coast than off the Dutch and Belgian coast. The common skate, *R. batis*, is no longer caught in the North Sea and no rays of any species are caught in the coastal area of the German Bight. No thornback rays were caught in areas where they had been common (southern Bight coast and German Bight) in 1906-1909. The presence of *R. naevus* off the Dutch coast in 1993 (Figure 13, area 5) is based on a single individual. The central North Sea has replaced the south-east coast of Britain as the major area for rays in the North Sea and *R. radiata* has replaced *R. clavata* as the most abundant species. Moreover, impoverishment in the number of species is apparent in all areas, except area 7 (coast of N. England and Scotland), where the same number of species are caught in 1993 as in 1906-1909. However, *R. naevus* has replaced *R. batis* in this area and *R. clavata* and *R. montagui* are relatively less abundant in 1993 than at the beginning of the century.

Figure 15.

Average catch per hour of seven ray species between 1970 and 1993. Data from ICES International Bottom Trawl Survey (IBTS).

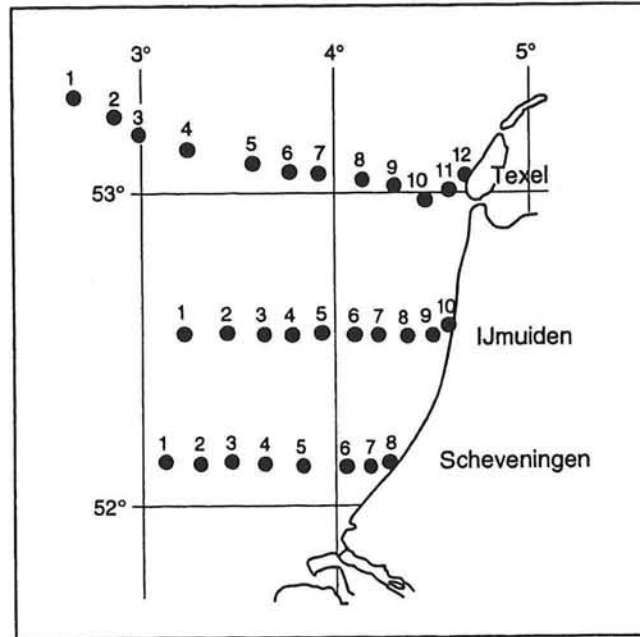


4.4 Data from the RIVO transect programme and Sole Net Survey

4.4.1 RIVO transect programme: 1950-1960 & 1965-1967

Three transects of 45-60 nautical miles were sampled by the Netherlands Institute for Fisheries Research (RIVO) in April/May and October/November for 14 years (1950-1960 & 1965-1967). This programme was continued as the Sole Net Survey from 1969 until the present day.

Figure 16.
Positions of transects as used in the RIVO transect and sole surveys, 1950-1993.



The positions of the transects sampled are shown in Figure 16. The catch data for all rays in April/May are shown in Figure 17. Species caught were: *R. batis*, *R. clavata*, *R. microocellata* and *R. montagui*. The thornback ray (*R. clavata*) was the most abundant, representing more than 90% of the catches. Few rays were caught directly off the coast of Texel, most were caught more than 20 nautical miles offshore (Figure 17). Two peaks in numbers were seen along the other two transects, one along the coast, and one 20-30 nautical miles offshore (Figure 17). No rays were caught in any of the transects from 1957 until the end of the survey period in 1967. The average length of the rays caught is shown in Figure 18. The smallest rays were caught at the coastal stations off Scheveningen, the length was variable along the other transects.

4.4.2 Rivo Sole Net Survey: 1969-1994

During the entire period only three rays were caught. Two thornback rays were caught, one in each of the IJmuiden and Scheveningen transects in 1983 (station 9 - coast) and 1990 (station 8 - coast), respectively. One Raja sp. was caught in the Texel transect in 1984 at station 6 (open sea).

Figure 17.

Average catch per hour of *Raja spec.* along three transects perpendicular to the Dutch coast (see Figure 14 for positions) at Texel, IJmuiden and Scheveningen.

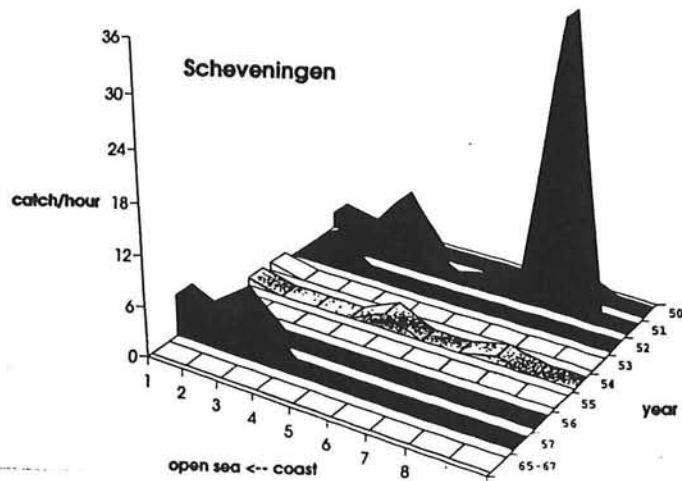
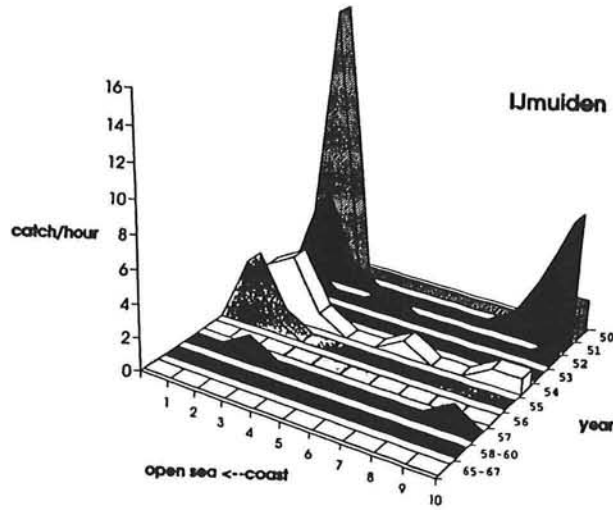
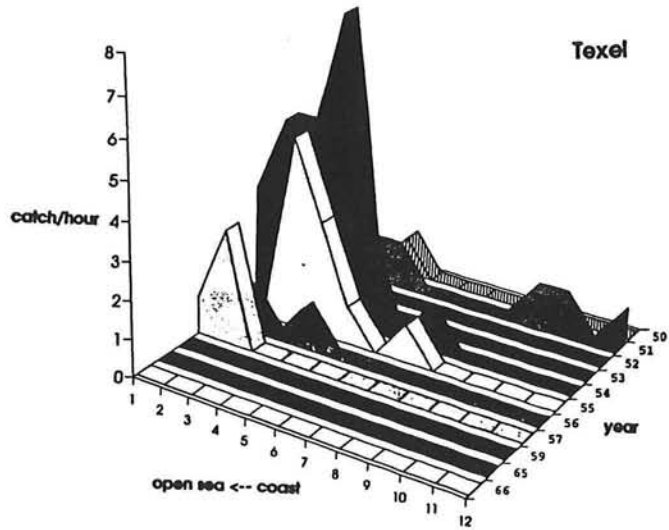
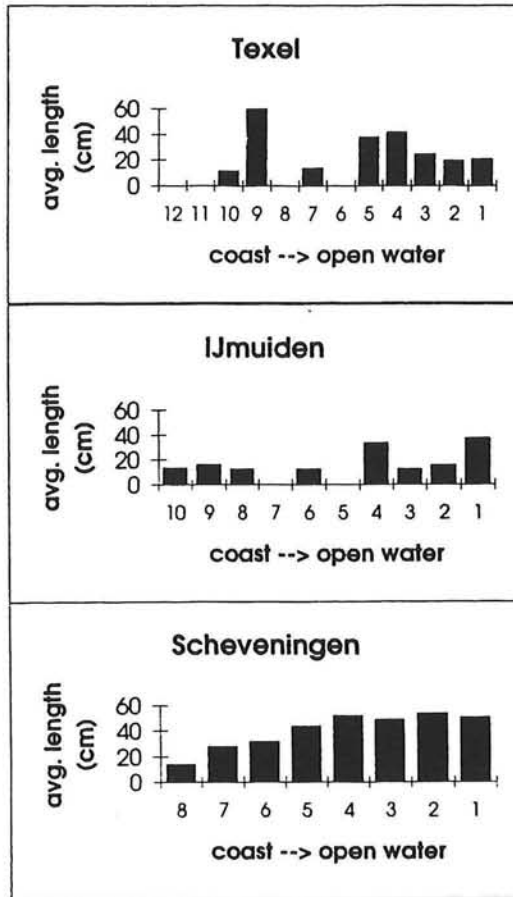


Figure 18.
Length-frequency of rays caught in RIVO
transect programme, 1950-1967.



4.5 NIOZ register of rare fish species

In the archives of the Netherlands Institute for Sea Research (NIOZ) there is a register of rare fish species caught by local fishermen between 1930 and 1990. Catch position and date were registered and the area covered was 52° and 55° North and 3° and 7° East, which approximately corresponds to northern part of the Dutch Continental Shelf. The data have been published for 16 fish species (Vooijs *et al.*, 1990), including three ray species: *Raja batis*, *R. clavata* and *Dasyatis pastinaca*. The marbled electric ray (*Torpedo marmorata*) was caught regularly between 1966 and 1978, but incidentally/sporadically at other times. The electric ray (*Torpedo nobiliana*) was rarely caught.

The relative frequency was calculated by taking values 0 (no fish) and 1 (fish) and calculating the five year mean. The war years were excluded from the calculations. Individual observations made in quadrants of 10 * 12 nautical miles (10 * 10 (minutes)) were summed over six 10-year periods and are shown in maps per period and per species.

There was an increase in numbers of common skate (*Raja batis*) both before and after the second World War which reached a peak in the early 1950's and dropped quite dramatically to zero in the mid-1970's (Figure 19A). The skates were mostly caught in offshore areas, deeper than 20-30 m (Figure 20). The frequency of observations of the thornback ray (*R. clavata*) was variable, showing a minimum in the late 1950's to early 1960's (Figure 19B). After the mid-1980's no thornbacks were recorded. This species was caught in the Wadden Sea, coastal and offshore areas in the period 1930-1960 but was caught increasingly further offshore between 1960 and 1970 (Figure 21). Stingrays (*Dasyatis pastinaca*) were caught quite regularly until the early 1970's, after which the numbers dropped (Figure 19C). The Wadden Sea was an important area of distribution during this period, but after this catches were limited to the coastal areas (Figure 22).

Figure 19.

Relative abundance of rays caught on the central and northern parts of the Dutch continental shelf. See text for details. A: common skate (*Raja batis*); B: thornback ray (*R. clavata*); C: stingray (*Dasyatis pastinaca*). From de Vooijs *et al.*, 1991.

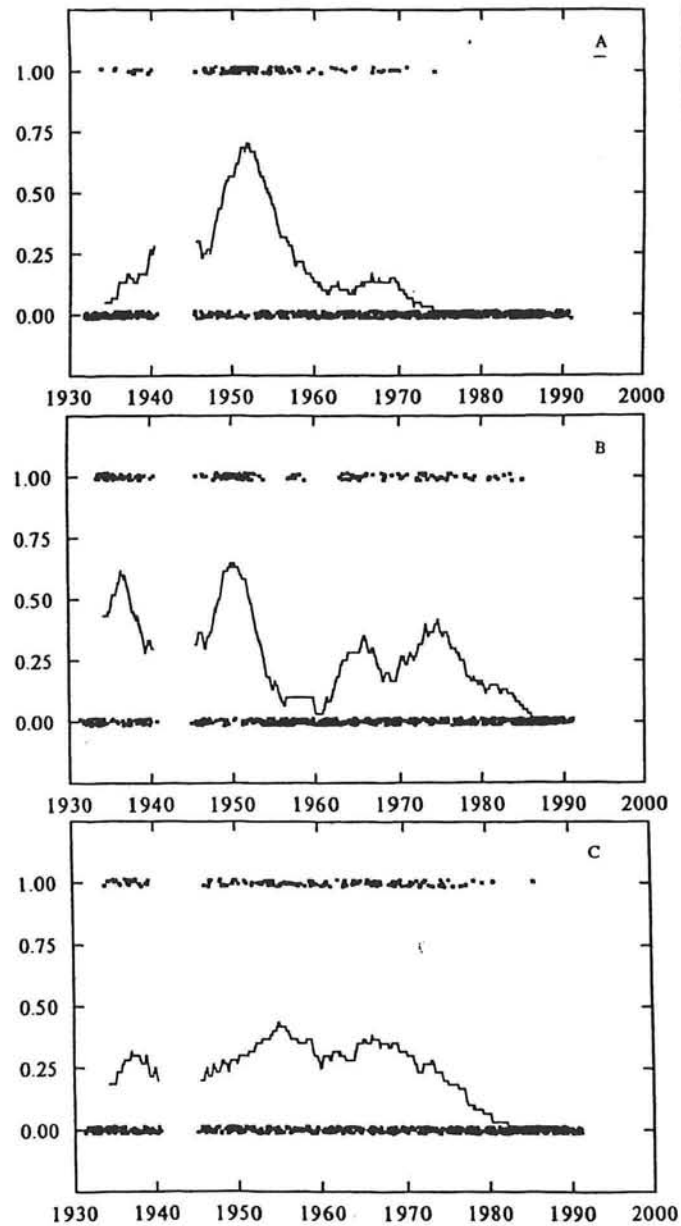


Figure 20.
 Distribution of the common skate over
 four ten-year periods. Data from de Vooijs
et al., 1991.

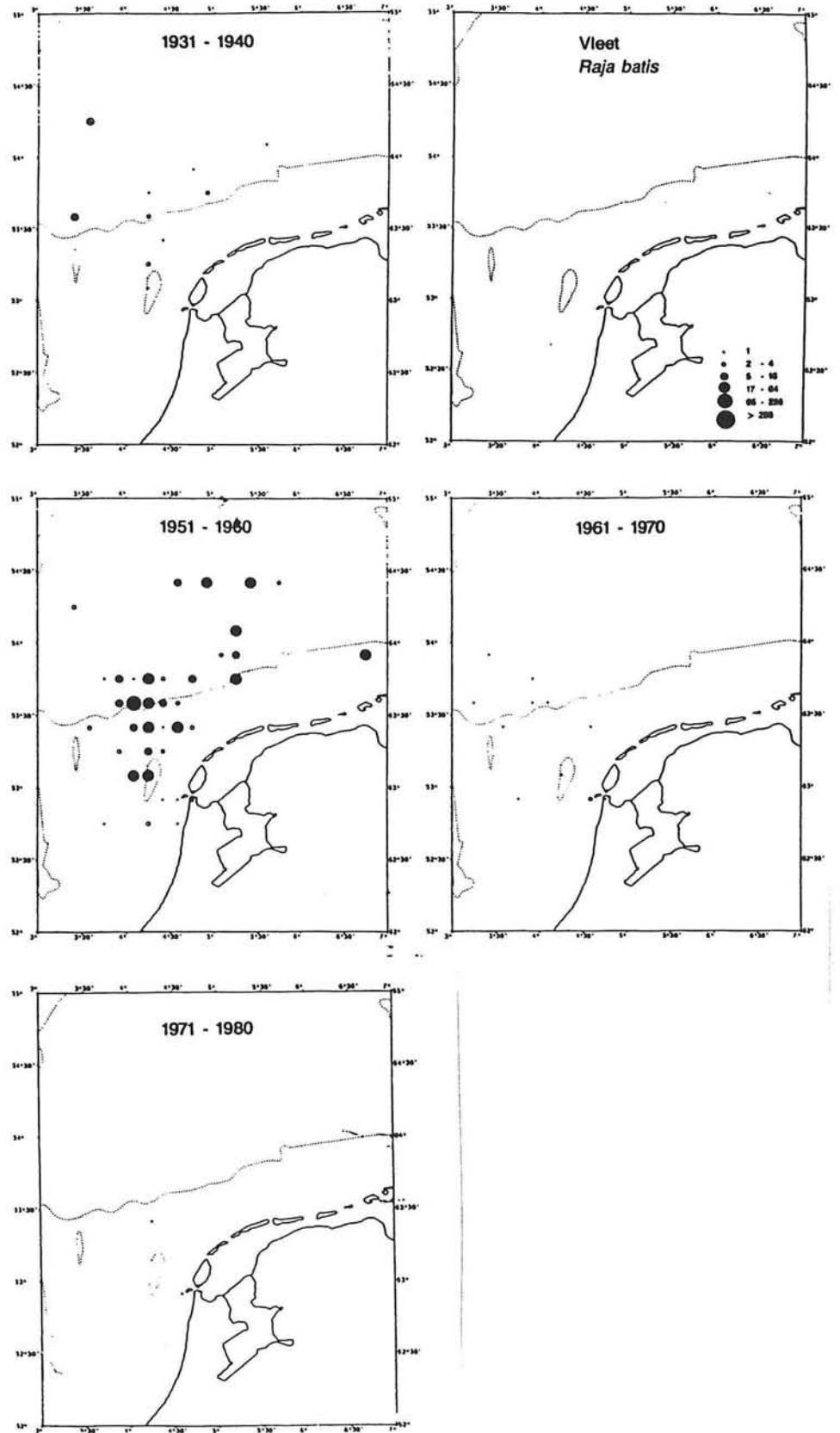


Figure 21.
Distribution of the thornback ray over five
ten-year periods. Data from de Vooijs et
al., 1991.

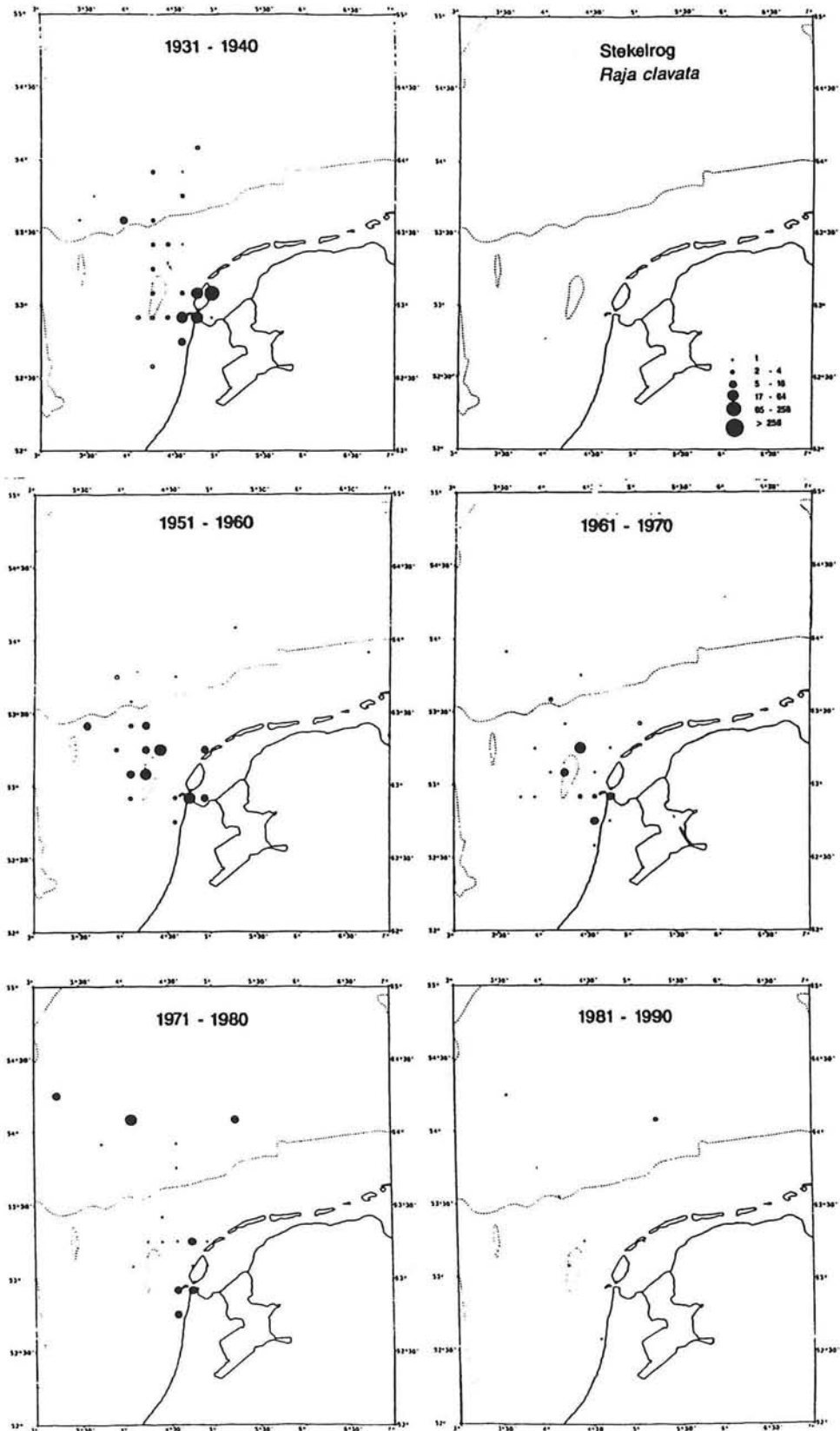
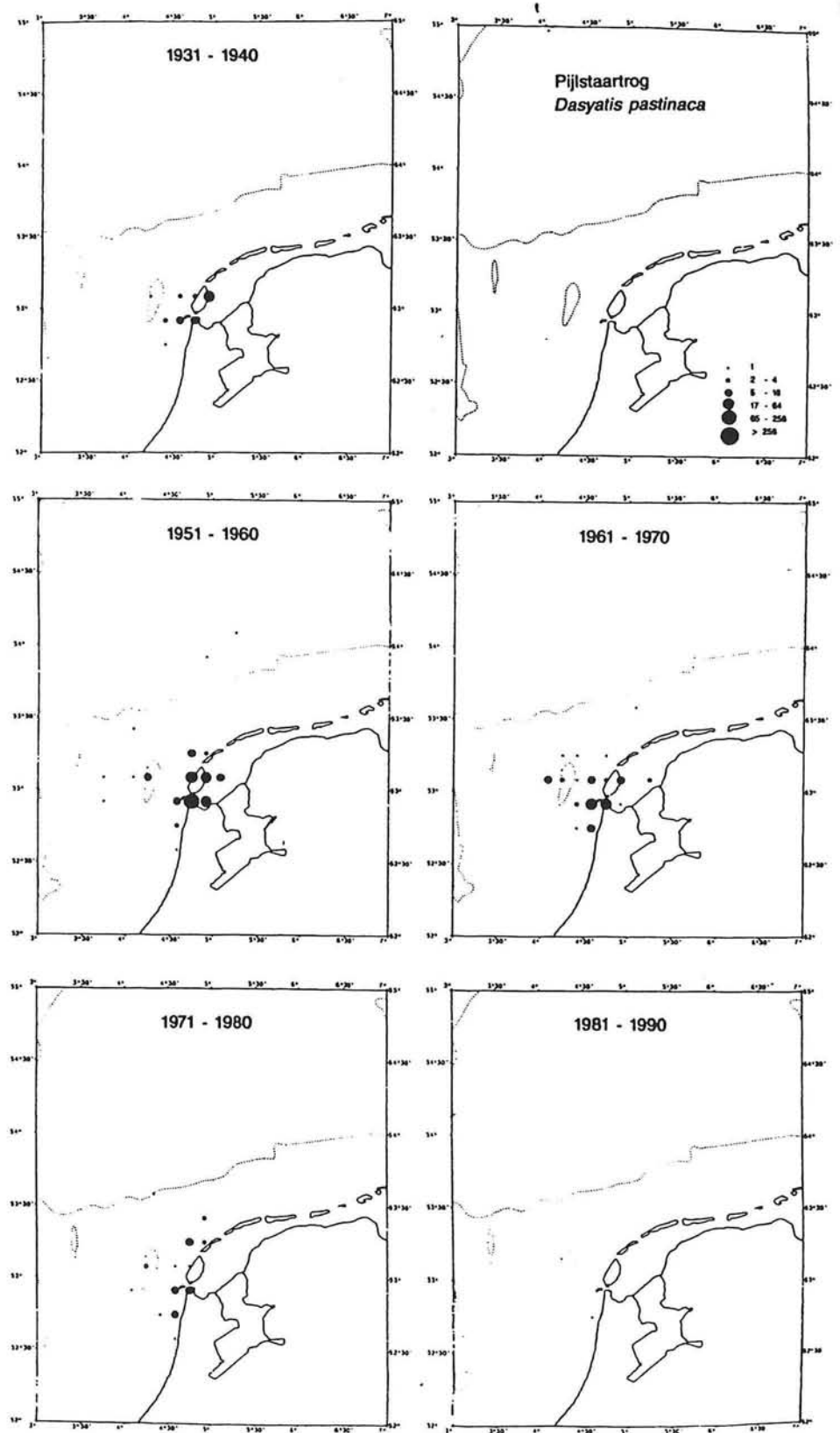


Figure 22.
 Distribution of the stingray over five ten-year periods. Data from de Vooijis *et al.*, 1991.

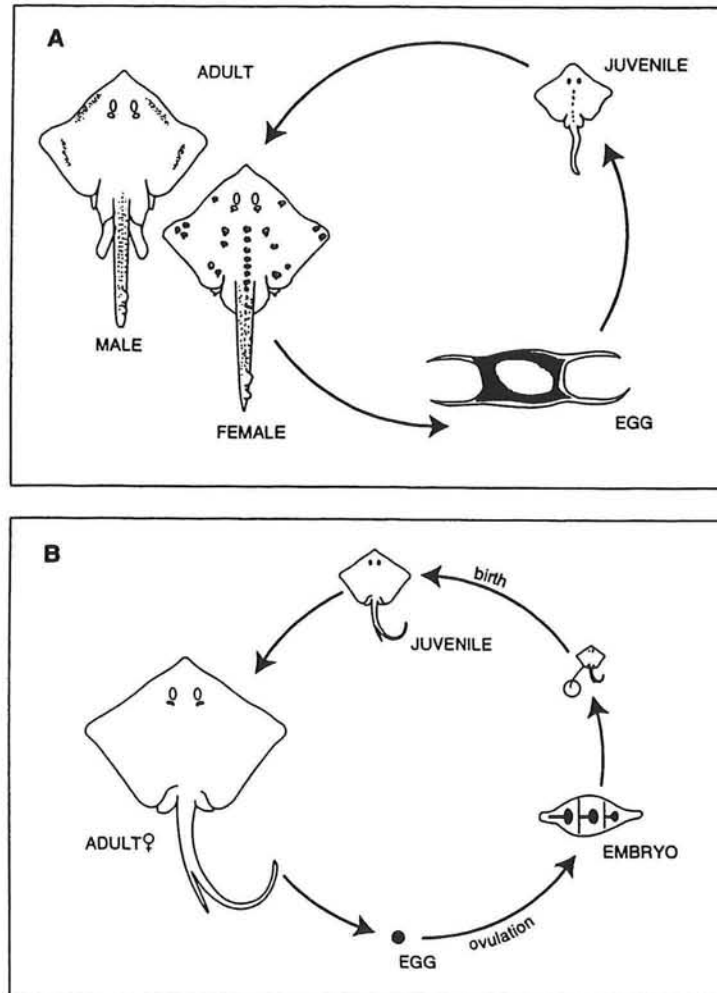


5 Autecology

5.1 Reproductive strategies

Rays and skates are long-lived and produce relatively few, well-developed eggs or young, and generally have a high age at maturity (Holden, 1973; Fahy, 1989; Hoenig & Gruber, 1990). There is internal fertilisation, rays and skates laying hard capsules which contain fertilised eggs, whilst stingrays and electric rays are ovoviviparous, bearing live young in the summer months (Wheeler, 1969; 1978). Stingrays nourish the embryo's from secretions in the uterus wall, whilst the embryo's of electric rays are nourished from a yolksac. It is probable that Rajids can store sperm for several months as fertilised eggs have been laid by females kept in captivity (Clark, 1922; Richards *et al.*, 1963; Holden *et al.*, 1971; Holden 1975).

Figure 23.
Life-cycle and morphology of:
A: Rajids;
B: Stingrays.



5.1.1 *Rajid species*

All species show sexual dimorphism (Figure 23A), the males having mixopterygia or claspers, cartilaginous appendages which are inserted into the cloaca of the female to implant the spermatophores (Friedman, 1935; Steven, 1934; Richards *et al.*, 1963). These claspers are good external characteristics of sexual maturity in the male. Adult males develop retrac-tile hooks known as alar and malar spines on wings and ventral surface respectively in order to hold the female during mating which occurs either from behind or from the front, with the ventral surfaces together (Steven, 1934; Friedman, 1935; Richards *et al.*, 1963). The egg becomes fertilised either before or during passage into the nidamental gland, where encapsulation takes place (Clark, 1922; Richards *et al.*, 1963; Holden *et al.*, 1971). Stingrays and electric rays do not have a nidamental gland, the embryo's develop within the uterus.

Table 12.

Reproductive parameters for six *Raja* species and one stingray. Data on L_{max} and size and hatching of capsules from Wheeler (1969; 1978) and Whitehead *et al.*, (1984); data on *R. batis* from Du Buit (1972); *R. brachyura*, *R. clavata*, *R. montagui* from Holden (1974a) and Holden *et al.* (1971); *R. naevus* from Du Buit (1975;1976); *R. radiata* from Vinther (1989); and *Dasyatis pastinaca* from Wheeler (1969; 1978). * = Wheeler (1969;1978); ** = estimated as 70% of L_{max} ; na = not applicable.

Species	L_{max}	Length at maturity - females (cm)	Age at maturity females	Eggs/year average	Eggs/year max	Capsule length (cm)	Hatching time (months)	Length at hatching (cm)
<i>R. batis</i>	237	180*	11	40	90	14-25	12	21
<i>R. brachyura</i>	118	92**	9	40	140-153	11-14	7	
<i>R. clavata</i>	107	72	9-12	52	61	6-9	4-5	13
<i>R. montagui</i>	73	65**	9-11	24	150	6-8	5-6	
<i>R. naevus</i>	73	59	9	71-90		6-7	8	12
<i>R. radiata</i>	67	40*	4-6	13-21		4-7		9-11
<i>Dasyatis pastinaca</i>	106	74		4-9 young		na	Gestation: 4	25

The eggs become attached to stones, rocks or vegetation and remain on the seabed for 4-12 months until they hatch, the time taken depending on the species and the ambient temperature conditions (Clark, 1922; Clark, 1926; Du Buit, 1976; Ryland & Ajayi, 1984). Also see Table 12. Rays are hatched fully developed and capable of exogenous feeding. Due to the long spawning season and incubation time, juvenile rays hatch throughout the spring, summer and autumn, and there appears to be a peak in late summer for most species (Clark, 1922; Brander & Palmer, 1985). Juvenile thornback rays off the Southwest coast of Britain and Brittany were observed to remain in the shallow waters, where they were hatched, for several years before moving away (Steven, 1936; Holden, 1974a; Ryland & Ajayi, 1984; Rousset, 1990).

Estimates of egg production are presented in Table 12. *Raja naevus* seems to be the most fecund of the species studied. This is probably so because this species has been observed to lay eggs throughout the entire year (Du Buit, 1976). However, this was the only species studied throughout the year and it was studied in the southern Celtic Sea, not the North Sea. Holden based his estimates of fecundity from his own data on egg-laying data from individuals kept for a number of months in the laboratory (Holden *et al.*, 1971) and information published by Clark (1922) on catch data of egg-bearing females.

5.1.2 *Dasyatis pastinaca*

There is little information available about the life-cycle of the stingray, except that 4-7 (Whitehead *et al.*, 1984) or 6-9 (Wheeler, 1969; 1978) young are produced each summer. It is unlikely that this species reproduces in the relatively cold waters of the North Sea. See Figure 23B for the life-cycle of stingrays.

5.2 Growth

Most of the published growth parameters are from the Von Bertalanffy growth equation and are based on observations of rays off the (south)west coast of Britain or in the Irish Sea (Du Buit, 1972; Holden, 1972; Ryland & Ajayi, 1984; Brander & Palmer, 1985 and Fahy, 1989). Data from Holden (1972) are shown for *Raja clavata* and *R. montagui*, together with unpublished data based on tagging experiments carried out in the North Sea (Walker *et al.*, in preparation). Vinther (1989) aged stary rays in the northern North Sea to estimate their growth. Rays caught during the IBTS surveys between 1992 and 1995 are presently being aged and preliminary results for *Raja clavata*, *R. montagui* and *R. radiata* will be presented in this report.

Growth data for the above three species are shown in Figure 24. It appears that the length at age of the thornback ray (*Raja clavata*) is similar or slightly higher in the 1990's than in the 1970's for both areas, whereas the spotted ray (*R. montagui*) more obviously reaches a higher length at age in the 1990's than in the 1970's both the North Sea and off the west coast of Britain. The stary ray (*R. radiata*) seems to be similar or smaller at age, especially at ages 3 and 4, as compared to the 1980's.

Figure 24.

Growth curves of three *Raja* species. The solid lines represent growth based on published von Bertalanffy growth parameters. *Raja clavata* and *R. montagui* from tagging data off the west coast of Britain (Holden, 1972). Unpublished growth data based on tagging experiments in the North Sea are shown for *R. clavata* and *R. montagui* as a dotted line. Data for *R. radiata* are from Vither (1989). Dots represent ageing data from rays caught between 1992 and 1995 (Walker *et al.*, in preparation).

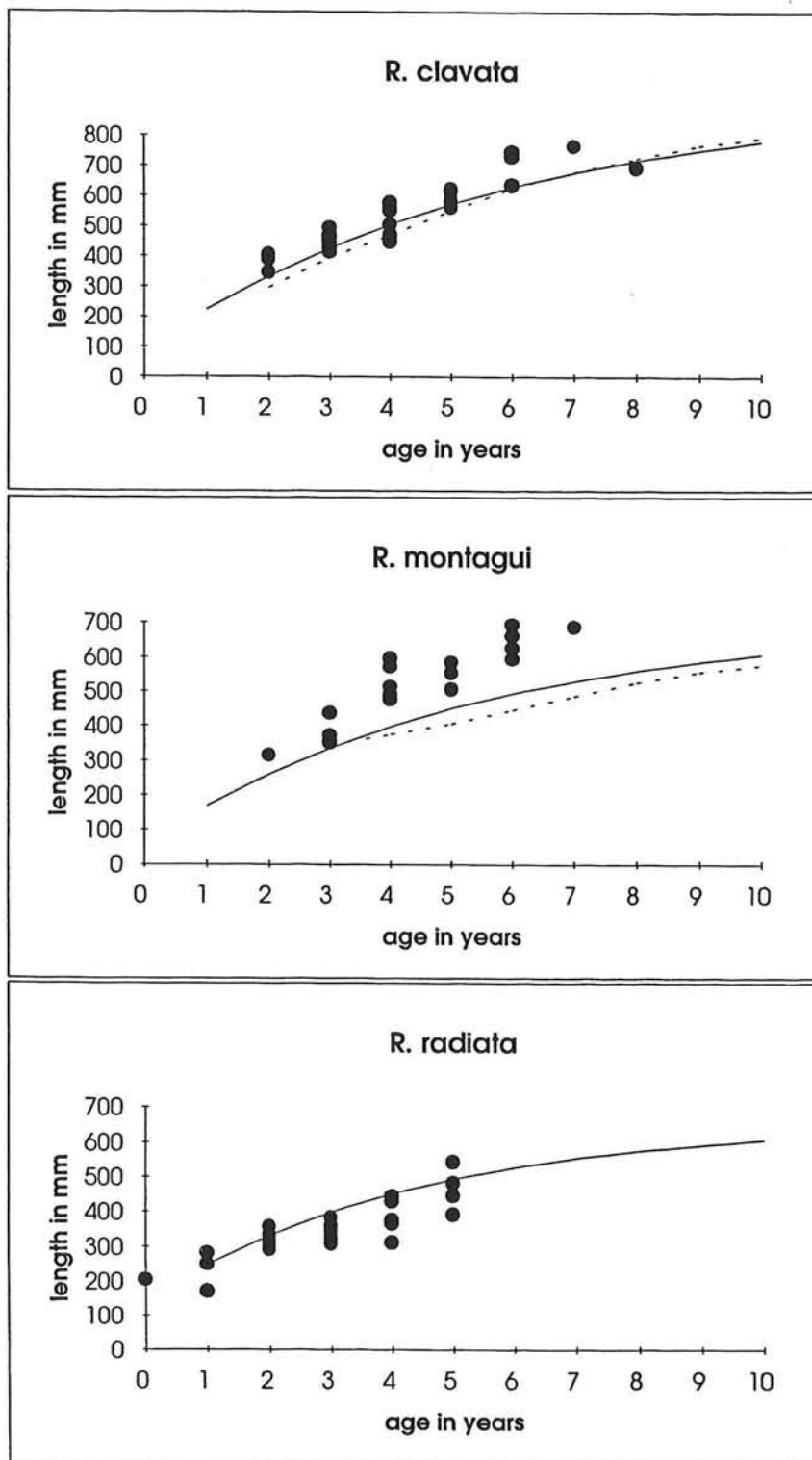


Table 13.

Data set for growth curves.

	1970's/1980's	1990's
Length range (cm)		
<i>R. clavata</i>	30-100	35-80
<i>R. montagui</i>	30- 70	30-70
<i>R. radiata</i>	10- 60	15-60
Age range		
<i>R. clavata</i>	2-14	2-8
<i>R. montagui</i>	3-16	2-7
<i>R. radiata</i>	??	0-5
Capture method		
<i>R. clavata</i>	commercial vessels	commercial
<i>R. montagui</i>	commercial vessels	&
<i>R. radiata</i>	commercial & research vessels	research vessels

Holden (1972) based his calculations on rays aged between two and fourteen for thornbacks (30-90 cm) and between three and sixteen for the spotted ray (30-70 cm). See Table 13. All individuals were tagged and were returned by commercial vessels. In the present data series there were no thornbacks older than eight years old and no spotted rays older than seven. For the latter species the oldest fish caught in the 1990's were seven years old and were larger than those of the same age in the 1970's and were comparable in length to fish of ten years or older, which is strongly suggestive of an increase in growth rate (see also Figure 24). One of the characteristics of exploited fish populations is an apparent increase in growth rate, either following the increase in food available per capita or because the slower growing fish are selected out of the population so that the remaining fish are, by definition, those that grow faster because these are the only ones which survive to maturity. It is, therefore, possible that the higher length at age seen for the spotted ray was caused by fisheries exploitation removing large numbers of fish (not necessarily of the same species). However, the thornback ray has also been heavily exploited and the increase in length at age is marginal in this species (Figure 24). Species specific differences are to be expected, as there are differences in feeding behaviour and reproductive biology. The starry ray is not exploited, and has been increasing in numbers in the past years. This species shows a lower length at age in the 1990's as compared to the 1980's, especially for 3 and 4 year olds, which could be due to intraspecific food competition.

5.3 Food and Feeding Habits

Rays are nocturnal feeders, locating their prey by smell and touch (Ajayi, 1982; Berestovskiy, 1989). They are able to detect weak electric potentials from the prey using sensitive electric receptors (Kalmijn, 1966; Ajayi, 1982; Berestovskiy, 1989). Long-term observations by Berestovskiy (1989) on *Raja radiata* showed that this species catches its prey by covering it with its body and pressing it against the substrate. In order to swallow large prey the ray swims vertically in the water column to allow passage of food through the oesophagus (Berestovskiy, 1989). It was noted that the starry ray can extract molluscs from their shells (Templeman, 1982b) and that several species (*Raja clavata*, *R. montagui*, *R. naevus* and *R. radiata*) probably chew their food prior to ingestion (Daan *et al.*, 1993). *Raja batis* is a semi-benthic feeder, foraging off the bottom but also catching mid-water fishes (Wheeler, 1978). The ventral side of this species and others with a similar feeding behaviour, is usually dark grey or blue in colour (Wheeler, 1978).

The stomach content observed in most studies reflects the abundance and availability of a particular prey type and is not indicative of a strong preference for a particular food type (Steven, 1930; Holden & Tucker, 1974; Ajayi, 1982; Templeman, 1982b; Ebeling, 1988; Daan *et al.*, 1993). However, most authors seem to agree that in general rays choose more active prey as they get older, moving from benthic to semi-pelagic prey and from crustaceans to fish (Holden & Tucker, 1974; McEachran, *et al.* 1976; Ajayi, 1982; Templeman, 1982b; Robichaud *et al.*, 1986; Daan *et al.*, 1993).

The size at which rays switch from benthic prey to fish is species specific. Observations carried out in the North Sea showed that *Raja naevus* eats predominantly fish from about 15 cm length and *Raja radiata* from 25 cm whereas *Raja montagui* and *Raja clavata* eat mostly crustaceans until 50 and 80 cm, respectively (Daan *et al.*, 1993).

These authors conclude that *Raja naevus* feeds more intensively on fish than either *Raja clavata* or *Raja montagui*, because it starts feeding on fish at a smaller size. However, of the species occurring in the North Sea, *Raja radiata* will have the highest impact on the fish stock because of its relatively high biomass (ca. 300 thousand tons) and relatively small size at switching to fish prey (Daan *et al.*, 1990; 1993). Once larger than 25 cm this species eats mostly gadoids, both in the North Sea and in the Northwest Atlantic (Templeman, 1982b; Daan *et al.*, 1993). However, at times of food scarcity the starry ray switched to eating polychaetes and feeding migrations were carried out (Berestovskiy, 1989).

The prey does not have to be caught alive and in the Northwest Atlantic starry rays probably pick up fish discarded by the otter trawl, as well as discarded fish offal (Templeman, 1982b). Between 13 and 20% of the stomach content of starry rays was composed of fish offal, depending on fish length and depth range, more in shallow waters (17-200 m) and for larger fish (> 61 cm) (Templeman, 1982b). Possibly this scavenging behaviour has enabled the starry ray in the North Sea to flourish in areas where the amount of discards is high, and the fisheries mortality is low enough i.e. the central North Sea (balance between F and food! - see Chapter 6). However, material discarded from a beam trawl is usually composed of

damaged molluscs and benthic invertebrates and small fish, as opposed to the relatively clean discards (mostly fish and fish offal), coming from an otter trawl, which is what Templeman (1982b) observed.

In conclusion it appears that most ray species are opportunistic in their feeding preferences and are able to shift from one prey to another, depending on seasonal abundance. It does not seem likely that the distribution of these species is limited by the distribution of their prey.

5.4 Migration and distribution

Both the thornback and spotted rays are at the northern limits of their distribution in the North Sea and are quite common in the English Channel and off the west coast of Britain. The starry ray is at the southern limits of its distribution in the North Sea, occurring widespread in more northern waters. For the common skate the North Sea represented the eastern limits. This means that the changes occurring locally (i.e. off the Dutch coast) are not necessarily indicative of changes in the entire stock. Local depletions may be replenished from elsewhere, up to a point. This is borne out by the fact that tagging experiments in the North Sea showed that thornback, spotted and starry rays were part of one North Sea stock, per species (Walker *et al.*, in press).

Assuming that fisheries was a cause for the decrease in thornback rays in Dutch waters, a fisheries moratorium in the southern North Sea would allow the slow redistribution of thornback rays from the English coast. However, for the common skate, which has been pushed further northwards, it is unlikely that this species will return, even if the North Sea fisheries is drastically reduced.

Holden (1974b) has concluded from tagging data from the west coast of England that there is not always a return migration to the 'nursery areas' once the mature rays have left. Juvenile rays tagged in the Bristol Channel and Liverpool Bay migrated to the east coast of Ireland where they apparently remained, the population there being composed of all length-classes, whilst in the Bristol Channel and Liverpool Bay only juveniles were present. Holden suggests that the movement of juveniles occurs by random dispersal and that in areas where conditions are favourable and migration is limited, populations will build up, as off the east coast of Ireland. In areas where conditions are unfavourable the populations are small and primarily composed of juveniles not yet large enough to migrate. Dispersal is possible because a mature ray can spawn in any suitable habitat, the egg is attached to the substrate and there is no pelagic phase, making the rays independent of current systems for successful reproduction (Holden, 1974b).

5.5 Abiotic parameters

One of the factors influencing the distribution of the ray species is the ambient water temperature. The southern limits of the starry ray, *Raja radiata*, are determined by the highest temperature, this species is rarely found in water warmer than 7°C (Templeman, 1982a). The presence of stingrays and thornback rays in the shallow estuaries and Wadden Sea in the summer months, shows the preference of these species for warm water and their tolerance of less saline, estuarine water. As mentioned above, according to Holden (1974b), rays are independent of current systems. It is therefore unlikely that changes in oceanic current systems will influence the distribution of ray species.

6 Anthropogenic effects

6.1 Fisheries

6.1.1 Exploitation

Rays and skates are thought to be vulnerable to high rates of fishing because of their low fecundity compared with teleosts. However, the resilience of an exploited species (i.e. its' ability to replace itself under fishing pressure) depends on the net fecundity (number of young which survive to maturity), rather than the gross fecundity (number of young produced by a mature female) (Holden, 1974a; Brander, 1981; Brander, personal communication).

For a stock to maintain its numbers every mature female must on average produce one mature female offspring during her lifetime, i.e. the replacement condition is that lifetime net fecundity = 1.

$$\text{lifetime net fecundity} = \text{annual net fecundity} * \text{years of spawning} \quad (1)$$

If the annual instantaneous total mortality rate on mature fish is Z and the number of years since first maturity is t then:

$$\text{years of spawning} = \int \exp(-Zt) = 1/Z(\text{years}) \quad (2)$$

If lifetime net fecundity = 1 mature offspring (for replacement) and annual net fecundity = lifetime net fecundity/years of spawning (from the first equation) then:

$$\text{annual net fecundity} = Z \text{ mature offspring each year (individual/year)} \quad (3)$$

This replacement relationship between Z and annual net fecundity (the left hand side of the equation) has been expressed by Holden (1974) as:

$$Z' = x * \exp(-Z't_m) \quad (4)$$

where Z' = average annual total instantaneous mortality rate; x = average annual production of female young by a mature female (annual gross fecundity); t_m = average age of first maturity of female fish (Holden, 1974).

Therefore, if we know the annual gross fecundity and age of first maturity we can solve the equation to give the mortality at which the population will exactly replace itself. Holden (1974) used his own observations on the rate of egg laying (annual gross fecundity) and Steven's (1936) estimates

of age of maturity to calculate the replacement mortalities for *Raja clavata* (0.54), *R. montagui* (0.48) and *R. brachyura* (0.48).

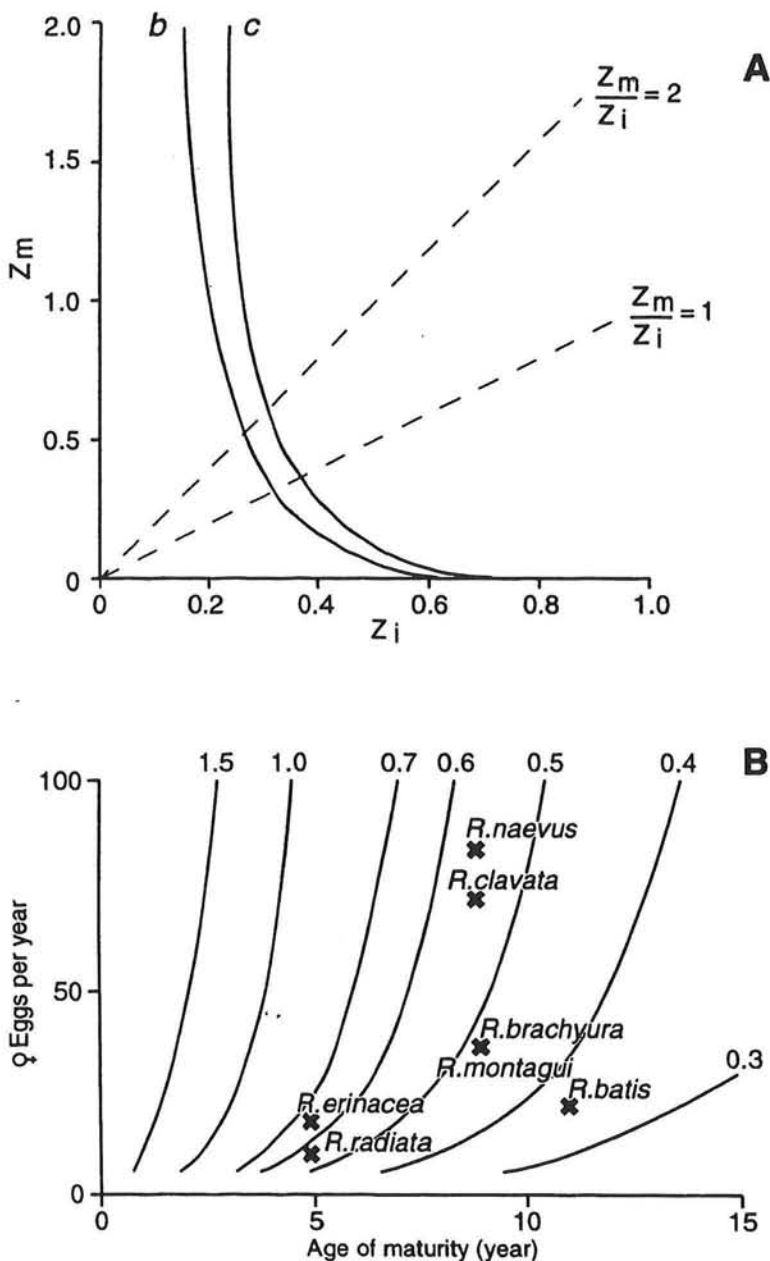
Brander (1981) adapted Holden's replacement equation in order to distinguish between the mortality rates on mature and immature fish and to make explicit the assumption that half of the eggs produced are female:

$$Z_m = E/2 * \exp(-Z_i t_m) \tag{5}$$

where Z_m and Z_i are the mortality rates on mature and immature individuals; E = annual gross fecundity including both sexes.

Figure 25.

A: Values of Z_m (mortality rate on mature fish) and Z_i (mortality rate on immature fish) to maintain the population in equilibrium. Fecundity = 20 female eggs/year (a) and 10 female eggs/year (b). B: Replacement trajectories for total mortality ($Z_i = Z_m$) beyond which the population will collapse for a number of different species. From Brander (1981).



He applied this equation to determine whether the disappearance of the common skate (*R. batis*) from the Irish Sea could be due to fishing. If E and t_m are fixed then Brander's replacement equation can be made to balance for differing levels of Z_m and Z_i . Replacement level trajectories of these two mortalities are shown in Figure 25A. *R. batis* is vulnerable to many fishing methods from hatching on, so one must assume that fishing mortality also acts on immature fish. This is expressed in Figure 25A by the hatched lines, which represent the conditions $Z_m = Z_i$ and $Z_m = 2 * Z_i$. Under the first condition (equal mortality on mature and immature fish) the replacement mortality is 0.37. Under the second condition the replacement mortalities are $Z_m = 0.62$ and $Z_i = 0.31$. Therefore, if Z_i is low (0.2-0.3) then the stock could withstand high fishing pressure. Although there were no estimates of mortality of rays and skates in the Irish Sea, Brander (1981) assumed that they would be similar to the rates for other demersal species, which at that time were 0.4-1.2. These rates exceeded the replacement level for *R. batis* and the disappearance of the species from the Irish Sea was probably due to over fishing.

Analysis of the published data on fecundity as shown in Table 12 with Brander's formula gives the following replacement levels (assuming $Z_i=Z_m$):

<i>R. batis</i>	0.36
<i>R. brachyura</i>	0.39
<i>R. clavata</i>	0.40
<i>R. montagui</i>	0.35
<i>R. naevus</i>	0.55
<i>R. radiata</i>	0.55

These values are lower than those calculated by Holden (1974a) and Brander (1981) as shown in Figure 25B, because average annual gross egg production was used, instead of maximum, as used by Holden (1974a) and Brander (1981).

Total mortality on adult *R. clavata* was estimated from tagging returns to be 0.48 between 1960 and 1969 in the Southwest North Sea (Walker, in preparation). Assuming that all species experience a similar mortality, this exceeds the replacement levels for *R. batis*, *R. montagui*, *R. clavata* and *R. brachyura*, but is below that for *R. naevus* and *R. radiata*. However, this relationship does not take into account any compensatory changes in fecundity and/or age at maturity.

6.1.2 Harvestable biomass

A number of species have been signalled as being susceptible to fishing exploitation (6.1.1). Between 1977 and 1986 an average of 5 thousand tonnes of rays were landed, representing 1.6% of the total biomass of 300 thousand tonnes (Sparholt & Vinther, 1991). However the starry ray comprised more than 80% of the biomass in sea and this species was not landed for consumption. If only the commercial species are taken into account (i.e. if *R. radiata* is excluded from the data) then an average of 10% was landed, varying between 3% and 25%. This seems quite high and complies with the data above that the pressure of fishing exploitation has been (too) high for a number ray of species.

6.1.3 Discards

Rays and skates themselves often qualify as discards, especially small individuals and the species which are not usually consumed (i.e. *Raja radiata*). Unfortunately no data are available on discard mortality. If food is limiting to growth then rays can also benefit from the increased abundance of food, either discarded fish or fish offal or fish and benthos damaged by trawling, as a result of intensive fisheries. This scavenging behaviour might be a competitive advantage to the species in areas where the amount of discards and damaged benthic organisms is high (cf. trawled areas and distribution). Templeman (1982b) noted that between 13 and 20% of the stomach content of starry rays caught in the Northwest Atlantic were composed of fish offal, discarded from the otter trawlers. The distribution of starry rays is further north than the area in which most of the beam trawling takes place, but corresponds to areas of otter trawling. Therefore, it is possible that the starry ray in the North Sea can benefit from an artificially enhanced and easily accessible food supply from fishing. Prerequisite is, of course, that the fishing pressure allows species survival. For the starry ray Z (total mortality) must not be above 0.55, to ensure replacement (see 6.1.1).

6.2 Habitat changes

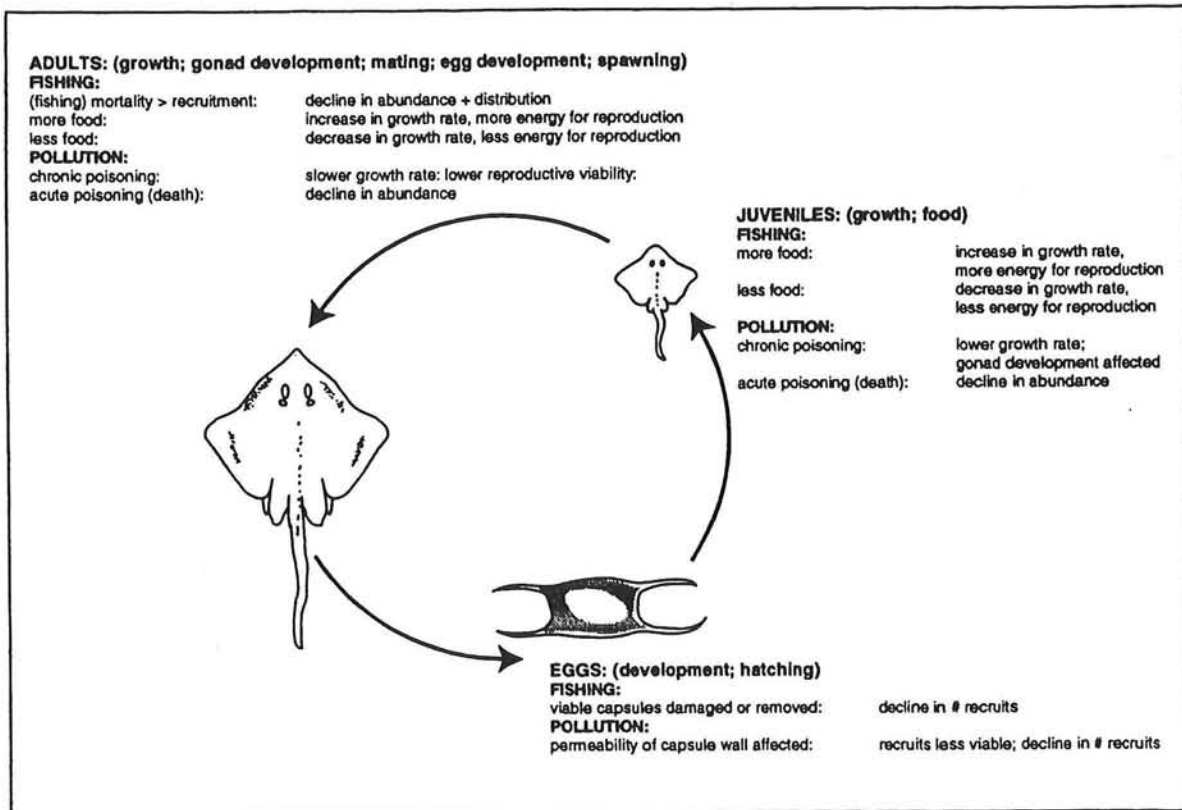
The decline of the ray fisheries in the Wadden Sea in the 1930's coincided with the completion in 1932 of a 30-km long dike (Afsluitdijk) between Friesland and North Holland, which transformed the Zuiderzee into a large, freshwater lake and changed the tidal system of the Wadden Sea. At the same time (1932) the sea grass *Zostera marina* disappeared suddenly from the subtidal zone in the Dutch Wadden Sea, probably due to a disease (Short *et al.*, 1988; Philippart, 1994). The sea grasses remaining in the littoral zone (*Z. noltii* and *Z. marina*) declined in the 1960's (Short *et al.*, 1988; Philippart, 1994). It would go too far to define a causal relationship between the two catastrophic events and the decline in rays. However, in theory it is possible that the changes occurring were detrimental for the sensitive early life stages i.e. loss of anchoring for egg capsules and consequent transport to outside the 'nursery area', lack of protection against predators for juveniles, changes in benthic food supply for juveniles.

6.3 Contaminants

The high inputs of PCB's into the Dutch coastal systems in the late 1950's, early 1960's coincide with a disappearance of rays from the Wadden Sea and the coastal waters but this cannot, in retrospect, be proven to be causal. In 1965 the Wadden Sea was poisoned by the discharge of telodrin but levels declined following the closing of the factory and the sanitation of other pesticide industries in 1967 (Koeman, 1971). This does not mean that the problem is over. Input of contaminants into the sea is an ongoing process and the effects are difficult to trace in the population, unless organisms die as a result of acute poisoning. Moreover, rays and skates can be classified as top-predators in the marine demersal ecosystem and as such

will have high concentrations of (lipophilic) contaminants stored in their bodies (cf. seals). Rays and skates store fat in their livers and use this supply at times of low food density or non-foraging behaviour (Oguri, 1990). If this coincides with the production of gonads (many teleost fish do not eat while spawning, but the feeding habits of rays during gonad production are unknown) then transport of contaminants to the eggs can occur. This has been described for teleost fish, but there is no consensus on the detrimental effects (Fonds *et al.*, 1995; Dethlefsen & Westernhagen, in press). Figure 26 gives a theoretical framework for the (differing) effects of fisheries and contaminants on the life-history stages of Rajids. It is unknown which stage is most susceptible or what the relative contribution of mortality at each stage is to total survival. The expression of poisoning in the population cannot be identified for rays at the present level of knowledge but it is unlikely to be of the same magnitude as fisheries effects, in view of the high susceptibility of some species of rays and skates to fishing mortality (6.1.1).

Figure 26.
Schematic representation of the possible effects of fishing and contaminants on the life cycle of rajid species.



6.4 Eutrophication

One of the results of eutrophication and increased run-off following large scale waterworks is an increase in turbidity. Effects of turbidity are speculative, but cannot be ruled out for a species with a highly developed sensory system. Rays are nocturnal feeders, so are not dependent on light for localising and capturing prey, but may be disturbed by high concentrations of suspended matter.

7 Recommendations

It would be ideal to be able to give a list of 'achievable' recommendations in order to turn the clock back to the days of 'ray plenty'. However, the pressures on the coastal ecosystem and the expectations of those using it are so high that any attempt to increase rays stock size will implicitly mean limiting the exploitation of the natural resources which we all take for granted. Moreover, it is unclear if it is the mortality occurring in the egg, juvenile or adult stage which is the limiting factor to the recolonisation of Dutch waters. Therefore, in order to get the thornback back it is necessary either to:

- allow recolonisation of adults from the coast of the British Isles and allow survival to maturity by ensuring that the local fishing mortality is low enough;
or to introduce eggs and/or juveniles and to:
- allow undisturbed anchoring of eggs and hatching of juveniles in coastal areas and Wadden Sea and to allow development to maturity.

Little is known of the survival of eggs and juveniles and this aspect needs more attention.

A similar approach would also benefit the skate, except that the area over which the conditions would have to apply has to be much larger, as the skate is now present only in the northern North Sea.

8 Amoeba values

The thornback ray (*Raja clavata*) has been chosen as the species for management objectives as this is the species most typical for Dutch waters, despite the fact that it is seldom caught at the present time. During the first half of the century the species was common in Dutch waters and it had a high commercial value. Consequently, the reference data available from the beginning of the century mostly concerns this species. The common skate (*R. batis*) was also caught, but was much less abundant than the thornback ray and was seldom caught in coastal waters. Reference and present values for the landings of the thornback ray are shown in Table 14.

Reference species is the thornback ray (stekelrog) - *Raja clavata*

Reference period criteria are:

- * least influence from fisheries;
- * reference and current data of same type (numbers, kg etc)
- * data as detailed as possible.

This has led to different reference periods for each area. For example the reference period for the North Sea (including international waters) is the late 1940's because this followed six years of low fishing intensity and because the data are divided into three areas. Previous data was for the entire North Sea. It is likely that the majority of the present catches are from outside the DCS, but it is not possible to separate the data further. All data are landing data from commercial fisheries. There are no independent estimates of abundance. Taking the increase in fishing effort into consideration, it is likely that the actual decrease in stocks is larger than the catch statistics would suggest. However, without reliable biomass estimates it is difficult to ascertain the exact decrease in abundance. All values are in kg caught per year and are averaged over the given period.

Table 14.

Reference data and present values of landings of thornback rays (*Raja clavata*) for use in the 'Amoeba' management model.

Area	RWS No.	Reference situation (kg)	Current situation (kg)
Wadden Sea - east & west	63	1912-1914: 9 379 1919-1920: 73 145	1994-1995: none
Eems-Dollard	39	outside area of distribution	outside area of distribution
Oosterschelde - east	55	1912-1914: 8 332 1918-1920: 8 291	
Oosterschelde - west	55	1912-1914: 17 289 1918-1920: 13 407	1994-1995: none
Grevelingen	56	1912-1914: 1 654 1918-1920: 2 749	1994-1995: none
Westerschelde	47	1918-1920: 250 (750 kg caught in 1918 other years = 0)	1994-1995: none
Zeeland & SH estuaries	47,55, 56	1947: 16 965 1948: 30 050	1994-1995: none
Coastal waters (+ voordelta)	57-58	1929-1931: 30* 10 ³	1994-1995: incidental catches
North Sea - south (Belgian data)		1946-1947: coast 2 430* 10 ³ 1946-1947: IVc 3 765* 10 ³ *	1987-1988: IVc 373* 10 ³
North Sea - south (IVc) - all	59*	1947-1948: 6 174* 10 ³	1992-1993: 1 363* 10 ³
North Sea - central (IVb)	60*	1947-1948: 6 374* 10 ³	1992-1993: 1 077* 10 ³

* including international waters.

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Appendix I

Yang (1982b) has divided the North Sea fish fauna into three groups, the Boreal (northern), Lusitanian (southern) and Atlantic. The Boreal contains the following ray species: *Raja radiata*, *R. batis*, *R. nidarosiensis*, *R. fullonica* and *R. fyllae*. In the Lusitanian group are: *R. brachyura*, *R. clavata*, *R. microocellata*, *R. montagui*, *R. oxyrinchus*, *R. circularis*, *R. naevus* and *R. undulata*. There were no ray species in the Atlantic group as defined by Yang (1982b). Yang identified that Boreal fish fauna as being the dominant one in the North Sea in terms of biomass. Estimates of ray biomass would agree, *Raja radiata* has the highest biomass in the North Sea, although the other 'Boreal' species are virtually non-existent (Table 9). The Lusitanian group had the highest number of species present in the North Sea (Table 9). The faunas as described by Yang provide a simple categorisation of fish species and offer insight into the spatial dynamics of the North Sea, i.e. that the species composition is primarily influenced by species from the North and not from the Channel. It is interesting to note that a number of Lusitanian species, as defined by Yang (e.g. *Raja naevus*, *Raja oxyrinchus*, *Raja circularis*), have a distribution which is limited to the very north of the North Sea (Yang, 1982b). Other species (e.g. *Raja clavata*, *Raja montagui*) have a patchy distribution in the North Sea. These anomalies may be due to factors affecting distribution such as ocean currents (the Atlantic current arriving in the north of the North Sea) or to human influence i.e. enhanced fishing pressure in the central and southern North Sea as compared to earlier times (Cushing, 1988).

Ray and skate species occurring, or known to have been caught, on the Dutch continental shelf (DCS), both past and present, are the listed below. * = occasional visitor as the DCS is outside the principal distribution of the species mentioned. Dutch names are given in parentheses.

Raja batis Linnaeus, 1758 common skate (vleet): commercial value; increasingly less common; coastal waters to 600 m depth, mostly within 200 m; Iceland, Faroes and northern coast of Norway, northern and central North Sea, western Baltic, western Mediterranean to Maderia and northern Morocco; food consists of lobsters, crabs, herring, gurnards and flatfish, also rays and dogfish.

*Raja brachyura** Lafont, 1873 blonde ray (blonde rog): commercial value; common locally, inshore waters to 100 m, sandy bottoms, Atlantic coast from Shetlands, western British coast, Ireland, western Channel, western North Sea (rare), western Mediterranean to Madeira and Morocco; at northern limits of range in British waters; food consists of hermit crabs, pink shrimps, hering, sprat, sand eels.

Raja clavata Linnaeus, 1758 thornback ray (stekelrog): commercial value; shallow waters to 300 m; coasts of Iceland and Norway (rare), North Sea, western Baltic (rare), coasts of Britain, Ireland southwards to Madeira and Morocco, Mediterranean, western Black Sea, southward to South Africa,

also present south-western Indian Ocean; food consists of amphipods, brown shrimps, masked crabs, swimming crabs, sand eels, herring.

*Raja microcellata** Monatgu, 1818 small-eyed ray (kleinoog rog): commercial value; moderately common; from inshore waters to 100 m depth, sandy bottoms, southwest England and Ireland southwards to Morocco, not in North Sea or Mediterranean; food habits unknown.

Raja montagui Fowler, 1910 spotted ray (gladde rog): commercial value; inshore waters to 100 m, Shetlands, southern and central North Sea, Baltic Sea, western Mediterranean to western Greece and Tunisia, southwards to Morocco; food consists of crabs, shrimps, amphipods and fish.

Raja radiata Donovan, 1808 starry ray/thorny skate (sterrog): no commercial value; common; from coastal waters to depths of 1000 m in boreal and arctic latitudes, mostly 50-100m; NE Atlantic, northern and central North Sea, western Baltic, NW Atlantic southwards to South Carolina, also found in deepwater off west coast of South Africa; at southern limits of range in North Sea; food consists of brown and pink shrimps, hermit and spider crabs, amphipods, anemones, worms and fish, .

*Raja naevus** Muller & Henle, 1841 cuckoo ray (grootoog rog): little commercial value; common; coastal waters 20-250 m northern North Sea to Kattegat, Ireland to northern Morocco, western Mediterranean; food consists of pink shrimps, ragworms and sand eels.

*Raja undulata** Linnaeus, 1758 undulate ray (golfrog); little commercial value; uncommon in North Sea; sandy bottoms in shallow water up to 200m; not found close inshore; western English Channel, Bay of Biscay; southwards to Mediterranean and North African coasts; there is no information on the feeding habits.

Dasyatis pastinaca (Linnaeus, 1758) common stingray (pijlstaartrog); caught for liver oil; common locally; estuaries and shallow coastal waters, up to 75 m depth; soft bottoms, sand or mud; Atlantic coasts from Madeira and Morocco, northwards to British Isles and southern Norway, Mediterranean, Black Sea, Canaries and southward to South Africa; food exclusively benthos, molluscs and crustaceans.

*Torpedo marmorata** Risso, 1810 marbled electric ray (gemarmerde sidderrog); uncommon in North Sea; 10-30 m above sandy and rocky bottoms; Bay of Biscay and Mediterranean; no information is available on feeding habits.

*Torpedo nobiliana** Bonaparte, 1835 electric ray (sidderrog); shallow to moderate depths (10-100 m); rare in North Sea; common off south and west coast of Britain; northwards to Shetlands; southwards to Mediterranean and North African coast; food consists of demersal fish, dogfish and poor cod.

Appendix II

Landing data from Dutch fish markets from ICES Fisheries Statistics.
Data expressed in metric tonnes.

Year	Metric tonnes	Year	Metric tonnes
1994	675	1943	20
1983	410	1942	7
1982	344	1941	24
1981	280	1940	98
1980	308	1939	148
1979	621	1938	291
1978	289	1937	271
1977	315	1936	292
1976	337	1935	270
1975	288	1934	370
1974	284	1933	286
1973	186	1932	490
1972	173	1931	581
1971		1930	614
1970	111	1929	708
1969	132	1928	1010
1968	106	1927	841
1967	122	1926	884
1966	344	1925	766
1965	269	1924	1014
1964	172	1923	1244
1963	307	1922	1702
1962	178	1921	1423
1961	183	1920	770
1960	181	1919	920
1959	200	1918	744
1958	190	1917	624
1957	289	1916	713
1956	207	1915	968
1955	204	1914	1196
1954	201	1913	1442
1953	263	1912	1434
1952	231	1911	1142
1951	185	1910	885
1950	213	1909	886
1949	274	1908	983
1948	246	1907	1006
1947	162	1906	976
1946	277	1905	741
1945	257	1904	871
1944	11	1903	575

Year	(Thornback) rays (kg)	Skates (kg)	Rays & Skates (kg)
1930	382482	246175	628657
1931	354619	215940	570559
1932	249882	239795	489677
1933	175207	106280	281487
1934	217376	153950	371326
1935	168812	97910	266722
1936	175719	110392	286111
1937	164837	92750	257587
1938	156638	120281	276919
1939	75795	62279	138074
1940-1945	0	0	0
1946	188645	75691	264336
1947	66265	37228	103493
1948	153701	58390	212091
1949	155824	85018	240842
1950	109949	58146	168095
1951	92890	42183	135073
1952	130246	59788	190034
1953	150563	61718	212281
1954	109249	60131	169380
1955	134704	54101	188805
1956	117981	60127	178108
1957	142221	68970	211191
1958	89712	57439	147151
1959	99818	53389	153207
1960	95792	50446	146238
1961	102915	49137	152052
1962	97716	44081	141797
1963	213116	37338	250454
1964	99836	38292	138128
1965	172435	46085	218520
1966	94081	37011	131092
1967	71827	26480	98307
1968	69471	18369	87840
1969	94531	12878	107409
1970	81095	7115	88210
1971			103808
1972			134908
1973			148372
1974			223958
1975			219495
1976			257149
1977			246111
1978			225583
1979			503095
1980			245536
1981			220942
1982			269059
1983			327279