United States
Department of
Agriculture

**Forest Service**

Pacific Northwest
Research Station

Research Paper
PNW-RP 521
September 1999

# Sand Lance: A Review of Biology and Predator Relations and Annotated Bibliography

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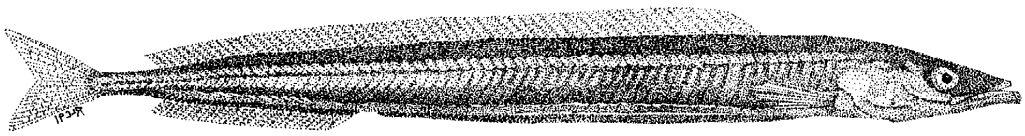
Cover photo by Robert H. Armstrong; drawing by Richard Carstensen.



# Sand Lance: A Review of Biology and Predator Relations and Annotated Bibliography

Martin D. Robards
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*Exxon Valdez* Oil Spill
Restoration Project 99346
Final Report

U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, Oregon
Research Paper PNW-RP-521
September 1999

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## Abstract

**Robards, Martin D.; Willson, Mary F.; Armstrong, Robert H.; Piatt, John F., eds. 1999.** Sand lance: a review of biology and predator relations and annotated bibliography. Res. Pap. PNW-RP-521. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 327 p.

Six species of sand lance (*Ammodytes)* in temperate and boreal regions are currently recognized. Sand lance can occupy a wide range of environmental conditions, but all appear to be dormant predominantly in winter, and one species is in summer also. They lack a swim bladder and spend much of their time buried in specific substrates. Copepods are the primary food. Spawning usually occurs in fall or winter (although some species also spawn in spring), eggs are demersal, and larvae may hatch at times of low food abundance. Sand lance usually occur in schools and are regarded as a relatively high-quality forage fish.

Sand lance constitute a major prey for at least some populations of over 100 species of consumer, including 40 species of birds, 12 species of marine mammals, 45 species of fishes, and some invertebrates. Variation in the availability of sand lance (and other forage fishes) can have major effects on the breeding success and survival of their predators. Commercial fishing and other pressures on sand lance populations potentially have ramifying effects on many species of wildlife.

The bibliography contains over 1,700 references on the family Ammodytidae, with an emphasis on the genus *Ammodytes.* Keywords are provided for each reference and have been further organized into taxonomic, geographic, subject, and predator indexes.

Keywords: Sand lance, sand eel, *Ammodytes, personatus, hexapterus, americanus, dubius, tobianus, marinus,* predator/prey relations, seabirds, marine mammals, forage fish, predatory fish, Alaska, adaptations, spawning, phenology, morphology, habitat, recruitment, ecology, bibliography.

## Summary

Although much taxonomic confusion exists within the genus Ammodytes, six species are currently recognized: *personatus, hexapterus, americanus, dubius, tobianus,* and *marinus*. Sand lance are both euryhaline and eurythermal, as well as tolerant of reduced oxygen concentrations. The absence of a swim bladder allows this narrow, elongate fish to spend much time buried dormant in intertidal and shallow subtidal substrates, venturing out only to feed or spawn. All *Ammodytes* species appear to be relatively dormant in winter and one (*A. personatus*) also estivates during summer. Copepods are the primary food source, allowing for rapid energy accumulation during secondary production blooms. Life spans range from 3 to 12 years within the genus. Spawning usually occurs in fall or winter (although some species spawn in spring) with the production of demersal, slightly adhesive eggs. Early development is oxygen and temperature dependent. Larval sand lance hatch before spring plankton blooms and have several mechanisms to resist starvation. Density-dependent conditions are common for both adults and juveniles. Sand lance are host to a wide variety of parasites.

Sand lance are a nutitrious and important prey for over 100 species of consumers, including 40 species of birds, 12 species of marine mammals, 45 species of fishes (including many of commercial importance, such as salmon and flatfishes), and some

squid. Reproductive success of at least 10 avian species has been correlated with availability of sand lance prey: great skua, parasitic jaeger, shag, black-legged kittiwake, arctic tern, common tern, common murre, Atlantic puffin, tufted puffin, and rhinoceros auklet. Sand lance are among the more nutritious of forage fishes, with relatively high levels of certain vitamins and energy density; however, they also are capable of transmitting paralytic shellfish poisoning and other toxins to their predators.

Sand lance constitute an important element in many marine food webs. Cascading effects throughout the marine food web may occur when severe perturbations are imposed on critical parts of the web. In areas where sand lance are commercially harvested, future problems in resource exploitation may be avoided, not only by using more and better science but also by using conservative harvesting strategies.

Over 1,700 published and unpublished references on sand lance are listed for the family Ammodytidae, with emphasis on the genus *Ammodytes.* Keywords accompany each reference and are organized further into taxonomic, geographic, subject, and predator indexes. The taxonomic listings use names as given by authors, with no attempt at making synonomies. Abstracts are provided when available.

**Study History:** *Exxon Valdez* Oil Spill Trustee Council restoration project 98346 was initiated out of interest by M. Willson and R. Armstrong in the behavior of birds foraging for buried sand lance in intertidal areas of southeast Alaska. As the bibliographic work proceeded, these two authors learned of work begun earlier in APEX project 96306 on ecology and demographics of the sand lance in Lower Cook Inlet, Alaska, by M. Robards and J. Piatt. This latter work included a review of the known biology and literature pertaining to sand lance. APEX project 99346 was established to support publication of the review and a comprehensive bibliography of 1,700 citations in one volume. Cooperation with various libraries (particularly ARLIS and the Forestry Sciences Library in Juneau) was invaluable to this effort.

**Project Data:** *Description of data*—The bibliography was compiled from a variety of sources, including computer searches and traditional literature searches. *Format*—The bibliographic data were entered into ClarisWork® and reformatted by the Pacific Northwest Research Station, Communications Group. *Custodian*—None. *Availability*—Hard copies will be available for 2 years from date of publication from the Pacific Northwest Research Station, PO Box 3890, Portland, OR 97208-3890. The entire document also is available online in Portable Document Format (pdf). To view publications and see instructions about downloading the Adobe Acrobat Reader, navigate to http://www.fs.fed.us/pnw/pubs.htm.

## Contents

# Biology of the Genus *Ammodytes*, The Sand Lances

Martin D. Robards and John F. Piatt

## Abstract

Although much taxonomic confusion exists within the genus Ammodytes, six species are currently recognized: *personatus, hexapterus, americanus, dubius, tobianus,* and *marinus.* Sand lance are both euryhaline and eurythermal, as well as tolerant of reduced oxygen concentrations. The absence of a swim bladder allows this narrow, elongate fish to spend much time buried dormant in intertidal and shallow subtidal substrates, venturing out only to feed or spawn. All *Ammodytes* species appear to be relatively dormant in the winter and one (*A. personatus*) also estivates during summer. Copepods are their primary food source, allowing for rapid energy accumulation during secondary production blooms. Life spans range from 3 to 12 years within the genus. Spawning usually occurs in fall or winter (although some species spawn in spring) with the production of demersal, slightly adhesive eggs. Early development is oxygen and temperature dependent. Larval sand lance hatch before spring plankton blooms and have several mechanisms to resist starvation. Density-dependent conditions are common for both adults and juveniles. Sand lance are host to a wide variety of parasites, although prevalence is unclear. Because of their abundance, schooling behavior, energetic content, and size, sand lance are an important forage species throughout their range for a wide variety of marine predators.

Keywords: Sand lance, sand eel, *Ammodytes, personatus, hexapterus, americanus, dubius, tobianus, marinus,* forage fish.

## Taxonomy and Distribution

| | |
|---|---|
| Phylum: | Chordata |
| Subphylum: | Vertebrata (Craniata) |
| Superclass: | Gnathostomata |
| Grade: | Pisces |
| Class: | Osteichthyes |
| Subclass: | Actinopterygii |
| Infraclass: | Neopterygii |
| Division: | Halecostomi |
| Subdivision: | Teleostei |
| Infradivision: | Euteleostei |
| Superorder: | Acanthopterygii |
| Order: | Perciformes |
| Suborder: | Ammodytoidei |
| Family: | Ammodytidae |
| Subfamily: | Ammodytinae |
| Genus: | *Ammodytes* |
| Species: | *personatus, hexapterus, americanus, dubius, marinus, tobianus* |

Ammodytidae is the sole family within the suborder Ammodytoidei. Numerous papers have been written on the designations below this level of classification, for which there is considerable confusion, continuing the thought of Gill (1904) who stated:

> There are few fishes respecting whose affinities there has been so much diversity of opinion...as the sand launces or Ammodytids.

Current literature suggests that the Ammodytidae includes 7 genera including a total of 20 species (Ida and others 1994, Stevens and others 1984): *Gymnammodytes, Hyperoplus,* and *Ammodytes* usually live in temperate and boreal conditions, unlike *Protammodytes, Lepidammodytes, Bleekeria,* and *Ammodytoides*, which live in more tropical regions (Ida and others 1994, Stevens and others 1984).

Artedi (1738) derived the name for the genus *Ammodytes* from the Latin *ammos* meaning “sand” and *dytes* meaning “diver.” Species designations and names have changed often during the past 30 years. Confusion results largely from the overlapping meristic characteristics among species, which differ with environmental conditions and are therefore suggestive, rather than conclusive, for making species designations (Inoue and others 1967, Okamoto 1989). The wide latitudinal range of sand lance

compounds this problem. Recent genetic research (e.g., Donaghy and others 1995, Okamoto 1989) has started to shed a clearer light on species designations. Debate continues, however, concerning the number of species within the genus, geographic regions, and distributional ranges. Although 23 nominal species of the genus have been described, current literature consistently recognizes only six based on a combination of genetic, meristic, ecological, and biological parameters (e.g., Donaghy and others 1995, Nizinski and others 1990, Okamoto and others 1989). *Gymnammodytes semisquamatus* is often referred to in conjunction with Atlantic *Ammodytes* species. This species is found in the northeastern Atlantic and Mediterranean (Sabates and others 1990) but is genetically distinct from the genus *Ammodytes* (Donaghy and others 1995). Research is still needed to establish if (1) two genetically distinct species are present in the northern parts of the Pacific as proposed by Grigorev and Sedova (1997) and which exist in Japanese and Atlantic waters, and (2) if *A. americanus* belongs to a single trans-Atlantic species, *A. marinus* (Winters and Dalley 1988), which also may be circumpolar and synonymous with *A. hexapterus* (Nizinski and others 1990).

**North Pacific Species**

*A. hexapterus* Pallas 1814: Pacific sand lance

Distributed in the eastern North Pacific from California to the Beaufort Sea and as far west as the Sea of Okhotsk and Hokkaido (northernmost island in the Japanese archipelago; Craig 1984, Hashimoto 1984, Kitaguchi 1979, Trumble 1973).

*A. personatus* Girard 1857: Japanese sand lance

Distributed from Asan Bay on the Yellow Sea coast of South Korea, into the China Sea (possibly as far south as Hong Kong; Fowler 1931) and north to southern Hokkaido Island along the west and east coasts of Japan (Hashimoto 1984, Kim and others 1994).

**Western North Atlantic Species**

*A. americanus* DeKay 1842

Distributed from Cape Hatteras, North Carolina, to the north of Labrador and Hudson Bay in shallow coastal waters, protected bays, and estuaries (Nizinski and others 1990, Smigielski and others 1984).

*A. dubius* Reinhardt 1838

Distributed in coastal and shelf waters from North Carolina to at least Coburg Island in the Canadian high arctic (pers. obs., Robards) and south along the Greenland coast. Tends to be offshore in comparison to *A. americanus* (Nizinski and others 1990).

**Eastern North Atlantic Species**

*A. marinus* Raitt 1934

Distributed from the Barents Sea along the coast of Novaya Zemlaya to Krestovaya Bay. Common in the White Sea and in the northeast Atlantic along the coasts of Norway, Scotland, Faeroes, Shetland Islands, Iceland, and into the North Sea and western part of the Baltic (Andriyashev 1954)

*A. tobianus* Linnaeus 1758

Distributed from the Murman Sea (Poland) to the west coast of Iceland in the north, the Baltic Sea in the east, and the Spanish coast in the south. *Ammodytes tobianus* also has been reported from the Balearic Islands within the Mediterranean (O'Connell and Fives 1995). This species has not been reported from the coasts of Greenland (Andriyashev 1954). *Ammodytes tobianus* is generally regarded as the most biologically distinct species of the *Ammodytes* (Field 1988).

Numerous common names have been attributed to this genus. Although the term "candlefish" is sometimes used in North America, this correctly refers to smelts (Osmeridae). The regional common names are summarized by Reay (1970) as:

| | |
|---|---|
| Danish: | Tobis |
| Dutch: | Zandspiering, Smeelte |
| English: | Sandeel, Lesser Sandeel |
| Faerose: | Nebbasild |
| Finnish: | Tuulenkalat |
| French: | Equille |
| German: | Sandaal, Sandspierling, Tobias Fisch |
| Greenlandic: | Putorutotoq |
| Icelandic: | Tronusilli, Sandsili |
| Irish (Gaelic): | Corr |
| Norwegian: | Sil, Tobis |
| Polish: | Tobiasz, Dobijak |
| Portugese: | Franchao, Agulhae |
| Spanish: | Lanzon |
| Swedish: | Tobis |
| Former U.S.S.R: | Peschanka |
| North America: | Launce, Sand Launce, Sand Lance, Needle Fish |

## Morphology

All sand lance have a narrow, elongate, subcylindrical body; premaxilla is protractile; dorsal and anal fins are composed of soft rays only, no spines, and caudal fin is deeply forked; the lower jaw projects forward beyond the upper jaw (thought to be an adaptation for digging into substrates); and they have no swim bladder. Lack of a swim bladder results in sand lance producing weak echo returns during hydroacoustic surveys. Little target-strength research has been done for this species with the only reported values being -45 dB to -55 dB re. 1 kilogram at 38 kHz (Armstrong 1986), equivalent to a return of -68 dB for a 5-gram sand lance.

Scales are cycloid and minute; pelvic fins are usually minute or more often absent; lateral line is high, close to the base of the dorsal fin; a greater number of abdominal vertebrae are present than caudal vertebrae; and there are no teeth (Hart 1973, Nelson 1994, Pietsch and Zabetian 1990). There are fine diagonal folds (plicae) along the length of the body (Hart 1973, Nizinski and others 1990); and a fleshy ridge, one on each side near midbelly, sometimes extends the length of the body (Hart 1973, Eschmeyer and others 1983).

Larval morphology is typically elongate, with rounded snouts that become elongated with age (Matarese and others 1989), and pre-anal length is slightly more than 50 percent of body length (Stevens and others 1984). Gut length is about 60 percent of standard length, there is light pigmentation, a double row of post-anal ventral pigments exists, and dorsal and anal fins begin development opposed to each other.

Sand lance are polychromatic, at least in Japanese waters (Inoue and others 1967), varying color from their usual metallic blue (dorsal; silvery ventrally) to reddish-yellow over a period of about 20 seconds when disturbed.

## Habitat

Sand lance are abundant in shallow nearshore areas ranging in depth to 100 meters (Field 1988, Reay 1970) but are most common at depths less than 50 meters (Macer 1966, Macy and others 1978) and often in as little as 6 meters (Houghton and Isakson 1989, Kusakabe and Nakajima 1995). The greatest depths reported for the genus is a single *A. dubius* specimen found at an unusually deep 400 meters over the Nova Scotian banks (Scott 1968). This shallow distribution probably results from their preference for light (Winslade 1974b) and accessibility of prey.

Species of *Ammodytes* (juveniles as well as adults) exhibit the rather unusual habit of alternating between lying buried in the substrate and swimming pelagically in well-formed schools (Dick and Warner 1982, Inoue and others 1967, Macer 1966, Meyer and others 1979, Reay 1970). Hence, they are typically associated with fine gravel and sandy substrates up to and including the intertidal zone (O'Connell and Fives 1995). Their choice of substrates appears to be highly specific (Inoue and others 1967, Pinto and others 1984). In the natural environment, substrates used by sand lance have been consistently characterized as well washed, drained, and unpacked and typically contain coarse sands with little or no mud and silt (e.g., Dick and Warner 1982, Meyer and others 1979, Yamazaki 1995). Sand lance also avoid oil-contaminated sediments (Pinto and others 1984). Although wide ranging, sand lance preference for specific shallow substrates results in a patchy distribution of populations (Macer 1966, Scott 1968). Sand lance bury themselves within the substrates during periods of low light (<0.1 lux; Winslade 1974b), during estivation and dormant periods, or occasionally in response to predators (Girsa and Danilov 1976).

## Behavior

### Daily

Several authors (e.g., Hobson 1986, Inoue and others 1967) have described distinct crepuscular vertical movements of adults between benthic substrates, where they bury themselves, to pelagic waters, where they school and forage. Movements typically occur during the morning and evening of each day, although it is unclear if sand lance that enter the water column at dawn are active throughout daylight hours. Laboratory experiments suggest twice daily migrations into the water column to feed rather than a single long outing (Inoue and others 1967). In either case, *Ammodytes* spp. effectively reduce predation over the diel cycle by schooling in the day while feeding and burrowing at night (Hobson 1986, Reay 1970). Isolated reports of trawl catches at night are probably attributable to ships lights (Macer 1966), to which sand lance are attracted, or to high-latitude summer conditions where there is little distinction between day and night (Inoue and others 1967, Kühlman and Karst 1967, Langham 1971, Reay 1970). In laboratory experiments, Winslade (1974) found that sand lance activity is directly related to food availability, light intensity, and temperature. Futhermore, sand lance remained buried at night even if food was available, which corroborates the above field observations. Feeding was maximal at light intensities between 100 and 1000 lux, much reduced at 10 lux, and very low at 1 lux. Activity during daylight was high at 10 and 15 °C but lower at 5 °C.

### Seasonal

Most investigators have reported that sand lance are abundant in preferred habitats from spring to late summer and uncommon during the remainder of the year (Field 1988). Sand lance are rarely caught in the water column during the winter months and appear to remain inactive or in hibernation while buried in intertidal and shallow subtidal substrates (Blackburn and Jackson 1980, O'Connell and Fives 1995; pers. obs., Robards). If disturbed during winter on extreme low tides, however, they can move spontaneously and quickly. Juvenile sand lance are occasionally caught in beach seines during the winter, but normally they are found buried in substrates with adults (pers. obs., Robards).

During early summer, adult sand lance (mostly second year) are the most abundant of early winter-spawning species (Dick and Warner 1982). Later in the summer, juveniles become the most numerous age class as they migrate inshore and recruit to nearshore populations. Older fish may disappear early in summer, possibly because of reduced food requirements for growth or the need for earlier accumulation of fat (Winslade 1974c). Evidence from bird diets (Monaghan 1996) also indicates that adults are less common in late summer. Other reasons that adults may avoid the nearshore at this time are (1) body cavities in late summer are filled with turgid gonads and this may negate the value of spending time in the water column because feeding is physically difficult, and (2) adults may compete for food with the numerically dominant young-of-the-year recruits.

The Japanese sand lance begins to burrow into bottom substrates to start estivation in early May (Inoue and others 1967) when temperatures rise over 24 °C. Summer estivation may be unique to this species and may result from the peculiarly high water temperatures in this area. Although summer estivation is not reported for other species of *Ammodytes*, midsummer reductions in fishing catch are noted (Robards and others 2000).

Several reports have alluded to the possibility that sand lance migrate to deeper waters in winter (e.g., Kandler 1941). This conjecture may result from the fact that adult sand lance bury themselves in benthic substrates during winter and therefore are not caught in conventional fishing gear. Substantiating this statement, sand lance are caught during winter in modified scallop dredges (Cameron 1958), by hand from exposed sediments at extreme low tide (Robards and others 1999), or even in grab samples taken from under the winter sea-ice (Petersen 1977). Increases in abundance and reduction in mean size during late spring and summer are generally the result of juvenile sand lance recruiting nearshore. Only *A. marinus* appears to migrate; tagged *A. marinus* migrated within the North Sea, traveling 27 to 64 kilometers within a season (Gauld 1990). This species also migrates along the Murman coast, moving between deep water in winter and shallow nearshore waters in summer (Andriyashev 1954).

## Physiological Adaptations

### Temperature and Salinity

Sand lance are eurythermal, being found in temperatures from at least -2 °C (*A. dubius*; Scott 1968) to over 24 °C *(A. personatus*; Inoue and others 1967). Ranges for individual species span about 13 °C (Reay 1970), although they generally appear to favor cooler waters as demonstrated by their boreo-arctic distribution (except *A. personatus*). Sand lance also appear to be euryhaline, occurring in estuaries as well as the open ocean (Inoue and others 1967, Reay 1970).

### Exposure

The use of shallow intertidal substrates for refuge by sand lance can leave them exposed to air at extreme low tide. Sand lance can survive for at least 5.5 hours in damp exposed sand (pers. obs., Robards). They seem to have several physiological mechanisms to deal with living in sand and being exposed during low tide. Gill cavities have a relatively high volume and large brachiostegal membranes, which are fully expanded in sand lance buried in exposed sediments (pers. obs., Robards). Interstitial water may be pumped over gills as well as held within the gill cavity, aiding oxygen transfer while the sand lance is buried in damp sand (Quinn and Schneider 1991). On hot days, it seems that a physiological threshold is reached and spontaneous surfacing ensues (Dick and Warner 1982), perhaps because metabolic rates are too high for prolonged survival in a limited oxygen environment. Sand lance also have been observed to emerge spontaneously from Alaska nearshore substrates in extremely cold conditions (-13 °C; pers. obs., Robards). As sand lance emerged, they spontaneously froze at the surface. Further research is required to ascertain if sand lance are able to use atmospheric oxygen during periods of exposure.

### Summer Estivation

Japanese sand lance bury themselves in nearshore substrates each summer, when water temperatures are maximal, for up to 2.5 months without feeding. Fat deposits are accumulated during spring to allow for this estivation, during which gonads mature (Inoue and others 1967, Sekiguchi 1977). Fish caught during the estivation period have high quantities of mesenteric fat and empty stomachs (Inoue and others 1967).

### Winter Hibernation

Physiological adaptations for winter conditions include reduced oxygen consumption (by 17 percent) and ability to survive at significantly lower oxygen concentrations in the water (Quinn and Schneider 1991). Sand lance can tolerate oxygen tensions as low as 2 milliliters per liter (Inoue and others 1967). During this period of winter dormancy, sand lance are rarely caught in the water column (Dick and Warner 1982, Petersen 1977, Robards and others 2000). Ciannelli (1997) also found prolonged gut evacuation times for overwintering sand lance. Food was retained in the stomach for

as long as 30 hours, with an overall digestion time of 45 to 80 hours. This may be due, however, to reduced metabolism (Quinn and Schneider 1991) rather than a direct adaptation in itself. Normal gut evacuation time is about 12 hours (Inoue and others 1967). Resistance to starvation seems to be an important characteristic of both adult and juvenile sand lance. Adult *A. personatus* were able to survive for 24 weeks in an aquarium with no food (Inoue and others 1967), and their larvae can survive from 2 to over 3 weeks depending on temperature (Yamashita and Aoyama 1986).

## Schooling Behavior

Schooling behavior of sand lance is well documented from surface (Cameron 1958) and subsurface (Kühlman and Karst 1967) observations, as well as from hydroacoustic surveys (Armstrong 1986). Interspecific schooling with herring has been documented frequently (e.g., Kühlman and Karst 1967), although interspecies predation may be a partial reason (herring eating sand lance, Hopkins and others 1989; and sand lance eating herring, Rankine and Morrison 1988).

Kühlman and Karst (1967) made detailed observations of underwater schooling by *A. tobianus*. Close, inshore schools usually include hundreds or low thousands of individuals, but offshore schools usually number in the thousands. The shape of the school is horizontally flattened and blunt-linear in surface view. Other shapes were frequently observed close inshore. In a normal swimming school, interfish distance was about two-thirds of a body length and about one-third of a body length between head and tail. During threatening situations or at spawning, schools tighten considerably in formation (Robards and others 1999). Fish usually swim at about 30 to 40 centimeters per second, although short bursts of 300 to 500 centimeters per second are possible. Larger sand lance may remain within the center of the school (Meyer and others 1979). Schools swimming normally become more or less stationary when feeding, and spread out vertically and radially, sometimes filling the entire water column. Individuals with the body at an angle of 15° from horizontal search for food independently of others, seldom snapping for longer than 20 to 30 seconds in one place (Kühlmann and Karst 1967).

## Feeding

Feeding occurs primarily in the water column, although epibenthic invertebrates occasionally appear in the diet (Rogers and others 1979, Simenstad and others 1979). Several researchers (e.g., Helmich and others 1982, Winslade 1974a) have shown that for sand lance vision is far more important than olfaction in feeding.

Feeding habits of sand lance change with age (Inoue and others 1967). Larvae feed on phytoplankton, diatoms, and dinoflagellates (Trumble 1973), and after juveniles reach 10 millimeters they feed on nauplii of copepods in summer and euphausiids in winter (Craig 1987). Adult fish prey on macrocopepods, chaetognatha, and fish larvae. In Japan the food of faster growing sand lance is predominantly chaetognatha. Inoue and others (1967) report that about 20,000 copepods are consumed daily by sand lance in the size range of 72 to 74 millimeters. Overall, copepods (particularly *Calanus* and *Temora*) are the predominant prey source for postlarval stages (e.g., Field 1988, O'Connell and Fives 1995, Scott 1973a).

Other prey reported from diets include crustacea, amphipoda, isopod larvae, mysids, gammarid amphipods, harpacticoid copepods, larvaceans, annelids, polychaetes, juvenile bivalves and gastropods, insect flotsam, fish larvae, and invertebrate and fish eggs (Field 1988, Macer 1966, O'Connell and Fives 1995, Rankine and Morrison

1988). Rogers and others (1979) and Richards (1982) indicate that epibenthic invertebrates become more important in the diet during autumn and winter, although total stomach contents are lower. This change in diet probably results from the seasonal decline of pelagic prey and the shift of sand lance from pelagic to predominantly benthic habitats. Although there are numerous reports of sand lance preying on herring (*Clupea harengus*) larvae and eggs (e.g., Fuiman and Gamble 1988, Rankine and Morrison 1988), it is unclear if sand lance prey on herring larvae preferentially to other fish larvae.

Cannibalism appears rare in *A. hexapterus* (only 1 in 3,000 fish collected in Cook Inlet, Alaska: a single large female consumed eight juveniles of about 60 millimeters; pers. obs., Robards). Prevalence of cannibalism among Ammodytids is unknown but is reported for *A. personatus* (Kimura and others 1992, Okamoto and others 1989) and *A. tobianus* (Bowman 1914).

## Seasonal Changes in Proximate Composition

Lipid reserves in sand lance differ markedly with season (Hislop and others 1991; Sekiguchi 1977), with increases of about 31 percent between February and June for *A. hexapterus* (Robards and others, in press). Fat deposition and growth begin with the onset of vigorous feeding in February and continue until the summer dormant phase (Sekiguchi 1977, Sekiguchi and others 1976). Increases in fat content from 3 to 9 percent (juveniles) and 2 to 8 percent (adults) by late April were observed for *A. personatus*, and total lipids accounted for almost 40 percent of dry mass by May (Inoue and others 1967, Sekiguchi and others 1976). Average peak energy values of about 21 kilojoules per gram dry mass, equivalent to 5-6 kilojoules per gram wet mass are reported for various species of *Ammodytes* (Hislop and others 1991; Mårtensson and others 1996; Robards and others, in press; Van Pelt and others 1997).

Female sand lance contain greater lipid reserves than males during summer (Anthony and Roby 1997; Robards and others, in press). Energy content declines after a peak in early summer. A decline in energy density of at least 24 percent was observed in summer and autumn prior to spawning for *A. hexapterus* (Robards and others, in press). Therefore, early feeding and the accumulation of lipid reserves are probably critical for gonadal development and maintenance of metabolism throughout the rest of the year (Sekiguchi and others 1976, Winslade 1974c).

Juvenile sand lance initially favor somatic growth. At a threshold of about 80 millimeters for *A. hexapterus* (Robards and others, in press) and 45 to 50 millimeters for *A. personatus* (Sekiguchi and others 1976), rapid deposition of lipid reserves begins in preparation for winter. Juvenile *A. hexapterus* achieve high energy densities of about 20 kilojoules per gram. Initial growth therefore may be important for subsequent survival, as juveniles must reach sufficient size to establish lipid reserves for winter.

**Table 1—Maximum lifespan and length for *Ammodytes* species**

| Species | Lifespan | Maximum size | References |
|---|---|---|---|
| | *Years* | *mm* | |
| *A. personatus* | 3 | 212 | Hashimoto 1984, Inoue and others 1967 |
| *A. hexapterus* | 7 | 260 | Field 1988, Robards and others 1999 |
| *A. americanus* | 12[a] | 220 | Brêthes and others 1992, Leim and Scott 1966 |
| *A. dubius* | 10 | 372 | Scott 1973b, Winters 1983 |
| *A. marinus* | 9 | 250 | Macer 1966 |
| *A. tobianus* | 7 | 280 | Reay 1970 |

[a] Possibly a misread otolith; Winters (1983) reported 10 years.

## Age, Growth, and Life Span

Sand lance can be aged from otoliths (Macer 1966, Scott 1973b, Winters 1981). These are located immediately posterior to the skull (visible through their skin). Juveniles develop an opaque otolith, followed by a hyaline ring in their first winter. Subsequent opaque rings are deposited once per year (Brêthes and others 1992) during the spring period of rapid feeding. The period of opaque material deposition is about 3 months (O'Connell and Fives 1995). Numerous researchers (e.g., Brêthes and others 1992, Lidster and others 1994, Macer 1966) have described a linear correlation between otolith size (radius, diameter, or area) and fish length. A single equation is inadequate, however, to describe the age-otolith relation. Robards and others[1] found significant differences between juvenile (0-group) and adult (≥ 1-group) relations. Wright and Bailey (1996) use three equations to fully describe juvenile relations, and Winters (1981) uses two equations to describe adult relations.

Growth appears to be density and food dependent (Inoue and others 1967, Nagoshi and Sano 1979). Seasonal growth occurs mostly in spring and early summer (March-August) for species of *Ammodytes* (Macer 1966, Nagoshi and Sano 1979). Most growth occurs during the first 2 years (Macer 1966) with about one-half to one-third of total growth occurring in the first year (Trumble 1973). Large interannual and geographic differences in growth exist in this genus (Dick and Warner 1982, Macer 1966), but no gender differences are reported (Nagoshi and Sano 1979). In exceptionally unfavorable years, no growth may occur, as observed by Macer (1966) in the North Sea.

Estimated life spans of different *Ammodytes* species are summarized in table 1. Within most populations, age-groups 0 and 1 are the numerically dominant age classes, and numbers of older fish, particularly those over age-group 3, rarely are found in significant numbers for most species. Typical of *Ammodytes* species, estimates of maximum size for *A. hexapterus* range widely with area. Lengths as great as 270 millimeters occur in the Bering Sea; however, in the northern Gulf of Alaska and off California, length reaches only about 200 millimeters. Maximum lengths reported for other species are summarized in table 1.

[1] Robards, M.D.; Rose, G.A.; Piatt, J.F. Somatic growth and otolith development for Pacific sand lance (*Ammodytes hexapterus*) under differing oceanographic conditions. On file with: USGS Biological Resources Division, 1011 E. Tudor Road, Anchorage, AK 99503.

## Maturation

Sand lance typically reach maturity in their second year, although a few individuals remain immature for longer periods. Maturation in the second year occurs in *A. hexapterus* (Robards and others 1999), *A. personatus* (Kitaguchi 1979), *A. americanus* (Richards 1982), and *A. tobianus* (O'Connell and Fives 1995). In contrast, *A. dubius* (Scott 1968, Winters 1983) and *A. marinus* (Reay 1970) can mature as second-year fish but usually mature at later ages.

Gonadal development is initially slow and differs between sexes (Robards and others 1999). No sexual dimorphism exists in length-to-weight ratios or length-at-age relations. Initial maturation in sand lance is quite slow (Nelson and Ross 1991, O'Connell and Fives 1995, Reay 1970, Okamoto and others 1989, Winters 1983), and females mature more slowly than males. Autumn-spawning sand lance (e.g., *A. hexapterus*) require about 3 months to mature (Robards and others 1999), in contrast to winter- and spring-spawning sand lance (e.g., *A. tobianus* and *A. marinus*), which require 5 to 7 months to reach maturity (Reay 1970).

Normal sex ratios are about 1:1 or slightly in favor of females (Inoue and others 1967, Macer 1966). All ammodytids appear to be single batch spawners with a single, normally distributed size distribution of ovarian eggs, single peak in annual gonadosomatic indices, and few eggs remaining in ovaries after spawning (Smigielski and others 1984). Males mature earlier in the season than females, but the oviparous females attain a higher gonadosomatic index of 31 percent compared to 21 percent for males (*A. hexapterus*). Fecundity of females is proportional (after $\log_{10}$ transformation) to length. Fecundities are reported to range from 1,468 to 16,081 ova per female in *A. hexapterus* (Robards and others 1999) and 1,000 to 8,000 in the smaller *A. persontaus* (Trumble 1973). Values for North Atlantic sand lance are 4,821 to 18,416 for *A. americanus*; 1,169 to 22,904 for *A. dubius* (Nelson 1990); 3,300 to 22,100 for *A. marinus* (Andriyashev 1954); and 2,900 to 42,600 for *A. tobianus* (O'Connell and Fives 1995). Although ova mature more quickly at higher temperatures, full maturation may not be reached at overly high temperatures (Inoue and others 1967).

## Spawning

Most species spawn once a year (Reay 1970), although *A. tobianus* populations may contain two separate spawning components, one spawning in autumn and one in spring (O'Connell and Fives 1995). Immediately before spawning, gonads are turgid and fill the body cavity. Spawning for *A. hexapterus* occurs in late September and October on fine gravel and sandy beaches, soon after the summer water temperatures began to decline (Robards and others 1999). *Ammodytes hexapterus*, dominated in a 2:1 ratio by males, approach the intertidal zone at sites where spawning has sometimes taken place for decades. Spawning occurs in dense formations. Female sand lance burrow through the substrate while releasing eggs (McIntosh and Masterman 1897), which results in the formation of scour pits in intertidal beach sediments (Penttila 1995, Robards and others 1999). It is still unclear, however, whether sand lance are obligate intertidal spawners. *Ammodytes hexapterus* in other areas of Alaska are presumed to spawn subtidally (McGurk and Warburton 1992).

All species of *Ammodytes* spawn either inshore or on offshore shallow banks (e.g., Dogger Bank of the North Sea or the Grand Bank off Newfoundland) at depths to 100 meters (Garrison and Miller 1982, Reay 1970). For all species, spawning appears to occur within habitat that they occupy year-round, and spawning migrations have not been observed.

## Eggs

Eggs are demersal and slightly adhesive. Diameters are about 1 millimeter for *A. hexapterus* (Pinto 1984, Robards and others 1999), 0.66 millimeter for *A. personatus* (Inoue and others 1964), 0.83 to 1.0 millimeter for *A. americanus* (Smigielski and others 1984, Williams and others 1964), 1.02 millimeters for *A. marinus* (Winslade 1971), and 1 millimeter for *A. dubius* (Scott 1972).

*Ammodytes hexapterus* eggs are deposited in the intertidal zone just below the waterline, whereas other species deposit eggs in the subtidal, particularly on offshore banks. Eggs are occasionally collected pelagically, presumably as waves and currents wash eggs up and off the substrate (Senta 1965, Williams and others 1964). Egg membranes are pitted, the perivitelline space is small, and the yolk is pale dull yellow or white. One bright amber oil globule is usually present, but sometimes 0, 2, or 3 oil globules are present (Garrison and Miller 1982, Robards and others 1999). Roe of sand lance (along with capelin, *Mallotus villosus*) has the highest total lipid content among a wide array of northwest European marine fish (Tocher and Sargent 1984).

Incubation times are highly variable and depend on ambient temperatures and oxygen levels (Winslade 1971). Incubation times of permanently immersed eggs range from as much as 62 days at 2 °C to as little as 13 days at 15.7 °C (Field 1988). Smigielski and others (1984) found increased incubation times and time-to-hatch-completion with decreasing temperatures (10 to 2 °C). Maximum hatch rate also may show a negative relation with temperature; maximal hatch rate for *A. personatus* was at 8.2 °C and was much lower at 15.7 °C (Inoue and others 1967). Winslade (1971) related increased incubation time and mortality to decreasing oxygen concentrations. No eggs hatched at oxygen concentrations of 2.1 parts-per-million, although newly hatched larvae were able to tolerate such low concentrations for about 1 week.

Sand lance eggs that are spawned intertidally (e.g., *A. hexapterus*) are subjected to periodic exposure, and in some areas (e.g., Alaska) subfreezing temperatures. Embryos in these eggs have a more protracted development, with up to 67 days needed until hatch (Robards and others 1999).

## Larvae

*Ammodytes* larvae hatch at a size of 4.5 to 5.5 millimeters (Field 1988) before the spring plankton bloom (Haldorson and others 1993). Jaws are functional and gut is complete at hatch in *A. americanus*, and some individuals feed within hours of hatching in the laboratory (Smigielski and others 1984). *Ammodytes hexapterus* does not have functional jaws or a complete gut during the first week posthatch (Pinto 1984). All species of *Ammodytes* larvae are able to feed prior to yolk sac absorption (Yamashita and Aoyama 1985). Yolk sac absorption is usually complete within about 2 weeks of hatching (Winslade 1971). Time taken for yolk sac and subsequent oil globule absorption is positively correlated with temperature for *A. marinus* (Winslade 1971) and negatively correlated with size (Smigielski and others 1984).

Larvae of *A. americanus, A. personatus,* and *A. marinus* are able to survive for long periods without food after hatching. When kept without food, time to 50 percent mortality was about 11, 16, and 21 days after hatching at 15.5, 10.5, and 6.5 °C, respectively. Nine days and two weeks were estimated as the period of recoverable starvation for *A. personatus* (Yamashita and Aoyama 1985) and *A. americanus* (Buckley and others 1984), respectively. Larvae of *A. marinus* are able to survive longer without food at lower temperatures (Winslade 1971). Due to early feeding prior to yolk absorption, larvae of *A. americanus* had the highest survival when compared to larval haddock (*Melanogrammus aeglefinus*) and mackerel (*Scomber scombrus*) that were fed a wide range of prey densities (Buckley and others 1984, 1987).

Growth rate varies with temperature and food availability. Growth rate ranges from 0.2 to 0.4 millimeter per day and dry weight increases by about 2 to 6 percent per day, depending on temperature (Smigielski and others 1984, Yamashita and Aoyama 1985). Buckley (1984) determined that a minimum growth rate is required to prevent starvation of *A. americanus* larvae; 2.4, 2.5, and 3.4 percent change in protein content were required per day at 2, 4, and 7 °C, respectively.

Postyolk-absorption *Ammodytes* larvae undergo marked diel vertical migrations, moving between shallow depths (5 to 30 meters) during daylight to deeper depths (30 to 50 meters) at night (Covill 1959, Inoue and others 1967, Richards and Kendall 1973, Ryland 1964, Yamashita and others 1985). The range of these migrations increases with larval size. Movements occur during crepuscular hours and have been attributed to predator avoidance (Yamashita and others 1985) and that larvae, as adults, are light-dependent feeders. Ryland (1964) notes that *A. marinus* larvae also fed only during daylight hours. Preyolk-absorption larvae (<5 millimeters) do not undergo any vertical migrations.

Horizontal distribution, and possibly abundance of sand lance larvae, is strongly influenced by tidal currents, oceanography, and wind conditions (Inoue and others 1967, Kimura and others 1992, McGurk and Warburton 1992, Nakata 1988), although at least for some species, offshore dispersal is not pronounced (Trumble 1973). Current eddies may accumulate larvae (Altukhov 1978).

## Recruitment

Metamorphosis of larval *A. americanus* is temperature dependent and occurs at 29 millimeters (131 days at 4 °C and 102 days at 7 °C; Smigielski and others 1984). Metamorphosis of *A. marinus* is at 30 to 40 days. Schooling behavior was observed before metamorphosis at 25 to 30 millimeters. Recruiting sand lance first appear nearshore after this size is reached (Cameron 1958).

Annual recruitment is highly variable (Inoue and others 1967, Sherman and others 1981). Large fluctuations in abundance are observed every few years for all species in this genus (e.g., Kimura and others 1992, Sherman and others 1981). Recruitment of *Ammodytes* larvae to the spawning stock is highly dependent on juvenile survival, as they immediately recruit to the next-year spawning adults (Kimura and others 1992). Hamada (1966c) correlated increased catches of juvenile sand lance with low water temperatures and wind direction during the spawning season.

A high negative correlation has been found between abundance of adult fish and size of age-1 *A. personatus* (Hamada 1967), as well as with growth and abundance of juveniles (Nagoshi and Sano 1979). Density-dependent factors may influence both survival and growth of juveniles and adults. A strong negative correlation (r =-0.87) between the percentage of age-1's and numbers of age-0's was observed for *A. personatus* (Hamada 1966a). In addition, the number of eggs spawned and the catch of juvenile *A. personatus* were negatively correlated (r = -0.81; Hamada 1967). First-year growth was limited in areas with large numbers of adult fish (Hamada 1967, Nagoshi and Sano 1979) or other juveniles (Nagoshi and Yuba 1988).

## Mortality

Most mortality estimates are based on fished stocks and are undoubtedly subject to considerable imprecision (Bailey and others 1991). Although Reay (1970) suggested that little difference existed for mortality between fished and unfished stocks, this was before fishing pressure increased during the last three decades. Macer (1966) estimated an annual mortality of 70 to 80 percent (z=1.2). High annual variability in mortality was observed in Newfoundland waters by Winters (1983), who reports declines in z-values from over 1.0 to less than 0.5 from 1968 to 1979. Because there is no fishery for sand lance in Newfoundland, these rates must arise from natural mortality (Field 1988). Increased survival was linked to declines in cod stocks, a major sand lance predator in the northwestern Atlantic. In areas of seabird colonies, predation rates can account for 30 to 40 percent of total mortality. For the Shetland area in the eastern Atlantic, this value equates to about 49 000 tonnes of sand eels consumed annually (1981-83) and is similar in value to annual peak fishing catches (Bailey and others 1991). These results highlight the importance of incorporating consumption of seabirds and other predators in future assessments of forage fish stocks.

Larval sand lance mortality rates for *A. americanus* and *dubius* between 1974 and 1980 ranged from 0.207 to 0.363, corresponding to a daily mortality rate of 6 to 10 percent for larvae of 5 to 27 millimeters (Morse 1982). Mortality rates of older larvae (30 to 43 days) ranged from 0.20 to 0.02 and decreased with increasing food levels. Wright and Bailey (1996) suggest that the degree of coupling between hatching and the onset of spring secondary production may be an important contributory factor to year-class variability in sand lance.

Mass die-offs of sand lance have been reported in England in association with blooms of *Gonyaulax* sp. (Adams, in Reay 1970). Sand lance also have been intermediary to die-offs of common terns (*Sterna hirundo*) by passing on *Gonyaulax.* Oil pollution and subsequent detergent pollution from the Torrey Canyon cleanup (United Kingdom) also resulted in mass die-off of sand lance (Smith, in Reay 1970).

## Predation

Ammodytes are a quintessential forage fish, and as a group are possibly the single most important taxon of forage fish in the Northern Hemisphere (Springer and Speckman 1997). Sand lance are preyed on by numerous species of seabird, marine mammal, and fish, as well as miscellaneous land birds and animals (see next chapter). Population fluctuations and distribution of these predators are frequently linked to sand lance abundance (e.g., Bailey 1991, Martin 1989, Monaghan 1992, Monaghan and others 1989, Sherman and others 1981). Sand lance also play an important role in the ecosystem as a consumer of zooplankton (Payne and others 1990, Sherman and others 1981).

## Parasites

Relatively little information is available on parasites of sand lance. Up to 100 percent infestation (n = 54) in *A. tobianus* (Groenewold and others 1996) is reported. Scott (1973c) reports generally low incidence, never exceeding 50 percent (n= 438). Burdens can be relatively high with a mean burden of 88 parasites per host in *A. tobianus* (Groenewold and others 1996) and maximum loads of 93 individual Nematoda parasites within *A. personatus* (Inoue and others 1967) and 120 *Lecithaster gibbosus* in *A. hexapterus* (Arai 1969).

Groenewold and others (1996) found seven species of parasite associated with the lesser sand eel (*A. tobianus*) in the Wadden Sea (eastern North Sea), of which two were larval stage parasites, indicating that sand lance were intermediate or paratenic hosts in their life cycle. The digenean *Brachyphallus crenatus* was both the dominant (>96 percent of hosts) and most abundant parasite in this study. Larval anisakine nematodes were the dominant group in an Icelandic study (Hauksson 1992) in which larvae of *Contracaecum* and *Hysterothylacium* (found in the gut cavity) were the most abundant species. Neither sealworm nor whaleworm (Nematoda) appear to be common in sand lance, compared to more pelagic species (Hauksson 1992).

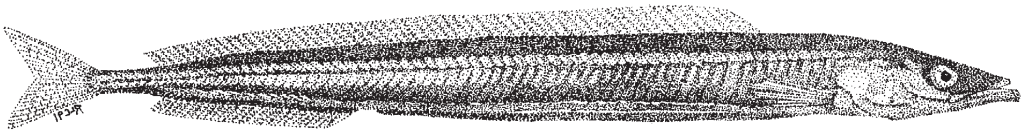
Diet is the primary factor influencing the parasitic fauna found within any area (Groenewold and others 1996). Sand eel play a very important role in parasite transmission to predaceous fish and seabirds (Groenewold and others 1996). The array of parasites that have been found in sand lance has not been summarized prior to this report (table 2).

## Acknowledgments

We are indebted to our librarian, Nancy Tileston, ARLIS, for her long hours researching obscure journals. The Exxon Valdez Oil Spill Trustee Council provided funding for literature review and publication as part of Restoration Project 98306. We are grateful to Stan Senner and Robert Spies for encouragement and support of this effort. We also thank Kathy Turco for her endless enthusiasm for sand lance. This work was part of the Cook Inlet Seabird Forage Fish study conducted by the U.S.G.S. Alaska Biological Science Center, Anchorage.

**Table 2—Parasite species found in host species of *Ammodytes***

| Parasite species | Host | Preferred organ | References |
|---|---|---|---|
| **Digenea:** | | | |
| *Brachyphallus crenatus* | *tobianus, dubius, marinus, americanus* | Stomach | Groenewold and others 1996, Polianskii 1955, Scott 1973c |
| *Hemiurus communis* | *tobianus* | Stomach | Groenewold and others 1996 |
| *Hemiurus luehei* | *tobianus* | Stomach | Groenewold and others 1996 |
| *Derogenes varicus* | *tobianus, dubius, marinus* | Stomach | Groenewold and others 1996, Polianskii 1955 |
| *Cryptocotyle lingua* (cyst) | *tobianus* | Skin | Groenewold and others 1996 |
| *Galactosomum* sp. | *hexapterus* | ? | Arai 1969 |
| *Hemiurus appendiculatus* | *tobianus* | ? | Scott 1973c |
| *Hemiurus communis* | *tobianus* | ? | Scott 1973c |
| *Lecithaster gibbosus* | *hexapterus, dubius* | Intestine | Arai 1969, Scott 1973c |
| *Lepocreadium pyriforme* | *americanus* | ? | Scott 1973c |
| *Opecoeloides vitellosus* | *americanus* | ? | Scott 1973c |
| *Podocotyle olsoni* | *americanus* | ? | Scott 1973c |
| *Stephanostomum tenue* | *americanus* | ? | Scott 1973c |
| *Torticaecum fenestratum* | *americanus* | ? | Scott 1973c |
| **Monogenea:** | | | |
| *Gyrodactyloidea* | *hexapterus* | ? | Arai 1969 |
| **Cestoda** (larval)**:** | | | |
| *Bothriocephalus scorpii* | *tobianus, dubius* | ? | Scott 1973c |
| *Phyllobothrium* sp. | *hexapterus* | ? | Arai 1969, Sanmartin and others 1989 |
| *Tetraphyllid* | *dubius* | ? | Scott 1973c |
| **Eucestoda:** | | | |
| *Scolex polymorphus* | *marinus* | ? | Polianskii 1955 |
| **Nematoda:** | | | |
| *Hysterothylacium* sp. (larval) | *tobianus* | Body cavity | Groenewold and others 1996 |
| *Contacaecum aduncum* | *marinus* | ? | Polianskii 1955 |
| *Contracaecum aduncum* (larval) | *dubius, marinus* | ? | Scott 1973c |
| *Contracaecum* sp. (larval) | *tobianus* | Body cavity | Groenewold and others 1996 |
| *Anisakis* sp. (larval) | *hexapterus, marinus* | ? | Arai 1969, Polianskii 1955 |
| **Acanthocephala:** | | | |
| *Echinorhynchus gadi* | *hexapterus, marinus* | ? | Arai 1969, Polianskii 1955 |
| **Copepoda:** | | | |
| *Lepeophtheirus* sp. | *hexapterus* | ? | Arai 1969 |
| **Protozoa:** | | | |
| *Sinuolinea murmanika* | *marinus* | ? | Polianskii 1955 |
| A*eromonas salmonicida* | *lancea* ( now *tobianus*) | ? | Dalsgaard and Paulsen 1986 |
| *Myxosporidia* (protozoa) | *tobianus* | ? | Gayerskaya and Kovaleva 1984 |



# Sand Lance as Cornerstone Prey for Predator Populations

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**Abstract**

Sand lance (*Ammodytes*) constitute a major prey for at least some populations of over 100 species of consumer, including 40 species of birds, 12 species of marine mammals, 45 species of fishes, and some invertebrates. Variation in the availability of sand lance (and other forage fishes) can have major effects on the breeding success and survival of their predators. Commercial fishing and other pressures on sand lance populations potentially have ramifying effects on many species of wildlife.

Keywords: Sand lance, *Ammodytes,* predator-prey, seabirds, marine mammals, forage fish, predatory fish, Alaska.

## Introduction

Sand lance (*Ammodytes*) are important forage for many vertebrate predators —birds, marine mammals, other fishes—from north-temperate to arctic regions of the world. As larvae, they are probably also important prey for an array of invertebrates (Yamashita and others 1984, 1985a). Indeed, sand lance have been called the "quintessential forage fish" in the Northern Hemisphere (Springer and Speckman 1997). Their central importance as prey has been documented at least for some vertebrate predators in many parts of their ranges. This review chapter covers the nutritional value of sand lance as prey, antipredator behaviors of sand lance, the predators that are known to depend heavily on sand lance, and the relation of predator reproductive success to prey availability. We conclude with a brief review of the complex interactions between sand lance and their numerous predators. Scientific names of predators discussed here are given in the "Predator Index" to the "Annotated Bibliography."

## Sand Lance as Prey

Sand lance occur in subboreal, boreal, and arctic seas in the Northern Hemisphere. Diurnal (vertical) migration patterns appear to differ among species (e.g., Richards and Kendall 1973, Senta 1965, Yamashita and others 1985b), which also probably affects the availability of sand lance to predators. At times, sand lance burrow in sand, a behavior that probably gave them their common name.

Sand lance spawn over sandy substrates (Penttila 1997, Robards and others 1999). Most sand lance are reported to spawn in fall or winter, although some populations apparently spawn in spring or summer (*A. americanus*, Winters 1989; *A. hexapterus*, McGurk and Warburton 1992a, 1992b, 1992c, Penttila 1997; *A. tobianus*, Macer 1965, Masterman 1895, O'Connell and Fives 1995, Reay 1973; *A. lancea*, Berner 1986; *A. marinus,* Gauld and Hutcheon 1990, Macer 1966, Winslade 1974c; *A. dubius*, Gilman 1994, Scott 1968, 1972a, Winters 1983, 1989; *A. americanus*, Buckley and others 1984; *A. personatus*, Hamada 1966b, Senta 1965, Yamashita 1985, Yamashita and Aoyama 1985). *Ammodytes personatus* is reported to become dormant in summer, so that presumably only young of the year are available to pelagic predators from about May or June onward through the summer (Sekiguchi and others 1976, Senta 1965).

Most sand lance grow and gain weight during a spring or summer feeding period (Blackburn and Anderson 1997; Brêthes and others 1992; Kitakata 1957; Macer 1966; Masterman 1895; Reay 1973; Robards and others, in press; Sekiguchi 1977b; Sekiguchi and others 1976; Senta 1965; Winslade 1974a) and therefore provide their maximum food value (in terms of grams of fish per capture) to predators after that season. Sand lance usually mature at age 1 to 3 years, occasionally later (Buckley and others 1984, Gilman 1994, Macer 1966, Masterman 1895, Reay 1973, Winters 1983), and are capable of living for several years as adults (Reay 1973). Different populations have different recruitment success, length distributions, and ontogenetic growth curves (Kitakata 1957, Reay 1973, Winters 1981). In *A. hexapterus*, weight increase is small while the larva depends on stored yolk but begins to increase rapidly when the young begin to feed (McGurk and Warburton 1992b); weight gain is rapid

during the spring plankton bloom (Robards and others, in press). Likewise, *A. marinus* gains little weight in relation to length when the fish is small (a few centimeters), but then relative weight gain is rapid and the proportion of fat in the body increases (Harris and Hislop 1978, Macer 1966). Rates of weight gain no doubt depend on food availability and water temperature, among other factors. Fat deposits increase during the feeding season, before spawning; they build up first in the muscles and then in the mesenteries (Reay 1973). Mesenteric fat of *A. tobianus* increased from 1 to 13 percent of the dry mass of the fish from February to May (Reay 1973), and the total fat content of *A. personatus* increased to almost 40 percent of fish dry mass (in larger individuals) by May (Sekiguchi and others 1976). Maturation of gonads depletes body reserves of lipids and slows growth (Pinto 1984; Reay 1973; Robards and others, in press; Senta 1965b; Winslade 1974a). Ripe gonads constitute about 25 percent of body mass in *A. dubius* (Gilman 1994); postspawning adult *A. hexapterus* lose about 22 percent of body mass (Robards and others, in press), and *A. americanus* and *A. personatus* lose as much as 45 percent of their body mass (Nagoshi and Sano 1979, Smigielski and others 1984, Westin and others 1979). Maximum energy content is achieved in early summer, so that sand lance appear to be a rewarding prey especially for summer-foraging predators (in contrast to capelin [*Mallotus villosus*], which have low energy value in summer; Montevecchi and Piatt 1984).

Sand lance have an elongate, cylindrical shape that makes them relatively easy to swallow, compared to a deeper bodied fish (such as adult herring). They are probably more easily swallowed, particularly by very young seabird chicks, than are some other forage fishes of similar length but greater body depth (Ainley and others 1996, Reimchen and Douglas 1984, Vermeer 1980); however, it seems unlikely that prey size commonly limits intake by larger chicks or adults: older Atlantic puffin chicks have an impressive swallowing capacity (Harris and Hislop 1978), and common murres appear to prefer smaller prey than the maximum size they are able to swallow (Swennen and Duiven 1991). The elongate shape of sand lance also facilitates the carrying of dozens at a time in the bill of a parental seabird, such as a puffin (e.g., Ainley and others 1996, Harris and Hislop 1978, Hislop and others 1991).

In general, fish appear to be more valuable foods than crustaceans, and high-lipid fish yield high energy gains. Fish can be digested more rapidly than crustaceans (Singh-Renton and Bromley 1996); moreover, some predators, including cod, that fed on high-lipid (11 percent) sand lance stored more fat than those fed on low-lipid (1 percent) prawns (Buchman and Børresen 1988). Tufted puffins and black-legged kittiwakes gained weight more rapidly and stored more fat on a diet of sand lance than on a diet of walleyed pollock; kittiwakes also exhibited lower levels of stress hormones (Kitaysky and others 1999).

It is, however, difficult to assemble from the literature an accurate picture of the food value of sand lance, because papers on the nutrient content of fishes often neglect to report the season in which their specimens were harvested, the ages and genders of the fish, and their spawning status (see, however, Montevecchi and Piatt 1984 and Robards and others, in press, for examples of data on seasonal and gender variation). Furthermore, it is very likely that there is variation among species and populations of sand lance in the energetic rewards provided to predators (e.g., Anthony and Roby 1997; Robards and others, in press). Nevertheless, we summarize here the

information we can glean; energy density (kilojoules/gram) is commonly associated primarily with fat content, but for simplicity, we deal here directly with energy density (on a wet-mass basis, because predators consume prey as wet not dry mass).

Sand lance are reported to rank lower in energy density than other forage fishes, such as unspawned eulachon (*Thaleichthyes pacificus*; Payne and others 1997) and large herring and sprat (*Sprattus sprattus*; Harris and Wanless 1985, Hislop and others 1991, Vermeer and Devito 1986); most available values for energy density of nonlarval sand lance range from about 5.0 to 7.9 kilojoules/gram (Anthony and Roby 1997; Barrett and others 1987; Harris and Hislop 1978; Harris and Wanless 1985; Robards and others, in press; Van Pelt and others 1997), juveniles generally having lower values (about 3.1-5.8 kilojoules/gram; Anthony and Roby 1997, Harris and Hislop 1978, Van Pelt and others 1997). The range of average energy densities for nonlarval sand lance overlaps that for herring (Ashwell-Erickson and Elsner 1981, Barrett and others 1987, Hislop and others 1991; depending on age of fish, Anthony and Roby 1997) and capelin (Anthony and Roby 1997, Ashwell-Erickson and Elsner 1981, Perez 1994, Van Pelt and others 1997). The energy density of sand lance markedly exceeds that of small gadoids (1.1-3.6 kilojoules/gram; Anthony and Roby 1997, Van Pelt and others 1997; see also Hislop and others 1991, Perez 1994). The total nutrient content per captured fish varies with fish size, from about 7 kilojoules for a 2-gram sand lance to about 60 to 80 kilojoules for a 15-gram individual (compared to about 12 for a 3-gram herring and 62 for a 13-gram herring; Anthony and Roby 1997). Gram for gram, then, sand lance seem to be a very rewarding prey.

Furthermore, predators may exhibit foraging preferences for specific genders of prey: Female fish tend to contain more energy than males, at least in some seasons (sand lance, Anthony and Roby 1997; Robards and others, in press; capelin, Montevecchi and Piatt 1984, Van Pelt and others 1997), and female capelin were preferred by breeding Atlantic puffins in Newfoundland (Montevecchi and Piatt 1984, Piatt 1987).

The protein content of sand lance is roughly equivalent to that of other forage fishes, so protein intake of sand-lance predators does not suffer. Protein content of sand lance is reported to be about 16 percent of fish wet mass, or 65 to 79 percent of fish dry mass—slightly higher than herring, on average, but slightly lower than gadoids (presumably because gadoids have proportionately less fat; Anthony and Roby 1997, Payne and others 1997).

The identity and quantity of various lipids in nonreproductive sand lance appear to be similar to that in herring and capelin, and seasonal variations are to be expected (Ackman and Eaton 1971, Dahlberg 1969, Hart and others 1940). A more recent analysis of lipid composition of sand lance revealed similarities with herring and other forage fishes and, in addition, noted changes in lipid composition with size, age, and location of some species (Iverson and others 1997). Clearly, a comprehensive picture of lipid variation has yet to emerge. The vitamin and mineral content of fish meal derived from sand lance differs from that of some other forage fishes, with higher levels of some of the B vitamins and iodine (Jangaard and others 1974).

On the negative side, however, sand lance are not only subject to paralytic shellfish poisoning (PSP or red tide) and other such toxins (e.g., Adams and others 1968, Longbottom 1968; see Burkholder 1998 for a general review), but they also can

transmit them to at least some of their predators (Clifford and others 1993, Falandysz and others 1996, Nisbet 1983 and refs. therein, Potts and others 1980). Deaths of large numbers of common murres, shags, great cormorants, fulmars, herring gulls, loons, and terns have been associated with PSP; mortality in common terns was greatest in females of certain age classes and breeding condition (Nisbet 1983). In addition, sand lance, along with other fishes (e.g., Hunter 1998), may carry toxic pollutants and be capable of passing them on to their predators.

## Antipredator Behavior

Sand lance have distinctive tactics for evading predators. One is to bury themselves in soft, wet sand in the intertidal and subtidal zones (Girsa and Danilov 1976, Pearson and others 1984, Pinto and others 1984), especially in summer (for *A. hexapterus*, Dick and Warner 1982). This behavior is not specifically induced by predatory chases (Richards 1976). As the tide recedes, some individuals remain even in sand that is dry on the surface and quite firm (the authors' observations). Ravens (*Corvus corax*), northwestern crows (*C. caurinus*), gulls (*Larus* spp.), and bald eagles (*Haliaeetus leucocephalus*) forage on intertidal sand lance (Robinette and Ha 1997; Shepherd 1988; Willson and Armstrong 1998). Corvids and gulls often dig for sand lance with their bills, repeatedly moving sand to the side with a twist of the head; they often are successful in such efforts. Bald eagles also rapidly pat the wet sand with their feet, which disturbs buried sand lance and often brings them to the surface, where the predator seizes them. On 10 occasions in summer 1996, we sampled the abundance of sand lance in areas where these birds were digging and in randomly selected areas in the intertidal sand flats near the mouth of the Mendenhall River in Juneau, Alaska; each sample consisted of one shovelful of wet sand ($N > 100$ in both random and foraged areas). In eight of these cases, the abundance of sand lance was markedly higher (from about 2 to 100 times higher) in areas where birds were digging; in the remaining two cases, the number of sand lance found was very low everywhere (0 or 1 for a total effort of 400 shovelfuls). Thus, the birds appeared to be able to detect locations where sand lance were abundant and concentrate their foraging efforts there. In addition, humpback whales (*Megaptera novaengliae*) may scuff the seafloor with their jaws to disturb subtidally buried sand lance and flush them from their hiding places (Hain and others 1995). We do not know the probability of escape by sand lance in different burial sites, but it is clear that high densities can be detected and exploited by predators.

A second defensive tactic is a form of the "selfish herd" (Hamilton 1971). Sand lance normally move about in schools (Meyer and others 1979, Potts 1986), but when they are pursued by a predator, the school may condense into a ball of closely packed fish (Girsa and Danilov 1976, Grover and Olla 1983, Hunt 1995, Mahon and others 1992, Vermeer and others 1987; but see also Pitcher and Wyche 1983). Presumably, such tactics usually reduce the risk of predation to each individual, as suggested by the selfish-herd idea, but balling-up brings with it some risks as well. When the balls of fish are near the surface, some individuals jump above the water surface and become vulnerable to the attacks of gulls and other avian piscivores that are drawn to the spot (Mahon and others 1992, Perkins and others 1982, Pierotti 1988, Safina and Burger 1985). Foraging success of gulls feeding on schools of fish can be greater for birds in flocks than for single birds (e.g., Götmark and others 1986), and thus, when several gulls are drawn to a surface school, the risk of predation on forage fishes may increase. Bald eagles have been observed to forage on dense balls of sand

lance near the surface of the water, where they are able to grasp several fish simultaneously in their talons. Furthermore, baleen whales are known to herd small fishes into concentrated clusters by enclosing them in bubble nets and then engulfing a large portion of the cluster (Hain and others 1982, Weinrich and others 1992).

In addition to these behaviors, the silvery color and reflective surface of the fish can provide camouflage during calm swimming and distraction to predators during a chase (Denton and Rowe 1994, Hobson 1979).

## Predators

Table 1 (page 28) summarizes the available (to us) information concerning the predators for which sand lance are known to constitute a significant fraction (>10 percent, by some measure) of the diet at some time in some place. We chose to include data based on frequency of occurrence, percentage of diet by weight, number, or volume, or various indices of dietary importance, in order to include as much information as possible, despite the obvious fact that these several measures are not equivalent (Lavigne 1996). There are numerous other predators for which the only available records show an incidental foraging on sand lance (see “Predator Index” in “Annotated Bibliography”); some of these seemingly incidental predators probably depend more heavily on sand lance at other times or places.

Although there is much annual and geographic variation, and sampling of predators has not been well distributed taxonomically, seasonally, or geographically, it is clear that sand lance constitute an important prey species for many vertebrate predators. They comprise >50 percent of the diet (at some time and place) for 31 species of birds (table 1A), 9 marine mammals (table 1B), and 27 fishes (table 1C); they comprise at least 10 to 50 percent of the diet for 9 additional bird species, 3 additional marine mammals, and about 19 additional fishes. They sometimes constitute an important prey for squid (table 1D). More thorough sampling would undoubtedly turn up many more species of predators for which sand lance are important prey.

Among birds, several families are prominent in the list of major sand-lance predators: Procellariidae (shearwaters; 3 species), Phalacrocoracidae (cormorants; 5 species), Laridae (gulls and terns; 15 species), and Alcidae (puffins, murres, auklets, etc.; 14 species). There are six species of pinnipeds (4 phocids, 2 otariids) and three cetaceans among the principal mammalian predators. Among the piscine predators, Salmonidae (salmon and char; 10 species), Gadidae (cod, etc.; 6 species), and Pleuronectidae (flounders; 7 species) stand out. The strongest documentation for the importance of sand lance in diets is, in general, for seabirds, particularly the alcids and larids (table 1), and our discussion emphasizes these predators.

Food availability is an important factor often affecting reproductive success of seabirds, either directly, by diminished food supply leading to starvation, or indirectly, by increased foraging time leading to decreased nest guarding and thence to increased predation (e.g., Ainley and others 1994; Barrett and others 1987; Bukacinska and others 1996; Coulson and Thomas 1985; Erikstad 1990; Evans and Nettleship 1985; Furness and Barrett 1985; Hamer and others 1991; Harris 1969, 1984; Martin 1989; Monaghan and others 1989; Nettleship 1972; Piatt and Anderson 1996; Vader and others 1990; and many others). Food quality also can affect reproductive success (e.g., Harris and Hislop 1978, Hunt and others 1996, Thompson and others 1996, Vermeer 1978). The effect of availability of sand lance, in particular, on reproductive

success of their predators clearly depends on the availability of suitable alternate prey—not only on the population size of other forage species but also on their distribution, in terms of their distance and depth relative to the flying and diving abilities of the predators and diurnal migrations in the water column (e.g., Anker-Nilssen and others 1997, Brown and Nettleship 1982, Harris and Riddiford 1989, Pearson 1968, Phillips and others 1997, Piatt and Nettleship 1985, Vermeer and others 1979). In some cases, predators can partially mitigate the effects of poor foraging conditions by adjusting their time budgets (e.g., Burger and Piatt 1990; Furness 1996; Monaghan and others 1994, 1996; Piatt 1987; Thompson and others 1996; Uttley 1992; Uttley and others 1994), and sometimes adjustments are made in avian fledging time (Barrett and Rikardsen 1992). The ability to adjust time and energy budgets is limited (Hamer and others 1993, Thompson and others 1996), however, not only by seasonal and behavioral constraints but also by the life history of the predator, including the costs of deferred reproduction. Furthermore, the information in Furness and Barrett (1991b) and Bailey and others (1991) shows that factors other than simple availability and accessibility must also be involved.

In some cases, sand lance seem to have a clear importance for seabird reproductive success, although most of the relevant data are, of necessity, correlative. Most studies that investigated the relation between sand lance availability and seabird nesting success have found a close association between them. Sand lance are likely to be important in many other cases, perhaps especially in the period when juveniles first become independent, which is a time of high mortality for many vertebrates. We present here the cases with the best evidence for the impact of sand lance on reproductive success: Great skuas in the United Kingdom switched to other foods as sand lance diminished, but the switch in diet necessitated a decrease in territory attendance; reproductive success then declined, because of increased predation on unguarded chicks by neighboring adults (Hamer and others 1991). Furthermore, in years of high abundance of sand lance, laying dates were earlier, clutch volumes were greater, and fledging success was higher than in years of low sand lance abundance (Ratcliffe and others 1998). Low reproductive success of parasitic jaegers was correlated with low territory attendance and slow chick growth rates in years when sand lance recruitment in the United Kingdom was poor; body condition was poor and breeding commonly was deferred (Phillips and others 1996). Breeding densities of shags plummeted when stocks of herring and sand lance crashed, and in another situation, poor breeding success was related to herring abundance and sand lance size (Aebischer 1986 and Wanless 1992). Black-legged kittiwakes in several locations, and Arctic terns and common terns in the United Kingdom, reproduced poorly when sand lance were not abundant (Beaman 1978; Furness and others 1996; Harris and Riddiford 1989; Monaghan and others 1989, 1992; Springer and others 1984). In addition, the distribution of kittiwake breeding colonies may reflect sand lance distribution and abundance (Lock 1986). Common murres had higher rates of chick feeding, higher chick weights, and higher fledging success in years when sand lance were abundant; in poor sand lance years, they increased their foraging effort, but this was insufficient to prevent high rates of chick loss in the United Kingdom, where sand lance are a primary prey (Uttley and others 1994). Likewise, in Norway, reproductive success of Atlantic puffins and other seabirds plummeted when herring and sand lance stocks crashed, except where sand lance remained sufficiently available as alternate prey (Barrett and others 1987, Lid 1981). Additional studies have shown that Atlantic puffins in the United Kingdom had low reproductive success (smaller

food loads, low chick weights, high chick mortality) when sand lance became rarer (Harris 1984, Harris and Birkhead 1985, Martin 1989). Tufted puffins also are sensitive to low abundances of sand lance at several sites in British Columbia and Alaska (Vermeer 1978, 1979, 1980; Vermeer and others 1979; Wehle 1983). The reproductive success of rhinoceros auklets seems to depend quite often on the abundance of sand lance on the coasts of British Columbia and Washington: food loads were larger, chicks grew faster, larger, and fledged sooner and more often when sand lance were readily available (Bertram and Kaiser 1993; Bertram and others 1991; Vermeer 1978, 1979, 1980; Wilson and Manuwal 1986). In northern Japan, rhinoceros auklet chick survival, growth, and fledging weight were higher in a year when food was delivered in larger loads and more frequently; sand lance (*A. personatus*) was one of two species delivered in larger loads in the more successful breeding year (Watanuki 1987).

Interestingly, there may be ramifying effects in other parts of the food web of variation in the relation between avian predators and piscine prey: sand lance are an important prey for the black-legged kittiwake in the Bering Sea, as elsewhere. When the kittiwake had poor foraging conditions and reproductive success on Round Island, Alaska, the mating system of red foxes, whose principal prey there is kittiwakes, changed from polygyny to monogamy, and reproductive success declined (Zabel and Taggert 1989). Foxes also prey opportunistically on sand lance when the substrata the latter are buried in are exposed during low tides (Nairn 1977, Shepherd 1988). On Kodiak Island, Alaska, foxes have been reported to displace crows that have located buried sand lance and excavate the fish for themselves, and conversely, crows sometimes obtain sand lance from holes dug by foxes (Shepherd 1988).

## Complex Interactions of Forage Fishes, Their Predators, and Commercial Fisheries

Links between decreased abundance of suitable forage fish and marine predators' reproductive success or population size have been suggested or reported from many regions of the world, from the coasts of Peru (Idyll 1973, McCall 1984, Schaefer 1970) and South Africa (Burger and Cooper 1984, Crawford and Dyer 1995, Crawford and Shelton 1978) to the Bering (National Research Council 1996, Straty and Haight 1979) and Barents Seas (Erikstad 1990, Vader and others 1990). In most of these cases, intense commercial fisheries are believed to play at least some role, and in some cases a major role, in the depletion of prey stocks. Indeed, some authors show that any diversion of prey from avian or mammalian predators to industrial fisheries (or vice versa) probably reduces energy available to the other (e.g., Furness 1978, 1996; Schaefer 1970). We found two cases in which depletion of sand lance stocks by commercial fisheries probably contributed to decreases in seabird reproduc-tive success (in the North Sea; e.g., Barrett and others 1987, Evans and Nettleship 1985, Lid 1981, Monaghan 1992; and in some locations near Japan, Hashimoto 1991), although it is uncertain that fisheries are solely accountable (Bailey 1989a, 1991). In any case, despite the lack of systematic examination of the ecological consequences of commercial fishing (Parsons 1996), the number of accumulating correlations between prey depletion and predator population crashes sends a cautionary message that intensive harvesting of prey can cause or contribute to predator population crashes and prevent predator population recovery (even when the crash was caused initially by some other factor, such as an El Niño event).

If sand lance begin to be commercially harvested in regions where they have not previously been harvested (such as Alaska), their availability to consumers is likely to change. Some of the predator species most likely to be affected by a serious decrease

in sand lance availability in the northeastern Pacific (see table 1, A and B) include sooty shearwaters, pelagic and red-faced cormorants, glaucous-winged gulls, black-legged kittiwakes, common murres, pigeon guillemots, horned and tufted puffins, and rhinoceros auklets, as well as several species of marine mammals. Furthermore, because sand lance have the unusual behavior of burying themselves in sand and only some predators are known to be able to extract them from burial sites, it is possible that this particular source of food (and style of foraging) is ecologically important to these predators (crows, ravens, eagles, some gulls; perhaps cod [see Girsa and Danilov 1976], and humpback whales [see Hain and others 1995]).

On the other hand, intensive harvest of certain predators (or competitors) of sand lance may release sand lance populations, thereby increasing their availability to others, as is suggested for other systems (Beddington and May 1982, Fogarty and Murawski 1998, Furness 1984b, Furness and Ainley 1984). For example, in the North Sea and in the northwest Atlantic, massive harvesting of herring, mackerel, whiting, and cod was associated with an increase of sand lance (Bowman and others 1984; Fogarty and others 1991; Furness 1982; Hempel 1978a, 1978b; Payne and others 1990; Sherman and others 1981; Winters 1983). Because sand lance may compete with planktivorous whales for copepods (Payne and others 1990), industrial harvesting of such whales might increase the sand lance populations, which in turn become prey for piscivorous predators. Harvest of adult pollock in the Bering Sea may have led to an increase of sand lance and capelin in the Bering Sea (Ainley and others 1994), although it also may have reduced the availability of an important prey for Steller sea lions (Merrick and others 1997).

Although the number of prey fish taken by some predators is sometimes used as an argument for predator control to “protect” commercial and sport fisheries, a mere count (or estimate) of the numbers of fish consumed by the predator is insufficient to establish that this predator is responsible for limiting the size of the prey fish population (e.g., Furness 1984a). Even though bird and mammal predators are sometimes estimated to take large numbers of a prey-fish population (e.g., Furness 1984a, 1990; Furness and Tasker 1997; Rae and Shearer 1965; Wiens and Scott 1975), the impact of this source of mortality on the population often may be small compared to others; for instance, commercial pelagic fisheries commonly take 50 to 70 percent of their prey population, leaving little for their natural predators (Furness and Ainley 1984). One must take into account that some of the fish taken by the predator would have died anyway, of other causes. What is really needed is the entire, age-specific schedule of mortality for the prey population, by predator species, so that the effect of all predators can be put in perspective. The location of the fishery in relation to predator colonies also needs to be considered, as well as the response of both predators and fisheries to changes in prey abundance (Furness and Tasker 1997, Harwood and Croxall 1988). Still more important is the effect on predator success of changing prey availability (daily, seasonal, annual, decadal, etc.; e.g., Hofmann and Powell 1998, Lauck and others 1998, Steele 1998). To address the impact of fisheries on wildlife populations is as important as the reverse, in the context of current global concerns about the preservation of biodiversity.

Sand lance, along with eulachon, herring, capelin, and other small schooling fishes have long been recognized as a critically important resource for a multitude of predators (Ashmole 1971, Bowman 1913, Einarsson 1951, Isakson and others 1971,

Langham 1971b, May and others 1979, Norcross and others 1961, Reay 1970, Winters 1981, Wright and others 1996, and many others). The lesson of the forage fishes reaches far back into Native lore: traditional knowledge among the Tlingit tribal groups along the coast of southeast Alaska emphasizes the idea that herring supported everybody, from whales to bears to humans.[1] Forage fishes constitute an ecological cornerstone (Willson and others 1998, many others) for a widely ramifying food web that encompasses not only the pelagic zone, the nearshore, and the intertidal zone but also terrestrial areas. Corvids and eagles carry sand lance and other forage fishes to their nestlings, and corvids sometimes store prey in trees or in meadow grasses (authors' observations); both processes bring marine-derived nutrients to terrestrial systems. More dramatic is the deposition of unused prey and digested fish material around the nests of seabirds. These deposits have been exploited commercially in many parts of the world (e.g., Crawford and Shelton 1978, Hutchinson 1950, Idyll 1973), but in addition, they can alter soils and plant communities in colonies (e.g., Furness and Barrett 1985; Smith 1978, 1979), contribute nutrients to the sea near the bird colonies (e.g., Bosman and Hockey 1986, Bosman and others 1986, Wiens and Scott 1975; but see also Bédard and others 1980), and support an enriched terrestrial food web near the colonies, at least in some situations (e.g., Polis and Hurd 1996).

The abundant evidence of important ecological links between forage fishes as prey and their numerous predators, and among the predators themselves, raises the obvious issue of cascading ecological effects when one portion of the interlocking web is altered. Furthermore, it is not to be expected that responses to perturbation will necessarily be linear (e.g., Anker-Nilssen and others 1997, Piatt and Methven 1992). May and others (1979) state that multispecies systems "will often manifest complex 'catastrophic' behavior..., whereby the system is discontinuously transformed to a different equilibrium state as harvesting rates increase, or as environmental circumstances alter. This transformation will not usually be continuously reversible....Since these catastrophic changes are seldom, if ever, predictable in a quantitative sense, and since they can be expected to occur in almost any severely exploited ecosystem, the need for conservatism and contingency planning is emphasized." When such ecological thresholds may be crossed, it becomes especially important to set harvesting levels that account for uncertainty of stock abundance and biological condition (e.g., Frederick and Peterman 1995). Considering the ramifying effects of these predator-prey interactions for both aquatic and coastal terrestrial foodwebs, it is clear that any factor (from overfishing to global warming) that impacts forage-fish populations may have cascading effects in the broad foodweb.

The general procedure of harvesting natural resources, perhaps especially fish stocks, has customarily been virtually unbridled exploitation, until the resource is depleted or some watchdog notices serious ecological damage (e.g., Avery and Green 1989, Dayton 1998). Because intense harvesting almost invariably disrupts natural systems, some negative impacts can readily be predicted in anticipation of the harvesting activity, but little is done about the ecological problem until damage becomes painfully evident. Therefore, the above authors argue that the burden of

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[1] Personal communication. [Date unknown]. Sitka Tribal Group, [address unknown].

proof would be better placed on the exploiters of the resources, to show that resource harvesting would not lead to unacceptable resource depletion, habitat destruction, and ecosystem disruption. Others have specifically suggested a very conservative upper limit on harvest levels (e.g., Roughgarden 1998), the avoidance of harvesting juvenile fish (e.g., Myers and Mertz 1998), and the establishment of new management goals and institutions (Fujita and others 1998).

As industrial fish harvesting continues, the higher trophic levels become depleted, and harvesting then shifts to lower trophic levels (Pauly and others 1998). Forage fishes are now harvested intensively in many regions of the world, but case studies indicate that "fishing down the food web" is inherently unsustainable (Pauly and others 1998). Much of the harvest of certain forage fishes is destined, moreover, for the production of fish meal for farmed fish, often in parts of the world far from the origin of the forage fishes (e.g., Fischer and others 1997, Jensen and Keller 1990, Kaushik 1986). Thus, nutrient cycling in the area of origin is disrupted by depletion, and that in the destination area is disrupted by augmentation, both of which have the potential to alter important ecological relations.

## What Do We Need to Know?

Foremost among the information needs is the need for more understanding of the biology of sand lance in relation to predation and the rest of the food web (Smith 1995): variation in food value, seasonality, and vulnerability of different populations and different species in differing circumstances. For example, it seems that the seasonal pattern of *A. personatus* may differ from that of its congeners; if so, it would be interesting to know why, and how this seasonal difference affects potential predators. The food value of sand lance differs among species, populations, locations, and seasons, not to mention age and sex, but much more information is required on this variation, set in a context of such variation among other forage fishes (and hence their substitutability as prey) and energy budgets of the predators. Age-specific mortality risks are essential to understanding the impacts of predation and commercial harvesting on sand lance populations. Furthermore, the paucity of information on predator diets in the nonbreeding season, while understandable, is regrettable, because this time of year can be critical to population status and because juvenile vertebrates, newly independent of their parents, commonly forage less effectively than adults and suffer heavy mortality as a result. It is also important to learn more about the relation of sand lance and other forage fishes to predator reproductive success—information is needed on more species of predator, in more places, under more conditions.

More and better science, however, is obviously insuffient to protect any marine food web from disruption by humans. Appropriate incorporation of scientific understanding into management plans depends on economic, and hence on social and political, forces, which must be understood themselves (Lavigne 1996, Policansky 1998). Scientific understanding therefore must be available to and comprehended by the relevant decisionmaking bodies and the general public to permit informed, balanced decisions.

## Acknowledgments

We are most grateful to our long-suffering and talented librarian, Lillian Petershoare, and her assiduous assistant, Rebecca Wright, for tracking down most of these references, to the Exxon Valdez Trustee Council for funding most of the publication costs, and to R. Dunlap, S.M. Gende, and L. Haldorson for reviewing the manuscript.

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region**

| | | Proportion of sand lance in diet[b] | | | |
|---|---|---|---|---|---|
| Species | Location[a] | <10% | 10-50% | >50% | References |
| Red-throated loon | BC | | XC’ | | Reimchen and Douglas 1984 |
| | UK | | | XC’ | Furness and Barrett 1991 |
| Fulmar | AK-GoA | X | X’? | | Sanger 1986, 1987; Hatch 1993 |
| | Bering | none | | | Fisher 1952 |
| | UK | | X’ | X’ X’ X | Furness and Todd 1984, Furness and Barrett 1991, Fowler and Dye 1987, Harris and Riddiford 1989 |
| | Barents | none | | | Fisher 1952 |
| Sooty shearwater | BC | | | X | Sealy 1973 |
| | CA | none | | | Chu 1984 |
| | AK-GoA | X | | X’ | Krasnow and Sanger 1986; Krasnow and others 1979; Sanger 1986, 1987 |
| Short-tailed shearwater | AK-GoA | XA | XA’ | | Krasnow and Sanger 1986; Sanger 1986, 1987 |
| | AK-Bering | | XA’ | | Ogi and others 1980 |
| Gannet | UK | | XC? | X’ X’ | Martin 1989, Nelson 1966, Wanless 1984 |
| | Gulf St. Lawrence | | X | | Cairns and others 1991 |
| Double-crested cormorant | BC | | XC | | Robertson 1974 |
| | Gulf St. Lawrence | | X’ | X’ X’ | Cairns and others 1991, Pilon and others 1983, Rail and Chapdelaine 1998 |
| | CA | X | | | Ainley and others 1990 |
| Pelagic cormorant | BC | | XC XA | XC | Robertson 1974; Sanger 1986, 1987 |
| | AK-Aleut | | | X | Springer 1991 |
| | CA | none | | | Ainley and others 1990 |
| Red-faced cormorant | Bering | X XA | XA’ | XC’ X | Bradstreet 1985; Hunt and others 1981a, 1981c; Schneider and Hunt 1984; Springer 1991; Springer and others 1996 |
| Shag | UK | | | X XC XC | Furness and Barrett 1991; Harris and Riddiford 1989; Harris and Wanless 1991, 1993; Lunsden and Haddow 1946; Pearson 1968; Snow 1960; Wanless and others 1993 |
| | | | | XA XC | |
| | | | | XA XC | |
| | | | | XA XA | |

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region (continued)**

| Species | Location[a] | Proportion of sand lance in diet[b] <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| | Norway | | X’ | XC’ XA’ | Barrett 1996, Barrett and Furness 1990, Barrett and others 1990 |
| Great cormorant | UK | | X | XC, XC’ | Davies and Feltham 1996, Okill and others 1992, Pearson 1968 |
| | Norway | | XA | | Barrett and others 1990 |
| | Gulf St. Lawrence | X | | X’ | Cairns and others 1991, Pilon and others 1983 |
| Oldsquaw | AK-GoA | | X X(W) | | Nettleship and others 1984; Sanger 1986; Sanger and Jones 1982b, 1984; Sanger and others 1979, 1984 |
| | Beaufort | none | | | Johnson 1984 |
| Parasitic jaeger | UK | | | X XC | Furness and Barrett 1991a, Phillips and others 1996 |
| Great skua | UK | X | XA XA | XC XC’ XA’ X XC’ XC | Beaman 1978, Furness 1979, Furness and Hislop 1981, Hamer and others 1991, Klomp and Furness 1992, Phillips and others 1997 |
| | Iceland | | | X | Furness 1979 |
| Slaty-backed gull | Japan | X’ | | | Watanuki 1988 |
| Great black-backed gull | UK | | XA’ | X | Beaman 1978, Furness and Barrett 1991 |
| Lesser black-backed gull | UK | | | XC | Pearson 1968 |
| Mew gull | AK-GoA | | X | | Sanger 1986 |
| Glaucous gull | Chukchi | | X | | Schwartz 1996 |
| Glaucous-winged gull | AK-GoA | | XA XC XC | XS XC’ XC’ XC’ XC XC | Baird 1986, 1990; Hatch and others 1978; Moe and Day 1979; Murphy and others 1984; Sanger 1986; Wehle 1978 |
| | AK-Aleut. | | XA’? | | Trapp 1979 |
| | BC | | XC’ | | Vermeer 1982 |
| Black-legged kittiwake | AK-GoA | | X XA XS | XA’ XC’ XC’ XC, XA X XC XC | Baird 1990; Hatch and others 1978, 1993; Jones and Peterson 1979; Krasnow and Sanger 1986; Krasnow and others 1979; Nysewander 1986; Piatt and Anderson 1995; Sanger 1986, 1987 |
| | Bering | X XA’ | XA’ | XA’ XA’ XC’ XC’ X | Bradstreet 1985; Hatch and others 1993; Hunt and others 1981a, 1981c; Murphy and others 1991; Schneider and Hunt 1984; Springer 1991; Springer and others 1987, 1996; Wehle 1978 |
| | Chukchi | | X’ XA | XC | Schwartz 1966, Springer and others 1984 |

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region (continued)**

| Species | Location[a] | Proportion of sand lance in diet[b] <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| | Norway, Russia | X X | XC’ | X’ | Barrett 1996, Barrett and Krasnow 1996, Furness and Barrett 1985 |
| | UK | | XA | XC XC<br>XC XC<br>X’ XC<br>XC’ XC’ | Coulson and Thomas 1985, Furness and Barrett 1991a, Galbraith 1983, Hamer and others 1993, Harris and Riddiford 1989, Harris and Wanless 1990, Monaghan and others 1996, Pearson 1968, Wanless and Harris 1992 |
| Aleutian tern | AK-GoA | | XA XS XC’ | | Baird 1986, Sanger 1986, |
| Arctic tern | AK-GoA | XA | XS XC’ | | Baird 1986, Sanger 1986 |
| | Quebec | | XC’ | | Chapdelaine and others 1985 |
| | UK | | | XC’ XC<br>XC’ XC<br>XC’ XC | Ewins 1985; Furness and Barrett 1991; Monaghan and others 1989a, 1992; Pearson 1968; Suddaby and Ratcliffe 1997; Uttley and others 1989 |
| | Germany | X | | | Frick and Becker 1995 |
| Roseate tern | CT, NY, ME | | | XC’ XC’ | Richards and Schew 1998, Safina and others 1990, Shealer and Kress 1994 |
| Common tern | NY, VA | X | XC’ X? | | Erwin 1977, Safina and Burger 1988, Safina and others 1990 |
| | Quebec | | XC | | Chapdelaine and others 1985 |
| | Ontario | none | | | Morris 1986 |
| | UK | | XC XC | XA’ | Pearson 1968, Taylor 1979, Uttley and others 1989 |
| | Germany | | XC | | Frick and Becker 1995 |
| Sandwich tern | UK | | | XC X’ | Fuchs 1977, Pearson 1968 |
| Little tern | UK | | X’? | | Norman 1992 |
| Razorbill | UK | | | XC XC’<br>XC XC<br>XC’ X<br>XA (W) | Blake 1984, in Bradstreet and Brown 1985; Furness and Barrett 1991; Harris and Wanless 1986; Harris and Riddiford 1989; Lloyd 1979 |
| | Norway, Russia | | XC’ | XC XA’, XC | Barrett and Furness 1990, in Bradstreet and Brown 1985; Furness and Barrett 1985 |
| | Denmark, Sweden | | | XA’ (W) | Blake 1983 |
| | E. Can. | none | | XC’ XC | Bédard 1969, in Bradstreet and Brown 1985 |
| | W. Grnld | | | XC | Chapdelaine and Brousseau 1996 |
| Common murre | AK-GoA | XC X(W) | X’ | X’ | Hatch and others 1978; Krasnow and Sanger 1986; Krasnow and others 1979; |

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region (continued)**

| Species | Location[a] | Proportion of sand lance in diet[b] <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| | | | | | Peterson 1986; Piatt and Anderson 1996; Sanger 1986,1987; Sanger and others 1979 |
| | Bering | XC XA | XC XA' | X' X' X | Bradstreet 1985; Hunt and others 1981a, 1981c; Piatt and others 1988; Springer 1991; Springer and others 1987, 1996 |
| | Chukchi | | XA X | | Schwartz 1966, Springer and others 1984 |
| | OR, CA | none | XA | | Ainley and others 1996, Scott 1990 |
| | BC | | XA | | Vermeer 1992 |
| | Nfld., Labrador | X(W) XA XC XC | XC' XC' | X | Birkhead and Nettleship 1987, Bradstreet and Brown 1985, Burger and Piatt 1990, Cairns and others 1990, Tuck 1960 |
| | Norway, Russia | XC' | XC X XC' | XC' X | Barrett and Krasnov 1996; Barrett and others 1997; Furness and Barrett 1985; Gabrielson 1996, in Tuck 1960 |
| | Denmark, Sweden, Germany | XC | XA'(W), XA(W) | | Blake 1983, Durinck and others 1991, Leopold and others 1992 |
| | UK | XC | XC XA'(W) | XC XC, XC' XC, XC X XC' XC XC' XA' XC XC XA | Birkhead 1977; Blake 1984; Blake and others 1985; Bradstreet and Brown 1985; Furness and Barrett 1991a; Halley and others 1995; Harris and Riddiford 1989; Harris and Wanless 1985, 1986, 1988, 1995; Hatchwell 1991; Pearson 1968; Uttley and others 1994 |
| | N. Atlantic | | | XC' | Bradstreet and Brown 1985 |
| Thick-billed murre | AK-GoA | X | | | Sanger 1986, 1987 |
| | Bering | XA XA' X XA' | XC' X | | Bradstreet 1985; Hunt and others 1981; Pearson 1968; Piatt and others 1988; Springer 1991; Springer and others 1987, 1996 |
| | Chukchi | X,X | | | Schwartz 1966, Springer and others 1984 |
| | N. Pacific | none | | | Ogi 1980 |
| | Japan | | | X (W) | Hashimoto 1993 |
| | NWT | none, none XC' | | | Bradstreet 1980, Bradstreet and Brown 1985, Gaston and Nettleship 1981 |
| | Nfld., Labrador | X(W) XC | X'(W) | | Birkhead and Nettleship 1987, Elliot and others 1990, Tuck 1960 |
| | Quebec | XC | | | Tuck and Squires 1955 |
| | Norway, Russia | XC XA | XC' | X X XC' | Barrett and Furness 1990; Barrett and others 1997; Furness and Barrett 1985, in Tuck 1960 |

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region (continued)**

| Species | Location[a] | Proportion of sand lance in diet[b] <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| Pigeon guillemot | AK-GoA | X | | XC' XC' XC' | Hayes and Kuletz 1997, Krasnow and Sanger 1986, Oakley and Kuletz 1996, Sanger 1986 |
| | BC | XC | XC' | | Drent 1965; Ewins 1993, and refs. therein |
| Black guillemot | Quebec, Gulf St. Lawrence | XC XC XC XA X XC | | | Cairns 1981, 1987; Cairns and others 1991; Gaston and others 1985; Winn 1950 |
| | NWT | none | | | Bradstreet 1980 |
| | Norway | | XC' | X | Barrett and Furness 1990, Furness and Barrett 1985 |
| | UK | XA (W) | XC' | XC' XC' | Ewins 1990, Furness and Barrett 1991a, Harris and Riddiford 1989 |
| | N. Atlantic | | XC' | | Bradstreet and Brown 1985 |
| Spectacled guillemot | Japan | | | XC XC | Aotuka et al. 1995, Minami and others 1995 |
| Horned puffin | AK-GoA | | X XA XC XC XC' XA XS XC' | X' XC X' XC' XC XC' XC XC | Amaral 1977; Hatch 1984; Hatch and Sanger 1992; Hatch and others 1978; Jones and Peterson 1979; Krasnow and Sanger 1986; Manuwal and Boersma 1978; More and Day 1979; Peterson 1986; Piatt and Anderson 1996; Sanger 1986, 1987, in Vermeer and others 1979; Wehle 1983 |
| | Bering | X XA XA, XS | X X' | XC | Bradstreet 1985; Hunt and others 1981a, 1981c; Springer and others 1996; Wehle 1983 |
| Tufted puffin | AK-GoA | XC XA none | XC X' XS XA XS XC XC' | XC' XC' XC XC | Amaral 1977; Baird 1990; Baird and Jones 1986; Hatch 1984; Hatch and Sanger 1992; Krasnow and Sanger 1986; Manuwal and Boersma 1978; Sanger 1986; 1987; Piatt and Anderson 1996, in Vermeer and others 1979; Wehle 1978, 1983 |
| | Bering | none | XC | X' | Hunt and others 1981a, 1981c; Springer and others 1996; Wehle 1983 |
| | BC | | | XC' XC | Vermeer 1979, Vermeer and others 1979 |
| Atlantic puffin | UK | | XC' | XC' XC' XC XC' XC' XC' XC' XC' XC XC' XC XC' | Barrett and Rikardsen 1992; Bradstreet and Brown 1985; Corkhill 1973; Harris 1970, 1984, 1988; Furness and Barrett 1991; Harris and Hislop 1978; Harris and Riddiford 1989; Harris and Wanless 1986; Hislop and Harris 1985; Hudson 1979; Martin 1989; Pearson 1968; Rodway and Montivecchi 1996 |

**Table 1A—Summary of the relative importance of sand lance in the diets of seabirds, by species and geographic region (continued)**

| Species | Location[a] | Proportion of sand lance in diet[b] <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| | Norway, Russia | X(W) | X X’ | XC? XC’ XA’ | Barrett 1996, Barrett and Krasnow 1996, Barrett and others 1987, Falk and others 1992, Furness and Barrett 1985, Lid 1981 |
| | N. Atlantic | | | XC’ X(W) | Bradstreet and Brown 1985, Falk and others 1992 |
| | Nfld. | | XC’ | XC’ | Bradstreet and Brown 1985, Brown and Nettleship 1982 |
| Rhinoceros auklet | N. Pacific | | | XC | Vermeer 1979 |
| | Japan | | X’C | | Watanuki 1987 |
| | BC | | XC’ | XC’ XC’ XC XC’ XC’ XC | Bertram and Kaiser 1993; Bertram and others 1991; Burger and others 1993; Gaston and Dechesne 1996; Summers and Drent 1979; Vermeer 1979, 1980; Vermeer and Westrheim 1984 |
| | WA | | | XC XC’ XC | Richardson 1961, Wilson and Manuwal 1986 |
| | AK | | XC XA | XC XC | Hatch 1984; Hatch and others 1984; Sanger 1986, 1987 |
| | CA | none | | | Gaston and Dechesne 1996 |
| Cassin’s auklet | BC | | | XA | Burger and Powell 1990 |
| | AK-GoA | none | | | Sanger 1987 |
| | CA | none | | | Manuwal 1974 |
| Kittlitz murrelet | AK | X | X | | Sanger 1986, 1987 |
| Ancient murrelet | BC | none (W), XA | XS | XF | Gaston and others 1993, Sealy 1975b |
| | Okhotsk | | X? | | Gaston 1994 |
| | AK-GoA | X | | | Sanger 1986 |
| Marbled murrelet | AK-GoA | X | X X X X? X(W) | | Hobson and others 1994; Krasnow and Sanger 1986; Krasnow and others 1979; Piatt and Anderson 1996; Sanger 1986, 1987; Sanger and Jones 1982a; Sanger and others 1979; Vermeer and others 1979, 1986 |
| | BC | | XA? XC? X? | XA XC XA, XF | Carter 1984, in Carter and Sealy 1990; Mahon and others 1992; Rodway and others 1992; Sealy 1975b; Vermeer 1992; Vermeer and others 1986, in Hobson and others 1994 |
| | Okhotsk | | X? | | Konyukhov and Kitaysky 1995 |

[a] Abbreviations for locations are standard, except that AK-GoA indicates the Gulf of Alaska, Nfld. is Newfoundland, Grnld. is Greenland.
[b] Proportion in the diet is based on whatever measures were used by the authors (mass, volume, numbers, frequency, or some combination). An X shows that the stated proportion was sometimes achieved by the species in that region; the X is placed in the highest category recorded, and lower proportions (variation among years, seasons, or sites) also may have occurred (indicated by X’). Very small samples (approximately < 10 predators of that species) are omitted. A = adult, C = chick, S = subadult., F = fledglings, (W) = winter, ? = estimates.

**Table 1B—Marine mammals that prey on sand lance[a]**

| Species | Location | Proportion of sand lance in diet | | | References |
|---|---|---|---|---|---|
| | | <10% | 10-50% | >50% | |
| Grey seal | UK | | X' X' | X' X' X | Hammond and Prime 1990, Hammond and others 1994, Prime and Hammond 1990, Rae 1968, Thompson and others 1996 |
| | Iceland | X | | X' X' | Hauksson 1984, Hauksson and Ólafsdóttir 1995, Hauksson and others 1995 |
| | NS, Nfld | none X | | X X | Benoit and Bowen 1990a, 1990b; Bowen and Harrison 1994; Bowen and others 1993 |
| Harbor seal | OR | | X | | Brown and Mate 1983 |
| | BC | none | X | | Olesiuk and others 1990, Spalding 1964 |
| | AK-GoA | X' none X | | | Imler and Sarber 1947, Pitcher 1980, Pitcher and Calkins 1979 |
| | Bering | X none | | X' | Kenyon 1965; Lowry and Frost 1981, in Lowry and others 1982 |
| | Okhotsk | none | | | Wilke 1954 |
| | MA, NH | | | X' | Payne and Selzer 1989 |
| | Iceland | X | | X' | Hauksson 1984, Payne and Selzer 1989 |
| | UK | X | | X' X' X'(W) | des Clers and Prime 1996; Pierce and others 1990, 1991; Thompson and others 1996; Tollit and Thompson 1996 |
| | Norway | none | | X' | Bjørge and others 1995, Olsen and Bjørge 1995 |
| Spotted seal | Bering | | X? X | X' | Bukhtiyarov and others 1984, in Lowry and others 1982 |
| Harp seal | Nfld., Labrador | | XJ' XA' | X' XJ'[b] | Beck and others 1993; Lawson and Stenson 1995, 1997 |
| | Arctic Canada | X | | | Kapel 1995 |
| | Grnld. | | | X' X' | Kapel 1995, Kapel and Angantyr 1989 |
| | Barents | X' X | | X' | Nilssen 1995, Nilssen and others 1995, Nordøy and others 1995 |
| Northern fur seal | Bering | X X X none, none, none none, none | X? X | X X | Antonelis and others 1986; Fiscus and others 1964; Hacker and Antonelis 1986, in Frost and Lowry 1987; Kajimura 1984; Kenyon 1956; Livingston and Dwyer 1986, in Lowry and others 1982; Lucas 1899; Perez and Bigg 1986; Wilke and Kenyon 1957 |
| | AK-southeast | none | | | Wilke and Kenyon 1952 |
| | AK-GoA | X | | X, X | Kajimura 1984, Perez and Bigg 1986, Taylor and others 1955 |
| | CA, WA, BC | X, none, X | | | Kajimura 1984, Perez and Bigg 1986, Spalding 1964 |
| | Japan | none | | | Taylor and others 1955 |

**Table 1B—Marine mammals that prey on sand lance[a] (continued)**

| Species | Location | Proportion of sand lance in diet <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| Steller sea lion | Bering | X? | X? | X'? | Castellini 1993; Frost and Lowry 1987, in Lowry and others 1982 |
| | AK-GoA | none none X | X X? | | Fiscus and Baines 1966, Imler and Sarber 1947, Mathisen and others 1962, Pitcher 1981, Thorsteinson and Lensink 1962 |
| | CA, BC | none, X | | | Pike 1958, Spalding 1964 |
| | AK | none | X | | Fiscus and Baines 1966, Imler and Sarber 1947 |
| Humpback whale | N. Pacific | | | X? | Frost and Lowry 1987 |
| | Bering | X? X? | | | Frost and Lowry 1981, Lowry and others 1982 |
| | AK-southeast | X? | | X'? | Baker and others 1992, in Mathews 1996 |
| | Nfld. | none | | | Whitehead and Glass 1985 |
| | MA, ME | | | X X' X | Overholtz and Nicolas 1979, Payne and others 1986, Weinrich and others 1992 |
| Fin whale | MA | | | X | Overholtz and Nicolas 1979 |
| | Nfld. | | X | | Lavigne 1996 |
| | Bering | none, X | X? | | Frost and Lowry 1987, Lowry and others 1982 |
| Minke whale | Bering, N. Pacific | X? | X? | | Frost and Lowry 1981, 1987; Nemoto 1957; Omura and Sakiura 1956, in Mathews 1996 |
| | Yellow Sea | | | X | Xu and others 1983 |
| | Okhotsk | | | X' | Kasamatsu and Tanaka 1992 |
| | Grnld. | | X? | X? | Jonsgård 1982, Larsen and Kapel 1993 |
| | Norway, Russia | X | X' | X' | Haug and others 1995, Nordøy and others 1995 |
| Beluga | E. Can. | X | X'? | | Lowry and others 1982 |
| | Grnld. | X | | | Lowry and others 1982 |
| | Barents, Bering, Chukchi, Okhotsk | X, none | | | Lowry and others 1982, Seaman and others 1982 |
| Atlantic white-sided dolphin | ME | | | X? | Gaskin 1992 |

[a] Footnotes as in table 1A, page 33.

**Table 1C—Predatory fishes that feed on sand lance[a]**

| Species | Location | Proportion of sand lance in diet | | | References |
|---|---|---|---|---|---|
| | | <10% | 10-50% | >50% | |
| Spiny dogfish | UK | X’ | X | | Rae 1967c, Holden 1966 |
| | MA | X(W) | | | Bowman and Langton 1978 |
| Pacific dogfish | BC | X’ | X | | Chatwin and Forrester 1953 |
| Small-spotted ray | France | | | X? | Rousset 1987 |
| Winter skate | MA | | X (W)?? | | Bowman and Langton 1978 |
| Thorny skate | NW Atlantic | | X’ | | Templeman 1982 |
| Herring | North Sea | | X’ | X’ X’ | Hopkins 1989, Hopkins and others 1989, Last 1989 |
| | NW Atlantic | X | | | Warzocha 1988 |
| Capelin | Nfld., Labrador | | X? | | Gerasimova 1994 |
| Rainbow smelt | Bering | | | X | Naumenko 1996 |
| Coho salmon | WA, OR | X | | | Brodeur 1991 |
| | BC | X none | X X’ | X | Beacham 1986, Healey 1978, Manzer 1969, Pritchard and Tester 1944, Robinson and others 1982 |
| | AK-GoA | none | | | Pearcy and others 1988 |
| | AK-southeast | | X X? | X’ | Murphy and others 1988, Reid 1961, Wing 1977 |
| | Bering | X? | | | Karpenko 1979, Morrow 1980, Wespestad 1987 |
| Sockeye salmon | BC | X X X | X? | | Beacham 1986; Healey 1978, 1991; Manzer 1969 |
| | AK-GoA | none | | | Pearcy and others 1988 |
| | Bering | | X? X? | X | Karpenko 1979, Morrow 1980, Straty 1974, Wespestad 1987 |
| | N. Pacific | none | | | Takeuchi 1972 |
| Pink salmon | BC | X? | X’ | | Beacham 1986, Healey 1991 |
| | AK-Aleut. | X | | | Simenstad and others 1977 |
| | AK-GoA | none, none | | | Pearcy and others 1988, Sturdevant and others 1996 |
| | AK-southeast | X | | | Murphy and others 1988 |
| | N. Pacific | none | | | Takeuchi 1972 |
| Chinook salmon | OR, WA | X | | | Brodeur 1991 |
| | BC | X | X X X’ | | Beacham 1986, Hart 1973, Healey 1978, Pritchard and Tester 1944, Robinson and others 1982 |
| | AK | X, none | | X X’ | Morrow 1980, Pearcy and others 1988, Reid 1961, Wing 1977 |
| Masu salmon | Japan | | X | X’ XJ XA X X | Asami and Hayano 1995, Fukataki 1969, Kato 1991, Kiso 1994, Kiso and Takeuchi 1994, Sasaki 1978 |

**Table 1C—Predatory fishes that feed on sand lance[a] (continued)**

| Species | Location | Proportion of sand lance in diet | | | References |
|---|---|---|---|---|---|
| | | <10% | 10-50% | >50% | |
| Amago salmon | Japan | | | X | Kato 1991 |
| Atlantic salmon | N. Atlantic | | X | X' X X | Dutil and Coutu 1988; Fraser 1987; Hislop and Webb 1992; Lear 1972, 1980, and refs. therein; Morgan and others 1986 |
| | Norway | X | | | Grønvik and Klemetsen 1987 |
| | NWT | X | | | Neilson and Gillis 1979 |
| Brown trout | Norway | | | X' | Grønvik and Klemetsen 1987 |
| Arctic char | Norway | | | X' | Grønvik and Klemetsen 1987 and refs. therein |
| | Baffin, Labrador, Quebec | X X | X' | X | Andrews and Lear 1956, Grainger 1953, Moore and Moore 1974 |
| Dolly Varden | AK-GoA | | | X | Narver and Dahlberg 1965, Townsend 1942 |
| | AK-southeast | | X | | Lagler and Wright 1962 |
| | Bering | | X | | Simenstad and others 1977 |
| | Okhotsk | | X | | Tokranov 1995 |
| Pollock | UK | | | X' | Potts 1986 |
| Pacific hake | BC | none | X | | Outram and Haegele 1972, Rexstad and Pikitch 1986 |
| Atlantic cod | Iceland | X? | | X' X' | Brown and Cheng 1946, Pálsson 1980, Rae 1968 |
| | Norway, Russia | none | | | Brown and Cheng 1946 |
| | UK | X | | X' X' | Brook 1885, Gibson and Robb 1996, Rae 1967a |
| | Faroes | | X | X' | Du Buit 1982, Rae 1967b |
| | North Sea, Baltic | | X? | | Brown and Cheng 1946 |
| | Quebec | none | | | Dunbar and Hildebrand 1952 |
| | NS, NB, Nfld. | X X X | X? | X' X' X X X' | Brown and Cheng 1946, Corbeil 1954, Kohler and Fitzgerald 1969, Lilly 1982, Lilly and Fleming 1981, Powles 1958, Scott 1968 |
| | MA | | | | Bowman and Langton 1978 |
| Greenland cod | Grnld. | | | X' | Jensen and Hansen 1931 |
| Pacific cod | BC | | | X' | Westrheim 1977, Westrheim and Harling 1983 |
| | Bering | X | X' | | Feder and Jewett 1981, Simenstad and others 1977 |
| | AK-GoA | X, none | X? | | Albers and Anderson 1985, Feder and Jewett 1981, Jewett 1978 |
| Haddock | Iceland | X X? | | | Brown and Cheng 1946, Pálsson 1980 |
| | Faroes | X | | | Du Buit 1982 |
| | Norway, Russia | none | | | Brown and Cheng 1946 |
| | NB, NS | X | X' X | | Homans and Needler 1944, Kohler and Fitzgerald 1969, Leim and Scott 1966, Scott 1968 |

**Table 1C—Predatory fishes that feed on sand lance[a] (continued)**

| Species | Location | Proportion of sand lance in diet <10% | 10-50% | >50% | References |
|---|---|---|---|---|---|
| | MA | X(W) | | | Bowman and Langton 1978 |
| Whiting | UK | | X’ | X? X’ X’ X’ X | Casey and others 1986, in Bromley 1988; Gibson and Robb 1996; Hislop and others 1991; Jones 1954; Mergardt and Temming 1997; Patterson 1985 |
| | Iceland | | X? | | Pálsson 1980 |
| Black rockfish | AK-GoA | | | X X | Rosenthal 1980, Rosenthal and others 1988 |
| Yellowtail rockfish | AK-GoA | | X | | Rosenthal and others 1988 |
| Dusky rockfish | AK-GoA | | X | | Rosenthal and others 1988 |
| Widow rockfish | AK-GoA | | X | | Rosenthal and others 1988 |
| Yelloweye rockfish | AK-GoA | | | X | Rosenthal and others 1988 |
| Quillback rockfish | AK-GoA | | X | | Rosenthal and others 1988 |
| Copper rockfish | AK-GoA | | X | | Rosenthal and others 1988 |
| Gray gurnard | UK | | | X’ | Gibson and Robb 1996 |
| Pacific sandfish | AK-GoA | | | X | Paul and others 1997 |
| | AK-Aleut. | | X | | Simenstad and others 1977 |
| Sand lance | Japan | | X? | | Okamoto and others 1989 |
| Yellow croaker *(Nibea albiflora)* | Japan | | X | | Nakai and others 1987 |
| European seabass | UK | | X’? | | Kelley 1987 |
| Mackerel | NW Atlant. | | X | | Warzocha 1988 |
| Spanish mackerel | Japan | | | X | Kishida 1986 |
| Petrale sole | BC | | | X | Westrheim and Harling 1983 |
| Rock sole | BC | | X | X X’ X’ | Simenstand and others 1977, Westrheim and Harling 1983 |
| | Bering | X | X’ | | Feder and Jewett 1981, Smith and others 1978 |
| | AK-GoA | | X | | Rosenthal 1983 |
| Yellowtail flounder | NS, NB | X | | X (eggs) | Pitt 1976; Scott 1968, 1972b |
| Starry flounder | Okhotsk | | X | | Tokranov 1995 |
| Pacific halibut | Bering | X | X | | Feder and Jewett 1981, in Simenstad and others 1977 |
| | NE Pacif. | | | X | Best and St. Pierre 1986 |
| | NW Pacif. | none | | | Orlov 1997 |
| | AK-GoA | X | X | | Roseneau and Byrd 1997, Rosenthal 1983 |
| Atlantic halibut | Norway | | | X | Andreason and others 1989 |
| | Iceland | none | | | McIntyre 1953 |
| | Faroes | | X’ | | McIntyre 1953 |
| American plaice | Nfld. | | | X X’ | Pitt 1973, Zamarro 1992 |
| | NW Europe | X | X’ X’ | | Gibson and Robb 1996, Pihl 1994, Todd 1915 |
| Turbot | Spain | | X | | Iglesias and Rodríguez-Ojea 1994 |

[a] Footnotes as in table 1A, page 33.

**Table 1D—Invertebrate predators of sand lance[a]**

| Species | Location | Proportion of sand lance in diet | | | References |
|---|---|---|---|---|---|
| | | <10% | 10-50% | >50% | |
| Veined squid | UK | | X | X | Collins and Pierce 1996; Pierce and Santos 1996; Pierce and others 1994, in Collins and Pierce 1996 |
| Short-finned squid | Nfld. | | | X' | Dawe and others 1997 |

[a] Footnotes as in table 1A, page 33.

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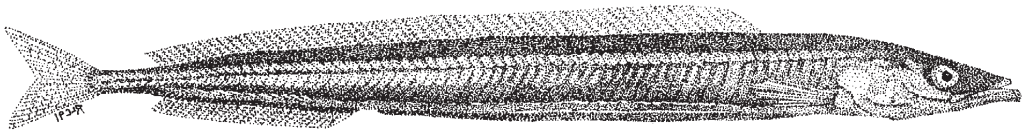

# Annotated Bibliography

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## Introduction

This bibliography contains over 1,700 published and unpublished references on the family Ammodytidae with an emphasis on the genus *Ammodytes*. The references are alphabetical by author and then by year of publication.

Abstracts and summaries are included for the references we have seen and those provided electronically by others. Abstracts written by the original authors are within quotation marks; abstracts not in quotation marks were written by the compilers of this bibliography.

For each reference, we provide keywords. For references obtained electronically, we used the keywords provided by others. References we were not able to review personally may contain information on additional subjects about sand lance not mentioned in the index.

The keywords have been further organized into taxonomic, geographic, subject, and predator indexes. For the taxonomic and predator indexes, we used the scientific or common name provided by the authors. No attempt was made to combine synonyms. For references in which no scientific name was provided, we used the most likely taxon.

## Bibliography

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Keywords: *Ammodytes*; commercial fishing.

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The study was conducted in the Saint Lawrence estuary, including adjacent portions of the Saguenay River and the northwestern Gulf of Saint Lawrence, during June-July 1973, June-Oct. 1974, and May-Sept. 1975. Probable spawning times, areas, and growth of larvae are discussed for sand lance.

Keywords: *Ammodytes*; Gulf of Saint Lawrence; growth; larvae; spawning.

**Ackman, R.G. 1971.** Pristane and other hydrocarbons in some fresh water and marine fish oils. Lipids. 6: 520-522.

Keywords: *Ammodytes*; composition.

**Ackman, R.G.; Eaton, C.A. 1971.** Investigation of the fatty-acid composition of oils and lipids from the sand launce *Ammodytes americanus* from Nova Scotia waters. Journal of the Fisheries Research Board of Canada. 28: 601-606.

“A commercial oil from sand launce (*Ammodytes americanus*), and triglyceride fractions from lipids of two samples of fish also from Nova Scotia waters, showed essentially the same fatty acid composition as herring oils, indicating that commercial utilization of sand launce oil would be practical. Minor differencies in the sand launce oil fatty acids included about the same levels of 20:1 and 22:1, and a somewhat higher figure for 16:1. Comparisons are also made with capelin oil and sand launce oils from Danish production.”

Keywords: *A. americanus*; Nova Scotia; lipids.

**Adams, J.A.; Seaton, D.D.; Buchanan, J.B.; Longbottom, M.R. 1968.** Biological observations associated with the toxic phytoplankton bloom off the east coast. Nature (London). 220: 24-25.

Keywords: *Ammodytes*; Atlantic; paralitic shellfish poisoning.

**Adkison, M.; Pascual, M.; Hilborn, R. [and others]. 1993.** Modeling the trophic relationships between fish and marine mammal populations in Alaskan waters. In: Is it food?: addressing marine mammal and seabird declines: workshop summary; [dates of meeting unknown]; [location unknown]. Alaska Sea Grant Rep. 93-01. Fairbanks, AK: University of Alaska: 54-56.

“It was also clear that the underlying fisheries data base had quite incomplete coverage of many of the important forage species, such as sand lance and squid. The fisheries data base was most complete for key commercial species, which were often not the primary food items of the age classes of mammals or birds that were of concern.”

Keywords: *A. hexapterus*; Alaska; importance.

**Aebischer, N.J. 1986.** Retrospective investigation of an ecological disaster in the shag *Phalacrocorax aristotelis*: a general method based on long term marking. Journal of Animal Ecology. 55: 613-630.

Between 1974 and 1976, the numbers of shags breeding on the Isle of May, southeast Scotland, changed from 1,076 to 497 pairs. Failure of the food supply (herring and sandeel stocks) was probably the main reason for poor breeding in those years.

Keywords: *Ammodytes*; Scotland; Isle of May; predators, (birds, shag).

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Keywords: *Ammodytes*; food web.

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“Annual chick production and first-year survival rates were each positively related to local herring abundance and to the mean size of sandeels collected by puffins rearing chicks on the island, but not to overall sandeel biomass in the southern North Sea.”

Keywords: *Ammodytes*; Scotland; Isle of May; importance; predators (birds, puffin, shag).

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Keywords: *Ammodytes*; predators (birds).

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Keywords: *Ammodytes*; Farallon Islands; predators (birds).

**Ainley, D.G.; Carter, H.R.; Anderson, D.W. [and others]. 1988.** Effects of the 1982-1983 El Niño-Southern Oscillation on Pacific Ocean bird populations. In: Ouellet, H., ed. Proceedings of the 19th international ornithological congress; [dates of meeting unknown]; [location unknown]. Ottawa, ON: University of Ottawa Press: 1747-1758.

Keywords: *A. hexapterus*; Pacific Ocean; predators (birds).

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Keywords: *A. hexapterus*; predators (birds, rhinoceros auklet, tufted puffin).

**Ainley, D.G.; Norton, J.; Sydeman, W.J. [In press].** Apex predators indicate interannual negative and positive anomalies in the California Current food web. Marine Ecology Progress Series.

Keywords: *A. hexapterus*; food web; predators (birds).

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Keywords: *A. hexapterus*; Bering Sea; Gulf of Alaska; predators (birds); trophic relationships.

**Ainley, D.G.; Spear, L.B.; Allen, S.G.; Ribic, C.A. 1996.** Temporal and spatial patterns in the diet of the common murre in California waters. The Condor. 98: 691-705.

Although this paper does not mention sand lance occurring in the diet of murres in California (out of range), it does review other studies. Mentioned that the sand lance commonly is eaten by common murres in Oregon (Matthews 1983). Studies in the Barents Sea have described serious effects on murres after fisheries depleted capelin (Erikstad 1990); in the North Sea, seabirds (including murres) were affected after depletion of capelin and sand lance *Ammodytes hexapterus* (Furness and Barrett 1991). Murres avoid feeding on surfperch and other fish

that have a body depth > 40 mm, preferring instead those fish species having a fusiliform shape (Swennen and Duiven 1991)—anchovies, herring, sand lance, capelin, and juvenile rockfish. Adults especially avoid feeding deep-bodied fish to their chicks, which have mouths too small to swallow them.

Keywords: *A. hexapterus*; importance; fisheries; predators (birds, common murre).

**Ainley, D.G.; Sydeman, W.J.; Hatch, S.A.; Wilson, U.W. 1994.** Seabird population trends along the coast of North America: causes and the extent of regional concordance. In: Jehl, J.R., Jr.; Johnson, N.K., eds. A century of avifaunal changes in western North America. Studies in Avian Biology. 15: 119-133.

“The California Current and the eastern Bering Sea now seem unable to support historic populations of natural, top-trophic predators. The major factor responsible appears to be overfishing by humans of important seabird prey, especially, in a period when climate has been unstable. In some areas prey switching may no longer be a viable alternative to seabirds (or individual fishermen) as virtually the entire suite of important prey species are now fished to their maximum. Annually extracting from this food web the amount and type of fish now accomplished by commercial fisheries cannot occur without consequences to the food web, and especially top carnivores (see Ludwig et al. 1993).

“The causes of decline in the Bering Sea are unclear. Planktivorous auklets have increased while murres and kittiwakes have declined. Auklets may compete with juvenile pollock for euphausiids and other zooplankton, whereas murres and kittiwakes take juvenile pollock. The role of fishing in this scenario is unclear, because the adult pollock (age 2+) taken in the fishery are important predators on juvenile pollock and other seabird prey such as herring, myctophids, capelin and sand lance. An analysis requires critical information on seabird demography and trophic relationships during winter. Experience has shown us that understanding the whole system, both prey and predators, ultimately benefits man’s commercial interests in the long-term perspective.”

Keywords: *A. hexapterus*; Bering Sea; importance; predators (fish, walleye pollock).

**Albon, S; Brazier, H.; Frost, D. [and others]. 1975.** The food and feeding of the puffin. University of East Anglia Shetland Isles Expeditions. Norwich, United Kingdom: School of Environmental Sciences, University of East Anglia: 32-37.

Keywords: *Ammodytes*; Shetland; predators (birds, puffin).

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Keywords: *Ammodytes*; eggs.

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Keywords: *Ammodytes*; composition.

**Allen, G.H. 1956.** Food of salmonid fishes of the north Pacific Ocean. B: Food of chum salmon (*O. keta*) with notes on the food of sockeye and pink salmon. Fish. Rep. 2. [Seattle, WA]: University of Washington, Department of Oceanography, Collection and Analysis of Oceanographic Data from the North Pacific Ocean.

Out of six chum salmon stomachs examined from King Cove, two contained about 20 to 25 sand lance and nothing else.

Keywords: *A. hexapterus*; Alaska; predators (fish, chum salmon).

**Allen, M.J. 1987**. Demersal fish predators of pelagic forage fishes in the southeastern Bering Sea. In: Forage fishes of the southeastern Bering Sea, conference proceedings; [Dates of meeting unknown]; [location unknown]. Outer Continental Shelf Study, Marine Ms. 87-0017. [Place of publication unknown]: [publisher unknown]: 29-32.

This article lists a number of demersal fish that probably feed on Pacific sand lance but presents no data.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (fish).

**Alton, M.S. 1974.** Bering Sea benthos as a food resource for demersal fish populations. In: Hood, D.W.; Kelley, E.J., eds. Oceanography of the Bering Sea. Occas. Publ. 2. Fairbanks, AK: University of Alaska, Fairbanks, Institute of Marine Science: 257-267.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (fish).

**Altukhov, K.A. 1978.** On the reproduction and abundance of the lesser sandlance, *A. marinus*, in the White Sea. Journal of Ichthyology. 18(4): 560-567.

Keywords: *A. marinus*; White Sea; behavior; importance; predators (fish, navaga, smelt).

**Amaral, M.J. 1977.** A comparative biology of the tufted and horned puffins on the Barren Islands, Alaska. Seattle, WA: University of Washington. M.S. thesis.

“Although the number of bill-loads collected from horned puffins is small, these data in addition to ancillary observations indicate that capelin and sand lance, *Ammodytes hexapterus* are the two most important items in the diet of this species.”

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, horned puffin).

**Amores, A.; Thode, G.; Martinez, G., Giles, V. 1993.** Chromosome complement, c-banding and ag-nor in *Gymnammodytes cicerelus* (Ammodytidae, Perciformes). Journal of Fish Biology. 43: 649-651.

“The karyotype of a sandlance species comprises: seven metacentric, seven submetacentric and nine subtelocentric-acrocentric pairs (2n=46, FN=74). The C-bands appear in paracentromeric and telomeric areas of most chromosomes and the NOR regions, in two pairs of larger chromosomes. All these characteristics indicate that a large number of rearrangements seem to have been involved in the karyotype evolution of this species.”

Keywords: *Gymnammodytes cicerelus*; genetics.

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Keywords: *Ammodytes*; North Sea; commercial fishing.

**Anderson, J.W. 1985.** Toxicity of dispersed and undispersed Prudhoe Bay crude oil fractions to shrimp, fish and their larvae. API Publication. 1985(4441): 1-18.

Keywords: *A. hexapterus*; Alaska; oil toxicity.

**Anderson, W.D. 1964.** Eggs of Ammodytes hexapterus from Long Island, New York. Copeia. 1242-1244.

Keywords: *A. hexapterus*; New York; eggs.

**Andreasen, T.V.; Haug, T.; Ringo, E. 1989.** Food condition and the lipid and protein contents of young Atlantic halibut (*Hippoglossus hippoglossus* L.) captured in the autumn in north Norway. International Council for the Exploration of the Sea. Report of the Mariculture Committee. Issue F:3. 17 p.

"The diet of young (2-4 years), immature Atlantic halibut from nursery areas in North Norway was dominated by 0-group gadoids (*Gadus morhua* in particular) and sand eels (*Ammodyte*s sp.). No variation was observed among the sexes in general condition (liver and body) or in the content of total lipids or proteins in red myotomal muscle, however, significant intersexual heterogeneity was observed in lipid and protein contents."

Keywords: *Ammodytes*; Norway; importance; lipid content; predators (fish, Atlantic halibut).

**Andrews, C.W.; Lear, E. 1956.** The biology of arctic char (*Salvelinus alpinus* L.) in northern Labrador. Journal of the Fisheries Research Board of Canada. 13(6): 843-860.

Keywords: *A. americanus*; Labrador; predators (fish, arctic char).

**Andriashev, A.P. 1954.** Determination of the fauna of the USSR: fishes of the northern seas of the USSR. 38. Ammodytidae. Zool. Inst. Akad. Nauk, Moscow: 315-323. In Russian.

Keywords: Ammodytidae; USSR; distribution.

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Keywords: *Ammodytes*; Pacific Ocean (northwestern); predators (fish).

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Keywords: *Ammodytes*; predators (fish).

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Keywords: *Ammodytes*; USSR; distribution.

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Keywords: *A. hexapterus*; Washington; Puget Sound; predators (birds, mammals).

**Anker-Nilssen, T.; Barrett, R.T.; Krasnov, J.V. 1997.** Long- and short-term responses of seabirds in the Norwegian and Barents Seas to changes in stocks of prey fish. In: Forage fishes in marine ecosystems; Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]; [Anchorage, AK]. Program Rep. 97-01: Fairbanks, AK: University of Alaska, Fairbanks, Alaska Sea Grant College: 683-698.

“About 3 million pairs of seabirds breed in north Norway and along the Kola Peninsula in some of the largest seabird colonies in the North Atlantic. The most numerous species are Atlantic puffins, kittiwakes, and common murres and their main prey consists of capelin, herring, and sand lance (*Ammodytes* sp.).”

Keywords: *Ammodytes*; North Atlantic; Norway; importance; predators (birds, Atlantic puffin, kittiwake, common murre).

**Anonymous. 1954.** An unusual catch of green sturgeon. Fisheries Research Board Canada, Pacific Progress Report. 100: 19.

Keywords: *A hexapterus*; predators (fish, green sturgeon).

**Anonymous. 1957.** 90,000 tons of sandeels. World Fishing. 6(9): 39-41.

Keywords: *Ammodytes*; commercial fishing.

**Anonymous. 1958**. Exploratory trawling for commercial quantities of launce by MV. Metacomet. Commercial Fisheries Review. 20(8): 39-40.

Keywords: *Ammodytes*; commercial fishing.

**Anonymous. 1960.** The sand eel story. World Fishing. 9(7): 30-33.

Keywords: *Ammodytes*; commercial fishing.

**Anonymous. 1964.** Dead sandeels on the Wee Bankie. Scottish Fisheries Bulletin. (22): 18.

“Throughout August, seine-net skippers reported the occurrence of dead sand-eels in catches on the Wee Bankie east of the Isle of May. Although many of the dead fish exhibited prominent abrasions or lesions, mainly on the head and anal regions, all appeared to be in good condition and revealed no evidence of any disease, parasites or injury which might have caused their death. The abrasions may possibly have been caused by the action of scavengers on the sea bottom after death. It is understood that no other species of fish was found dead in the catches.”

Keywords: *Ammodytes*; Isle of May; mortality.

**Anonymous. 1977a.** Report on the international O-group fish survey in Iceland and Greenland waters in July-August 1975. Annals of Biology Copenhagen. 32: 191-199.

“In 1975, the Iceland and Greenland waters were investigated by 1 Soviet and 2 Icelandic vessels. Water temperature data are given for the Irminger Sea, North of Iceland and East of Greenland. 1975 is classified as a very cold year. The distribution and density, and length distributions of O-group cod, haddock, redfish, capelin, sand-eel and Norway pout are given. The maximum concentrations of O-group sand-eel (an important species in food chains) were located 30-60 miles to the west of Reykjanes, west of Latrabjarg, and in major fjords of the NW peninsula as well as off the western north coast.”

Keywords: *Ammodytes*; Greenland; age; distribution; fisheries; O-group.

**Anonymous. 1977b.** Report on the international O-group fish survey in the Barents Sea and adjacent waters in August-September 1975. Annals of Biology Copenhagen. 32: 199-205.

Brief notes on herring, mackerel, catfish, saithe, and O-group *Leptagonus*, *Liparis*, *Cottus*, and sand-eels, are given.

Keywords: *Ammodytes*; Barents Sea; age; fisheries; temperature; O-group.

**Anonymous. 1978.** Another big fishing year for Norway. Fishing News International. 179.

The commercial harvest of sandeel increased from 44,408 to 78,500 tons.

Keywords: *Ammodytes*; Norway; commercial harvest.

**Anonymous. 1979a.** Japanese catch figures. Fishing News International. 184.

There were increases in catches of sardines, mackerel, and saury but sharp declines in Alaska pollock, sand eels, and albacore.

Keywords: *Ammodytes*; Japan; commercial harvest.

**Anonymous. 1979b.** Norway catch worst for years. Landings tumble in both volume and in value. Fishing News International. 1864.

Sandeel catch increased from 78,761 to 94,000 tons.

Keywords: *Ammodytes*; Norway; commercial harvest.

**Anonymous. 1980.** EEC-Norway quotas. Fishing News International. 192.

South of 62° N. latitude, EEC fishermen will be allowed to take 150,000 tons of sandeels.

Keywords: *Ammodytes*; Norway; commercial harvest.

**Anonymous. 1981.** Il pulcinella di mare (*Fratercula arctica*). Quaderni del Museo di Paleontologia e Scienze Naturali di Voghyera. 436: [pages unknown].

Keywords: *Ammodytes*; predators (birds, puffin).

**Anonymous. (1982, 1984, 1987, 1988).** Reports of the working group for Norway pout, sandeel and sprat fisheries in the North Sea and adjacent waters. Copenhagen, Denmark: International Council for the Exploration of the Sea.

Keywords: *Ammodytes*; North Sea; commercial fishing.

**Anonymous. 1993.** Sandeel ships fish millionaire trawls–Danish netmaker supplies British Isles. Fishing News International. 32(2): 15.

Keywords: *Ammodytes*; British Isles; fisheries.

**Anonymous. 1994.** Fish notes: greater sand eel *Hyperoplus lanceolatus* (les sauvage). Irish Naturalists' Journal. 24: 410-411.

Keywords: *H. lanceolatus*.

**Anthony, J.A.; Roby, D.D. 1997.** Variation in lipid content of forage fishes and its effect on energy provisioning rates to seabird nestlings. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]; [location unknown]. Prog. Rep. 97-01. [Fairbanks, AK]; University of Alaska Fairbanks, Alaska Sea Grant College: 725-729.

“Among the forage fishes collected in PWS [Prince William Sound] as part of the APEX project, juvenile herring, sand lance, and capelin had the highest energy densities, and were important prey of kittiwakes, juvenile gadids, prowfish, and juvenile salmonids had the lowest energy densities, and were important prey of puffins. Nearshore demersal fishes e.g. gunnels, pricklebacks, eelblennies, shannies, were intermediate between herring and gadids in lipid content and energy density. The lipid content of herring, sand lance, and capelin, though generally high, was variable depending on age sex, and reproductive status. We hypothesize that the productivity of kittiwakes and the nesting density of guillemots are limited by availability of high-quality, schooling forage fishes (sand lance, herring, or capelin).”

Keywords: *A. hexapterus*; Alaska; Prince William Sound; importance; lipid content.

**Antonelis, G.A., Jr.; Gearin, P.; DeLong, R.L.; Loughlin, T.R. 1986.** Fur seal food habits identified from scats and colons. NWAFC Processed Rep. 86-19. [Place of publication unknown]: National Marine Fisheries Service.

Of 195 scats containing identifiable material, Pacific sand lance were found in 3 percent.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (mammals, fur seal).

**Aotsuka, M., Terasawa, T.; Minami, H. [and others]. 1995.** Breeding ecology of the spectacled guillemot (*Cepphus carbo*) on Teuri Island. Yamashina Chorui Kenkyujo Kenkyu Hokoku. 27(1): 30-40.

“Chick growth and parental feeding behavior of the spectacled guillemot (*Cepphus carbo*) were studied on Teuri Island, Hokkaido in 1989. Increase in chick body weight was closely fitted to the von Bertalanffy equation. Chick growth rate peaked at a maximum of 22.1g/day at 15.3 days after hatching; being highest among the Alcidae. Its weight was 620g at fledging, 91.2% of the average adult weight. Lengths of wing, culmen and tail for two chicks grew to 60-79% of adult lengths at fledging, with only the tarsus attaining the full length. Chick diets in the nestling period consisted of three species of benthic fishes, *Sebastes minor, Ammodytes personatus,* and *Blennioidei* sp. Feeding frequency was 9.8 times/day for one chick brood, and 9.3 times/day for two chick broods. These figures are remarkably high compared to other Alcidae. High feeding ability of the parents may account for high growth rates and large body sizes at fledging for the chicks.”

Keywords: *A. personatus*; Japan; predators (birds, spectacled guillemot).

**Arai, H.P. 1969.** Preliminary report on the parasites of certain marine fishes of British Columbia. Journal of the Fisheries Research Board of Canada. 26: 2319-2337.

Keywords: *A. hexapterus*; British Columbia; parasites.

**Arefjord, M. 1979.** NorSeaMink–production and the quality in 1979. Meldinger SSF. 3: 25-26.

NorSeaMink is the name of a special product intended for mink, fur animals, and fish farming. In 1979, about 21,000 tons of NorSeaMink was produced from January to October, about 4,000 tons more than the production in the whole of 1978. The raw material for the NorSeaMink production in 1979 was winter capelin, mackerel, sand eel, sprat, and blue whiting. The meal quality of different types of raw material was tabulated, and the quality of NorSeaMink produced in 1979 is shown.

Keywords: *Ammodytes*; fisheries.

**Arkhipov, A.G. 1993.** Population estimates and distribution of commercially important fishes in the Black Sea during early ontogeny. Journal of Ichthyology. 33(7): 100-114.

Keywords: *Ammodytes*; Black Sea; distribution; eggs; fisheries; larvae; population dynamics; seasonal variation.

**Armstrong, E; Edwards, J.I. 1985.** Target strength of sandeels. International Council for the Exploration of the Sea B. 20: 1-3.

Keywords: *A. americanus*; hydroacoustics.

**Armstrong, F. 1986.** Target strength of sandeels. Council meeting of the International Council for the Exploration of the Sea; 1986 October 9; Copenhagen, Denmark. [Place of publication unknown]: [publisher unknown]. 6 p.

This paper describes further measurements in a series designed to investigate the acoustic target strength of pelagic fish. In this case, the target strength of sandeels (*Ammodytes*) was measured and was found to be of the same order of magnitude as in the previous year's experiments; i.e. -45 dB to -55 dB re 1 kilogram at 38 kHz.

Keywords: *A. americanus*; hydroacoustics.

**Armstrong, R.H. 1965.** Some feeding habits of the anadromous Dolly Varden *Salvelinus malma* (Walbaum) in southeastern Alaska. Inf. Leafl. 51. Juneau, AK: Alaska Department of Fish and Game. 27 p.

Found salmon young to be the most common prey in the stomachs of Dolly Varden, followed by capelin, herring, and sand lance.

Keywords: *A. hexapterus*; Alaska; predators (fish, Dolly Varden).

**Armstrong, R.H. 1996.** Alaska's fish. Seattle, WA: Alaska Northwest Books.

"The Pacific sand lance is one of the most important fish in our marine waters. When the food habits of fish-eating birds, mammals, and other fish are studied, the sand lance usually shows up as the major item on the menu. Pink, coho, chinook, and sockeye salmon all eat sand lance, as do halibut, cod, Dolly Varden, and even herring, which feed on their larvae. The sand lance is also the most important fish in the diet of nesting marbled murrelets and a major food of kittiwakes, murres, puffins, and seals. Arctic terns and Bonaparte's gulls hover and plunge after sand lance. Bald eagles may swoop and snatch them from the water in their talons or stand alongside a water-filled pocket in the sand, waiting patiently for one to emerge. Crows and ravens dig for them in the sand with a sideways motion of their bills."

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, fish, mammals).

**Armstrong, R.H. [In press].** The importance of fish to bald eagles in southeast Alaska, a review: Proceedings of the bald eagle conference. [dates of meeting unknown]; Juneau, AK. [Place of publication unknown]: [publisher unknown].

"Sand lance may be important in the diet of Southeast eagles. On numerous occasions I have counted between 20 and 80 bald eagles feeding on Pacific sand lance during minus tides on the Mendenhall Wetlands near Juneau. On a minus tide the sand lance's burial grounds are often exposed. I have observed bald eagles walking over these areas. This seems to panic the sand lance, which squirt out of the sand, making them easy prey for the eagles. Concentrations of bald eagles near the edge of sandy tidal flats, especially at minus tides, may be feeding on Pacific sand lance."

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, bald eagle).

**Arnason, E. 1974.** Ecology and feeding behaviour of the arctic skua (*Stercorarius parasiticus* Linnaeus) in Iceland. Montreal, PQ: McGill University. M.S. thesis.

Keywords: *Ammodytes*; Iceland; predators (birds, arctic skua).

**Artedi, Petri. 1738.** Bibkiotheca ichthyologica seu historia litteraria ichthyologiae. General Piscium. Ichthyologiae pars III. Malacopterygii. Ammodytes: 55-57.

Keywords: *Ammodytes*; historical.

**Asahara, M.; Ogushi, Y. 1995.** Oni–stinger culture test (Yamaguchi Prefect.). Tokutei Kaiiki Yoshokugyo Suishin Chosa Hokokusho. Heisei 6 Nendo. Seibu Nihonkai Burokku: 149-203. In Japanese.

Keywords: *A. personatus*; Pacific Ocean; fisheries.

**Asami, H.; Hayano, H. 1995.** Feeding ecology of juvenile masu salmon *Oncorhynchus masou* in the coasts of Hokkaido with special reference to stomach contents. Fisheries Science (Tokyo). 61(4): 590-593.

“Feeding ecology of juvenile masu salmon, *Oncorhynchus masou*, collected by commercial set nets, was studied in the coastal waters of Hokkaido between 1991 and 1993. Stomach fullness indices varied among sampling dates and two areas sampled (Japan Sea and Pacific Ocean). The stomach contents of juveniles collected along the coasts of the northern Japan Sea were composed entirely of sand lances (*Ammodytes personatus*), which were ¼-½ of the body lengths of the juvenile salmon. In contrast, stomach contents of the juveniles collected along the coast of the Pacific Ocean included a variety of organisms, and size ratios of prey to juveniles were lower than those in the northern Japan Sea. The results of comparisons of juvenile stomach contents between the Japan Sea and Pacific Ocean indicate that juvenile masu salmon occupy different ecological niches in the two areas. Production of juveniles in the northern Japan Sea may depend on the abundance of sand lance.”

Keywords: *A. personatus*; Japan Sea; Pacific Ocean; importance; predators (fish, masu salmon).

**Asbirk, S. 1979.** The adaptive significance of the reproductive pattern in the black guillemot *Cepphus grylle*. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i Kobenhavn. 141: 29-80.

Keywords: *Ammodytes*; predators (birds, black guillemot).

**Ashcroft, R.E. 1977.** Breeding biology and survival of puffins. Oxford, England: University of Oxford. Ph.D. dissertation.

Keywords: *Ammodytes*; predators (birds, puffin).

**Ashmole, N.P. 1971.** Seabird ecology and the marine environment. In: Farner, D.S.; King, J.R., eds. Avian biology. New York: Academic Press.

“In the boreal and low-arctic zones, where there are large areas of neritic waters (because the continental shelves are very wide) fish form a large proportion of the diet of many sea birds. The families Clupeidae (herrings and sardines), Ammodytidae (sand eels), and Gadidae (codfishes), and the capelin (*Mallotus villosus*, family Osmeridae) are of special importance. Although few cases have been investigated in detail, it is clear that the spatial and temporal variation in the abundance of these fish are major determinants of the breeding seasons, breeding places, and movements of the boreal sea birds.”

Keywords: *Ammodytes*; distribution; importance; predators (birds).

**Auster, P.J.; Stewart, L.L. 1986.** Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)—sand lance. Biol. Rep. 82 (11.66). TREL-82-4. [Place of publication unknown]: U.S. Fish and Wildlife Service. 11 p.

“The systematic classification of the sand lances *Ammodytes americanus* and *Ammodytes dubius* is confusing because of overlapping meristic values. In the report, all sand lances in the North Atlantic area off the coast of the United States are treated as a combined group (*Ammodytes* spp.). Sand lances occur in estuarine, open coast, and offshore habitats. They are important prey to many commercially and recreationally valuable fish and marine mammals. Exploitation of sand lances off the Northeast coast of the United States is presently only for baitfish.”

Keywords: *A. americanus*; *A. dubius*; Atlantic (north); life history; reviews.

**Avery, M. 1990a.** Seabirds, fisheries and politics. RSPB Conservation Review. 4: 36-39.

Keywords: *A. marinus*; Atlantic (northeast); abundance; fisheries; predators (birds).

**Avery, M. 1990b.** Shetland seabird update. Birds. 13(1): 40-41.

“Describes the bird populations of the Shetland Islands, giving the results of the 1989 breeding season when Arctic tern *Sterna paradisaea* failed to produce young. Kittiwake *Rissa tridactyla*, puffin *Fratercula arctica* and Arctic skua *Stercorarius parasiticus* numbers were also low. Results may have been due to mismanagement of fish stocks. A study is being undertaken by Glasgow University and the Department of Agriculture and Fisheries Scotland to examine seabird foraging; it will also monitor sandeel *Ammodytes* numbers and distribution within the feeding ranges of the seabird colonies.”

Keywords: *Ammodytes*; Shetland; predators (birds, arctic skua, arctic tern, kittiwake, puffin, skua).

**Avery, M.; Green, R. 1989a**. Not enough fish in the sea. New Scientist. 123(1674): 28-29.

The relations between sand-eel fisheries around the Shetland isles and the death of young seabirds and the failure of the birds to breed are discussed.

Keywords: *A. tobianus*; Shetland; commercial fishing; importance; predators (birds, arctic skua, arctic tern, fulmar, great skua, puffin, red-throated diver).

**Avery, M.; Green, R. 1989b.** Shetlands sand eels.

Keywords: *Ammodytes*; Shetland; predators (birds).

**Avery, M.I. 1991.** The Shetland sandeel fishery: mismanagement or misadventure? Institute of Fisheries Management Annual Study Course Proceedings. 22: 21-29.

Keywords: *A. marinus*; Atlantic (northeast); abundance; fisheries; predators (birds).

**Avery, M.I.; Suddaby, D.; Innes, P.M.E.; Sim, M.W. 1992.** Exceptionally low body weights of arctic terns *Sterna paradisaea* on Shetland. Ibis. 134(1): 87-88.

A shortage of sandeels has led to repeated breeding failure of thousands of pairs of arctic terns on Shetland every year since 1984. The authors present evidence that the sandeel shortage also has led to low adult body weights of arctic terns.

Keywords: *A. marinus*; Shetland; predators (birds, arctic tern).

**Backus, R.H. 1957.** The fishes of Labrador: Ammodytidae. Bulletin of the American Museum of Natural History. 113(4): 307-308.

The number of vertebrae differs among species of sand lance. *Ammodytes lancea* ranges from 60 to 66, *A. marinus* from 66 to 73, and *A. dubius* from 73 to 78. *Ammodytes dubius* is a more northern form than *A. americanus.*

Keywords: *A. americanus*; *A. dubius*; *A. lancea*; *A. marinus*; Labrador; description; distribution; taxonomy.

**Backus, R.H.; Bourne, D.W., eds. 1987.** Georges Bank. Cambridge, MA: Massachusetts Institute of Technology Press. 593 p.

**Baggot, C.M. 1992.** Reproductive ecology of kittiwakes on Buldir Island, Alaska. St. Paul, MN: University of Minnesota. M.S. thesis.

Keywords: *A. hexapterus*; Alaska; predators (birds).

**Bahr, K. 1935.** Der kleine sandaal *Ammodytes tobianus* L. der Ostsee. Zeitschrift für Fischerei und deren Hilfswissenschaften. 33: 125-219.

Keywords: *A. tobianus.*

**Bailey, A.M. 1922.** Notes on the yellow-billed loon. Condor. 24: 204-205.

Keywords: *Ammodytes*; predators (birds, yellow billed loon).

**Bailey, R.S. 1982.** The sandeel fishery: sandeels: risk in raising Shetland catch. Fishing News. 3611: 40-41.

“An assessment of the sandeel fishery in the North Sea and Shetland area is presented. There is no evidence that exploitation of *Ammodytes marinus* (sandeel) in the North Sea up to 1980 had a deleterious effect on the stocks. Although there is no evidence of over-exploitation of Shetland sandeels, the dependence of the fishery on young, immature fish makes it very vulnerable to changes in the level of recruitment. Therefore it would be advisable to avoid any further increase in fishing intensity for sandeels in the Shetland area.”

Keywords: *A. marinus*; British Isles; North Sea; Shetland; catch; fisheries.

**Bailey, R.S. 1986.** Food consumption of seabirds in the North Sea in relation to the natural mortality of fish stocks. Report of the demersal fish committee: Council meeting of the International Council for the Exploration of the Sea. 1986/G:5. [Place of publication unknown]: [publisher unknown].

Keywords: *Ammodytes*; North Sea; predators (birds).

**Bailey, R.S. 1989a.** Interactions between fisheries, fish stocks and seabirds. Marine Pollution Bulletin. 20: 427-430.

An interesting viewpoint where the author concludes that “seabird populations may well be affected by the abundance of their food, but the abundance of that food is affected by a number of factors of which fishing is only one. The uncritical amalgamation of these two steps into an assertion that the exploitation of fish stocks is the main factor affecting seabird populations is thus unwarranted. This is not of course to claim that the fisheries have no effect, simply that a more thorough approach to the whole question is required.”

Keywords: *Ammodytes*; North Sea; commercial fisheries; importance; predators (birds).

**Bailey, R.S. 1989b.** Shetlands sandeels. New Scientist. 123(1678): 64-65.

Keywords: *Ammodytes*; Scotland.

**Bailey, R.S. 1991.** The interactions between sandeels and seabirds—a case history at Shetland: Council meeting of the International Council for the Exploration of the Sea; 1991 Sept. 26-Oct. 4; La Rochelle, France. [Place of publication unknown]: [publisher unknown]: 20 p.

“Several species of seabird at Shetland have shown reduced breeding success in the past few years and in the case of the Arctic tern, *Sterna paradisaea*, almost no young were produced in the period 1984-1990. During the breeding season, the surface feeding and smaller pursuit diving species feed their young predominantly on 0-group sandeels,

*Ammodytes marinus*. Seabird studies indicate that breeding failed as a result of inadequate provisioning of chicks by the parents. Virtual population analysis indicates that the abundance of 0-group sandeels increased over the period 1974 to 1982 and decreased to a very low level in 1987 and 1988. The factors affecting 0-group survival are not known, but do not appear to be related to fishing or low egg production. There is evidence of an abrupt change in distribution of the 0-group in the early 1980s. The change in distribution and survival may be related to changes in water circulation and/or predation."

Keywords: *A. marinus*; Shetland; predators (birds, arctic tern).

**Bailey, R.S.; Furness, R.W.; Gauld, J.A.; Kunzlik, P.A. 1991.** Recent changes in the population of the sandeel (*Ammodytes marinus* Raitt) at Shetland in relation to estimates of seabird predation. International Council for the Exploration of the Sea Marine Science Symposium. 193: 209-216.

"Recent changes in the Shetland population of the lesser sandeel (*Ammodytes marinus* Raitt) have been investigated using data from commercial catches and research-vessel surveys using small-mesh midwater trawls. Both recruitment and total stock size have decreased since the early 1980's. Over the period 1981-1988 there has also been a decrease in consumption of sandeels by seabirds. On the assumption that the natural mortality rate has not changed, the predation mortality caused by seabirds (i. e. the fraction of the population taken) has not decreased significantly. These findings indicate that the switching of seabirds from sandeels to other prey is in approximate proportion to the abundance of sandeels, and that there is no evidence of a non-linear functional response. The estimates on which this analysis is based are subject to considerable uncertainty, however, and annual data on the consumption of sandeels and other prey (in terms of numbers at age) by each of the main groups of predators would be needed to refine the analysis significantly. The importance of incorporating consumption by seabirds and other predators in future assessments of this stock is stressed."

Keywords: *A. marinus*; Shetland; abundance; commercial fishery; predators (birds, red-throated loon, fulmar, gannet, shag, arctic skua, great skua, herring gull, great black-backed gull, kittiwake, arctic tern, guillemot, razorbill, black guillemot, puffin).

**Bailey, R.S.; Galbraith, D.; Hutcheon, J.R.; Walsh, M. 1983.** Experimental fishing for Norway pout using a horizontally-divided trawl. Council Meeting of the International Council for the Exploration of the Sea; 1983 October 10; Gothenburg Sweden. [Place of publication unknown]: [publisher unknown]. 14 p.

Keywords: *Ammodytes*; Norway; fisheries.

**Bailey, R.S.; Gauld, J.A. 1984.** Sandeels up by 10,000 tonnes...but there are warnings. Fishing News. 3680: 13.

"Landings of sandeels at Scottish ports increased from 53,000 tonnes in 1981, to 63,000 tonnes in 1982. The largest catches in 1982 (52,000 tonnes) were made in the Shetland fishery. While sandeels can live up to 8 years or more, the fisheries depend heavily on very young sandeels. A fishery so dependent on incoming recruitment, is vunerable to even a single poor year class. Landing cannot increase indefinitely without an associated increase in the likelihood of poor recruitment."

Keywords: *Ammodytes*; North Sea; Scotland; Shetland; catch; recruitment.

**Bailey, R.S.; Hislop, J.R.G.; Mason, J. 1979.** The fish and shellfish resources in seas adjacent to the Outer Hebrides. In: Morton, Boyd J. The natural environment of the Outer Hebrides: Proceedings of the Royal Society of Edinburgh Section B; [dates of meeting unknown]; [location unknown]. [Place of publication unknown]: [publisher unknown]; 77: 479-494.

"The demersal fishery in Hebridean seas is based mainly on haddock, whiting and cod, mostly from local spawning grounds, with some recruitment from the North Sea. Sandeels may also occur in commercial quantities in some areas."

Keywords: *Ammodytes*; British Isles; catch; fisheries.

**Baird, P.A.; Gould, P.J., eds. 1986.** The breeding biology and feeding ecology of marine birds in the Gulf of Alaska. U.S. National Oceanic Atmospheric Administration, Outer Continental Shelf Environmental Assessment Program Final Report of the Principal Investigator. 45: 121-503.

This report reviews numerous earlier reports and concludes that “seabirds in the Gulf of Alaska were mainly piscivorous, with capelin and sand lance the predominant prey fed to chicks. These two species of fish comprised 48-84% of the diets of the chicks of all the seabird species.”

Keywords: *A. hexapterus*; Alaska; Gulf of Alaska; importance; predators (birds, red-faced cormorant, pelagic cormorant, glaucous-winged gull, black-legged kittiwake, arctic tern, Aleutian tern, common murre, thick-billed murre, horned puffin, tufted puffin).

**Baird, P.A.; Hatch, M.A. 1979.** Breeding biology and feeding habits of seabirds of Sitkalidak Strait, 1977-1978. In: Environmental assessment of the Alaskan Continental Shelf. Annual reports of principal investigators, No. 2. Boulder, CO: National Oceanic Atmospheric Administration, Environmental Research Laboratory: 107-186.

“The prey base for all of the species we studied changed radically from 1977 to 1978. In 1977, capelin was by far the most important prey with respect to numbers and frequency of occurrence. In 1978 capelin was replaced by sandlance as the most important prey and was found in significantly fewer numbers and in significantly fewer of the regurgitations and bill loads of the birds than it was in 1977. This decline of capelin in 1978 may have somehow influenced the decrease in numbers of breeding birds and also their lowered reproductive success.”

Keywords: *A. hexapterus*; Alaska; Kodiak Island; Sitkalidak Strait; importance; predators (birds, tufted puffin, black-legged kittiwake, glaucous-winged gull).

**Baird, P.A.; Moe, R.A. 1978.** The breeding biology and feeding ecology of marine birds in Sitkalidak Strait area, Kodiak Island, 1977. In: Environmental assessment of the Alaskan Continental Shelf, annual reports of principal investigators, No. 3. Boulder, CO: National Oceanic Atmospheric Administration, Environmental Research Laboratory: 313-524.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; predators (birds).

**Baird, P.H. 1990.** Influence of abiotic factors and prey distribution on diet and reproductive success of three seabird species in Alaska. Ornis Scandinavica. 21: 224-235.

Keywords: *A. hexapterus*; Alaska; predators (birds).

**Baird, P.H. 1994.** Black-legged kittiwake. In: Poole, A; Stennheim, P.; Gill, F., eds. The birds of North America. Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologist’ Union. No. 92.

Keywords: *Ammodytes*; predators (birds, black-legged kittiwake).

**Baker, C.S.; Straley, J.M.; Perry, A. 1992.** Population characteristics of individually identified humpback whales in southeastern Alaska: summer and fall 1986. U.S. National Marine Fisheries Service, Fish Bulletin. 90: 429-437.

In Glacier Bay, small schooling fish, mainly capelin and sand lance, appear to be important prey for humpback whales, and more whales are observed in early summer than in August.

Keywords: *A. hexapterus*; Alaska; southeastern Alaska; importance; predators (mammals, humpback whale).

**Bakkala, R.G.; Smith, G.B. 1978.** Demersal fish resources of the eastern Bering Sea: spring, 1976. N. W. Alaska fisheries center processed report, Seattle, WA: U.S. Department Commerce, National Marine Fisheries Service.

Keywords: *A. hexapterus*; Alaska; Bering Sea; distribution.

**Bal, D.V. 1944.** A study of fish eggs and larvae from Manx waters. II: Observations on the fish larvae. Journal of the University of Bombay. 12(5): 14-41.

Keywords: *Ammodytes*; larvae.

**Balykina, N.V.; Vinnikov, A.V.; Maksimenkov, V.V. 1991.** Ichthyoplankton on the eastern part of the Sea of Okhotsk in May-June 1987. Journal of Ichthyology. 31(5): 31-35.

Keywords: *A. personatus*; Sea of Okhotsk; distribution; larvae; recruitment.

**Barraclough, W.E. 1967.** Number, size, and food of larval and juvenile fish caught with an Isaacs Kidd trawl in the surface waters of the Strait of Georgia, April 25-29, 1966. Fisheries Research Board of Canada, Manuscript Report Series. 926: 1-79.

Keywords: *A. hexapterus*; Canada; abundance; food; juveniles; larvae.

**Barraclough, W.E.; Fulton, J.D. 1968.** Food of larval and juvenile fish caught with a surface trawl in Saanich Inlet during June and July 1966. Fisheries Research Board of Canada, Manuscript Report. 1003: 1-78.

Keywords: *A. hexapterus*; Canada; food; juveniles; larvae.

**Barraclough, W.E.; Robinson, D.G.; Fulton, D.G. 1968.** Number, size composition, weight and food of larval and juvenile fish caught with a two-boat surface trawl in Saanich Inlet April 23-July 21. Fisheries Research Board of Canada, Manuscript Report. 1004: 1-305.

Keywords: *A. hexapterus*; Canada; food; juveniles; larvae; size; weight.

**Barrett, R.T. 1983.** Seabird research on Hornoy, East Finnmark with notes from Nordland, Troms and West Finnmark 1980-1983. Tromsø, Norway: Tromsø Museum.

Keywords: *Ammodytes*; predators (birds).

**Barrett, R.T. 1996.** Prey harvest, chick growth, and production of three seabird species on Bleiksoy, North Norway, during years of variable food availability. In: Montevecchi, W.A., ed. Studies of high-latitude seabirds. 4: Trophic relationships and energetics of endotherms in cold ocean systems. Canadian Wildlife Service Occasional Papers. 91: 20-26.

Keywords: *Ammodytes*; Norway; predators (birds, Atlantic puffin, black-legged kittiwake, shag).

**Barrett, R.T.; Anker-Nelssen, T.; Rikardsen, F. [and others]. 1987.** The food, growth and fledging success of Norwegian puffin chicks *Fratercula arctica* in 1980-1983. Ornis Scandinavica. 18: 73-83.

“Of the four fish species analyzed, sandeels and large herring had the highest calorific values (6.0-7.9 kJ g -1 wet weight) while those of small capelin were lowest (3.2-3.3 kJ g-1 wet weight).

“Sandeels were important everywhere. Many Puffins carried single sandeels bent double in their beaks, possibly to reduce flight impairment and conspicuousness to kleptoparasites. A 90-95% decline in Norwegian herring stocks and the apparent dearth of alternative prey must inevitably have affected the Puffins on Rost. This study demostrates yet again how seabirds can act as indicators of marine ecological processes.”

Keywords: *A. marinus*; Norway; calorific value; importance; lipid content; predators (birds, puffin).

**Barrett, R.T.; Asheim, M.; Bakken, V. 1997.** Ecological relationships between two sympatric congeneric species, common murres and thick-billed murres, *Uria aalge* and *U. lomvia*, breeding in the Barents Sea. Canadian Journal of Zoology. 75(4): 618-631.

“Concurrent studies of the breeding ecology of Common Murres and Thick-billed Murres, *Uria aalge* and *U. lomvia*, on Hornoya, a colony in northern Norway, showed significant differences between the species in the timing of egg laying but no consistent differences in food choice, feeding frequency and rhythm, divedepth, or chick growth. Both species fed their chicks on capelin, *Mallotus villosus*, sand lance *Ammodytes* sp., and herring *Clupea harengus*. However, on Bear Island in the Barents Sea, the diet differed significantly, with Common Murre chicks being fed nearly exclusively capelin while Thick-billed Murre chicks received capelin, squid *Gonatus fabricii*, Arctic cod, *Boreogadus saida*, sculpins (Cottidae), shannies *Lumpenus* sp., and eelpouts (Zoarcidae). The lack of dietary segregation on Hornoya was in strong contrast with the results of earlier studies of sympatrically breeding murres and was probably due to a near superabundance of food around the colony.”

Keywords: *Ammodytes*; Barents Sea; Norway; predators (birds, common murre, thick-billed murre).

**Barrett, R.T.; Furness, R.W. 1990.** The prey and diving depths of seabirds on Hornoy, north Norway after a decrease in the Barents Sea capelin stocks. Ornis Scandinavica. 21: 179-186.

“Following a supposed decrease in food availability during the breeding season as a result of a collapse in the Barents Sea capelin *Mallotus villosus* stock in 1986/87, it was hypothesized that there would be an increase in food competition and partitioning between the seabird species breeding in the region. A comparison of the diets collected from seven seabird species breeding on Hornoy in 1983 and 1989 showed that, despite a much lower capelin stock they actually caught a higher proportion of capelin in 1989 but fewer sandeels *Ammodytes* sp. It seems that the seabirds on Hornoy were more dependent on the sandeels than initially anticipated, and that sandeels have declined in abundance. We propose that the seabirds on Hornoy may also exploit a separate, late-spawning fjordic stock of capelin during the chick-rearing period. The median maximum diving depths attained by Common and Brunnich’s Guillemots *Uria aalge* and *U. lomvia* were ca. 50 m, while Razorbills *Alca torda*, Puffins *Fratercula arctica* and Shags *Phalacrocorax aristotelis* reached 25-30 m (median). These depths reflected the distribution of prey more than the birds’ diving abilities.”

Keywords: *Ammodytes*; Barents Sea; Norway; importance; predators (birds, brunnich’s guillemot, common guillemot, puffin, razorbill, shag).

**Barrett, R.T.; Krasnov, Y.V. 1996.** Recent responses to changes in stocks of prey species by seabirds breeding in the southern Barents Sea. International Council for the Exploration of the Sea. Journal of Marine Science. 53(4): 713-722.

“Seabirds breeding in the southern Barents Sea feed mainly on pelagic fishes–capelin *Mallotus villosus*, herring *Clupea harengus*, sand eels *Ammodytes* sp., and polar cod *Boreogadus saida*. This study shows how seabirds breeding in two colonies, one in northern Norway and one off the Kola Peninsula, Russia have responded to the recent huge changes in the capelin and herring stocks through changes in chick diet and breeding success. It seems that after recent collapses in the capelin stocks, the surface-feeding kittiwakes *Rissa tridactyla* are now having difficulty in finding enough food to maintain high breeding success and a positive population trend. While the pursuit diving common guillemots *Uria aalge* and puffins *Fratercula arctica* are faring better, there are signs that they too are having more difficulty in finding sufficient food despite the return of I-group herring to their foraging areas.”

Keywords: *Ammodytes*; Barents Sea; Norway; Russia; predators (birds, common guillemot, kittiwake, puffin).

**Barrett, R.T.; Rikardsen, F. 1992.** Chick growth, fledging periods and adult mass loss of Atlantic puffins *Fratercula arctica* during years of prolonged food stress. Colonial Waterbirds. 15(1): 24-32.

“By the end of the month [July] sandlance dominated the chick diet.”

Keywords: *Ammodytes*; Norway; predators (birds, Atlantic puffin).

**Barrett, R.T.; Roev, N.; Loen, J.; Montevecchi, W.A. 1990.** Diets of shags *Phalacrocorax aristotelis* and cormorants *P. carbo* in Norway and possible implications for gadoid stock recruitment. Marine Ecology Progress Series. 66(3): 205-218.

“The diets of shags (*Phalacrocorax aristotelis*) and cormorants (*P. carbo*) were studied in Norway through analyses of regurgitated pellets. Although this method has many limitations, indications were that both species rely heavily on small gadoids (Gadidae) and sand eels (Ammodytidae) for food throughout their range, but also eat other fish species when available. There was considerable dietary overlap between species, despite a tendency for cormorants to eat larger fish and more benthic items than shags. Predation by shags and cormorants could be a factor limiting the recruitment of cod and saithe into what are now severely reduced, but commercially important stocks in the Norwegian and Barents Seas.”

Keywords: *Ammodytes*; Barents Sea; Norway; importance; predators (birds, cormorant, shag).

**Barsukov, V.V. 1958.** Fishes of Providence Bay and adjacent waters of the Chukotsk Peninsula. Proceedings of the Zoological Institute USSR Academy of Sciences. 25: 130-163.

Keywords: *Ammodytes*; Russia; distribution.

**Barton, L.H. 1978.** Finfish resource surveys in Norton Sound and Kotzebue Sound. U.S. Department of Commerce, National Oceanic Atmospheric Administration, OCSEAP Final Report. 4: 75-313. RV0019.

Keywords: *A. hexapterus*; Alaska; distribution.

**Bartonek, J.C.; Nettleship, D.N., eds. 1979.** Conservation of marine birds of northern North America. Wildl. Res. Rep. 11. [Place of publication unknown]: U.S. Fish and Wildlife Service. 319 p.

Keywords: *Ammodytes*; predators (birds).

**Bauza, R.J. 1973**. Contribution to the knowledge of the otoliths of modern fishes: part 2. Boletin de la Real Sociedad Española de Historia Natural, Seccion Biologica. 69(4): 307-315.

Keywords: *A. tobianus*; otoliths.

**Bax, N.; Eliassen, J.-E. 1990.** Multispecies analysis in Balsfjord, northern Norway: solution and sensitivity analysis of a simple ecosystem model. Conseil International pour l’Exploration de la Mer. 47(2): 175-204.

Keywords: *Ammodytes*; Norway; ecology; fisheries; food and feeding habits; growth; length; modeling; predators.

**Bayes, J.C.; Dawson, M.J.; Potts, M.J. 1964.** The food and feeding behaviour of the great skua in the Faroes. Bird Study. 11: 272-279.

Keywords: *Ammodytes*; Faroes; predators (birds, great skua).

**Beacham, T.D. 1986.** Type quantity and size of food of Pacific salmon *Oncorhynchus* in the Strait of Juan-de-Fuca British Columbia Canada. U.S. National Marine Fisheries Service Fishery Bulletin. 84(1): 77-90.

“The volume, numbers, and size of prey of sockeye, *Oncorhynchus nerka*; pink, *O. gorbuscha*; coho, *O. kisutch*; and chinook, *O. tshawytscha*, salmon were investigated for troll-caught salmon in the Strait of Juan de Fuca off southwestern Vancouver Island during 1967-68. Sockeye salmon was the least piscivorous species with only 7% of the stomach volume comprised of fish, while chinook salmon was the most piscivorous species at 56%. Sand lance, *Ammodytes hexapterus*, and euphausiids were the most important fish and invertebrate prey, respectively. As predator size increased, mean size of fish prey increased, and predators shifted to species of larger mean size. Similar

results were found for the invertebrate prey, with mean number of prey consumed per predator increasing for the larger invertebrate species as predator size increased. Rate of increase in invertebrate size with increasing predator length was not statistically significant. Although chinook and coho salmon had similar diets, they were caught at significantly different water depths. *Oncorhynchus* species with fewer, shorter, and more widely spaced gill rakers have higher proportions of fish in their diet than species with numerous, long, and narrow set gillrakers."

Keywords: *A. hexapterus*; British Columbia; Strait of Juan de Fuca; predators (fish, chinook salmon, coho salmon, pink salmon, sockeye salmon).

**Beaman, M.A.S. 1978.** The feeding and population ecology of the great black-backed gull in northern Scotland. Ibis. 120: 126-127.

"The great majority of Great Black-backs as well as Great Skuas, in the area are feeding almost exclusively during spring and summer on surface-shoaling sandeels *Ammodytes* spp. Sand eels are obtained from the shoals at the surface and gulls, skuas and even Fulmars collected in large groups around such shoals, bringing up sandeels by making brief plunge-dives from a sitting position on the water. Analysis of Great Black-backed Gull guts collected in Orkney and Shetland showed that sandeels were found in up to 85% of the samples, forming up to 79% of the fresh weight of material collected. Adults and unfledged young showed a higher proportion of sandeels in the diet than did immatures."

Keywords: *Ammodytes*; Scotland; importance; predators (birds, great black-backed gull; great skua; fulmar).

**Beck, G.G.; Hammill, M.O.; Smith, T.G. 1993.** Seasonal variation in the diet of harp seals (*Phoca groenlandica*) from the Gulf of St. Lawrence and western Hudson Strait. Canadian Journal of Fisheries and Aquatic Sciences. 50(7): 1363-1371.

"Harp seals obtained from the northern Gulf of St. Lawrence during their southward migration fed less intensively, and on a wider variety of both invertebrate and fish prey, notably *Parathemisto libellula*, *Pandalus* sp., sand lance (*Ammodytes* sp.), and Atlantic cod (*Gadus morhua*). Feeding was more intensive and specialized in Hudson Strait and the St. Lawrence estuary where capelin (*Mallotus villosus*) dominated in the diet. Capelin contributed 89 and 98% of gross energy in samples from Hudson Strait (1990) and the estuary (April)."

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; predators (mammals, harp seal).

**Bedard, J. 1969a.** Adaptive radiation in Alcidae. Ibis. 111: 189-198.

Fish-feeders include *Uria*, *Alca* and *Cepphus.* Abundant shoaling fishes, such as capelin, herring, polar cod and sand eels, make up the bulk of their diet. The puffins *Fratercula*, *Lunda*, and *Cerorhinca* are known to feed on both plankton and fish. All species bring only fish to their nestlings.

Keywords: *Ammodytes*; importance; predators (birds).

**Bedard, J. 1969b.** Feeding of the least, crested, and parakeet auklets around St. Lawrence Island, Alaska. Canadian Journal of Zoology. 47: 1025-1050.

Keywords: *A. hexapterus*; Alaska; Saint Lawrence Island; predators (birds).

**Bedard, J. 1969c.** Histoire naturelle du Gode, Alca torda L., dans le golfe Saint-Laurent, province de Québec, Canada. Etude du Service Canadien de la Faune. 7: 1-79.

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; predators (birds, razorbill).

**Beddington, J.R.; May, R.M. 1982.** The harvesting of interacting species in a natural ecosystem. Scientific American. 247: 62-69.

Keywords: *Ammodytes*; fisheries.

**Belopol'skii, L.C. 1957.** Ecology of sea colony birds of the Barents Sea. Naukovi S.S.R. Moscow-Leningrad Izdatel'stvo Akad. In Russian. Translated 1961 Israel Program for Scientific Translations, Jerusalem.

Keywords: Ammodytes*; Barents Sea; predators (birds).*

**Benoit, D.; Bowen, W.D. 1990.** Seasonal and geographic variation in the diet of gray seals (*Halichoerus grypu*s) in eastern Canada. In: Bowen, W.D., ed. Population biology of sealworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Canadian Bulletin of Fisheries and Aquatic Sciences. 222: 215-226.

"At Sable Island, cod, haddock, silver hake and sand lance accounted for the majority (63.6%) of items identified from stomachs."

Keywords: *A. americanus*; Canada; Sable Island; predators (mammals, gray seal).

**Bent, A.C. 1921.** Life histories of North American gulls and terns. U.S., National Museum, Bulletin. No. 113.

Sand lance were eaten by the following species: herring gull, Cabot's tern, common tern, arctic tern, roseate tern, and least tern. Relative to the feeding of young roseate terns, "the sand launce was the chief fish food probably because it is so soft and easily digested."

Keywords: *Ammodytes*; predators (birds, herring gull, Cabot's tern, common tern, arctic tern, roseate tern, least tern).

**Bent, A.C. 1922.** Life Histories of North American petrels, pelicans, and their allies. U.S., National Museum, Bulletin. No. 121. 343 p.

The greater shearwater (*Ardenna gravis*) feeds on sand eels, with the following interesting tidbit from a Mr. Rich: "Apart from that furnished by the fishing industry, the food of the hag consists of surface-swimming young fish of various species, a large amount of squid, and the 'sand eels,' the later, no doubt, furnishing a considerable portion in the menu. At the turn of the tide when the water is slack there is great activity among the hags, the birds flying about constantly at a considerable height—for them—sometimes fifty yards in the air, apparently searching for these fish, the lancelets, which are said to school at the surface in vast numbers at this time. I have seen vast schools of these 'sand eels' with thousands of hags, an occasional shark, and even whales pursuing them".

Keywords: *Ammodytes*; predators (birds, greater shearwater).

**Berg, L.A.; Bogdanov, A.S.; Koshen, N.I.; Rass, T.S., eds. 1949.** Commercial fishes of the USSR: Ammodytidae. [Place of publication unknown], USSR: Ministry of Fish Production: 621-623. In Russian.

Keywords: *Ammodytes*; USSR; commercial fishing.

**Bergman, G. 1971.** Grylllteisten *Cepphus grylle* in einen Randgebiet: Nahrung, Brutresultat, Tagesrhythmus und Ansiedlung. Commentationes Biologicae. 42: 1-26.

Keywords: *Ammodytes*; predators (birds, black guillemot).

**Bergman, G. 1978.** Av naringsbrist fovorsakade stormingar i tejsterns (tobisgrisslans) *Cepphus grylle* hackning. Memoranda Societatis pro Fauna et Flora Fennica. 54: 31-32.

Keywords: *Ammodytes*; predators (birds, black guillemot).

**Berner, M. 1986.** Seasonal growth in length of some sandeels (Ammodytidae) in the Baltic after data series from Kaendler. Fisheries Research by the GDR and the USSR in the Baltic Sea. 24(2): 105-110.

“According to the method of Pauly and Gaschuetz the Bertalanffy curves of simple and, especially, seasonally oscillating growth in length were calculated and constructed after basic data of *A. marinus* (1.), *A. lancea* /spring spawners (2.), *A. lanceolata* (3.), and *A. lancea* /autumn spawners (4.). In all forms a distinctly marked oscillation with an amplitude C > 1 was stated, later on reduced to C = 1. The beginning of the phases t sub(2) and the 0.5 years later ‘winter point’ WP, respectively, are of special interest because the forms of *Ammodytes* spec. spawn in the above cited succession from December/January to August/September and because an influence of temperature and spawning time on phases seems to be probable in our regions. The comparison of WP in sandeels was supplemented by some other species of sea animals in the northern European region.”

Keywords: *A. marinus*; *A. lancea*; A. *lanceolatus*; Baltic Sea; growth; seasonal variation.

**Berntsen, J.; Skagen, D.W.; Svendsen, E. 1994.** Modelling the transport of particles in the North Sea with reference to sandeel larvae. Fisheries Oceanography. 3(2): 81-91.

“The transport of particles representing sandeel larvae in the North Sea is simulated with a three-dimensional circulation model for the years 1976 to 1990. A great year-to-year variability in drift patterns is demonstrated. The results may explain some of the observed differences in recruitment between the main sandeel areas in the North Sea. In the northern sandeel area it seems that strong year classes are unlikely if the retention due to unfavourable currents is poor, and that a high retention in the summer may favour a good year class. In the southern sandeel area no clear coupling between year class strength and larval drift is found, possibly because the retention always seems large enough for a potentially good year class. For more quantitative use of such models in relation to sandeel recruitment, more biological knowledge is obviously needed on larval vertical distribution and timing of sandeel hatching and settling.”

Keywords: *Ammodytes*; North Sea; larvae; transport.

**Berrick, S. 1980.** The essential sand eel. Cape Naturalist. 9(3): 56-60.

Keywords: *A. americanus*; Atlantic (northwest); natural history.

**Bertelsen, E.; Popp Madsen, K. 1958.** Some observations on sand-eels (*Ammodytes*). Biology and fishery. ICES C.M. Near Northern Seas Comm. Document No. 99: 3 p. [Mimeo].

Keywords: *Ammodytes*; biology; fisheries.

**Bertram, D.F. 1988.** The provisioning of nestlings by parent rhinoceros auklets (*Cerorhinca monocerata*). Burnaby, BC: Simon Fraser University. M.S. thesis.

Keywords: *Ammodytes*; predators (birds, rhinoceros auklet).

**Bertram, D.F.; Kaiser, G.W. 1988**. Monitoring growth and diet of nestling rhinoceros auklets to gauge prey availability. Tech. Rep. 48. Delta, BC: Canadian Wildlife Service.

Keywords: *Ammodytes*; predators (birds, rhinoceros auklet).

**Bertram, D.F.; Kaiser, G.W. 1993**. Rhinoceros auklet (*Cerorhinca monocerata*) nestling diet may gauge Pacific sand lance (*Ammodytes hexapterus*) recruitment. Canadian Journal of Fisheries and Aquatic Sciences. 50: 1908-1915.

“We studied (1984-86) the diet of rhinoceros auklet nestlings at three colonies on the British Columbia coast. On the Lucy Islands, Pacific sand lance dominated nestling food loads in all years. In 1985, 0+ sand lance dominated the nestling diet on all colonies. Concurrent measures of nestling growth rate, independent indexes of ocean production, and the proportion of sand lance in groundfish stomach samples were also highest in 1985. This suggests a linkage

between ocean production, 0+ sand lance abundance, and events on seabird colonies over a broad geographic range. We emphasize the importance of sand lance to temperate seabirds and contrast British Columbia with areas where sand lance are commercially exploited."

Keywords: *A. hexapterus*; British Columbia; importance; O-age; predators (birds, rhinoceros auklet); recruitment.

**Bertram, D.F.; Kaiser, G.W.; Ydenberg, R.C. 1991.** Patterns in the provisioning and growth of nestling rhinoceros auklets. Auk. 108: 842-852.

Parents feed their chicks at night. A parent may deliver one large fish (up to 55 g) or up to 20 smaller fish carried cross-wise in its bill. In British Columbia, Pacific sandlance is the dominant prey species although herring and rock-fish are also common prey. Burrow loads (fish brought to the burrow by parents each night) ranged from 0 to 116 g, the modal load was 30-35 g—indicating that the majority of burrow loads are composed of a single bill load. The loads were, by mass, >85 percent Pacific sand lance.

Discusses the 1982-83 El Niño-Southern Oscillation event (a warm-water mass moved northward along the western North American coastline) and its probable effect on prey species and birds. In most cases, changes in prey popula-tions (primarily fish) were considered basic to seabird mortality and reproductive failure.

In British Columbia, there is no commercial fishery for sand lance, which may allow for more direct links among ocean production, prey populations, and events on seabird colonies than in systems where seabird prey are har-vested commercially.

March through August encompass the developmental period of the larvae, and juvenile sand lance predominate in the nestling diet.

Keywords: *A. hexapterus*; British Columbia; importance; predators (birds, rhinoceros auklet).

**Best, E.A.; Hardman, W.H. 1982.** Juvenile halibut surveys, 1973-1980. Tech. Rep. 20. [Place of publication unknown]: International Pacific Halibut Commission. 38 p.

Keywords: *A. hexapterus*; predators (fish, Pacific halibut).

**Best, E.A.; St-Pierre, G. 1986.** Pacific halibut as predator and prey. Tech. Rep. 21. [Place of publication unknown]: International Pacific Halibut Commission. 27 p.

"The stomachs of over 2,700 juvenile halibut (*Hippoglossus stenolepis*) collected from across a broad expanse of the Gulf of Alaska and over 1,300 adult halibut from waters off British Columbia and Alaska were examined. Halibut were found to be opportunistic feeders. Juvenile halibut fed almost exclusively on small crustaceans. With increasing size, the diet shifted to larger crustaceans and fish, Pacific sand lance, walleye pollock, octopus, and Tanner crab made up a significant proportion of the diet. A literature search was conducted to define the role of halibut as a prey item but little definitive information was found."

Keywords: *A. hexapterus*; Alaska; British Columbia; predators (fish, Pacific halibut).

**Bianki, V.V. 1977.** Gulls, shorebirds and alcids of Kandalaksha Bay. Jerusalem, Israel: Israel Program for Scientific Translations. 250 p. (Translated from Russian.)

Keywords: *Ammodytes*; predators (birds).

**Biderman, J.O.; Drury, W.H. 1978.** Ecological studies in the northern Bering Sea: studies of seabirds in the Bering Strait: In: Environmental assessment of the Alaskan Continental Shelf, annual reports of principal investigators. Boulder, CO: National Oceanic Atmospheric Administration, Environmental Research Laboratory. 2: 751-838.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (birds).

**Biderman, J.O.; Drury, W.H.; French, F.B., Jr.; Hinckley, S. 1978.** Ecological studies in the northern Bering Sea: birds of coastal habitats on the south shore of Seward Peninsula, Alaska. In: Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators. Boulder, CO: National Oceanic Atmospheric Administration, Environmental Research Laboratory. 2: 510-613.

Keywords: *A. hexapterus*; Bering Sea; predators (birds).

**Bigelow, H.B.; Schroeder, W.C. 1953.** Fishes of the Gulf of Maine. U.S. Fish and Wildlife Service Fishery Bulletin. 53(74): 1-577.

Keywords: *Ammodytes*; Gulf of Maine; general works.

**Bireley, L.E. 1984.** Multivariate analysis of species composition of shore-zone fish assemblages found in Long Island Sound. Estuaries. 7(3): 242-247.

“A nested design was used to analyze the variance of the proportions or percent species composition of shore-zone finfish assemblages in the vicinity of the Millstone Nuclear Power Station in eastern Long Island Sound. The relative importance of 5 selected shore-zone species [*Menida* spp., *Ammodytes* sp., *Fundulus* spp., *Brevoortia tyrannus* and *Apeltes quadracus*] was found to be significantly influenced by both station and season within a year. Also included in the nested analysis of variance (ANOVA) model were effects due to period of plant operation (no units operating, 1 unit operating and 2 units operating) and year within period. Neither of these 2 effects was found to influence the percent species composition. A nested ANOVA of percent species composition can be useful for detecting changes in assemblages of finfish species over time and space.”

Keywords: *Ammodytes*; Long Island Sound; distribution; model.

**Birkhead, T.R. 1976.** Breeding biology and survival of guillemots (Uria aalge). Oxford, England: Oxford University. 204 p. Ph.D. dissertation.

Keywords: *Ammodytes*; predators (birds, guillemot).

Birkhead, T.R. 1977. Adaptive significance of the nestling period of guillemots *Uria aalge*. Ibis. 119(4): 544-549.

“Observations at a colony of common guillemots on Skomer Island, Wales during 1972-75 are reported. Details are given of chick-losses at the colony, food consumption and development of chicks. Of 1140 fish fed to chicks, all but 9 were clupeids, the rest were *Ammodytes* spp. The mean consumption of a total of 60 chicks over the daylight period was 3.23 to 1.42 fish/chick. There was some evidence of a small peak in the rate of feeding chicks soon after first light in the morning. Feeding trips by parent birds were, on average, 15 min longer in the afternoon than in the morning (mean duration for whole day 85.6 to 49.9 min). Changes in chick wing-length and chick weight in relation to age are described. Calculations of the food requirements of adult and chick indicate that if the chick was to remain at the nest site until it attained adult weight food requirements would exceed the capabilities of the parents. Therefore there is pressure to reduce the nestling period from this direction but a significant time is required for growth after hatching to ensure that the chicks can glide safely from the nest site and swim underwater when it is necessary to escape from predators.”

Keywords: *Ammodytes*; Wales; predators (birds, common guillemot).

**Birkhead, T. 1986.** Feeding ecology of common guillemots on Fair Isle, 1985. British Ecological Society Bulletin.17(1): 13-15.

Keywords: *Ammodytes*; Scotland; predators (birds, common guillemot).

**Birkhead, T.R. 1992**. Skomer guillemot studies 1992. JNCC Report. 128: 1-4.

Keywords: *Ammodytes*; Wales; predators (birds, common guillemot).

**Birkhead, T.R.; Furness, R.W. 1984.** Seabird colony distributions suggest competition for food supplies during the breeding season. Nature. 311: 655-656.

Keywords: *Ammodytes*; predators (birds).

**Birkhead, T.R.; Furness, R.W. 1985.** Regulation of seabird populations. British Ecological Society Symposium. 25: 147-167.

Keywords: *Ammodytes*; predators (birds).

**Birkhead, T.R.; Harris, M.P. 1985.** Ecological adaptations for breeding in the Atlantic Alcidae. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. London England: Academic Press: 205-232.

Keywords: *Ammodytes*; predators (birds).

**Birkhead, T.R.; Nettleship, D.N. 1981.** Reproductive biology of thick-billed murres (*Uria lomvia*): an intercolony comparison. Auk. 98(2): 258-269.

Keywords: A*mmodytes*; predators (birds, thick-billed murre).

**Birkhead, T.R.; Nettleship, D.N. 1982a.** Studies of alcids breeding at the Gannet Clusters, Labrador, 1981. Studies on Northern Seabirds Ms. Rep. 125. [Place of publication unknown]: Canadian Wildlife Service: 1-144.

Keywords: *Ammodytes*; Labrador; predators (birds).

**Birkhead, T.R.; Nettleship, D.N. 1982b.** The adaptive significance of egg size and laying date in thick-billed murres (*Uria lomvia*). Ecology. 63: 300-306.

Keywords: *Ammodytes*; predators (birds, thick-billed murre).

**Birkhead, T.R.; Nettleship, D.N. 1987.** Ecological relations between common murres, *Uria aalge*, and thick-billed murres *Uria lomvia*, at the Gannet Islands, Labrador. III: Feeding ecology of the young. Canadian Journal of Zoology. 65: 1638-1649.

Keywords: *Ammodytes*; Labrador; predators (birds, common murre, thick-billed murre).

**Birman, I.B. 1960.** New information on the marine period of life and the marine fishery of Pacific salmon. In: Trudy Soveshchaniia po biologicheskim osnovam okeanicheskovo rybolovstva, 1958. Trudy Soveshchanii Ikhtiologischeskoi Komissii Akademii Nauk SSSR. 10. Translated from Russian: Fisheries Research Board Canada Translation Series 357: 151-164.

Keywords: *Ammodytes*; predators (fish, Pacific salmon).

**Birman, I.B. 1969.** Distribution and growth of young Pacific salmon of the genus *Oncorhynchus* in the sea. Problems in Ichthyology. 9: 651-666.

Keywords: *Ammodytes*; predators (fish, Pacific salmon).

**Birt, V.L.; Birt, T.P.; Goulet, D. [and others]. 1987.** Ashmole's halo: direct evidence for prey depletion by a seabird. Marine Ecology Progress Series. 40: 205-208.

Keywords: *Ammodytes*; predators (birds).

**Blackburn, J.E. 1973.** A survey of the abundance, distribution, and factors affecting distributions of ichthyoplankton in Skagit Bay. Seattle, WA: University of Washington. 136 p. M.S. thesis.

Keywords: *A. hexapterus*; Washington; distribution; larvae.

**Blackburn, J.E. 1978a.** Pelagic and demersal fish assessment in the lower Cook Inlet estuary system. Kodiak, AK: Alaska Department of Fish and Game: annual report to Outer Continental Shelf Environmental Assessment Program. 142 p.

Keywords: *A. hexapterus*; Cook Inlet; abundance; distribution.

**Blackburn, J.E. 1978b.** Pelagic and demersal fish assessment in the lower Cook Inlet estuary system. Kodiak, AK: Alaska Department of Fish and Game: final report, research unit 512. 293 p.

Keywords: *A. hexapterus*; Cook Inlet; abundance; distribution.

**Blackburn, J.E.; Anderson, P.J. 1997.** Pacific sand lance growth, seasonal availability, movements, catch variability, and food in the Kodiak-Cook Inlet area of Alaska. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]: [location unknown]. Prog. Rep. 97-01. [Fairbanks, AK]: University of Alaska Fairbanks, Alaska Sea Grant College: 409-426.

“A small-mesh surface tow net and beach seine were used to sample the nearshore fishes on the east side of the Kodiak archipelago and in Cook Inlet in 1976 and 1978-1979. Sampling was conducted from March through November, with lowest catches occurring in March and November and highest catches May through September. The growth of sand lance (*Ammodytes hexapterus*), based on length frequencies, indicated an August mean size of 87 mm for age-0 and 136 mm for age 1 in the Kodiak area. Very little growth occurred between August and following May. The August mean size of age-0 fish was 57 mm in Cook Inlet (size of age-1 fish was not well documented). In Cook Inlet both growth and catch rates were lower than in the Kodiak area. During August and September sand lance abundance increased in inshore areas, and in Cook Inlet, where growth was restricted, changes in size distribution occurred in a pattern that strongly suggested movement of the age-0 fish into nearshore waters. Catches stratified by tidal stage were not significantly different but suggested real differences exist that were not detected. Catch variability among samples was extremely high, with coefficients of variation typically from 4 to 6. A few fish in spawning condition were found from August through November. Food habit data from Cook Inlet showed >90% by weight of the food was calanoid copepods during summer; more variety of items in the diet occurred at other times.”

Keywords: *A. hexapterus*; Alaska; Cook Inlet; Kodiak Island; distribution; food; movements; seasonal abundance.

**Blackburn, J.E.; Anderson, K.; Hamilton, C.I.; Starr, S.J. 1980.** Pelagic and demersal fish assessment in the lower Cook Inlet estuary system. [Place of preparation unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, OCSEAP Final Report, Biological Studies. RV0512. 12: 259-602.

Keywords: *A. hexapterus*; Cook Inlet; abundance; distribution.

**Blackburn, J.E.; Jackson, P.B. 1980.** Seasonal composition, abundance and food web relationships of principal juvenile and adult marine finfish species inhabiting the nearshore zone of Kodiak Island’s eastside. [Place of preparation unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, OCSEAP Final Report. 101 p.

Keywords: *A. hexapterus*; Kodiak Island; predators (fish).

**Blackek, R.W. 1977.** Report on MAFF O-group fish survey at Faeroe, June 1975. Copenhagen, Denmark: Annals of Biology. 32: 205-208.

Some data on other fish are also given: Norway pout, sandeels, flatfish, O-group capelin, sprat, adult haddock, mackerel, blue whiting, lumpsuckers, angler (*Lophius*), cod argentine, capelin, *Crystallogobius*.

Keywords: *Ammodytes*; British Isles; catch; fisheries; O-age; size distribution.

**Blair, A.A. 1965.** Bay of Islands and Humber River Atlantic salmon investigations. Journal of the Fisheries Research Board Canada. 22(2): 599-620.

Keywords: *Ammodytes*; predators (fish, Atlantic salmon).

**Blake, B. 1983.** Threats to birds of the sea. New Scientist. 100(1380): 210-211.

Keywords: *A. lancea*; *A. marinus*; British Isles; fisheries; marine pollution; predators (birds, guillemot).

**Blake, B.F. 1983.** A comparative study of the diet of auks killed during an oil incident in the Skagerrak in January 1981. Journal of Zoology. 201(1): 1-12.

“Stomach contents were examined from guillemots *Uria aalge* razorbills *Alca torda*, and little auks *Alle alle* killed by oil in the Skagerrak in January 1981. The range of prey species was small; the commonest fish found in the stomachs were *Gobmsculus flavescens* (Fabricius), *Crystallogobius linearis* (Dueben), *Sprattus sprattus* (L.), *Trisopterus minutus* (L.) and *Ammodytes* sp. The relative importance of these fish depended on bird species and locality. Guillemots contained gadoids more frequently and sandeels less frequently than razorbills, and the composition of guillemot samples from Oslo Fjord differed from that of samples from Sweden. The frequency of occurrence of items in the diet of guillemots from Oslo Fjord was apparently influenced by the extent of oiling suffered by the birds.”

Keywords: *Ammodytes*; Norway; predators (birds, guillemot, razorbill).

**Blake, B.F. 1984**. Diet and fish stock availability as possible factors in the mass death of auks in the North Sea. Journal of Experimental Marine Biology and Ecology. 76: 289-304.

“In Feb. 1983 more than 30,000 birds died on the North Sea coasts of England and Scotland. The birds were unoiled, and there was no immediately obvious cause of death. Stomach contents of auks killed in this incident were examined to ascertain whether they provided any indication of the causal factors. Analysis of food remains showed differences between sample sites and between guillemots, *Uria aalge* (Pont.), and razorbills, *Alca torda* L. In all areas gadoid remains comprised a higher, and sandeels [*Ammodytes* spp.] a lesser, proportion of the stomach contents in guillemots than in razorbills. The relative importance of clupeid remains varied with area. These differences, combined with current trends in the fisheries biology of major prey species, provided an ecological basis for a hypothesis explaining the incident. Starvation was probably a major factor in the death of the auks, and this may have been related to a combination of adverse weather conditions and changing patterns of abundance in North Sea sprat, *Sprattus sprattus* (L.), populations.”

Keywords: *Ammodytes*; North Sea; predators (birds, guillemot, razorbill).

**Blake, B.F.; Dixon, T.J.; Jones, P.H.; Tasker, M.L. 1985.** Seasonal changes in the feeding ecology of guillemots *Uria aalge* off north and east Scotland, United Kingdom. Estuarine Coastal and Shelf Science. 20(5): 559-568.

“Stomach contents were examined from 750 guillemots collected at several sites in the northern North Sea. The dietary composition was compared between months and between localities in order to assess seasonal and geographical trends in feeding strategy. From March-Aug. sandeels dominated the diet, in Sept. a changeover period occurred when clupeid and gadoid remains became increasingly frequent in the stomach contents. This situation

persisted over the winter period, but the importance of the 2 fish families varied with area, clupeids being more important in more southerly samples and gadoids in the north. Dietary data were considered in relation to available fisheries information and to known guillermot distribution patterns."

Keywords: *Ammodytes*; North Sea; predators (birds, guillemot).

**Blaxter, J.H.S. 1986.** Development of sense organs and behavior of teleost larvae with special reference to feeding and predator avoidance. Transactions of the American Fisheries Society. 115(1): 98-114.

Keywords: *Ammodytes*; fisheries; physiology.

**Bodammer, J.E. 1987.** A preliminary study on the corneas of American sand lance larvae exposed to copper. In: Vernberg, W.B. [and others], eds. Pollution physiology of estuarine organisms; a symposium; 1985 Oct. 21-24; Georgetown, SC. The Belle W. Baruch Library in Marine Science 17. Columbia, SC: University of South Carolina Press: 439-448.

Keywords: *A. americanus*; heavy metal toxicity; physiology.

**Boddington, D. 1960.** Unusual mortality of young puffins on St. Kilda, 1959. Scottish Birds. 1: 218-220.

Keywords: *Ammodytes*; predators (birds, puffin).

**Boekelheide, R.J.; Ainley, D.G.; Morrell, S.S. [and others]. 1990.** Common murre. In: Ainley, D.G.; Boekelheide, R.J., eds. Seabirds of the Farallon Islands. Stanford, CA: Stanford University Press: 245-275.

Keywords: *Ammodytes*; Farallon Islands; predators (birds, common murre).

**Bogorov, B.G.; Manteufel, B.P.; Pavlova, A.E. 1939.** Nutrition of the small sandeel *Ammodytes tobianus* in Murman waters. Trudy Inst. Akad. Nauk SSSR. 4: [pages unknown].

Keywords: *A. tobianus*; Murman Coast; energy density.

**Bollens, S.M.; Osgood, K.; Frost, B.W.; Watts, S.D. 1993.** Vertical distributions and susceptibilities to vertebrate predation of the marine copepods *Metridia lucens* and *Calanus pacificus*. Limnology and Oceanography. 38(8): 1827-1837.

Keywords: *Ammodytes*; food and feeding habits.

**Boone, D.L. 1986**. Breeding biology and early life history of the tufted puffin (*Fratercula cirrhata*). Corvallis, OR: Oregon State University. 46 p. M.S. thesis.

Keywords: *Ammodytes*; predators (birds, tufted puffin).

**Borch-Jensen, C.; Staby, A.; Mollerup, J. 1993.** Supercritical fluid chromatographic analysis of a fish oil of the sand eel (*Ammodytes* sp.). Journal of High Resolution Chromatography. 16(10): 621-623.

Keywords: *Ammodytes*; composition; lipid content.

**Bourne, W.R.P. 1983.** Birds, fish and offal in the North Sea. Marine Pollution Bulletin. 14: 294-296.

Keywords: *Ammodytes*; North Sea.

**Bourne, W.R.P. 1990.** Scottish seabird fluctuations. Marine Pollution Bulletin. 20(1): [pages unknown].

Keywords: *Ammodytes*; Scotland; predators (birds, arctic skua, arctic tern, black guillemot, black-legged kittiwake, common murre, common tern, cormorant, gannet, great skua, puffin, razorbill, shag).

**Bowen, W.D.; Harrison, G.D. 1994.** Offshore diet of grey seals *Halichoerus grypus* near Sable Island, Canada. Marine Ecology Progress Series. 112(1-2): 1-11.

“Many pinnipeds forage considerable distances from mainland haul-out sites for much of the year, yet little is known about the composition of their offshore diets. This may result in an incomplete and potentially biased view of the diet of wide-ranging species such as the grey seal Halichoerus grypus. On the Scotian Shelf, offshore fish assemblages differ from those nearer the coastal mainland sites and thus we expected that grey seal diets would also differ. We studied the composition of grey seal diets at Sable Island, an offshore site 160 km east of Nova Scotia, Canada. Otoliths, squid beaks and other hard parts, representing more than 24 types of prey, were recovered from 365 of 393 grey seal faeces collected between July 1991 and January 1993. Despite the large number of taxa found, 3 prey, sand lance *Ammodytes dubius* (69.2 %), Atlantic cod *Gadus morhua* (15.5 %) and flatfishes (*Pleuronectiformes*, 10.7 %) accounted for 95.4 % of the estimated wet weight food consumed by grey seals. Despite within-year variation in the species composition of grey seal diets, sand lance was the most important food in all months sampled. Comparisons of prey species abundance in research trawl surveys to that in grey seal diets indicated that more abundant and more widely distributed species accounted for most of the prey eaten.”

Keywords: *A. dubius*; Nova Scotia; importance; predators (mammals, gray seal).

**Bowen, W.D.; Lawson, J.W.; Beck, B. 1993.** Seasonal and geographic variation in the species composition and size of prey consumed by grey seals (*Halichoerus grypus*) on the Scotian Shelf. Canadian Journal of Fisheries and Aquatic Sciences. 50(8): 1768-1778.

“Offshore at Sable Island, northern sand lance, silver hake, and squid (in order of importance) accounted for 86.1% of the wet weight ingested by seals during summer; sand lance and cod accounted for 96.1% of prey eaten in winter.”

Keywords: *A. dubius*; predators (mammals, gray seal).

**Bowman, A. 1914.** The spawning areas of sandeels in the North Sea. Scientific Investigations of the Fishery Board ofr Scotland. 1913: 1-13.

“At all periods of their existence, larvae or adult, they are preyed upon. They never reach a size at which they are immune from attack; and, occurring as they do in such countless numbers, they are a permanent source of food for many species, and in particular for cod, haddock, whiting, herring. Herring are often rendered less valuable for curing purposes merely because they have fed voraciously on sand-eels, and it is no uncommon thing to find cod, haddock, and whiting gorged with sand-eels: as many as 120 adults of *A. tobianus* were on one occasion (23-1-’08) taken from the stomach of a large cod caught by the “Goldseeker,” at Burghead Bay. In August, 1909, the plaice in Broad Bay (Minch) were found to be feeding almost exclusively on large *A. tobianus*. Even the stomachs of the adult sand-eels are sometimes found filled with post-larval forms.

“This communication deals with the spawning areas and the distribution of sand-eels in the northern North Sea during the first quarter of the year. It is shown that, with the exception of a comparatively few examples in the neighbourhood of the Firth of Forth, no larval sand-eels are found in the plankton in the northern portion of the North Sea in the first two months of the year. They suddenly appear in countless numbers in the month of March. This sudden appearance is explained. These early-hatched larvae are proved indirectly to belong almost exclusively to *Ammodytes tobianus*. These larvae are shown to be widely, but irregularly, distributed, and the localities where they are found in greatest numbers are indicated. Comparative figures are given proving that the area of greatest frequency is in the vicinity of the Orkney Islands and the Pentland Firth. The larvae occur with fair uniformity along the East Coast of Scotland from the Moray Firth to the Firth of Forth. Spawning areas depend on depth and bottom deposit. The frequency is low inshore and in the deeper parts of the central North Sea. The localisation of the spawning areas is a necessary preliminary to further investigations.”

Keywords: *A. lanceolatus*; A. tobianus; North Sea; distribution; larvae; predators (fish, cod, haddock, herring, plaice, whiting); spawning.

**Bowman, R.E.; Langton, R.W. 1978.** Fish predation on oil-contaminated prey from the region of the Argo Merchant oil spill. In: In the wake of the Argo Merchant. [City unknown], RI: University of Rhode Island Center for Ocean Managerial Studies: 137-141.

“The last major prey, American sand lance, represented 21.6% of the total weight of the combined stomach contents. Nine, or 43%, of the 21 predators utilized sand lance as prey. They were found in large amounts in the stomachs of pollock (68.0%), Atlantic cod (44.4%), winter skate (36.4%), and windowpane (11.4%).”

Keywords: *A. americanus*; oil pollution; predators (fish, Atlantic cod, pollock, windowpane, winter skate).

**Bowman, R.E.; Michaels, W. 1981.** Food habits of seventeen species of northwest Atlantic fish. Tech. Memo. NMFS-F/NEC-28. [Place of preparation unknown]: National Oceanic and Atmospheric Administration.

Keywords: *Ammodytes*; Atlantic (northwest); predators (fish).

**Bowman, R.; Warzocha, J.; Morris, T. 1984.** Trophic relationships between Atlantic mackerel and American sand lance. International Council for the Exploration of the Sea C.M.H. 27: 1-19.

Keywords: *A. americanus*; Atlantic (northeast, northwest); competition; population density; predators (fish, Atlantic mackerel).

**Bradstreet, M.S.W. 1985.** Feeding studies. In: Johnson, S.R., ed. Population estimation, productivity, and food habits of nesting seabirds at Cape Pierce and the Pribilof Islands, Bering Sea, Alaska. Anchorage, AK: LGL Ecological Research Associates, Inc., for Minerals Management Service; 257-306. Chapter IV.

Keywords: *A. hexapterus*; Bering Sea; Pribilof Islands; predators (birds, black-legged kittiwake, common murre, horned puffin, red-faced cormorant, red-legged kittiwake, thick-billed murre, tufted puffin).

**Bradstreet, M.S.W.; Brown, R.G.B. 1985.** Feeding ecology of the Atlantic Alcidae. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. London, England: Academic Press: 263-318.

This paper reviews numerous studies on the diet of seabird chicks and ranks food items by percentage of weight in diet. Sand lance ranked number one among dietary items fed to common murre, Atlantic puffin, and razorbill chicks and number two or three for items fed to thick-billed murre and black guillemot chicks.

Keywords: *Ammodyte*s; importance; predators (birds, thick-billed murre, common murre, Atlantic puffin, razorbill, black guillemot).

**Brander, K.; Huggins, W.; Vine, M. 1975.** Report on the international O group fish survey in Faeroe, Iceland and East Greenland waters in July-August 1973. Annales Biologiques. 30(1973): 222-234.

Keywords: *Ammodytes*; Faroes; Greenland; Iceland; fisheries.

**Braune, B.M.; Gaskin, D.E. 1982.** Feeding ecology of non-breeding populations of larids off Deer Island, New Brunswick. Auk. 99: 67-76.

Keywords: *Ammodytes*; New Brunswick; predators (birds).

**Breckling, P.; Neudecker, T. 1994.** Monitoring the fish fauna in the Wadden Sea with stow nets. Part 1: A comparison of demersal and pelagic fish fauna in a deep tidal channel. Archive of Fishery and Marine Research. 42(1): 3-15.

Keywords: *Ammodytes*; Wadden Sea; distribution; fisheries.

**Breder, C.M. 1956.** A sand launce *Ammodytes* in the coelom of a weak fish *Cynoscion* with earlier records of similar phenomena. New York: Zoologica. 41(2): 85-87.

Keywords: *Ammodytes*; predators (fish, weakfish).

**Brêthes, J.C.F.; Saint-Pierre, R.; Desrosiers, G. 1992.** Growth and sexual maturation of the American sand lance (*Ammodytes americanus* Dekay) off the north shore of the Gulf of St. Lawrence. Journal of Northwest Atlantic Fishery Science. 12: 41-48.

"Samples of American sand lance (*Ammodytes americanus*) were collected in June-September 1983 off the north shore of the Gulf of St. Lawrence (Canada), at depths varying from 1 to 40 m. Length-frequency modes identified by modal analysis corresponded closely with mean lengths of fish based on otolith annuli counts, supporting the hypothesis that the number of annuli corresponds to the age of the fish. The otolith length was linearly correlated with the fish length. An opaque annulus was deposited over a short period, primarily August. The study indicated that 75-100% of the annual growth was achieved during the June-September period. Maximum life span was estimated to be 12 years. The parameters of the von Bertalanffy growth equation were: K = 0.24 year-1, L. infin. = 188.2 mm, t0 = 1.14 year. The growth of the American sand lance in the study area was slower than for the same species and for *A. dubius* in more southern areas. The length-weight relationship indicated that the growth in weight was isometric and identical for both sexes. Length-weight relationship, gonadosomatic index and the observation of maturity stages suggested that reproduction takes place shortly after September. All the fishes were matured at 20 months of age. Males mature at a smaller size (< 85 mm) than the females (90 mm)."

Keywords: *A. americanus*; Gulf of St. Lawrence; gonadosomatic index; length; otolith.

**Briggs, K.T.; Varoujean, D.H.; Heinemann, D.; Ford, R.G. 1989.** Synthesis of information on seabirds of the eastern north Pacific, with emphasis on the Oregon and Washington OCS area. In: Brueggeman, J.J., ed. Oregon and Washington marine mammal and seabird surveys: information synthesis and hypothesis formulation. OCS Study MMS 89-1130. Los Angeles, CA: Minerals Management Service, Pacific Outer Continental Shelf Region. 374 p.

Keywords: *Ammodytes*; Oregon; Washington; predators (birds).

**Briggs, K.T.; Varoujean, D.H.; Williams, W.W. [and others]. 1992.** Seabirds of the Oregon and Washington OCWS, 1989-1990. In: Brueggeman, J.J., ed. Oregon and Washington marine mammal and seabird surveys. Los Angeles, CA: U.S. Department of the Interior, Minerals Management Service, Pacific Outer Continental Shelf Region; final report; OCS Study MMS 91-0093; contract no. 14-12-0001-30426. 162 p.

Keywords: *Ammodytes*; Oregon; Washington; predators (birds).

**Brodeur, R.D. 1991.** Ontogenetic variations in the type and size of prey consumed by juvenile coho, *Oncorhynchus kisutch*, and chinook, *O. tschawytscha* salmon. Environmental Biology of Fishes. 30: 303-315.

Keywords: *A. hexapterus*; predators (fish, chinook salmon, coho salmon).

**Brodeur, R.D.; Merati, N. 1993.** Predation on walleye pollock (*Theragra chalcogramma*) eggs in the western Gulf of Alaska: the roles of vertebrate and invertebrate predators. Marine Biology. 117: 483-493.

Keywords: *A. hexapterus*; Gulf of Alaska; food and feeding habits.

**Brodeur, R.D.; Pearcy, W.G. 1990.** Trophic relations of juvenile Pacific salmon off the Oregon and Washington coast. Fishery Bulletin. 88: 617-636.

Keywords: *A. hexapterus*; Oregon; Washington; predators (fish, Pacific salmon).

**Brodeur, R.D.; Rugen, W.C. 1994.** Diel vertical distribution of ichthyoplankton in the northern Gulf of Alaska. U.S. National Marine Fisheries Service, Fishery Bulletin. 92(2): 223-235.

Keywords: *A. hexapterus*; Gulf of Alaska; migration.

**Bromley, P.J. 1987.** The effects of food type meal size and body weight on digestion and gastric evacuation in turbot (*Scophthalmus maximus*). Journal of Fish Biology. 30(4): 501-512.

“Experiments were conducted on a size range of turbot using whole prey organisms. Stomach contents were serially sampled at intervals after feeding on a range of meal sizes of sandeels and sprats. Gastric evacuation was essentially linear with time, though some fluctuations was observed. Control over evacuation appeared to be by regulation of the processes leading to chyme production. Close agreement between evacuation rate and the satiation feeding rate of fish in laboratory experiments was observed. Implications of these findings for techniques of estimating the feeding rates of natural fish populations are discussed.”

Keywords: *Ammodytes*; predators (fish, turbot).

**Bromley, P.J. 1988.** Gastric digestion and evacuation in whiting (*Merlangius merlangus*). Journal of Fish Biology. 33(2): 331-338.

“Three meal sizes of sandeels were fed to whiting in order to monitor the evacuation of food out of the stomach. The stomach contents were sampled at intervals after feeding, using a stomach pump. In such experiments, the proportion of fish with empty stomachs tends to increase with time and, since stomach contents are limited to zero or positive values, the variance of the stomach contents becomes censored at zero. This tends to produce a curved relationship between mean stomach content and time, which gives the impression that evacuation rate slows down at low levels of stomach fullness. By taking account of censoring, it was shown that the evacuation curve generated for whiting was consistent with and could be generated from a linear model in which the rate of gastric evacuation exhibited by the fish was constant and independent of meal size, level of stomach fullness and time after feeding. The parameters of the linear model were estimated by maximum likelihood and then applied in a second model to predict the observed mean stomach content. The average gastric evacuation rate of whiting of mean weight 268 g at 10 °C was 0.31 g $h^{-1}$.”

Keywords: *Ammodytes*; predators (fish, whiting).

**Brook, G. 1885.** Preliminary report on the food of the cod. Annual Report, Fisheries Board of Scotland. 4: 134-147.

Keywords: *Ammodytes*; North Sea; predators (fish, cod).

**Brooke, M.L. 1972.** The puffin population of the Shiant Islands. Bird Study. 19: 1-6.

Keywords: *Ammodytes*; predators (birds, puffin).

**Brown, A.C.; McLachlan, A. 1990.** Ecology of sandy shores. New York: Elsevier Publications. 328 p.

Keywords: *Ammodytes*; habitat.

**Brown, E.G.; Pierce, G.J. 1997.** Diet of harbour seals at Mousa, Shetland, during the third quarter of 1994. Journal of the Marine Biological Association of the United Kingdom. 77(2): 539-555.

“Scats (N=200) of harbour seals (*Phoca vitulina*) were collected from haul-out sites on the Island of Mousa, southeast Shetland, during July, August and September 1994. A total of 5,531 fish otoliths were identified in scats and measured to reconstruct fish lengths and weight. Gadid fishes dominated the diet of harbour seals on Mousa during the study period, both in terms of weight and the frequency with which they occurred. There was evidence for the

existence of temporal trends. Over the period July-September the importance of gadids in the diet increased while that of sandeels declined. These temporal trends are probably associated with changes in prey availability. Comparisons of the size of sandeels, herring and whiting eaten by seals with trawl catches suggest that seals were probably not size-selective, but a corollary of this is that, while otolith size is reduced during passage through seal guts, application of correction factors derived from captive feeding experiments led to overestimates of fish size."

Keywords: *Ammodytes*; Shetland; Scotland; predators (mammals, harbor seal).

**Brown, J.A. 1986.** The development of feeding-behavior in the lumpfish, *Cyclopterus lumpus*. Journal of Fish Biology. 29: 171-178.

Keywords: *Ammodytes*; predators (fish, lumpfish).

**Brown, R.F.; Mate, B.R. 1983.** Abundance, movements, and feeding habits of harbor seals, *Phoca vitulina*, at Netarts and Tillamook Bays, Oregon. Fishery Bulletin. 81(2): 291-301.

"Patterns of seasonal abundance of harbor seals (*P. vitulina*) at Netarts and Tillamook bays, Oregon, were documented by recording numbers of seals hauling out on tidally exposed sand flats in both bays. Harbor seal abundance at Tillamook Bay peaked during pupping (May-June) and molting (August) periods, while peak abundance at Netarts Bay coincided with the annual return (October-November) of chum salmon, *Oncorhynchus keta* to a hatchery on Whiskey Creek. Observations of seals preying on adult salmon resulted in estimated losses of 6.1, 7.2, and 1.5% of the total chum returns for 1978, 1979, and 1980, respectively, due to seal predation in the Whiskey Creek area. Other prey species of harbor seals at Netarts Bay were identified by the recovery of prey hard parts from seal feces collected on haul-out areas. The Pacific sand lance, *Ammodytes hexapterus*, was the most frequently identified prey item. Ten species of flatfish (Order Pleuronectiformes) were identified as harbor seal prey."

Keywords: *A. hexapterus*; Oregon; predators (mammals, harbor seal).

**Brown, R.G.B. 1985.** The Atlantic Alcidae at sea. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. London: Academic Press: 383-426.

"For example, important prey of the Thick-billed Murre such as arctic cod and sculpins (Cottidae) are either not fished commercially at all, or are fished only in very limited areas. Others, such as capelin, sprat, sandlance, and the small clupeids marketed as 'sardines', are indeed harvested commercially.

"Sandlance and small clupeid fish are the principal foods of the Common Murres which breed in the British Isles and the movements of the birds from north British colonies coincide quite closely with the movements of suitable prey in that area."

Keywords: *Ammodytes*; British Isles; commercial fisheries; predators (birds, common murre, thick-billed murre).

**Brown, R.G.B.; Nettleship, D.N. 1982.** Capelin and seabirds in the northwest Atlantic. In: Pacific seabird group symposium: Marine birds: their feeding ecology and commercial fisheries relationships; [dates of meeting unknown]; [location unknown]. [Place of publication unknown]: [publisher unknown]: 184-194.

At Witless Bay, Newfoundland, sand lance occurred in 12.5 percent of the food of Atlantic puffin chicks.

Keywords: *Ammodytes*; Newfoundland; predators (birds, Atlantic puffin).

**Brown, W.W.; Cheng, C. 1946**. Investigations into the food of cod *Gadus callarias* L. off Bear Island, and of cod and haddock *G. aeglifinus* L. off Iceland and the Murman coast. Hull Bulletins of Marine Ecology. 3(18): 35-71.

"The cod off Andanes were feeding almost entirely upon fish, especially sand-eels, which constitute no less than 75% of total fish.

"*Ammodytes* spp. play a very important role in the food of the cod off Andanes and Iceland, especially in the Faxe Bay, where the cod taken on June 12th to 19th, 1937, appeared to feed on nothing else but sand-eels." For haddock sampled from Iceland, the only fish eaten were sand eels.

Keywords: *Ammodytes*; Barents Sea; Iceland; Murman Coast; predators (fish, cod, haddock).

**Bruun, A.Fr. 1941.** Observations on North Atlantic fishes. 2: The *Ammodytes lancea* group. Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i Khobenhavn. 104: 329-340.

The author presents total vertebrae and dorsal, anal and pectoral fin ray counts from sand lance sampled in the Faroes and Iceland. Notes are made on the taxonomic relationships and biology of sand lance from these two areas.

Keywords: *A. lancea*; *A. marinus*; Faroes; Iceland; meristic counts; taxonomy.

**Buchmann, K.; Bøerresen, T. 1988.** The effect of different food types and rations in the liver and muscle of cod (*Gadus morhua* L.). Acta Veterinaria Scandinavica. 29(1): 57-59.

"The liver weight of cod was significantly reduced in prawn-fed fish compared to sand-eel fed ones. The dry weight and protein content of the muscle was not significantly different. Short time energy deprivation of cod primarily affects the liver."

Keywords: *Ammodytes*; composition; predators (fish, cod).

**Buckley, L.J. 1984.** RNA-DNA ratio an index of larval fish growth in the sea. Marine Biology (Berlin). 80(3): 291-298.

"Data on water temperature, RNA-DNA ratio and growth of 8 spp. [*Paralichthys dentatus, Pseudopleuronectes americanus, Gadus morhua, Morone saxatilis, Melanogrammus aeglefinus, Clupea harengus, Ammodytes sp., Scomber scombrus*] of temperature marine fish larvae reared in the laboratory were fit to the equation: Gpi = 0.93 T + 4.75 RNA-DNA – 18.18, where Gpi is the protein growth rate in % d–1 and T is the water temperature. Water temperature and larval RNA-DNA ratio explained 92% of the variability in growth rate of laboratory-reared larvae. The model is useful over the entire range of feeding levels (starvation to excess), temperatures (2˚-20˚ C) and fish species studied. Estimates of recent growth of larval cod, haddock and sand lance caught at sea based on water temperature and RNA-DNA ratio ranged from negative to 26% d–1. These data demonstrate the importance of food availability in larval fish mortality and suggest that short-term growth under favorable conditions may be considerably higher than expected from long-term indicators. RNA-DNA ratio analysis offers new possibilities for understanding larval growth and mortality and their relation to environmental variability."

Keywords: *Ammodytes*; larvae; mortality; RNA/DNA; temperature.

**Buckley, L.J.; Halavik, T.A.; Smigielski, A.S.; Laurence, G.C. 1987.** Growth and survival of the larvae of three species of temperate marine fishes reared at discrete prey densities: Annual larval fish conference; 1986 May 18-23; Miami, FL. Symp. Ser. 10. Miami, FL: American Fisheries Society 2: 82-92.

"Larval haddock *Melanogrammus aeglefinus*, Atlantic mackerel *Scomber scombrus*, and sand lance (presumed to be American sand lance *Ammodytes americanus*) were reared from first feeding at plankton densities ranging from 10 to 2,000 plankters/L. Some larvae of all 3 species survived at all plankton densities tested. Survival and growth of the 3 species increased with increasing plankton density. The American sand lance, reared at 6 and 8 °C, had the highest survival at all feeding levels. Atlantic mackerel, reared at 15 °C, had the highest growth rate at all feeding levels. Survival of haddock to 1 mg dry weight at 6 °C did not exceed 10% at any of the prey levels, including the highest. Survival to 1 mg dry weight exceeded 20% for Atlantic mackerel reared at 2,000 plankters/L and exceeded 60% for American sand lance at feeding levels of 50 plankters/L and above. The wide range in growth rates and estimated age and survival to 1 mg dry weight observed at the different prey levels illustrates the importance of food availability as a factor in the mortality of larval fish whether from starvation or predation."

Keywords: *A. americanus*; food and feeding habits; growth; larvae; rearing; survival.

**Buckley, L.J.; Turner, S.I.; Halavik, T.A. [and others]. 1984.** Effects of temperature and food availability on growth, survival, and RNA-DNA ratio of larval sand lance (*Ammodytes americanus*). Marine Ecology Progress Series. 15: 91-97.

Sand lance larvae were reared for up to 2 weeks with and without food. No difference in mortality was noted between the two groups, indicating that sand lance larvae may be capable of surviving periods of starvation in excess of 2 weeks. Sand lance eggs are demersal, the embryonic stage long, and hatching extremely protracted. The newly hatched larva is large, very well developed, and carries an ample supply of endogenous energy reserves in the form of both oil and yolk. The larvae initiate feeding 1 to 2 days after hatching, well before yolk or oil is exhausted. Mortality rate at low plankton densities in the absence of predation is low compared to other temperate species such as cod or haddock. Embryos develop and larvae grow and survive for extended periods of time at temperatures at least as low as 2 ˚C. Sand lance are well adapted for spawning during the winter minimum in zooplankton abundance. Larval sand lance that survive through the winter can take advantage of the spring maximum in zooplankton abundance and increasing temperatures that favor rapid growth as juveniles.

Keywords: *A. americanus*; artificial propagation; eggs; embryo; larvae.

**Buckworth R. 1996.** Small pelagics. Fisheries Center Research Reports. 4(1): 40-41.

Pacific sand lance are either not fished in the northeast Pacific or there are not sufficient numbers to provide the basis of a fishery.

Keywords: *A. hexapterus*; Canada; fisheries.

**Buen, F.D. 1935.** Fauna ictiologica: catalogo de los peces Ibericos: aguas dulces, pelagicos y de los abismos proximos—Primera parte. Notas Instituto esp. Oceanography. 88: 1-149.

**Bukhtiyarov, Y.A.; Frost, K.J.; Lowry, L.F. 1984.** New information on food of the spotted seal, *Phoca largha*, in the Bering Sea in spring. In: Fay, F.H.; Fedoseev, G.A., eds. Soviet-American cooperative research on marine mammals Vol. 1: Pinnipeds. Tech. Rep. NMFS 12. [Place of publication unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration: 55-59.

“Information on foods of spotted seals was obtained by analysis of stomach contents from specimens taken in spring in Karaginskii Gulf, Anadyr Gulf, and southeastern, central, and northern Bering Sea. Pollock was the major food in southeastern Bering Sea and ranked second in northern Bering Sea. Arctic cod was the major food in Anadyr Gulf and northern Bering Sea. Sand lance was the major food in Karaginskii Gulf.”

Keywords: *A. hexapterus*; Bering Sea; predators (mammals, spotted seal).

**Bullock, I.D.; Gomersall, C.H. 1981.** The breeding population of terns in Orkney and Shetland in 1980. Bird Study. 28: 187-200.

Keywords: *Ammodytes*; Orkney; Shetland; predators (birds).

**Burger, A.E. 1995.** Marine distribution, abundance, and habitats of marbled murrelets in British Columbia. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 420 p.

Murrelet distribution was highly clumped and was associated with features such as gravel or sand substrates, where sand lance might burrow. Availability of sand lance appeared to affect both the spatial distribution and the seasonal densities of murrelets in Okeover Inlet, Desolation Sound, during the breeding season.

Keywords: *A. hexapterus*; British Columbia; importance; predators (birds, marbled murrelet).

**Burger, A.E.; Piatt, J.F.** 1990. Flexible time budgets in breeding common murres: buffers against variable prey abundance. Studies in Avian Biology. 14: 71-83.

“Adult murres compensated for periods of low capelin abundance by taking more of other fish, particularly sandlance (*Ammodytes* sp.), and by spending more time at sea. Chick survival (average 93%) did not vary significantly between years.”

Keywords: *Ammodytes*; Newfoundland; importance; predators (birds, common murre).

**Burger, A.E.; Powell, D.W. 1990.** Diving depths and diet of Cassin’s auklet at Reef Island, British Columbia. Canadian Journal of Zoology. 68: 1572-1577.

“Diving depths of Cassin’s auklets (*Ptychoramphus aleuticus*) breeding at Reef Island, Queen Charlotte Islands, British Columbia, were measured with miniature gauges attached to the birds. Maximum diving depths of 22 birds averaged 28 m, with a mode of 40 m. A time-at-depth recorder showed that one auklet dived to 29 m, but spent 80% of its time underwater at 3-13 m. Food delivered in gular pouches to chicks contained mainly euphausiids (predominantly *Thysanoessa spinifera*) and juvenile fish (*Ammodytes hexapterus*), with lesser amounts of copepods, amphipods, small pandalid shrimps, Brachyura larvae, and ctenophores. Euphausiid meals were most common during spring tides. Auklets that delivered significant amounts of euphausiids appeared to have dived deeper than those that delivered fish.”

Keywords: *A. hexapterus*; Canada; British Columbia; predators (birds, Cassin’s auklet).

**Burger, A.E.; Wilson, R.P.; Garnier, D.; Wilson, M.P.T. 1993.** Diving depths, diet, and underwater foraging of rhinoceros auklets in British Columbia. Canadian Journal of Zoology. 71(12): 2528-2540.

“Epipelagic schooling fish were consistently the most common prey delivered to auklet chicks at all three localities. Pacific sand lance, Pacific herring, juvenile salmon, Pacific saury, and juvenile rockfish were important prey. Bite marks on the fish showed that 73% were attacked from below.

“Sand lance were important at all sites and in all years. They accounted for 42, 32, and 96% of the combined mass of prey from Triangle Island, Seabird Rocks and Cleland Island respectively. From a sample of 170 sand lance it was determined that 68% were caught from below. Herring sometimes foraged in mixed schools with juvenile sand lance, which may account for their co-occurrence in the auklet meals. Several of the prey species were planktivores that often foraged near the surface in twilight or at night. Crepuscular or nocturnal feeding has been reported in several studies of Rhinoceros Auklets. During our study we caught two auklets on Cleland Island more than an hour after dark (at 23:14 and 23:24 on 9 July 1988) that were carrying live, freshly caught sand lance.”

“Sand lance are known to become dormant, buried in sand, with high sea temperature (above 20 C. in *A. personatus*.... Dietary changes and reduced breeding success associated with reduced predation on sand lance might be due to the inaccessibility of the prey rather than to reduced abundance.”

Keywords: *A. hexapterus*; Canada; British Columbia; importance; predators (birds, rhinoceros auklet).

**Burgess, G.H.; Link, G.W.J.; Ross, S.W. 1980.** Additional marine fishes new or rare to Carolina waters. Northeast Gulf Science. 3(2): 74-87.

Keywords: *Ammodytes*; Atlantic (northwest); North Carolina; distribution.

**Burkett, E.E. 1995.** Marbled murrelet food habits and prey ecology. In: Ralph, C.J; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech.Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 420 p.

Euphausiids and mysids were dominant during winter and spring. Small schooling fishes included sand lance. The fish portion was most important in summer and coincided with the nestling and fledgling period. In their food habits summary, the authors mention that the sand lance is the most common food of the murrelet across its range.

Keywords: *A. hexapterus*; importance; predators (birds, marbled murrelet).

**Burns, J.J. 1994a.** Ribbon seal. Wildlife Notebook Series. [Place of publication unknown]: Alaska Department of Fish and Game.

Sand lance may be an important food of the ribbon seal on occasion.

Keywords: *A. hexapterus*; Alaska; predators (mammals, ribbon seal).

**Burns, J.J. 1994b.** Spotted seal. Wildlife Notebook Series. [Place of publication unknown]: Alaska Department of Fish and Game.

Sand lance is mentioned as major prey in spring to early autumn in Karaginski Bay and the Gulf of Anadyr.

Keywords: *Ammodytes*; importance; predators (mammals, spotted seal).

**Burtt, E.H., Jr. 1974.** Success of 2 feeding methods of the black-legged kittiwake. Auk. 91(4): 827-829.

Keywords: *A. americanus*; predators (birds, black-legged kittiwake).

Burykin, Y.B.; Kublik, E.A. 19**91.** Ichthyoplankton of the Bab'e More Kandalaksha Bay of the White Sea. Voprosy Ikhtiologii. 31(6): 910-916.

The developmental stages and features of the distribution of pelagic eggs and fish eggs and larvae were studied.

Keywords: *A. americanus*; *A. marinus*; Russia; White Sea; eggs; larvae.

**Burykin, Y.B.; Kublik, Y.A. 1992.** Icthyoplankton of the Bab'ye Sea (Gulf of Kandalaksha on the White Sea). Journal of Ichthyology (Bethesda). 32(3): 24-31.

Keywords: *A. hexapterus*; *A. marinus*; Russia; White Sea; larvae; temperature.

**Butler, R.W. 1974.** The feeding ecology of the northwestern crow on Mitlenatch Island, British Columbia. Canadian Field Naturalist. 88: 313-316.

Keywords: *A. hexapterus*; Canada; British Columbia; predators (birds, northwestern crow).

**Butler, R.W. 1989.** Breeding ecology and population trends of the great blue heron (*Ardea herodias fannini*) in the Strait of Georgia. In: Vermeer, K.; Butler, R.W., eds. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Spec. Publ. Ottawa, ON: Canadian Wildlife Service: 112-117.

Keywords: *A. hexapterus*; Canada; British Columbia; predators (birds, great blue heron).

**Bye, V.J. 1990.** Temperate marine teleosts. In: Munroe, D.; Scott, P.; Lam, T.J. Reproductive seasonality in teleosts: environmental influences. Boca Raton, FL: CRC Press, Inc.

Keywords: *Ammodytes*; spawning.

**Byrd, G.V.; Merrick, R.L.; Piatt, J.F.; Norcross, B.L. 1997.** Seabird, marine mammal, and oceanography coordinated investigations (SMOCI) near Unimak Pass, Alaska. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]: [location

unknown]. Rep. 97-01. [Place of publication unknown]: University of Alaska Fairbanks, Alaska Sea Grant College: 351-364.

“Juvenile (age 0) walleye pollock were the most common fish captured in midwater trawls near Ugamak Island in mid-July 1995 (catch per unit of effort [CPUE] of 22.0 and 44.0 in two tows). Juvenile gray cod (*Gadus macrocephalus*; 7.7 CPUE in 1 tow and 0 in the other), and sand lance *(Ammodytes hexapterus*; 0.5 CPUE in 1 tow, 0 in the other) were also captured.”

Keywords: *A. hexapterus*; Alaska; Unimak Pass; abundance.

**Byrd, G.V.; Murphy, E.C.; Kaiser, G.W. [and others]. 1993.** Status and ecology of offshore fish-feeding alcids (murres and puffins) in the north Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D., eds. The status, ecology and conservation of marine birds of the north Pacific. Spec. Publ. Ottawa, ON: Canadian Wildlife Service, Environment Canada: 176-186.

Keywords: *A. hexapterus*; North Pacific; predators (birds).

**Cadegan, E. 1971.** Exploratory fishing for sand lance. [Place of publication unknown]: Nova Scotia Department of Fisheries, Research Development Division. 14 p.

Keywords: *A. americanus*; commercial fishing.

**Cadenat, J. 1950.** Poissons de mer du Senegal. Institut Francais D’Afrique Noire Initiations Africaines. 3(1): 1-345.

Families are listed with comments on biology and ecology and, sometimes, color notes of representative species. Full lists of species are provided.

Keywords: *Ammodytes*; distribution; ecology; taxonomy.

**Cain, S.L.; Hodges, J.I.; Robinson-Wilson, E. 1988.** Bird use of the Mendenhall wetlands in Juneau, Alaska. Juneau, AK: U.S. Fish and Wildlife Service.

Bald eagle numbers reached a peak of 82 birds on 21 June during anadromous fish runs (probably eulachon or Pacific sand lance) in the Mendenhall River. Eagles were seen congregating at the mouth of the river during low tides throughout the year. Numbers dropped off in autumn.

Keywords: *A. hexapterus*; Alaska; predators (birds, bald eagle).

**Cairns, D. 1981.** Breeding, feeding, and chick growth of the black guillemot (*Cepphus grylle*) in southern Quebec. Canadian Field-Naturalist. 95(3): 312-318.

Black guillemots delivered American sand lance to their chicks at Brandypot and St. Mary’s. Sand lance accounted for 8% of the food deliveries at both locations.

Keywords: *A. americanus*; Gulf of Saint Lawrence; predators (birds, black guillemot).

**Cairns, D.K. 1987**. The ecology and energetics of chick provisioning by black guillemots. Condor. 89: 627-635.

Keywords: *A. americanus*; predators (birds, black guillemot).

**Cairns, D.K. 1988.** Seabirds as indicators of marine food supplies. Biological Oceanography. 5: 261-271.

Keywords: *Ammodytes*; predators (birds).

**Cairns D.K. 1992a.** Bridging the gap between ornithology and fisheries science: use of seabird data in stock assessment models. Condor. 94: 811-824.

Keywords: *Ammodytes*; predators (birds).

**Cairns, D.K. 1992b.** Population regulation of seabird colonies. In: Power, D.M., ed. Current ornithology. New York: Plenum Press. 9: 37-61.

Keywords: *Ammodytes*; predators (birds).

**Cairns, D.K.; Chapdelaine, G.; Montevecchi, W.A. 1991.** Prey exploitation by seabirds in the Gulf of St. Lawrence. In: Gulf of St. Lawrence: small ocean or big estuary? Symposium on the oceanography and fishery of the Gulf of St. Lawrence; 1989 Mar. 14; Mont-Joli, PQ. Canadian Spec. Publ. Fisheries and Aquatic Science. Mont-Joli, PQ: [publisher unknown]: 277-291.

“A bioenergetics model is presented that estimates food consumption by seabirds in the Gulf of St. Lawrence. The 400,000 pairs of seabirds breeding in the Gulf and associated non-breeders are estimated to consume 80,000 t of marine prey annually. Seabird predation is most intense in the central and northern parts of the Gulf, particularly around the Gaspe Peninsula. The major prey groups are capelin (*Mallotus villosus*) and sand lance (*Ammodytes* spp.) (ca. 30,000-45,000 t) and mackerel (*Scomber scombrus*, ca. 9,000 t). Because seabirds favour small size-classes of prey and species that are not heavily fished, they do not compete directly with commercial fisheries.”

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; importance; model; predators (birds).

**Cairns, P.K.; Montevecchi, W.A.; Birt-Friesen, V.L.; Macko, S.A. 1990.** Energy expenditures, activity budgets and prey harvest of breeding common murres. Studies in Avian Biology. 14: 84-92.

Sand lance had a higher energy density than capelin or Atlantic cod.

Keywords: *Ammodytes*; energy density; predators (birds, common murre).

**Calambokidis, J.; Speich, S.M.; Peard, J. [and others]. 1985.** Biology of the Puget Sound marine mammals and marine birds: population health and evidence of pollution effects. Tech. Memo. NOSOMA 18. Rockville, MD: U.S. Deptartment of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. 159 p.

Keywords: *A. hexapterus*; Washington; Puget Sound; predators (birds, mammals).

**Caldarone, E.M.; Buckley, L.J. 1991.** Quantitation of DNA and RNA in crude tissue extracts by flow injection analysis. Analytical Biochemistry. 199(1): 137-141.

An automated two-dye flow injection analysis system to quantify DNA and RNA in crude extracts of tissues is described.

Keywords: *A. americanus*; RNA/ DNA .

**Caldow, R.W.G. 1988.** Studies on the morphology, feeding behaviour and breeding biology of skuas with reference to kleptoparasitism. [Glasgow, Scotland]: University of Glasgow. Ph.D. dissertation.

Keywords: *Ammodytes*; predators (birds, skua).

**Caldow, R.W.G.; Furness, R.W. 1991.** The relationship between kleptoparasitism and plumage polymorphism in the arctic skua S*tercorarius parasiticus*. Functional Ecology. 5(3): 331-339.

“The fledging success, territorial attendance patterns and kleptoparasitic behaviour of arctic skuas *Stercorarius parasiticus* (L.) were studied in 1978-1979 and in 1986-1987 to investigate the roles of aggressive camouflage and apostatic selection in the maintenance of the species’ plumage polymorphism. Over a period of time during which sandeel *Ammodytes marinus* (Raitt) availability around Shetland (Scotland, UK) declined, the amount of time spent foraging per day by arctic skuas with large chicks increased significantly whereas their fledging success decreased significantly. These results indicate that arctic skuas’ reproductive success is food limited in Shetland. Hence, an ecological explanation for the maintenance of the species’ plumage polymorphism is a possibility. Analyses of differences between the methods of attack and the chase success rates of light- and dark-phase birds, and of the victims’ responses to them, in 1986-1987 lend no support to either the aggressive camouflage or the apostatics election hypothesis. However, between 1978-1979 and 1986-1987 the chase success rates of light-phase birds increased by more than 40% relative to those of dark-phase birds. During this time the former decreased in abundance relative to the latter in the study population. It is suggested that these facts lend support to the hypothesis that the arctic skuas’ plumage polymorphism is maintained, at least in part, by differential chase success rates brought about through apostatic selection.”

Keywords: *A. marinus*; Scotland; predators (birds, arctic skua).

**Calkins, D.G.; Pitcher, K.W. 1983.** Population assessment, ecology, and trophic relationships of Steller sea lions in the Gulf of Alaska. In: Environmental assessment of the Alaska continental shelf. Juneau, AK: National Oceanic Atmospheric Administration National Ocean Service; final reports of the principal investigators.19: 445-456.

Keywords: *A. hexapterus*; Gulf of Alaska; predators (mammals, Steller sea lion).

**Cameron, J. 1958.** Studies on the Ammodytidae of Isle of Man waters. Liverpool, United Kingdom: University of Liverpool. Ph.D. thesis.

Keywords: Ammodytidae; Isle of Man.

**Cameron, J. 1959.** The larval and post-larval stages of *Gymnammodytes semisquamatus* (Jourdain). Journal of the Marine Biology Association of the United Kingdom. 38: 17-25.

Keywords: *G. semisquamatus*; juvenile; larvae.

**Cardwell, R.D.; Olsen, S.J.; Carr, M.I.; Sanborn, E.W. 1980.** Biotic water quality and hydrologic characteristics of Skyline Marina North Puget Sound Washington USA in 1978. Tech. Rep. 54 [Place of publication unknown]: Washington Department of Fisheries: 1-103.

“Fish, zooplankton and water quality characteristics of Skyline Marina in north Puget Sound were compared to the marina’s source water in monthly surveys conducted from March-Oct. 1978. A companion study defined the marina’s flushing properties. Fish were indexed mainly by purse seining and the food habits of 7 spp. of salmon (*Oncorhychus* spp.) and baitfish juveniles [*O. kisutch, O. tshawytscha, O. gorbuscha, O. keta, Hypomesus pretiosus, Ammodytes hexapterus* and *Clupea harengus pallasi*] in terms of ontogenic-seasonal variation. Water quality was described through measurements of general parameters (e.g., temperature, phytoplankton, nutrients), heavy metal and organic concentrations in sediments, heavy metal residues in adult Pacific oysters *(Crassostrea gigas*) and acute toxicity of ambient waters to Pacific oyster larvae. Predation on brachyurans, copepods, siphonophores and tunicates, diversity and density were examined. Heavy metal toxicities, possibly from antifouling paints, and their effects were discussed.”

Keywords: *A. hexapterus*; Washington; Puget Sound; food; predators (fish); pollution; seasonal variation; temperature.

**Carls, M.G. 1987.** Effects of dietary and water-borne oil exposure on larval Pacific herring (*Clupea harengus pallasi*). Marine Environmental Research. 22(4): 253-270.

Keywords: *Ammodytes*; pollution.

**Carter, C.G.; Grove, D.J.; Carter, D.M. 1991.** Trophic resource partitioning between two coexisting flatfish species off the north coast of Anglesey, North Wales. Netherlands Journal of Sea Research. 27(3-4): 325-335.

Keywords: *Ammodytes*; Wales; predators (fish, plaice).

**Carter, H.R. 1984.** At-sea biology of the marbled murrelet (*Brachyramphus marmoratus*) in Barkley Sound, British Columbia. Winnipeg, MB: University of Manitoba. 143 p. M.S. thesis.

In Barkley Sound on the southwest coast of Vancouver Island, 87 marbled murrelets were examined for diet from 10 May to 7 September, 18 and 19 December, and 8 June to 13 October. Breeding adults fed primarily on sand lance and Pacific herring, including larval and juvenile fish. Molting and hatching-year birds also fed primarily on herring and sand lance. Breeding murrelets consumed more sand lance (63 percent) and less herring (36 percent). Hatching-year murrelets consumed 81 percent herring and 13 percent sand lance.

Keywords: *A. hexapterus*; British Columbia; importance; predators (birds, marbled murrelet).

**Carter, H.R.; Sealy, S.G. 1987.** Fish-holding behavior of marbled murrelets. Wilson Bulletin. 99: 289-291.

“Pacific sandlance and small Pacific herring weighing 2-10 g were held crosswise by murrelets (estimated from observed lengths).”

Keywords: *A. hexapterus*; British Columbia; Barkley Sound; predators (birds, marbled murrelet).

**Carter, H.R.; Sealy, S.G. 1990.** Daily foraging behavior of marbled murrelets. In: Sealy, S.G., ed. Auks at sea. Studies in Avian Biology. 14: 93-102.

Adult murrelets fed primarily on juvenile Pacific herring and Pacific sand lance in Barkley Sound.

Keywords: *A. hexapterus*; predators (birds, marbled murrelet).

**Castellini, M. 1993.** Report of the marine mammal working group. In: Is it food?: Addressing marine mammal and seabird declines: Workshop summary; [dates of workshop unknown]; [location unknown]. Alaska Sea Grant Report 93-01. Fairbanks, AK: University of Alaska Fairbanks: 4-13.

Stomachs of 74 Steller sea lions from the Kodiak area were examined in 1985-86. The principal prey were pollock, octopus, flatfishes, and sand lance. For the Pribilof fur seal, sand lance was ranked tenth.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; Pribilof Islands; predators (mammals, Steller sea lion, fur seal).

**Chagnon, Y. 1978.** Quelques aspects de la biologie d’Ammodytes americanus du détroit de Manitounuk et du Golfe de Richmond (Nouveau-Québec). Sainte-Foy, PQ: University of Laval, Initiation a` la recherche. 23 p.

Keywords: *A. americanus*; biology.

**Chamberlain, F.M. 1907.** Some observations on salmon and trout in Alaska. Report United States Commission of Fisheries 1906 Special Papers, United States Bureau Fisheries Document 627. 112 p.

Keywords: *A. hexapterus*; Alaska; predators (fish).

**Chambers, R.C.; Leggett, W.C. 1987.** Size and age at metamorphosis in marine fishes–an analysis of laboratory-reared winter flounder (*Pseudopleuronectes americanus*) with a review of variation in other species. Canadian Journal of Fisheries and Aquatic Sciences. 44(11): 1936-1947.

Keywords: *Ammodytes*; larvae.

**Chapdelaine G. 1995.** Fourteenth census of seabird populations in the sanctuaries of the north shore of the Gulf of St Lawrence, 1993. Canadian Field Naturalist. 109(2): 220-226.

“The fourteenth census of seabirds in the sanctuaries on the north shore of the Gulf of St. Lawrence revealed major changes in the area’s seabird community. Among the larids, a sharp decline was observed in the herring gull population, which may be related to the decreased availability of fish offal. Other larid numbers also decreased, including black-legged kittiwakes, ring-billed gulls, common terns, arctic terns and caspian terns. On the other hand, alcid populations common murres, razorbills and atlantic puffins increased. It appears that the small prey fish (sand lance and capelin) that alcids feed on are still in plentiful supply, which may partly explain these increases. The continuation of vigorous enforcement programs in sanctuaries where numerous alcids breed also contributed to their increase.”

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; predators (birds).

**Chapdelaine, G.; Brousseau, P. 1996.** Diet of razorbill *Alca torda* chicks and breeding success in the St. Mary’s Islands, Gulf of St. Lawrence, Quebec, Canada, 1990-1992. Occas. Pap. 91. [Place of publication unknown]: Canadian Wildlife Service. 27-36.

“Between 1990 and 1992, sand lance (*Ammodytes* spp.) and capelin (*Mallotus villosus*) were the two main prey of razorbill chicks. Sand lance represented 64-78%, by number, of prey delivered by adults, but only 31-46% of total intake by weight. Conversely, capelin accounted for 21-36% of delivered prey by number and 53-69% by weight. The mean number of feeds was similar in all years, between 3.1 and 3.8 feeds per chick per day. Daily intake was estimated to range from 35 g/chick (251 kJ) in 1990 and 1991 to 50 g/chick (357 kJ) in 1992. Fledging success was 88.2% in 1990, 87.2% in 1991, and 95.1% in 1992.”

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; predators (birds, razorbill).

**Chapdelaine, G.; Brousseau, P.; Anderson, R.; Marsan, R. 1985.** Breeding ecology of common and arctic terns in the Mingan Archipelago, Quebec. Colonial Waterbirds. 8(2): 166-177.

“In 1983, Common Terns began egg laying on June 10, first hatching occurred July 3 and fledging started on July 29. For Arctic Terns the same events occurred on June 6, June 27, and July 24, respectively. Clutch size was 2.50 eggs for Common Terns and fledging success was 1.24 young per pair, whereas for Arctic Terns clutch size was 1.98 and fledging success was 1.25 per pair. Mean hatching weight was 15.7 g and mean fledging weight was 122.6 g for Common Terns compared to 14.2 g and 103.8 g for Arctic Terns. Instantaneous growth rate was 7.11 g/day in Common Terns and 6.90 g/day Arctic Terns. Chicks of the two species were mainly fed with fish (sand lance and caplin) and secondarily with invertebrates (*Gammarus* sp. and *Thysanoessa* sp.). Growth rates were comparable to these found in most other studies but for Common Terns were slower than in the Farne Islands and for Arctic Terns were slower than at Shetland, possibly because of different prey composition.”

Keywords: *Ammodytes*; Canada; Quebec; predators (birds, arctic tern, common tern).

**Chatwin, B.M.; Forrester, C.R. 1953.** Feeding habits of dogfish (*Squalus suckleyi* (Girard)). Progress Reports of the Pacific Coast Stations 95. Nanaimo, BC: Fisheries Research Board of Canada, Biological Station: 35-38.

Keywords: *A. hexapterus*; Canada; predators (fish, dogfish).

**Chen, A. 1989.** Relation between food intake and growth of immature saffron cod *Eleginus gracilis tilesius* in captivity. Bulletin of the Faculty of Fisheries, Hokkaido University. 40(4): 228-237.

“Consumption and growth rates of immature saffron cod weighing 26-117 g were measured at 2.7-14.5 °C. They were fed squid or sandlance. The net growth efficiencies and maintenance requirements with these energy sources was; R=0.589G x W0.248 + 0.008W0.823 x 100.037T g/day where R is food intake (g/day), G is growth (g/day), T is °C and W is body weight (g). Maintenance rations of saffron cod were similar to those of other immature gadid

species. Both feeding rates and growth rates increased under the higher temperature and ration conditions. The caloric value of the laboratory food was twice that of common prey type consumed in nature, thus consumption would potentially be twice the captive estimate."

Keywords: *Ammodytes*; composition; energetics; predators (fish, saffron cod).

**Chikumi, S. 1985.** The fish resources of the northwest Pacific. FAO Fish. Tech. Pap. 266. [Place of publication unknown]: [publisher unknown]: 190.

Keywords: *Ammodytes*; Pacific Ocean (northwest); fisheries; plankton.

**Christensen, O. 1961.** Preliminary results of an investigation on the food of Baltic salmon. council meeting. [Place of preparation unknown]: International Council for the Exploration of the Sea, Salmon and Trout Committee, Document 93. 6 p. (Mimeographed).

Keywords: *Ammodytes*; predators (fish, Atlantic salmon).

**Christensen, V. 1983.** Predation by sand eel on herring larvae: council meeting. [Place of preparation unknown]: International Council for the Exploration of the Sea: Document 27: 1-10.

Keywords: *A. marinus*; food and feeding habits.

**Christensen, V. 1995.** A model of trophic interactions in the North Sea In 1981, the year of the stomach. Dana: A Journal of Fisheries and Marine Research (Charlottenlund). 11(1): 1-28.

Keywords: *Ammodytes*; North Sea; ecology; model; plankton; trophic interactions.

**Christensen, V.; Dahl, E.; Danielssen, D.S. [and others]. 1983.** A combined fish larval, phytoplankton and oceanographic survey in the Skagerrak and the Kattegat in April 1983: Council meeting of the International Council for the Exploration of the Sea; 1983 Oct. 10; Gothenburg, Sweden. Gothenburg, Sweden: [Publisher unknown]. 19 p.

Keywords: *A. marinus*; Denmark; abundance; larvae.

**Chrzan, F. 1960.** Results of investigations on the food of the salmon and sea trout of the Polish Baltic coasts: council meeting. [Place of preparation unknown]: International Council for the Exploration of the Sea, Salmon and Trout Committee: Document 70. 4 p. (Mimeographed).

Keywords: *Ammodytes*; predators (fish, Atlantic salmon).

**Chumakov, A.K.; Podrazhanskaya, S.G. 1986.** Feeding of greenland halibut *Reinhardtius hippoglossoides* in the northwest Atlantic. Northwest Atlantic Fisheries Organization Scientific Council Studies. 10: 47-52.

"The seasonal feeding of Greenland halibut in the shelf and slope areas of the Northwest Atlantic from Davis Strait to eastern Newfoundland was studied from the field analysis of 76,700 stomachs during surveys in 1969-81. Roundnose grenadier, beaked redfish, Atlantic cod, young Greenland halibut, capelin, sand lance, squid and various crustaceans were important components of the diet of Greenland halibut. Consumption of the various food organisms seems to be closely associated with their distribution and the bathypelagic way of life of Greenland halibut. In the northern part of the survey area (Subareas 0, 1 and 2), where Greenland halibut were generally large, beaked redfish and roundnose grenadier were the major prey. In the southern part of the region off Newfoundland [Canada], where Greenland halibut were smaller in size, small food organisms (capelin, sand lance, young cod and crustaceans) were prevalent in the diet. The daily food requirements of both male and female Greenland halibut were

estimated to range from 1.2% of body weight at age 5 to 0.5% at ages 14-17 years. Quantitatively, females need more food than males of the same age. Use of minimum estimates of stock size from a bottom-trawl survey of the region implies that the population consumes more than 750,000 tons of food annually."

Keywords: *Ammodytes*; Canada; predators (fish, greenland halibut).

**Chun, C.I. 1974.** Biological studies on the sand eel Ammodytes personatus. Bulletin of the Korean Fisheries Society. 7(4): 215-220.

Keywords: *A. personatus*; sex ratio; spawning.

**Ciannelli, L. 1997.** Winter dormancy in the Pacific sand lance (*Ammodytes hexapterus*) in relation to gut evacuation time. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]; [location unknown]. Rep. 97-01. [Fairbanks, AK]: University of Alaska Fairbanks, Alaska Sea Grant College Program: 95-104.

"The life style of the Pacific sand lance (*Ammodytes hexapterus*) is very interesting and in some ways unique in that their habitat is divided on a diel basis. Sand lance spend part of the day feeding in the water column, where they are more exposed to predation. During the night they burrow in the sand; however, it is unclear how much of their entire life is spent in the sand on a seasonal basis. Low catches of Pacific sand lance during winter together with many morphological adaptations for a burrowing life style, suggest that they might enter a winter dormancy phase in the sand. *Ammodytes hexapterus* has a long digestion time (45-80 hr), and has the capability to retain food in the stomach for a long time (30 hr). This might be explained as an adaptation to optimize food uptake from the gut, to build up energy reserves in order to undertake a dormant winter stage."

Keywords: *A. hexapterus*; Washington; Puget Sound; behavior; digestion.

**Clapham, P.J. 1996.** The social and reproductive biology of humpback whales–an ecological perspective. Mammal Review. 26(1): 27-49.

Keywords: *A. americanus*; predators (mammals, humpback whale).

**Clapham, P.J.; Baraff, L.S.; Carlson, C.A. [and others]. 1993.** Seasonal occurrence and annual return of humpback whales, *Megaptera novaeangliae*, in the southern Gulf of Maine. Canadian Journal of Zoology. 71(2): 440-443.

Variation in the occurrence of individuals appears to be related to variability in the abundance of prey and perhaps to regional preferences.

Keywords: *A. americanus*; Gulf of Maine; predators (mammals, humpback whale).

**Clapham, P.J.; Leatherwood, S.; Szczepaniak, I.; Brownell, R.L. 1997**. Catches of humpback and other whales from shore stations at Moss Landing and Trinidad, California, 1919-1926. Marine Mammal Science. 13(3): 368-394.

Keywords: *Ammodytes*; predators (mammals, humpback whale).

**Clark, J.; Smith, W.G.; Kendall, A.W., Jr.; Fahay, M.P. 1969.** Studies of estuarine dependence of Atlantic coastal fishes: Data report 1: Northern section, Cape Cod to Cape Lookout, R.V. Dolphin cruises 1965-66: Zooplankton volumes, midwater trawl collections, temperatures and salinities. Tech. Pap. 28. [Place of publication unknown]: U.S. Bureau of Sport Fisheries and Wildlife. 132 p.

Keywords: *Ammodytes*; Atlantic; distribution; estuaries.

**Clark, R.S. 1920.** The pelagic young and early bottom stages of teleosteans. Journal Marine Biology Association. 12: 159-240.

Keywords: *Ammodytes*; distribution; juveniles; larvae.

**Clemens, W.A.; Wilby, G.V. 1961.** Fishes of the Pacific Coast of Canada. Fisheries Research Board of Canada, Bulletin. 68: [pages unknown].

The following species were mentioned as feeding on sand lance: Pacific dogfish, cutthroat trout, coho salmon, chinook salmon, walleye pollock, Pacific cod, brill, rock sole, lingcod, buffalo sculpin. Pacific sand lance was considered to be a major food of coho salmon, chinook salmon, and Pacific cod.

Keywords: *A. hexapterus*; Canada; importance; predators (fish, Pacific dogfish, cutthroat trout, coho salmon, chinook salmon, walleye pollock, Pacific cod, brill, rock sole, lingcod, buffalo sculpin).

**Clifford, M.N.; Walker, R.; Ijomah, P. [and others]. 1993.** Do saxitoxin-like substances have a role in scombrotoxicosis? Food Additions and Contaminants. 9(6): 657-667.

“Evidence is presented which establishes that mackerel fed in captivity can, by relay from contaminated shellfish via sand eels, accumulate paralytic shellfish poisons (PSP) in the edible flesh at a level (250 mu g saxitoxin equivalents per kg) similar to that in the contaminated shellfish. Data from ELISAs performed independently in two laboratories show that commercial mackerel fillets which have been associated with incidents of scombrotoxicosis contained 0.02-1.30 mu g saxitoxin equivalents per kg, concentrations some two to four orders of magnitude below that normally detectable by the mouse bioassay. The doses, expressed as saxitoxin equivalents, administered inadvertently during volunteer testing of such fillets ranged up to 0.5 ng/kg bw, at least four orders of magnitude less than the fatal oral dose for an adult. The doses associated with the rapid induction of nausea/vomiting and/or diarrhea, 0.11-1.0 ng/kg bw, could not be distinguished from the doses which failed to produce such symptoms in susceptible volunteers (up to 0.5 ng/kg bw). Factors that might explain this lack of correlation between dose (saxitoxin equivalents) and volunteer response are discussed along with previously published reports of PSP relay through the food web. It is suggested that the relay of algal toxins, particularly PSP, but possibly in combination with diarrhetic shellfish poisons, may be responsible for scombrotoxicosis.”

Keywords: A*mmodytes*; aquaculture; paralytic shellfish poisoning; toxicity.

**Clover, C. 1992.** Burning the sea’s resources. Salmon and Trout Association Yearbook. 1: 10-12.

Keywords: *Ammodytes*; Denmark; environmental impact; fisheries.

**Cody, M.L. 1973.** Coexistence, coevolution and convergent evolution in seabird communities. Ecology. 54(1): 31-44.

Marbled murrelets were seen to carry only anchovy and sand lance in their bills. The fish species may be ordered in importance: anchovy-smelt-sand lance-sea bass for the rhinoceros auklet; sand lance-anchovy-sea bass-smelt for the puffin; and smelt-anchovy-sand lance-sea bass for the murre.

Keywords: *Ammodytes*; importance; predators (birds, rhinoceros auklet, puffin, murre).

**Cohen, R.B.; Grosslein, M.D.; Sissenwine, M.P. [and others]. 1982.** An energy budget for Georges Bank. Canadian Special Publication Fisheries and Aquatic Sciences. 59: 95-107.

Keywords: *Ammodytes*; Georges Bank; energy budget.

**Cole, H.A.; Holden, M.J. 1973.** History of the North Sea fisheries 1950-1969 In: Goldberg, E.D., ed. North Sea science: NATO North Sea science conference; 1971 Nov. 15-20; Aviemore, Scotland. Cambridge, MA: MIT Press: 337-360.

Keywords: *Ammodytes*; North Sea; fisheries; pollution.

**Colgan, P.W.; Brown, J.A.; Orsatti, S.D. 1986.** Role of diet and experience in the development of feeding behavior in largemouth bass, *Micropterus salmoides*. Journal of Fish Biology. 28(2): 161-170.

Keywords: *Ammodytes*; predators (fish).

**Collett, R. 1904.** Meddelelser om Norges Fiske i Aarene 1884-1901. (3die Hoved-supplement til Norges Fiske) II. Forh. Vidensk Selsk. Krist. 9: 1-175.

**Collinge, W.E. 1925.** The food of some British wild birds. York, [England]: [publisher unknown].

Keywords: *Ammodytes*; British Isles; predators (birds).

**Collins, M.A.; Pierce, G.J. 1996.** Size selectivity in the diet of *Loligo forbesi* (Cephalopoda: Loliginidae). Journal of the Marine Biological Association of the United Kingdom. 76(4): 1081-1090.

“The size of fish and squid prey of Loligo forbesi was investigated using otoliths, beaks and statoliths collected from stomach contents analysis of samples obtained from Scottish and Irish waters between 1990 and 1993. *Loligo forbes*i was found to consume a large range of prey sizes, but prey size was always less than the predator size. Season was shown to significantly influence the predator size-prey size relationship for sprat and sandeel prey, but this itself could be influenced by seasonal changes in the size of prey.”

Keywords: *Ammodytes*; Ireland; Scotland; predators (invertebrates, squid).

**Conway, D.V.P.; Coombs, S.H.; Cmith, S. 1997.** Vertical distribution of fish eggs and larvae in the Irish Sea and southern North Sea. International Council for the Exploration of the Sea Journal of Marine Science. 54(1): 136-147.

“Fish eggs and larvae were analysed from 63 vertically stratified plankton hauls in the Irish Sea and southern North Sea. The dominant species were sprat (*Sprattus sprattu*s), dragonet (*Callionymus* spp.), dab (*Limanda limanda*) and to a lesser extent rockling species, sandeel (*Ammodyte*s spp.), whiting (*Merlangius merlangus*) and flounder (*Platichthys flesus*). There was little difference between species in the vertical distribution of either eggs or larvae. Most were concentrated in the upper 50 m of the water column, eggs in progressively increasing numbers towards the surface and larvae with a sub-surface peak at a depth of 10-15 m. The vertical distribution of eggs extended deeper in the water column than larvae, possibly due to some combination of eggs being spawned deeper and their passive susceptibility to turbulent mixing. There were no significant differences between day and night distributions and under mixed or isothermal conditions.”

Keywords: *Ammodytes*; Irish Sea; North Sea; eggs; larvae; vertical distribution.

**Cook, R.M. 1992.** An assessment of the Shetland sandeel stock using a seasonally separable fishing mortality model with auxiliary data: Council meeting of the International Council for the Exploration of the Sea; 1992 Sept. 2–Oct. 24; Rostock–Warnemuende, Germany. Rostock–Warnemuende Germany: [publisher unknown]: 6.

“The closure of the Shetland Islands sandeel (Ammodytes marinus) fishery has prevented an assessment of the stock using conventional analyses of commercial catch data. A model is developed which enables the estimation of present stock size and historical trends using research vessel survey data and historical catch and effort data. Diagnostics from the analysis allow the quality of the assessment to be evaluated.”

Keywords: *A. marinus*; Shetland; catch; fisheries; model.

**Cook, R.M.; Reeves, S.A. 1993.** Assessment of North Sea industrial fish stocks with incomplete catch-at-age data. International Council for the Exploration of the Sea Journal of Marine Science. 50(4): 425-434.

“The assessment of the stocks of North Sea Norway pout and sandeel has been inhibited by the absence of catch-at-age data in recent years. A statistical model for the analysis of seasonal catch-at-age, effort, and research vessel abundance data is developed in which all the model parameters can be estimated even when some data are missing. The model is used to estimate the age compositions for the year when data are missing and recent stock trends. The results compare very closely with the last conventional assessment of these stocks.”

Keywords: *A. marinus*; abundance; age; fisheries; model.

**Corbin, P.G. 1950a.** *Ammodytes immaculatus*, a new species of sand-eel found in European seas. Nature, London. 166: 525-526.

Keywords: *A. immaculatus*; taxonomy.

Corbin, P.G. 1950b. The occurrence of the smooth sandeel, *Gymnammodytes semisquamatus* (Jourdain), in the Plymouth area, with notes on *G. cicerelus* (Rafinesque) and *G. capensis* (Barnard). Journal of the Marine Biological Association of the United Kingdom. 29(1): 83-89.

"*Gymnammodytes semisquamatus*, the North Atlantic smooth sand-eel, has a continuous distribution from southern Norway to the southern Atlantic coast-line of Spain. its occurrence in the Irish Sea and in the Plymouth area are new records. In the latter area it is an off-shore species, apparently concentrating in shell gravel in winter for spawning. It has a mean vertebral number of slightly over 68 (Plymouth and Scottish speciments). A small sample of the Mediterranean species, *G. cicerelus*, gives a mean of just over 66, while the South African species, *G. capensis*, which is indistinguishable from *G. semisquamatus* by external non-metameric characters, has a much lower mean of 58.5."

Keywords: *G. semisquamatus; G. cicerelus; G. capensis*; Irish Sea; Plymouth; description; distribution; meristic counts; taxonomy.

**Corbin, P.G.; Vati, V. 1949.** The post-larval sand eels (Ammodytidae) of the Celtic Sea and Plymouth area. Journal of the Marine Biological Association of the United Kingdom. 28(1): 287-313.

"The post-larval sand-eels (Ammodytidae) occurring in the Celtic Sea and Plymouth area are identifiable as *Ammodytes lanceolatus, A. tobianus, A. marinus* (not previously recorded from the area), and a fourth species of *Ammodytes*, the adult of which, it is concluded, is not yet known. Adult *Gymnammodytes semisquamatus* (not previously recorded from the Plymouth area), the young of which are not yet known, increases the number of species in the area to five.

"It is evident that A. lanceolatus has a long spawning period lasting from early spring until autumn (February-October) with a maximum in mid-summer. *A. marinus* spawns in winter and early spring (January-April). The comparatively few records of *A. tobianus* post-larvae point to a spawning period lasting from spring until autumn (April-October), with a maximum in August and September."

Keywords: *A. lanceolatus; A. marinus; A. tobianus; G. cicerellus; G. semisquamatus*; Celtic Sea; Plymouth; description; distribution; identification; illustration; larvae; spawning.

**Corkhill, P. 1973.** Food and feeding ecology of puffins. Bird Study. 20: 207-220.

"This study shows that although annual fluctuations occur in the main prey types of Skomer Puffins, food availability does not appear to limit breeding success. Some interesting observations are given on the feeding of the chick and on kleptoparasitism of adults by Jackdaws and gulls. The two most important fish species brought to the colony (based on frequency of occurrence) were sand-eels *Ammodytes marinu*s and sprats *Clupea sprattus*; togther these comprised 95.6% of the total of 1,387 individual food items examined. Small numbers of the greater sand-eel *A. lanceolatus* also occurred."

Keywords: *A. marinus; A. lanceolatus*; Wales; importance; predators (birds, herring gull, lesser black-backed gull, jackdaw, puffin); size.

**Cottam, C. 1939**. Food habits of North American diving ducks. Tech. Bull. 643. [Place of publication unknown]: U.S. Department of Agriculture.

Keywords: *Ammodytes*; North America; predators (birds).

**Cottam, C.; Knappen, P. 1939.** Food of some uncommon North American birds. Auk. 56: 138-169.

Keywords: *Ammodytes*; North America; predators (birds).

**Coull, K.A.; Jermyn, A.S.; Newton, A.W. [and others]. 1989.** Length/weight relationships for 88 species of fish encountered in the north east Atlantic. Scottish Fisheries Research Report. 43: 1-81.

Keywords: *Ammodytes*; Atlantic (northeast); length-weight relationship.

**Coulson, J.C. 1987.** The population and breeding biology of the arctic tern *Sterna paradisaea* in Shetland, 1986. Nature Conservancy Council CSD Report. 688: 1-33.

Keywords: *Ammodytes*; Shetland; predators (birds, arctic tern).

**Coulson, J.C.; Pearson, T.H. 1985.** Food intake and weight increments of the common guillemot *Uria aalge*: the use of conversion ratio. Ibis. 127: 565-566.

Keywords: *Ammodytes*; predators (birds, common guillemot).

**Coulson, J.C.; Thomas, C.S. 1985.** Changes in the biology of the kittiwake *Rissa tridactyla*: a 31-year study of a breeding colony. Journal of Animal Ecology. 54: 9-26.

“Sandeels are a major source of food in the breeding season but appear to play a minor part in the food in winter and in spring.”

Keywords: *Ammodytes*; England; importance; predators (birds, kittiwake).

**Covill, R.W. 1959.** Food and feeding habits of the larvae and post-larvae of *Ammodytes americanus*, 1952-55. Bulletin Bingham Oceanography College. 17: 125-146.

“The stomachs of 200 *Ammodytes americanus* larvae, 3.2-23.1 mm, were observed for food content and composition. Diurnal, seasonal, and annual variations, as well as effects of size and location of capture, were studied. Several aspects of the nutrition of larvae were also considered. Comparison with data from other investigations showed a much lower incidence of empty stomachs in the L.I.S. specimens. Particulate material, especially copepods and their nauplii, was apparently more important than dissolved food material in the nutrition of these larvae; phytoplankton was also an important item, especially in young larvae. Major variations in stomach contents were due to size. Minor annual and monthly variations were also noted. Obviously larvae must ingest a considerably greater quantity of food per day for growth than that indicated by an analysis of this nature.”

Keywords: *A. americanus*; food and feeding habits; larvae.

**Cowan, J.H., Jr.; Birdsong, R.S. 1985.** Seasonal occurrence of larval and juvenile fishes in a Virginia USA Atlantic coast estuary with emphasis on drums family sciaenidae. Estuaries. 8(1): 48-59.

Keywords: *A. americanus*; abundance; juveniles; larvae.

**Craig, P.C. 1987a.** Forage fishes in the shallow waters of the north Aleutian shelf. In: Forage fishes of the southeastern Bering Sea: Proceedings of a conference; [dates of meeting unknown]; [location unknown]. OCS Study MMS 87-0017. [Place of publication unknown]: [publisher unknown]: 49-54.

Keywords: *A. hexapterus*; Alaska; Aleutian Islands; abundance; distribution.

**Craig, P.C. 1984.** Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Transactions of the American Fisheries Society. 113 (3): 265-282.

Pacific sand lance are present in the brackish nearshore areas of the Alaskan Beaufort Sea. Probably not widespread or abundant, judging from article.

Keywords: *A. hexapterus*; Alaska; Beaufort Sea; distribution.

**Craig, P.C. 1987b.** Subsistence fisheries at coastal villages in the Alaskan arctic, 1970-1986. [place of publication unknown]: Tech. Rep. 129. Alaska OCS (Outer Continental Shelf) Socioeconomic Studies Program. LGL Ecological Research Associates, Inc.; OCS/MMS-87/0044. 69 p.

Keywords: *A. hexapterus*; Alaska.

**Croker, R.A. 1965.** Planktonic fish eggs and larvae of Sandy Hook estuary. Chesapeake Science. 6(2): 92-95.

Keywords: *A. americanus*; eggs; larvae; seasonal variations.

**Cronan, J.M.; Halla, B.F. 1968**. Fall and winter foods of Rhode Island waterfowl. Pamphlet 7. [City unknown], RI: Rhode Island Department of Natural Resources, Division of Conservation Wildlife. 40 p.

Keywords: *Ammodytes*; Rhode Island; predators (birds).

**Cross, J.N.; Fresh, K.L.; Miller, B.S. [and others]. 1978.** Nearshore fish and macro-invertebrate assemblages along the Strait of Juan de Fuca including food habits of common nearshore fish: annual report. FRI-UW-7818. Seattle, WA: University of Washington, Fisheries Research Institute. 188 p.

Keywords: *A. hexapterus*; Strait of Juan de Fuca; distribution; predators (fish).

**Croxall, J.P. 1987.** Conclusions. In: Croxall, J.P., ed. Seabirds: feeding ecology and role in marine ecosystems. Cambridge, England: Cambridge University Press: 369-381.

Keywords: *Ammodytes*; predators (birds).

**Croxall, J.P.; Briggs, P.R. 1991.** Foraging economics and performance of polar and sub-polar Atlantic seabirds. Polar Research. 10: 561-578.

Keywords: *Ammodytes*; predators (birds).

**Cushing, D.H. 1983.** Are fish larvae too dilute to affect the density of their food organisms? Journal of Plankton Research. 5(6): 847-854.

“It is sometimes suggested that larval fish at a density of similar to 1 m super(–3) are too thinly distributed, too dilute, to affect the density of their food, 100 to 1000 m super(–3). Such densities are valid for the Northern and Central North Sea and for Georges Bank. In the Southern North Sea densities of sandeel larvae are very much higher and so are those of their food organisms. Fish larvae die quickly at 5-10% d super(–1) and they might become even more dilute with age under the diffusive processes in the sea. If larvae are too dilute one mechanism of population regulation is ruled out if food has to be shared amongst more animals, growth rate is reduced and they grow through a critical period more slowly and are subject to a predatory mortality for longer. If this mechanism were discarded the only other one in larval life suggested so far is the aggregation of predators. But if larvae are dilute it is difficult to see how or why predators might aggregate.”

Keywords: *Ammodytes*; Atlantic; North Sea; density; food; larvae.

**Czeczuga, B. 1982.** Carotenoids in fish 29: *Ammodytes tobianus* Ammodytidae from the Baltic Sea. Zoologica Poloniae. 29(1-2): 73-78.

“The presence was investigated of various carotenoids in *A. tobianu*s by columnar and chromatography and TLC. Carotenoids were present as follows: beta-carotene, alpha–cryptoxanthin, beta–cryptoxanthin, canthaxanthin, lutein, zeaxanthin, taraxanthin, neothxanthin, tunaxanthin, astaxanthin, astaxanthin ester, alpha–doradexanthin and mutatochrome. The total carotenoid content ranged from 0.623 (muscles) to 34.097 mug/g fresh weight (eggs).”

Keywords: *A. tobianus*; carotenoid; composition.

**D’Arcy B.J.; Thomas, M.P. 1978.** The occurrence and numbers of fish in screenings from a cooling tower intake on the Manchester Ship Canal. Bulletin of the Estuaries and Brackish Water Science Association, London. 20: 2-7.

Keywords: *Ammodytes*; distribution; environmental disturbance.

**Daan, N.; Bromley, P.J.; Hislop, J.R.; Nielsen, N.A. 1990.** Ecology of North Sea fish. Netherlands Journal of Sea Research. 26: 343-386.

Keywords: *Ammodytes*; North Sea; ecology.

**Daan, N.; Johnson, B.; Larsen, J.R.; Sparholt, H. 1993.** Analysis of the ray (*Raja* spec.) samples collected during the 1991 international stomach sampling project. Dublin [Eire]: [publisher unknown]:17.

“This report provides a first analysis of the food and feeding of four species of rays *(Raja clavata, Raja montagui, Raja naevus* and *Raja radiata*) in the North Sea based on 3732 stomach samples taken during research vessel surveys in 1991. Only for *R. radiata* a fairly consistent pattern of feeding predominantly on juvenile gadoids was apparent, whereas sandeels (*Ammodytes*) were found only infrequently.”

Keywords: *Ammodytes*; North Sea; predators (fish, *R. clavata, R. montagui, R. naevus, R. radiata*).

**Dabrowski, K.R. 1986.** Active metabolism in larval and juvenile fish–ontogenetic changes, effect of water temperature and fasting. Fish Physiology and Biochemistry. 1(3): 125-144.

Keywords: *Ammodytes*; fasting; fisheries; larvae; temperature.

**Dabrowski, K.R.; Kaushik, S.J. 1986.** Utilization of endogenous reserves during embryonic-development and larval life of sturgeon, Acipenser baeri Brandt (Chondrostei). Zoologischer Anzeiger. 216(5-6): 367-380.

Keywords: *Ammodytes*; fasting; food; larvae.

**Dabrowski, K.R.; Takashima, F.; Strussmann, C. 1986.** Does recovery growth occur in larval fish. Bulletin of the Japanese Society of Scientific Fisheries. 52(10): 1869.

Keywords: *Ammodytes*; fasting; food; larvae.

**Dagg, M.J.; Ortner, P.B.; Alyamani, F. 1988.** Winter-time distribution and abundance of copepod nauplii in the northern Gulf of Mexico. Fishery Bulletin. 86(2): 319-330.

Keywords: *Ammodytes*; Gulf of Mexico; distribution; food; larvae.

**Daggett, R.F. 1981.** Abundance of fish larvae and eggs in the nearshore area of the Strait of Juan de Fuca, Washington. Northwest Science. 55(1): 1-9.

“A quantitative study was made of fish eggs and larvae in the Strait of Juan de Fuca between Angeles Point and Dungeness Spit, Washington, from March through May, 1978. Thirty-three larval taxa represented by 13 fish families were identified during the study. The family Pleuronectidae contained the largest number of distinct taxa with 11, followed by Cottidae, Stichaeidae, and Liparidae with 10, 5, and 5, respectively. Based on total larvae densities for all six sample periods, the most abundant taxa included Pacific herring, unidentified pricklebacks, rockfishes, Pacific sand lances, and unidentified gunnels, with percent relative abundances of 17, 17, 14, 12, and 7 percent, respectively. Maximum larval densities during the six sample periods occurred in late April (385 larvae/100 $m^3$) minimum values were found in early March or May at all stations.”

Keywords: *A. hexapterus*; Strait of Juan de Fuca; Washington; abundance; distribution; eggs; larvae.

**Dall, K. 1918.** Salmon and trout: a handbook. London, [England]: Salmon Trout Association. 107 p.

Keywords: *Ammodytes*; predation (fish, Atlantic salmon).

**Dalley, E.L.; Winters, G.H. 1987.** Early life history of sand lance *Ammodytes* with evidence for spawning of *Ammodytes dubius* in Fortune Bay, Newfoundland, Canada. U.S. National Marine Fisheries Service, Fishery Bulletin. 85(3): 631-642.

“Ichthyoplankton surveys in Fortune Bay, Newfoundland, indicate that sand lance (*Ammodytes* sp.) larvae occur annually in Fortune Bay from February, when recently hatched yolk-sac larvae occur, until July/August when, it is assumed, the larvae have grown to the size of metamorphosis and have taken up a demersal existence. Length-frequency data indicate the spawning season to extend from December to May-June, and this extended spawning season probably accounts for the consistent polymodality in length-frequency distribution of sand lance larvae from the Newfoundland area. Meristic development is shown to be complete by the time a length of 35-40 mm is reached and analyses of meristic counts indicate that the large (> 20 mm) sand lance larvae caught in Fortune Bay belonged to the offshore species *Ammodytes dubius*. Further, analyses of pre-anal melanophore counts and oceanographic features of the area indicate that yolk-sac larvae taken in Fortune Bay in February were also *A. dubius*. This is the first record of the occurrence and spawning of *A. dubius* in coastal Newfoundland waters. This finding is significant in view of the current confusion regarding the appropriate taxonomy of sand lance populations in the Northwest Atlantic.”

Keywords: *A. dubius*; Newfoundland; development; distribution; growth; larvae; meristics; spawning.

**Dalsgaard, I.; Paulsen, H. 1996.** A typical *Aeromonas salmonicida* isolated from diseased sand-eels, *Ammodytes lancea* (Cuvier) and *Hyperoplus lanceolatus* (Lesauvege). Journal of Fish Diseases. 9(4): 361-364.

“*Aeromonas salmonicida* is known to attack a variety of freshwater fish. However, there have only been 2 reports of its presence in marine species, the sablefish, *Anoplopoma fimbria*, and Atlantic cod, *Gadus morhua*. This paper describes the first reported infection of sand-eels, *Ammodytes lancea*, and *Hyperoplus lanceolatus,* with *Aeromonas salmonicida*. In September 1984 approximately 500 sand-eels were caught in a pound net in the northern Kattegat. The fish were placed in partly recirculating seawater tanks. A few days after capture, some sand-eel were observed to have haemorrhages on the snout.The condition developed quickly and small haemorrhages appeared on the caudal fin with subsequent necrosis of the tail. Affected fish sometimes died within a week but often the disease progressed more slowly. At post-mortem, the main pathological features were haemorrhages in the musculature and focal haemorrhages in the liver and intestine. The mortality increased during the month after capture to a maximum of 5% per day, and then gradually declined to less than 0.5% per day. Thirty-six sand-eels were examined bacteriologically during the 10 mo following capture.”

Keywords: *A. lancea*; H. lanceolatus; diseases; parasites.

**Dann, J. 1986.** The fishery for sandeels (A. marinus) off the English coast 1978-1983. Annales Biologiques. 40: 179-181.

Keywords: *A. marinus*; England; age; distribution; fisheries; growth; size.

**Dann, N., ed. 1989.** Data base report on the stomach sampling project 1981. Cooperative Research Report Conservation International Exploration Mer. 164. 144 p.

Keywords: *Ammodytes*: predators (fish).

**Dannevig, A. 1918.** Biology of Atlantic waters of Canada: Canadian fish-eggs and larvae. Canadian Fisheries Exploration. 1914-1915: 3-74.

Keywords: *Ammodytes*: Atlantic; Canada; eggs; distribution; larvae.

**Daoulas, C.; Economou, A.N. 1986**. Seasonal-variation of egg size in the sardine, *Sardina pilchardus* Walb., of the Saroniko Gulf, causes and a probable explanation. Journal of Fish Biology. 28(4): 449-457.

Keywords: *Ammodytes*: eggs.

**Davenport, J.; Lonning, S.; Kjorsvik, E. 1986.** Some mechanical and morphological properties of the chorions of marine teleost eggs. Journal of Fish Biology. 29(3): 289-301.

Keywords: *Ammodytes*; eggs.

**Dawe, E.G. 1992.** Predation by short-finned squid on Atlantic cod and other fish at Newfoundland, Canada.; Council meeting of the International Council for the Exploration of the Sea;. 1992 Sept. 24-Oct.2; Rostock–Warnemuende Germany. Rostock–Warnemuende Germany: [publisher unknown]: 11.

“Fish otoliths were collected from stomachs of short-finned squid (*Illex illecebrosus*) at eight coastal Newfoundland localities over eight years during 1980-1990. Most otoliths were of young-of-the-year Atlantic cod (*Gadus morhua*) and they were common at all localities after July. Adult capelin (*Mallotus villosus*) otoliths were common early in the season at a southern locality, whereas otoliths of juvenile sand lance (*Ammodytes* sp.) were common later in the season at the northern localities.”

Keywords: *Ammodytes*; Newfoundland; predators (invertebrates, short-finned squid).

**Dawe, E.G.; Dalley, E.L.; Lidster, W.W. 1997.** Fish prey spectrum of short-finned squid (*Illex illecebrosus*) at Newfoundland. Canadian Journal of Fisheries and Aquatic Sciences. 54(supplement 1): 200-208.

“Fish otoliths were collected from stomachs of short-finned squid (*Illex illecebrosus*) at 11 coastal Newfoundland localities over 11 years during 1980-1993. Most otoliths were of the young-of-the-year Atlantic cod (*Gadus morhua*) and they were common at all localities after July. Adult capelin (*Mallotus villosus*) otoliths were common early in the season at a southern locality whereas otoliths of juvenile sand lance (*Ammodytes* sp.) were common later in the season at the northern localities.”

Keywords: *Ammodytes*; Newfoundland; predators (invertebrates, short-finned squid).

**Dawirs, R.R. 1987.** Influence of limited starvation periods on growth and elemental composition (c,n,h) of *Carcinus maenas* (Decapoda, Portunidae) larvae reared in the laboratory. Marine Biology. 93(4): 543-549.

Keywords: *Ammodytes*: fasting; larvae.

**Decker, M.B.; Hunt, G.L. 1996.** Foraging by murres (*Uria* spp.) at tidal fronts surrounding the Pribilof Islands, Alaska. Marine Ecology Progress Series (Amelinghausen). 139(1-3): 1-10.

Keywords: *A. hexapterus*; Alaska; Pribilof Islands; predators (birds, thick-billed murre).

**Decker, M.B.; Hunt, G.L., Jr.; Byrd, G.V. [In press].** The relationship between sea surface temperature, the abundance of juvenile walleye pollock (*Theragra chalcogramma*), and the reproductive performance and diets of seabirds at the Pribilof Islands, in the southeastern Bering Sea. Canadian Journal of Fisheries and Aquatic Science.

Keywords: *A. hexapterus*; Alaska; Pribilof Islands; predators (birds).

**DeGange, A.R.; Sanger, G.A. 1987.** Marine birds of the Gulf of Alaska. In: Hood, D.W.; Zimmerman, S., eds. The Gulf of Alaska: oceanography and resources. Rockville, MD: Office of Marine Pollution Assessment, National Oceanic and Atmospheric Administration, Mineral Management Service, U.S. Department of the Interior.

Keywords: *A. hexapterus*; Gulf of Alaska; predators (birds).

**deGroot, S.J. 1979.** The potential environmental impact of marine gravel extraction in the North Sea. Ocean Management. 5(3): 233-249.

“The rapid increase in the mining of marine gravels in the North Sea offers a serious threat to the marine environment and especially to the herring populations of the southern North Sea and Channel. The paper discusses the extraction methods for gravel and the usefulness of applying programmed dredging to minimize the effects on the sea-bed. The impact of gravel extraction on the sea-bed and on the herring and sand-eel fisheries is discussed. It is estimated that the resources of marine gravel in the southern North Sea will be depleted within 50 yr whereas the fisheries will be practised for many hundreds of years to come. Therefore a careful evaluation, on a European level, is needed of the relative short-term benefits for the marine gravel industry and the long-term interests of the fisheries.”

Keywords: *Ammodytes*; North Sea; dredging; environmental impact; pollution.

**DeKay, J.E. 1842.** Zoology of New York, or the New York fauna. Part IV: Genus Ammodytes. Albany, NY: W. & A. White and J. Visscher: 317-318.

Keywords: *Ammodytes*; New York; biology.

**DeLafontaine, Y. 1990.** Distribution and abundance of ichthyoplankton in the Manicouagan River estuary Quebec Canada a tributary of the lower St. Lawrence estuary. Estuaries. 13(1): 43-50.

“The estuary supports a depauperate ichthyoplankton community, including four species of pelagic fish eggs and eight species of fish larvae [*Gadus morhua, Scomber scombrus, Hippoglossoides platessoides, Osmerus mordax, Carastomus* sp., *Nototropis* sp., *Mallotus villosus, Ammodytes* sp., *Liparis* sp., *Pseudopleuronectes americanus* and *Sebastes fasciatus*]. Species richness increased with salinity.”

Keywords: *A. americanus*; Quebec; abundance; distribution; larvae.

**Denton, E.J.; Gray, J.A.B. 1982.** The rigidity of fish and patterns of lateral line stimulation. Nature (London). 297(5868): 679-681.

Keywords: *A. lanceolatus*; physiology.

**Denton, E.J.; Gray, J.A.B. 1983.** Mechanical factors in the excitation of clupeid lateral lines. Proceedings of the Royal Society of London, Series B: Biological Sciences. 218(1210): 1-26.

Keywords: *A. lanceolatus*; physiology.

**Denton, E.J.; Rowe, D.M. 1994.** Reflective communication between fish, with special reference to the greater sand eel, *Hyperoplus lanceolatus*. Philosophical Transactions of the Royal Society of London Series B: Biological Sciences. 344(1309): 221-237.

“The reflecting units in the surfaces of silvery fish are small ‘platelets’ which have various orientations with respect to the surfaces in which they lie. In the fields of light found in the sea, these orientations are often such as to enable fish to make themselves almost invisible from most points of view. Here we show that the platelets can also be useful in signalling information about the movements that the fish are making. Such signals are clearly graded. Some, e.g. those that accompany C–starts, will be strong and visible at distances many times the length of the fish. Others, e.g. those given by a spot of silveriness on the tail, will only be visible to near neighbors. We consider the movements of fish in terms of three components, rolling, pitching and yawing and show that, by virtue of the organization of the silvery layers, a given movement will produce, to the eye of a neighbor, a characteristic changing pattern of bright and dark surfaces. The changes in brightness accompanying quite small movements are large and, to us and almost certainly to the fish, much more visible than the changes in shape or position (the detection of which must also depend on differences in brightness). Diffusely reflecting surfaces can, to some degree, serve the same purpose but they are less good at doing so. They certainly cannot give a fish the facility of passing quickly from being almost invisible to presenting striking unequivocal signals to their neighbors, as silvery surfaces do. We give an account of the reflecting surfaces of the greater sand eel *Hyperoplus lanceolatus* (Le Sauvage), in relation to this hypothesis.”

Keywords: *Hyperoplus lanceolatus*; communication; movement; schools.

**DesLauriers, J.R.; Brattstrom, B.H.** 1965. Cooperative feeding behavior in red-breasted mergansers. Auk. 82: 639.

Keywords: *Ammodytes*; predators (birds, red-breasted merganser).

**deSylva, D.P.; Kalber, F.A., Jr.; Shuster, C.N., Jr. 1962.** Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. Inf. Ser. Publ. 5. [City unknown], DE: University of Delaware Marine Laboratory. 164 p.

Keywords: *Ammodytes*; Delaware; distribution; ecology.

**Dethlefsen, V.; Von Westernhagen, H. 1983.** Oxygen deficiency and effects on bottom fauna in the eastern German bight 1982. Meeresforschung. 30(1): 42-53.

“When operating underwater TV, dead fish (*A. cataphractus, Callionymus lyra*, *Ammodytes* sp. and flatfish) were detected lying on the bottom. Possible causes for the occurrence of $O_2$ deficiencies are discussed, and it is concluded that eutrophication processes, in combination with adverse hydrographic and meteorological conditions, have triggered low $O_2$ conditions in bottom waters.”

Keywords: *Ammodytes*; North Sea; environmental pollution; oxygen.

**Dick, M.H.; Warner, I.M. 1982.** Pacific sand lance, *Ammodytes hexapterus* Pallas, in the Kodiak Island group, Alaska. Syesis. 15: 43-50.

“Pacific sand lance were abundant, though highly variable in local distribution, in three widely separate areas along the eastern side of the Kodiak island group in summer, 1979. Mean lengths at age from two northern localities were not significantly different, but were significantly larger than those from the southernmost locality. The maximum length recorded was 189 mm. Six age classes (0-V) were found. Age frequency distributions from beach-seined samples were similar in all areas, but were different from a sample dug from the gravel, possibly indicating age segregation between schools. Kodiak sand lance spawned intertidally during spring tide series in October, and probably first spawned at age class II or III. On extreme low tides from May through October, sand lance were found intertidally, buried in coarse and fine gravel beaches.

“Purse seiners in the Kodiak region have frequently set on what appeared from the air to be commercially harvestable quantities of herring, only to have a school of sand lance swim through the seine mesh.

“Sand lance were collected by two methods, beach seining and digging. The intertidal habitat utilized by sand lance for burrowing was beaches of predominantly coarse, black-slate sand of grain size 1-4 mm or fine slate gravel 5-15 mm, or combinations of the two, with larger pebbles or finer sand commonly present. Substrate utilized by sand lance was invariably well washed, bearing no mud, and well drained. Generally, sand lance were more commonly present in bights or coves than on small islands or exposed beaches in straits; more commonly on moderately long or sloping beaches than on very tiny or flat ones. Schools of sand lance were observed swimming along rocky intertidal.

“From at least May through October, sand lance were found in the gravel of beaches, in the lower zone exposed on extreme low tides. Usually these beaches were the site of a stream or river mouth. Densities varied; sometimes it was difficult to find a single one while at times hundreds could be easily dug.

“Sand lance remained continuously along gravel beaches between 8-10 October. They schooled at high tide, the largest schools of an estimated 2-3 tons swimming back and forth at the mouths of small freshwater streams. At low tide, the fish were scattered across the surface of the gravel, heavily preyed upon by crows and gulls. Thousands were exposed to air but at the touch became quite active. Spawning took place at the beginning of the first spring tide series in October and perhaps again at the second-spring tide series in October.”

Keywords: *A. hexapterus*; Alaska; Kodiak Island; age; behavior; distribution; habitat; length; sampling; spawning.

**Dickson, R.R.; Kelly, P.M.; Colebrook, J.M. [and others]. 1988.** North winds and production in the eastern North Atlantic. Journal of Plankton Research. 10(1): 151-169.

Keywords: *Ammodytes*; North Atlantic; larvae.

**Docker, M.F.; Medland, T.E.; Beamish, F.W.H. 1986.** Energy requirements and survival in embryo mottled sculpin (*Cottus bairdi*). Canadian Journal of Zoology. 64(5): 1104-1109.

Keywords: *Ammodytes*; predators (fish, mottled sculpin).

**Dodson, J.; Morin, R.; Power, G. 1980.** Estuarine fish communities of the eastern James-Hudson Bay coast. Environmental Biology of Fishes. 5(2): 135-141.

“Sampling in the following 6 estuaries between 1973 and 77 revealed latitudinal differences in the composition of fish communities: Rupert’s Bay, Eastmain, La Grande, Great Whale, Little Whale, and Innuksuac. Arctic and subarctic marine species were more prominent in estuaries of Hudson Bay. Fewer species were found northwards with 35 species in lower rivers and estuaries of James Bay and only 24 in those of Hudson Bay, for a total of 38 species. Climate, postglacial dispersion, and restricted space are proposed as causes of the observed distribution of fish.”

Keywords: *Ammodytes*; Canada; distribution.

**Donaghy, M.J.; Verspoor, E.; Youngson, A.F. 1995.** Discrimination of the northeast Atlantic lesser sandeels, *Ammodytes marinus, Ammodytes tobianus and Gymnammodytes semisquamatus* by protein electrophoresis. Fisheries Research. 23: 1-9.

“The northeast Atlantic lesser sandeels *Ammodytes marinu*s Raitt, *Ammodytes tobianus* L. and *Gymnammodytes semisquamatus* Jourdain were screened by starch gel electrophoresis for species-specific enzyme variation. Morphological separation of the genera is reliable but distinguishing the two *Ammodytes* species is problematic, particulary in smaller specimens. The analysis revealed a number of diagnostic isozymes. Two, MEP-1 and MEP-2, appear particularly suitable for discriminating the three species. These isozymes show no intraspecific variation, can be typed using muscle, are relatively stable in frozen tissue, and can be resolved using a single gel and histochemical stain. The use of these diagnositc isozymes will facilitate species discrimination in fisheries assessment work and in studies of the ecological differences among the species.”

Keywords: *A. marinus; A. tobianus; Gymnammodytes semisquamatus*; Atlantic (northeast); protein electrophoresis.

**Dornheim, H.; Damm, U. 1996.** Results of investigations on industrial fisheries in 1995/96. Inf. Fischwirtsch. 43(4): 169-172.

“Information on the impact of industrial fishery on sandeel (Ammodytes) and sprat (*Sprattus sprattus*) is given. First results of experimental fishing on board RV Walther Herwig III and results of studies aboard commercial vessels within the German Economic Zone are presented.”

Keywords: *Ammodytes*; North Sea; fisheries.

**Doyle, M.J. 1992.** Neustonic ichthyoplankton in the northern region of the California Current ecosystem. Calififfornia Cooperative Oceanic Fisheries Investigation Report. 33: 141-161.

Keywords: *A. hexapterus*; northeast Pacific; distribution; eggs; larvae.

**Doyle, M.J.; Rugen, W.C.; Brodeur, R.D. 1995.** Neustonic ichthyoplankton in the western Gulf of Alaska during spring. U.S. National Marine Fisheries Service, Fishery Bulletin. 93(2): 231-53.

“Species diversity and abundance of fish eggs in shelf waters of the western Gulf of Alaska were similar in both surface neuston net tows and subsurface bongo net tows, but a unique group of fish larvae appear to be associated with the neuston in this region. The dominance of larvae of an osmerid, several hexagrammids, cottids, bathymasterids, *Anoplopoma fimbria*, *Cryptacanthodes aleutensis*, and *Ammodytes hexapterus* in this group resembles the neustonic assemblage of fish larvae found in the California Current region along the U.S. west coast and most of these taxa are considered obligate members of the neuston. Several taxa, however, appear to be abundant in the neuston only at night suggesting a facultative association with the neuston through a diel pattern of vertical migration. The facultative association of certain species of larvae with the neuston varies with larval size. The distribution patterns observed for most taxa of fish larvae in the neuston during this study suggest that during spring, spawning and emergence of larvae into the plankton and subsequently into the neuston take place mainly around Kodiak Island (except along the seaward side) and along the Alaska Peninsula to the southwest. Analysis of multispecies spatial patterns using recurrent group analysis and numerical classification did not reveal the existence of more than one neustonic assemblage of fish larvae in the study area. Apart from perhaps *Pleurogrammus monopterygius* larvae, which are known to occur throughout the Gulf of Alaska, and to a lesser extent *A. fimbria* and *Hemilepidotus hemilepidotus*, members of this neustonic assemblage of larvae are not commonly found in the oceanic zone. The ecological significance of a neustonic existence for larvae of fish that are primarily demersal spawners in the Gulf of Alaska is considered to be trophic in nature. Neustonic fish larvae seem to be able to exploit to their advantage the unique feeding conditions which exist at the sea surface.”

Keywords: *A. hexapterus*; Gulf of Alaska; abundance; distribution; larvae.

**Doyle, M.J.; Ryan, T.A. 1989.** Spatial patterns in a coastal ichthyoplankton community southwest of Ireland. Rapports et Procés-Verbaux des Reunions, Conseil International pour l’Exploration de la Mer. 191: 70-84.

Keywords: *A. tobianus*; Ireland; distribution; larvae.

**Draganik. B. 1995.** Resources for the Baltic inshore fishery (exclusive of the cod, herring and sprat stocks). Biuletyn Morskoi Institut Ryback. Gdynia/Bull. Sea Fish. Institut Gdynia: 50-58.

“Fish attaining small size, such as gobies, sticklebacks, bull-rout and sand-eel, should not be considered a direct fishery resource but rather a food resource for more economically valuable fish species; any increase in their uncontrolled mortality could have unexpected impact on the size of more valuable stocks.”

Keywords: *Ammodytes*; Baltic Sea; Poland; fisheries; importance.

**Dragoo, D.E. 1991.** Food habits and productivity of kittiwakes and murres at St. George Island, Alaska. Fairbanks, AK: University of Alaska. M.S. thesis.

Keywords: *A. hexapterus*; Alaska; St. George Island; predators (birds).

**Drent, R.H. 1965.** Breeding biology of the pigeon guillemot *Cepphus columba*. Ardea. 53: 99-160.

Sand lance (0.5 percent of the total) were included in the types of food brought to the nests of the pigeon guillemot.

Keywords: *A. tobianus*; predators (birds, pigeon guillemot).

**Drever, C.; Ellis, G. 1968.** Confusing echoes. 1: Sandeels. World Fishing. 17(5): 30-32.

Keywords: *Ammodytes*; hydroacoustics.

**Drolet, R. 1990.** Cycle de production des larves de poissons et de leur ressource en milieu subarctique (Baie D'Hudson). Québec, PQ: Universite Laval. 1.

"La production de microalgues des glaces a la baie d'Hudson au printemps permet d'allonger la période propice a la nutrition des larves de poissons, en favorisant une production hative des copepodes dont les stades immatures représentent la principale nourriture de l'ichtyoplancton. Les larves de lancon (*Ammodytes* sp.) et de morue arctique (*Boreogadus saida*) souffrent de la famine pendant la période suivant la resorption du sac vitellin. Cette periode critique est synchronisee avec l'abondance maximale des proies, ce qui contribue a minimiser la mortalité. Les variations interannuelles du synchronisme entre l'occurrence de la période critique et la production des proies pourraient influencer le recrutement chez les poissons marins."

Keywords: *Ammodytes*; Canada; Hudson Bay; food; larvae; mortality.

**Drolet, R.; Fortier, L.; Ponton, D.; Gilbert, M. 1991.** Production of fish larvae and their prey in sub-arctic southeastern Hudson Bay. Marine Ecology Progress Series. 77(2-3): 105-118.

"In the ice-covered southeastern Hudson Bay (northern Quebec, Canada), marine fish exhibited 2 distinct reproduction strategies. Sand lance *Ammodytes* sp, and arctic cod *Boreogadus saida* produced large numbers of small larvae that hatched before the ice break-up when the abundance of prey (copepod eggs and nauplii) was low, feeding incidence was low and the larvae fed on relatively small prey. A morphometric index of condition suggested that the 2 species suffered from starvation at first feeding. This critical period was approximately synchronized with peak abundance of prey, possibly an adaptation to minimize starvation mortality, Stichaeidae and Cottidae produced small numbers of large larvae that fed efficiently on relatively large prey before yolk resorption. These larvae emerged after the ice break-up, when phytoplankton production was well under way and prey were abundant. Interannual variations in the timing between first feeding and the production of prey could influence recruitment in sand lance and arctic cod but are unlikely to affect the early survival of Stichaeidae and Cottidae."

Keywords: *Ammodytes*; Hudson Bay; growth; larvae; mortality; starvation.

**Drost, M.R. 1987.** Relation between aiming and catch success in larval fishes. Canadian Journal of Fisheries and Aquatic Sciences. 44(2): 304-315.

Keywords: *Ammodytes*; food and feeding habits; larvae.

**Drost, M.R.; Muller, M.; Osse, J.W.M. 1988.** A quantitative hydrodynamical model of suction feeding in larval fishes–the role of frictional forces. Proceedings of the Royal Society of London, Series B: Biological Sciences. 234(1276): 263.

Keywords: *Ammodytes*; food and feeding habits; larvae.

**Drury, W.H. 1979.** Population dynamics in northern marine birds. In: Bartonek, J.C.; Nettleship, D.N., eds. Conservation of marine birds of northern North America. Wild. Res. Rep. 11. Washington, DC: U.S. Fish and Wildlife Service: 123-139.

Keywords: *Ammodytes*; predators (birds).

**Drury, W.H.; Ramsdell, C.; French, J.B., Jr. 1983.** Ecological studies in the Bering Strait region. In: Environmental assessment of the Alaskan Continental Shelf. Final Reports of Principal Investigators, Biological Studies. [Place of publication unknown]: National Oceanic Atmospheric Administration. 17 p.

“Springer and Roseneau (1977, 1978, 1979) recorded murres and kittiwakes flying from Cape Lisburne to the southwest, to the northwest, north and to the northeast. From Cape Thompson they observed birds flying to the west-southwest (as if to the edge of deeper water) and to the southeast. They emphasized the importance of the arrival of sand lance from the north, which was associated with an abrupt shift in the directions of flight so that the birds commuted directly to the shoals of sand lance as soon as they arrived. In the course of survey flights around Cape Thompson and Cape Lisburne in July and August 1978, we observed murres flying west and southwest from Cape Thompson and resting on the water over deeper water (40 meters). Most conspicuous however, were the flights of murres and kittiwakes commuting to shoals of sand lance southeast from Cape Thompson along the beaches almost 70 km and northeast from Cape Lisburne, almost 100 km.

“For kittiwakes: Roseneau and Springer 1978 etc, reported their eating 67% fish *Boreogadus* and *Ammodytes* and 53% invertebrates in a year (1976) which was a reproductive disaster. In Norton Sound (1975-1978), virtually all stomachs and food regurgitated by young kittiwakes contained sand lance. From the Kodiak area south of the Alaska Peninsula, Baird and Moe (1978) reported that capelin is the staple food, and sand lance is important in making the difference between ordinary reproductive performance and real success. Sand lance deserves special consideration because it becomes a major component of the food supply for all three types whenever and wherever it is available. Roseneau and Springer 1977, 78 & 79, have emphasized the movement of kittiwakes and murres along shore to areas where sand lance are caught. They report that sand lance move into the area northeast of Cape Lisburne from the north, then appear off Cape Thompson. When they arrive all species turn to feed on these, and their presence makes a major difference in the success or failure of the reproduction of all the species at Cape Lisburne and Cape Thompson. In our experience kittiwakes, puffins, and to a less extent murres, gather in melees over schools of sand lance as the fish move into Norton Sound during the summer. We have not seen feeding melees in the Bering Shelf waters; this may be due to absence of sand lance which forces the seabirds at Saint Lawrence Island (Searing 1977) to increase their use of crustacea and other, more dispersed fish. Presents tables of feeding by species of seabirds on fish by fish species and location.”

Keywords: *A. hexapterus*; Alaska; importance; predators (birds).

**Du Buit M.H. 1982.** The predation of the codfish *Gadus morhua melanogrammus* Aeglefinus and *Pollachius virens* in the Faeroe Islands Denmark. Cybium. 6(3): 3-19.

“Food intake of cod, coalfish and haddock collected during spring and summer from Faeroe was estimated by analysis of stomach contents. These species are chiefly piscivorous and exert 70% of predation on *Trisopterus esmark*i, *Ammodytes* sp. and *Micromesistius poutassou*.”

Keywords: *Ammodytes*; Denmark; predators (fish, cod, coalfish, haddock).

**Due, T.T.; Curtis, M.A. 1995.** Parasites of freshwater resident and anadromous Arctic charr (*Salvelinus alpinus*) in Greenland. Journal of Fish Biology. 46(4): 578-592.

Keywords: *Ammodytes*; parasites.

**Duffy, D.C. 1986.** Foraging at patches: interactions between common and roseate terns. Ornis Scandinavica. 17: 47-52.

Keywords: *Ammodytes*; predators (birds, common tern, roseate tern).

**Duffy, D.C. 1993.** Stalking the Southern Oscillation: environmental uncertainty, climate change, and north Pacific seabirds. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D., eds. The status, ecology, and conservation of marine birds of the north Pacific. Spec. Publ. [Place of publication unknown]: Canadian Wildlife Service, Environment Canada: 61-67.

Keywords: *A. hexapterus*; north Pacific; predators (birds).

**Dunbar, M.J.; Hildebrand, H.H. 1952.** Contribution to the study of the fishes of Ungava Bay. Journal of the Fisheries Research Board of Canada. 9(2): 83-128.

Keywords: *A. dubius*; Canada; Ungava Bay; distribution; meristic counts; taxonomy.

**Duncan, N. 1981.** Rock pipits feeding on fish. Bird Study. 28(3): 186.

“On the island of Boreray, St Kilda (Western Isles), the Rock Pipit *Anthus spinoletta* is the commonest breeding passerine. During an 18-day expedition to this little-known island in July 1980 the territories of about 17 pairs were counted, although at this time most territories were breaking up. Predominantly littoral feeders, Rock Pipits are greatly dependent upon this area for foraging, but also feed in the steep gullies and wet flushes up to an altitude of about 300 m. On 15 July an adult Rock Pipit was observed carrying fish to its recently-fledged brood of three. When viewed through binoculars from a distance of about 5 m, the fish were identified easily as small Rockling (probably *Gaidrospsarus vulgari*) about 20-25 mm in length. Clearly the fish originated from Puffins *Fratercular arctica* which were bringing onshore both Rockling and Sand Eels at this time (Taylor 1981). Many of the smaller fish are dropped at burrow entrances and many more are lost on land when Puffins are harassed in flight by gulls and skuas.”

Keywords: *Ammodytes*; predators (birds, rock pipit).

**Duncker, G. 1960.** Die Fische der Nordmark. 37: Ammodytidae. Abhandlungen und Verhandlungen Naturwissenschaftlichen Vereins in Hamburg. 3(Suppl.): 245-249.

Keywords: *Ammodytes*; Norway; distribution; taxonomy.

**Duncker, G.; Mohr, E. 1935.** Die nordeuropaischen Ammodytes-Arten des Hamburger Zoologischen Museums. Zool. Anz., Board. 110: 216-220.

Keywords: *Ammodytes*; taxonomy.

**Duncker, G.; Mohr, E. 1939.** Revision der Ammodytidae. Mitteilungen aus dem Zoologischen Museum in Berlin. 24(1): 8-31.

Keywords: *Ammodytes*; taxonomy.

**Dunn, E.K. 1972.** Studies on terns with particular reference to feeding ecology. [Place of publication unknown]: University of Durham. Ph.D. dissertation.

Keywords: *Ammodytes*; predators (birds).

**Dunn, E.K. 1973.** Changes in fishing ability of terns associated with windspeed and sea surface conditions. Nature (London). 224: 520-521.

Keywords: *Ammodytes*; predators (birds).

**Dunn, J.R.; Kendall, A.W.; Wolotira, R.J. 1981.** Seasonal composition and food web relationships of marine organisms in the nearshore zone-including components of the ichthyoplankton, meroplankton, and holoplankton. In: Environmental assessment of the Alaskan Continental Shelf. Juneau, AK: National Oceanic and Atmospheric Administration. Office of Marine Pollution Assessment; final reports of the principal investigators; biological studies; 13: 357-776.

Keywords: *A. hexapterus*; Alaska; distribution; food web.

**Dunn, J.R.; Naplin, N.A. 1974.** Fish eggs and larvae collected from waters adjacent to Kodiak Island, Alaska, during April and May 1972. Marmap Rep. 12. Seattle, WA: U.S. Department of Commerce, National Marine Fisheries Service. 61 p.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; distribution; eggs; larvae.

**Durinck, J.; Skov, H.; Danielsen, F. 1991.** Winter food of guillemots *Uria aalge* in the Skagerrak. Dansk Ornithologisk Forenings Tidsskrift. 85(3-4): 145-150.

“Studies from the North Sea have indicated sandeels and sprat as major prey species of Guillemots in that area.”

Keywords: *Ammodytes*; North Sea; predators (birds, guillemot).

**Dutil, J.D.; Coutu, J.M. 1988.** Early marine life of Atlantic salmon *Salmo sala*r post-smolts in the northern Gulf of St. Lawrence Canada. U.S. National Marine Fisheries Service Fishery Bulletin. 86(2): 197-212.

“In midsummer, stomach contents changed from insects and gammarids to sand lance, 40-100 mm in length; vertically migrating crustaceans also occurred in the stomachs in autumn.”

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; predators (fish, Atlantic salmon).

**Eadie, J.M.; Mallory, M.L.; Lumsden, H.G. 1995.** Common goldeneye. In: Poole, A.; Gill, F., eds. The birds of North America. No. 170. Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologist’ Union.

Keywords: *Ammodytes*; predators (birds, common goldeneye).

**Eaton, C.A. 1971.** Investigation of the fatty acid composition of oils and lipids from the sand lance (*Ammodytes americanus*) from Nova Scotia waters. Journal of the Fisheries Research Board of Canada. 28(4): 601-606.

Keywords: *A. americanus*; Nova Scotia; composition; lipids.

**Ebe, K. 1992.** Coastal waters–some case studies on the sand lance population. 1: Variations in the sand lance population in the coastal waters off Fukushima Prefecture. Suisan Kaiyo Kenkyu. 56(2): 194-198.

Keywords: *A. personatus*; Japan; distribution; larvae.

**Ebe, K. 1995.** Fluctuations on the abundance of sand lance on the coast of Fukushima Prefecture. Bulletin of the Japanese Society of Fisheries Oceanography. 59(3): 312-314.

Keywords: *A. personatus*; Japan; abundance; distribution.

**Ebe, K.; Hirakawa, H.; Ishida, T. [and others]. 1994.** Fish resource survey: pelagic fish resource survey: survey of distribution of larva and fry of sand lances. Fukushima–Ken Suisan Shikenjo Jigyo Hokokusho. 1993: 61-67.

Keywords: *A. personatus*; Japan; distribution; growth; larvae; length.

**Economou, A.N. 1991.** Food and feeding ecology of five gadoid larvae in the northern North Sea. Journal du Conseil. Conseil International pour l'Exploration de la Mer. 47(3): 339-351.

Keywords: *Ammodytes*; North Sea; competition; food; larvae.

"The diets of sandeels and long rough dab which were abundant in the area were also examined. The species-specific selectivity patterns with respect to size and mobility of prey fell into two categories: those dictated by the basic body morphology, and those determined by behavioral factors, which were intimately linked to adult behavior patterns. Competition for food was potentially possible between late larvae, but it could not be identified as a factor causing shifts in dietary characteristics."

**Edwards, R.L.; Bowman, R.E. 1979.** Food consumed by continental shelf fishes. In: Stroud, R.H.; Clepper, H., eds. Predator-prey systems in fisheries management. Washington, DC: Sport Fishery Institute: 387-405.

Keywords: *Ammodytes*; food and feeding habits.

**Ehrenbaum, E. 1904.** Eier und Larven von Fischen der Deutschen Bucht. III: Fische mit festsitzenden Eiern. Wiss. Meeresuntersuch., Abt. Helgoland, N.F. Bd. 6: 127-200.

Keywords: *Ammodytes*; eggs; larvae.

**Ehrenbaum, E. 1909.** Eier und Larven von fischen. Nord. Plankt., Bd. I, Teil. 2: 217-414.

Keywords: *Ammodytes*; eggs; larvae.

**Ehrenbaum, E.; Strodtmann, S. 1904.** Eier und Jugenformen der Ostseefische. I: Bericht. Wiss. Meeresuntersuch., Abt. Helgoland, N.F. Bd. 6: 57-126.

Keywords: *Ammodytes*; eggs; juveniles.

**Einarsson, H. 1951.** The post-larval stages of sand-eels (Ammodytidae) in Faroe, Iceland and W-Greenland waters. Acta Naturalia Islandica. 1(7): 5-75.

Very detailed account describing the postlarval stages of about four species of sand lance, including *Gymnammodytes semisquamatus* (Jourdain). It has been known for a long time that the species of sand eels are of great importance as food for various economically valuable fishes, such as cod, haddock, and plaice. Areas where these fishes are abundant are extremely fertile fishing grounds and owe their fertility in a high degree to the presence of shoals of these fishes. This has been emphasized by Saemundsson (1926) with regard to Faxafloi on the southwest coast of Iceland. Also includes information on the distribution of the different species.

Keywords: *Ammodytes*; *G. semisquamatus*; Iceland; description; distribution; importance; predators (fish); postlarval.

**Einarsson, H. 1955.** On the post-larval stages of *Ammodytes lancea* Cuvier. Acta Naturalia Islandica. 2(1): 3-7.

Keywords: *A. lancea*; postlarval.

**Eldridge, W.D.; Kuletz, K.J. 1980.** Breeding and feeding ecology of pigeon guillemots (*Cepphus columba*) at Naked Island, Alaska. Special Studies. Anchorage, AK: U.S. Fish and Wildlife Service. 22 p.

Keywords: *A. hexapterus*; Alaska; predators (birds, pigeon guillemot).

**Eleftheriou, A.; Robertson, M.R. 1992.** The effects of experimental scallop dredging on the fauna and physical environment of a shallow sandy community. Netherlands Journal of Sea Research. 30: 289-299.

“Very large concentrations of the burrowing sand eel *Ammodytes* were also destroyed. The overall conclusion to be drawn from this experimental dredging operation is that its effect was limited to the selective elimination of a fraction of the fragile and sedentary components of the infauna, and the destruction of the large epifaunal and infaunal organisms.”

Keywords: *Ammodytes*; dredging; environmental impact; habitat.

**Elliot, M.; Taylor, C.J.L. 1989.** The structure and functioning of an estuarine, marine fish community in the Forth Estuary, Scotland. In: Klekowski, R.Z.; Styczynska-Jurewicz, E.; Falkowski, L., eds. Proceedings of the 21st European marine biology symposium; [dates of meeting unknown]; Gdansk, Poland. [Place of publication unknown]: [publisher unknown]: 227-240.

Keywords: *A. tobianus;* Scotland; distribution; larvae; predators (fish).

**Elliot, R.D.; Ryan, P.C.; Lidster, W.W. 1990.** The winter diet of thick billed murres in coastal Newfoundland waters. In: Auks at sea: Proceedings of the international symposium of the Pacific seabird group; 1987 [dates unknown]; Pacific Grove, [CA]. [Place of publication unknown]: [publisher unknown]: 125-138.

“Fish, especially arctic cod *Boreogadus saida*, with fewer capelin *Mallotus villosus*, sand lance *Ammodytes* sp. and Atlantic cod *Gadus morhua*, predominated in samples from November-December in northern zones. Crustaceans, particularly euphausiids (*Thysanoessa* spp.), predominated from January-March as *Uria lomvia* gradually moved south. This switch in diet corresponded to a drop in surface temperature below °C as arctic peak ice moved into Newfoundland waters. Fish apparently descended in the water column to reach warmer layers at a time when *Thysanoessa* migrated into coastal areas and swarmed near the surface, reversing the relative availability of these prey for murres.”

Keywords: *Ammodytes*; Canada; Newfoundland; predators (birds, thick-billed murre).

**Ellis, G. 1968.** Confusing echoes. 1: Sandeels. World Fishing. 17(5): 30-32.

Keywords: *Ammodytes*; hydroacoustics.

**Ellis, H.I. 1984.** Energetics of free-ranging seabirds. In: Whittow, G.C.; Rahn, H., eds. Seabird energetics. New York City: Plenum Press: 203-234.

Keywords: *Ammodytes*; predators (birds).

**Elss, U. 1971.** By catch of German industrial fisheries in 1971. Annales Biologiques. 28(1973): 219.

Keywords: *Ammodytes*; Germany; fisheries.

**Emlen, S.T.; Ambrose, H.W., III. 1970.** Feeding interactions of snowy egrets and red-breasted mergansers. Auk. 87: 164-165.

Keywords: *Ammodytes*; predators (birds, red-breasted merganser).

**Emmett, R.L.; Hinton, S.A.; Stone, S.L.; Monaco, M.E. 1991.** Distribution and abundance of fishes and invertebrates in west coast estuaries. Volume II: Species life history summaries. National Oceanic and Atmospheric Administration, Estuarine Living Marine Resources. 8: 329.

Keywords: *A. hexapterus*; northeast Pacific; abundance; distribution; life history.

**Enobe, K. 1992.** Distribution of sand eel in the coast of Fukushima Prefecture. Bulletin of the Japanese Society of Fisheries and Oceanography. 56(2): 194-198.

Keywords: *A. personatus*; Japan; distribution; larvae; temperature.

**Erikstad, K.E. 1990.** Winter diets of four seabird species in the Barents Sea after a crash in the capelin stock. Polar Biology. 10: 619-627.

Keywords: *Ammodytes*; Barents Sea; predators (birds).

**Erwin, R.M. 1977.** Foraging and breeding adaptations to different food regimes in three seabirds: the common tern (*Sterna hirundo*), royal tern (*Sterna maxima*), and black skimmer (*Rynchops niger*). Ecology. 58: 389-397.

Common terns concentrate their feeding on the most abundant, small inshore fish species, such as sand eel, *Ammodytes americanus*, in New York.

Keywords: *A. americanus*; Atlantic; New York; predators (birds, common tern).

**Escaffre, A.M.; Bergot, P.** 1986. Quantitative morphology of liver in rainbow-trout alevins (*Salmo gairdnerii*) originating from big and small sized eggs, influence of the 1st meal time. Archiv für Hydrobiologie. 107(3): 331-348.

Keywords: *Ammodytes*; composition.

**Eschmeyer, W.N.; Herald, E.S.; Hammann, H. 1983.** A field guide to Pacific coast fishes of North America from the Gulf of Alaska to Baja California. Boston: Houghton Mifflin Co. 336 p.

Keywords: *A. hexapterus*; description.

**Estep, K.W.; Macintyre, F.; Hjorleifsson, E.; Sieburth, J.M. 1986.** Macimage—a user-friendly image-analysis system for the accurate mensuration of marine organisms. Marine Ecology Progress Series. 33(3): 243-353.

Keywords: *Ammodytes*; macimage.

**Evans, P.G.H. 1975.** Gulls and puffins on North Rona. Bird Study. 22: 239-247.

Keywords: *Ammodytes*; predators (birds).

**Evans, P.G.H.; Fisher, P.; Rees, I. [and others]. 1993.** Foraging ecology of harbour porpoises in Shetland. European Research on Cetaceans: 33-38.

Keywords: *A. marinus*; Shetland; predators (mammals, harbor porpoise).

**Evans, P.G.H.; Nettleship, D.N. 1985.** Conservation of the Atlantic Alcidae. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. London: Academic Press: 427-488.

This article discusses, in part, the effects of commercial fisheries on nesting success of alcids.

“To summarize, there are two instances to date where fisheries may be directly implicated as having a negative effect upon alcid populations (west Norway and Newfoundland), with the threat in both cases being a very recent one. This is not to say that some past status changes may not also be due to fisheries practices, but we do not have the data to test this adequately. Fisheries, particularly for sandlance, sprats and capelin, pose potentially serious threats in the future, possibly more so than any other single factor. Those alcid species most likely to be adversely affected at the present time are Atlantic Puffins, Common Murres and Razorbills. Any fisheries developments in the future should give careful thought to the possible interactive effects of depleting a particular prey species within a marine food web.”

Keywords: *Ammodytes*; commercial fisheries; importance.

**Ewins, P.J. 1985.** Growth, diet and mortality of arctic tern *Sterna paradisea* chicks in Shetland. Seabird. 8: 59-68.

“Growth data are presented for Arctic Tern chicks on the island of Mousa, Shetland, in 1983-84. Weight increase compared favourably with that in other parts of the range, but the average daily weight increment of chicks subsequently found dead was much lower than that of healthy chicks. Sandeels were the commonest prey in both years. Over 90% of pre-fledging mortality occurred in the first week of life and in 1983 unusually wet and windy conditions led to fatal chilling of some small chicks. In 1984 breeding success was low throughout Shetland but nestling mortality could not be attributed to adverse weather conditions causing chilling of chicks on Mousa. Most eggs and chicks were eaten by Herring Gulls and Great Skuas. As is the case of some arctic species, it is possible that a series of poor years may be offset by a few productive breeding seasons for Arctic Terns in Shetland.”

Keywords: *Ammodytes*; Shetland; predators (birds, arctic tern).

**Ewins, P.J. 1986.** The ecology of black guillemots *Cepphus grylle* in Shetland. Oxford, England: Oxford University. Ph.D. dissertation.

Keywords: *Ammodytes*; Shetland; predators (birds, black guillemot).

**Ewins, P.J. 1990.** The diet of black guillemots *Cepphus grylle* in Shetland, Scotland UK. Holarctic Ecology. 13(2): 90-97.

“The diet of black guillemots *Cepphus grylle* (L.) was studied in Shetland between 1982 and 1985, both during and outside the breeding season. Full grown birds consumed a wide variety of fish and invertebrate species in summer, broadly reflecting the diversity of the inshore benthic fauna. In winter a greater diversity of invertebrates was taken, which assumed increased importance in the diet as the availability of benthic fish probably declined. Chicks were fed a diet of fish, with 70-80% being sandeels *Ammodytes marinus* and butterfish *Pholis gunnellus* on the islands of Mousa. Sandeels were delivered more frequently in the early morning, coincident with a peak in their feeding activity. Older chicks were fed significantly longer fish. The compositon of chick diet varied significantly with date, not chick age. A seasonal decline in the proportion of sandeels in the chick diet may have reflected changes in zooplankton abundance, but the possibility that intensive industrial fishing of sandeels had adversely affected local stocks can not be ruled out.”

Keywords: *A. marinus*; Shetland; predators (birds, black guillemot).

**Ewins, P.J. 1993.** Pigeon guillemot. In: Poole, A.; Stennheim, P.; Gill, F., eds. The birds of North America. No. 49. Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologist’ Union.

The main fish species fed to pigeon guillemot chicks include sand lance (*Ammodytes tobianus, A. hyperboreus, A. hexapterus*).

Keywords: *A. hexapterus; A. hyperboreus; A. tobianus*; importance; predators (birds, pigeon guillemot).

**Ewins, P.J.; Carter, H.R.; Shibaev, Y.V.; Yurij, V. 1993.** The status, distribution, and ecology of inshore fish-feeding alcids (*Cepphus* guillemots and *Brachyramphus* murrelets) in the north Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K. H.; Siegel-Causey, D., eds. The status, ecology and conservation of marine birds of the north Pacific. Spec. Publ. Ottawa, ON: Canadian Wildlife Service, Environment Canada:164-175.

Keywords: *A. hexapterus*; north Pacific; predators (birds).

**Faber, D.J. 1976.** Hypo-neustonic fish larvae in the Northumberland Strait, Canada during summer 1962. Journal of the Fisheries Research Board of Canada. 33(5): 1167-1174.

“A neuston net with mesh openings of 1.3 mm was towed in the surface waters of the N basin of the Northumberland Strait at irregular intervals from mid-June—mid-Sept. 1962. Fifteen genera of teleost larvae belonging to 11 families were collected. Of these the following 8 spp. occurred in regular abundance and were termed abundant larvae: sand

lance, *Ammodytes americanus*; radiated shanny, *Ulvaria subbifurcata*; lumpfish, *Cyclopterus lumpus*; fourbeard rockling, *Enchelyopus cimbrius*; Atlantic mackerel, *Scomber scombrus*; cunner, *Tautogolabrus adspersus*; white hake, *Urophycis tenuis*; and Atlantic herring, *Clupea harengus harengus*. Larvae were collected in variable numbers, with the sampling data suggesting they were aggregated in the water. The total abundance of all larvae was about 50 larvae/tow except for a peak in July. The regular appearance of the abundant larvae resulted in unique combinations of spawning and hatching times for each species. The larvae of spring spawners were present in June and were gradually replaced by the larvae of summer spawners."

Keywords: *A. americanus*; Canada; abundance; distribution; larvae.

**Fabricius, O. 1780.** Fauna Groenlandica: Pisces. *Ammodytes tobianus*. 98: 140-141.

Keywords: *A. tobianus*; Greenland; distribution; taxonomy.

**Falandysz, J. 1985.** Residues of organochlorine compounds in muscular tissue of fish from the Polish fisheries zone in the Baltic. Biuletyn Morsk. Instytut Ryback. Gdynia. Bulletin Seafish. Institute Gdynia; Byull. Inst. Morsk Rybolov. Gdynia.16(1-2): 38-45.

"Investigations were carried out to determine residue levels of organochlorine pesticides (HCB, Sigma BHC, and Sigma DDT) and polychlorinated biphenyls in muscular tissue of fish netted in 1981 in the Polish fisheries zone in the Baltic. The residue analyses were done in 578 samples of the muscle meat of herring, sprat, cod, fourbearded rockling, whiting, belone, eel, salmon, and sand launce,and in 15 specimens of the three-spined stickleback. All fish contained in their muscles detectable levels of HCB, alfa-BHC, gamma-BHC, p,p super(4)-DDE and PCBs p,p super(4)-DDD and p,p super(4)-DDT were absent only in a few samples beta-BHC was present in trace amounts in most of the samples and delta-BHC was undetected. Generally, the residue levels found were low, i.e., below the acceptable tolerance limits in edible parts of fish."

Keywords: *Ammodytes*; Poland; bioaccumulation; chlorinated hydrocarbons.

**Falandysz, J.; Standberg, L.; Bergqvist, P.A. [and others]. 1996.** Polychlorinated naphthalenes in sediment and biota from the Gdansk Basin, Baltic Sea. Environmental Science and Technology. 30(11): 3266-3274.

"To identify potential sources and accumulation features concentrations, profiles, and patterns of polychlorinated naphthalene (PCN) residues were determined in sediment, mussel, crab, plankton, and fishes from the Gdansk Basin, Baltic Sea. Different marine organisms of the lower food web clearly bioaccumulate many PCN congeners. Depending on the matrix type, PCNs substituted with four or five chlorines dominate. Due to the characteristic profile and pattern of PCN congener groups found in subsurface plankton, mussel, and surface sediments, deposition from the atmosphere is postulated to be the main source of these pollutants. Nineteen of 22 tetra-, all 14 penta-, 9 of 10 hexa-, and both hepta-CNs could be quantified in the samples. The patterns of tetra-, penta-, and hexa-CNs varied largely between the samples or groups of the samples as well as when compared to the technical PCNs formulation Halowax 1014. This implies different absorption/retention rates and/or marked, structure-dependent metabolism of some PCN congeners by marine species."

Keywords: *A. tobianus*; Baltic Sea; bioaccumulation; environmental pollution; polychlorinated naphthalenes.

**Falk, K.; Jensen, J-K; Kampp, K. 1992.** Winter diet of Atlantic puffins (*Fratercula arctica*) in the northeast Atlantic. Colonial Waterbirds. 15(2): 230-235.

Authors present stomach contents of 36 puffins killed during January, February, and March—sand lances (*Ammodytes* spp.) were the most common fish species.

Keywords: *Ammodytes*; Atlantic (northeast); importance; predators (birds, Atlantic puffin).

**Favorite, F.; Laevastu, T. 1979.** A study of the ocean migrations of sockeye salmon and estimation of the carrying capacity of the north Pacific Ocean using a dynamical numerical salmon ecosystem model (NOPASA). [Place of publication unknown]: National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest and Alaska Fisheries Center; Processed Report 79. 16 p.

Keywords: *A. hexapterus*; north Pacific; predators (fish, sockeye salmon).

**Feder, H.M.; Jewett, S.C. 1981.** Feeding interactions in the eastern Bering Sea with emphasis on the benthos. In: Hood, D.W.; Calder, J.A., eds. The eastern Bering Sea shelf: oceanography and resources. [Place of publication unknown]: U.S. Department of Commerce: 2: 1229-1261.

Stomach contents of adult Pacific cod caught in summer months near Kodiak contained walleye pollock, Pacific sand lance, and flatfishes. Stomach contents of juvenile Pacific halibut from the southeastern Bering Sea contained, in percentage of frequency of occurrence, unidentified fishes (25 percent), sand lance (15 percent), and crabs (6 percent).

Keywords: *A. hexapterus*; Alaska; Bering Sea; Kodiak; predators (fish, Pacific cod, Pacific halibut).

**Fehervari, Z.; Naevdal, G. 1995.** A pilot study of inter- and intraspecific variations in sandeels (fam. Ammodytidae). Inst. Fisk. Marine Biology Rapp. 5: 19.

“The purpose of the present study was to identify genetic traits which may be used in studies in inter- and intraspecific variation in sandeels (fam. Ammodytidae). Samples of four species of sandeels from the North Sea, Scotland and Iceland have been analysed by starch-gel electrophoresis of muscle and liver tissue. Nine enzymes were stained for, and five of those (GPI, IDHP, LDH, MDH and PGM) gave clear-cut results. The electrophoretic patterns were species-specific for most of these enzymes showing that they may be used for identification of the species. Genetic variation within species were found in at least one species for all these enzymes except LDH. The most variable species appeared to be *Ammodytes marinus* while *Gymnammodytes semisquamatus* appeared least variable. These tentative results will be used in a more extensive study on the structure between and within species of sandeels.”

Keywords: *A. americanus; Gymnammodytes semisquamatus*; North Sea; fisheries; genetics.

**Field, L.J. 1988.** Pacific sand lance, *Ammodytes hexapterus*, with notes on related *Ammodytes* species. In: Wilimovsky, N.J.; Incze, L.S.; Westrheim, S.J., eds. Species synopses, life histories of selected fish and shellfish of the northeast Pacific and Bering Sea. [Place of publication unknown]: [publisher unknown]: 15-33. Available from: Washington Sea Grant Program, 3716 Brooklyn Ave. NE, Seattle, WA 98105.

Keywords: *A. hexapterus*; Bering Sea; Pacific Ocean; life history; reviews.

**Fischer, W. 1973.** Methods and results of studies on the schooling behavior of fishes using the diving method. Helgolaender Wissenschaftliche Meeresuntersuchungen. 24: 391-400.

Keywords: *A. lanceolatus*; *A. tobianus*; behavior; schooling.

**Fiscus, C.H.; Baines, G.A. 1966.** Food and feeding behavior of Steller and California sea lions. Journal of Mammalogy. 47: 195-200.

“Sea lions taken on land usually have empty stomachs. To obtain sea lions with food in their stomachs, 34 Steller sea lions and 7 California sea lions were taken at sea. Stomachs of California sea lions contained squids, hake and anchovies. Stomachs of Steller sea lion taken off California and Oregon contained flatfishes and rockfishes; those taken in Alaskan waters contained capelin, sand lance, rockfishes, sculpins, and flatfishes; one had fed on salmon.”

Four Steller sea lions taken in May, June, and September had Pacific sand lance in their stomachs. They were taken at Unimak Pass in the Bering Sea and at Marmot Island and Little Koniuji Island. Number of sand lance eaten ranged from 6 to 405. In three of the sea lions, Pacific sand lance was the dominant food eaten.

Keywords: *A. hexapterus*; Alaska; predators (mammals, Steller sea lion).

**Fiscus, C.H.; Baines, G.A.; Wilke, F. 1964.** Pelagic fur seal investigations, Alaska waters, 1962. U.S. Fish and Wildlife Service, Special Scientific Report. 475: 1-59.

Keywords: *A. hexapterus*; Alaska; predators (mammals, northern fur seal).

**Fisher, J. 1952.** The fulmar. London, England: Collins.

Keywords: *Ammodytes*; predators (birds, fulmar).

**Fitch, J.E.; Lavenberg, R.J. 1983.** Teleost fish otoliths from Lee Creek mine, Aurora North Carolina USA, Yorktown Formation Pliocene. Smithsonian Contributions to Paleobiology. 53: 509-529.

“Pliocene fossiliferous exposures at the Lee Creek Mine, Yorktown Formation, deposits yielded 8808 teleost otoliths. These represented at least 45 taxa distributed among 17 teleostean families including Ammodytidae.”

Keywords: Ammodytidae; fossils; otoliths.

**Fives, J.M. 1967.** Sandeels *Ammodytes* and their larvae off the Galway coast. Scientific Proceedings of the Royal Dublin Society, Series B. 2(4): 37-44.

Keywords: *Ammodytes*; Scotland; larvae.

**Flegg, J.J.M. 1972.** The puffin on St Kilda, 1969-71. Bird Study. 19: 7-17.

Keywords: *Ammodytes*; predators (birds, puffin).

**Foerster, R.E. 1955.** The Pacific salmon (genus *Oncorhynchus*) of the Canadian Pacific Coast with particular reference to their occurrence in or near fresh water. International North Pacific Fisheries Commission Bulletin. 1: 1-56.

Keywords: *A. hexapterus*; Canada; predators (fish, Pacific salmon).

**Foerster, R.E. 1968.** The sockeye salmon, *Oncorhynchus nerka*. Bulletin of the Fisheries Research Board of Canada. 162: 1-422.

Keywords: *A. hexapterus*; predators (fish, sockeye salmon).

**Fogarty, M.J.; Cohen, E.B.; Michaels, W.L.; Morse, W.W. 1991.** Predation and the regulation of sand lance populations: an exploratory analysis. ICES Marine Science Symposium. 193: 120-124.

“Large-scale shifts in abundance and relative species composition have been observed in the pelagic fish community on the continental shelf off the northeastern United States. Here, we examine empirical evidence for regulation of sand lance populations (*Ammodytes* spp.) by Atlantic mackerel (*Scomber scombrus*) and Atlantic herring (*Clupea harengus*) populations in an exploratory analysis. Changes in the abundance of sand lance are consistent with the hypothesis of predatory control by herring and mackerel. A significant negative interaction between sand lance recruitment and an integrated measure of herring and mackerel biomass was indicated. Direct evidence for predation by herring and mackerel is available to support these results.”

Keywords: *Ammodytes*; Atlantic (northwest); importance; predators (fish, Atlantic herring, Atlantic mackerel).

**Ford, E. 1920.** The post-larval stages of *Ammodytes* species captured during the cruises of S.S. Oithona in Plymouth waters in the year 1919. Journal of the Marine Biological Association, Plymouth. 12.

Keywords: *Ammodytes*; Plymouth; distribution; postlarvae.

**Ford, R.G.; Wiens, J.A.; Heinemann, D.; Hunt, G.L. 1982.** Modeling the sensitivity of colonially breeding marine birds to oil spills: Guillemot and Kittiwake populations on the Pribilof Islands, Bering Sea. Journal of Applied Ecology. 19: 1-31.

Keywords: A. hexapterus; Alaska; Bering Sea; Pribilof Islands; predators (birds).

**Forest, J. 1950.** Observations sur deux Ammodytides des cotes françaises, *Ammodytes lanceolatus* et *A. lancea.* Journal du Conseil, Conseil International pour l'Exploration de la Mer. 16(2): 179-182.

Keywords: *A. lancea; A. lanceolatus*.

**Fortier, L.; Fortier, M.; Demers, S. 1995.** Zooplankton and larval fish community development: comparative study under first-year sea ice at low and high latitudes in the Northern Hemisphere. Proceedings National Institute Polar Research Symposium Polar Biology. 8: 11-19.

Keywords: *Ammodytes*; Arctic Ocean; Sea of Okhotsk; larvae.

**Fortier, L.; Gilbert, M.; Ponton, D. [and others]. 1996.** Impact of freshwater on a subarctic coastal ecosystem under seasonal sea ice (southeastern Hudson Bay, Canada). 3: Feeding success of marine fish larvae. Journal of Marine Systems. 7(2-4): 251-265.

"We monitored the feeding success (percent feeding incidence at length and mean feeding ratio at length) of arctic cod (*Boreogadus saida*) and sand lance (*Ammodytes* sp.) larvae in relation to prey density, light, temperature and potential predator density under the ice cover of southeastern hudson bay in the spring of 1988, 1989 and 1990. Both prey density and light limited larval fish feeding. The relationship between feeding success and actual food availability (nauplii density $\times$ irradiance) was adequately described by an ivlev function which explained 64 and 76% of the variance in arctic cod and sand lance feeding success respectively. By affecting both prey density and irradiance, the thickness of the great whale river plume (as defined by the depth of the 25 isohaline) was the main determinant of prey availability. Arctic cod and sand lance larvae stopped feeding when the depth of the 25 isohaline exceeded 9 m. Limitation of feeding success attributable to freshwater inputs occurred exclusively in 1988, the only time when the depth of the 25 isohaline exceeded the 9 m threshold. The close dependence of larval fish feeding success on the timing of the freshet and plume dynamics suggests a direct link between climate and survival of arctic cod and sand lance larvae. The actual impact of climate fluctuations and/or hydro-electric developments on recruitment will depend on the fraction of the larval dispersal area of the two species that is affected by river plumes."

Keywords: *Ammodytes*; food; larvae; light; prey density; temperature.

**Fortier, L.; Levasseur, M.; Drolet, R.; Therriault, J.C. 1991.** Cross-frontal circulation, export production, and the dispersion of fish larvae and their prey in a coastal jet frontal region (northwestern Gulf of St. Lawrence). In: Council meeting of the International Council for the Exploration of the Sea; 1991 Sept. 26-Oct. 4; La Rochelle, [France]. [Place of publication unknown]: [publisher unknown]: 6.

"A permanent and well-delineated salinity front is formed between the Gaspe jet current and the cyclonic Anticosti gyre (NW Gulf of St. Lawrence). In late spring, the thermohaline stratification of nutrient-rich waters in the jet current favors the production of diatoms which trigger copepod reproduction. Copepod eggs and nauplii, the main prey of

fish larvae at first feeding, are 10 to 20 times more abundant in the surface waters of the jet current than in the adjacent Anticosti Gyre. The early larvae of capelin (*Mallotus villosus*) and American sand lance (*Ammodytes* sp.) are dispersed in the productive surface waters of the current. During the summer, the distribution of larger postlarvae and that of their copepod prey extend across the front to the Anticosti gyre."

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; distribution; food; larvae.

**Fortier, L.; Levasseur, M.E.; Drolet, R.; Therriault, J.C. 1992.** Export production and the distribution of fish larvae and their prey in a coastal jet frontal region. Marine Ecology Progress Series. 85(3): 203-218.

"Fine scale spatial sampling series and vertical cross sections were used to obtain quasi synoptic images of the distribution of fish larvae and their prey in the permanent frontal region formed by the Gaspe coastal jet current and the adjacent Anticosti gyre (NW Gulf of St. Lawrence, Canada). The accumulation of large diatoms triggered the reproduction of copepods in the Gaspe current where eggs and nauplii (the main prey of first feeding fish larvae) were 10 to 20 times more abundant than in the gyre. Estuarine circulation resulted in the coincidence of the small and abundant larvae of capelin *Mallotus villosus* and sand lance *Ammodytes* sp. with this intense production of their food in the jet current. The large and less abundant larvae of redfish *Sebastes* sp. and Arctic shanny *Stichaeus punctatus* exploited the scarcer food resources of the Anticosti gyre. We conclude that opportunistic species producing large numbers of small offspring with limited foraging skills depend on massive export production at hydrographic singularities (i.e. salient hydrographic features) for reproduction. Species producing fewer but larger and more competent larvae can colonize less productive areas of the ocean. Plankton dynamics in the dispersal area of the early larval stages appear to be a primary constraint defining the life strategy of a fish species."

Keywords: *Ammodytes*; Canada; Gulf of Saint Lawrence; larvae.

**Fortier, L.; Ponton, D.; Gilbert, M. 1995.** The match-mismatch hypothesis and the feeding success of fish larvae in ice-covered southeastern Hudson Bay. Marine Ecology Progress Series. 120(1-3): 11-27.

"We studied the synchronism between the seasonal occurrence of fish larvae and their prey in ice-covered southeastern Hudson Bay, Canada, in spring 1988, 1989 and 1990. Arctic cod *Boreogadus saida* and sand lance *Ammodytes* sp. larvae hatched several weeks before ice break-up and fed primarily on copepod nauplii. The timing of 50% yolk resorption was the same every year (11 to 18 May for Arctic cod and 5 to 11 June for sand lance) but the availability of copepod nauplii varied substantially between years, both in magnitude (7-fold) and timing (4 to 6 wk). Interannual differences in the under-ice abundance of nauplii were linked to variations in the abundance of female cyclopoid copepods, and appeared unrelated to the timing of the ice-algal or phytoplankton blooms. Interannual differences (2- to 4-fold) in the feeding success of fish larvae (percent feeding incidence at length and mean feeding ratio at length) were related to the availability of copepod nauplii. Consistent with the match/mismatch hypothesis, the fixity of the spawning season in relation to a variable cycle of prey abundance accounted for the observed variations in feeding success and apparent growth (length at date) of fish larvae. Yet, in this particular ecosystem, a match or mismatch between Arctic cod or sand lance larvae and their prey may depend more on the dynamics of cyclopoid copepods during the previous winter than on the timing of the spring algal blooms."

Keywords: *Ammodytes*; Canada; Hudson Bay; food; growth; larvae.

**Fortier, M.; Fortier, L. 1993.** Ice-covered Saroma-Ko as a nursery ground for fish larvae originating from Okhotsk Sea: The 8th international symposium on Okhotsk Sea and sea ice and ISY/polar ice extent workshop—abstracts; 1993 Feb. 1-5; Mombetsu, Japan. Mombetsu, Japan: Okhotsk Sea and Cold Ocean Research Association: 385-386.

"Kitagawa and Yamashita (1986) suggested that along the coast of Northern Honshu narrow bays and lagoons, where high abundances of copepod nauplii occur, could serve as important nurseries for sand lance (*Ammodytes* sp.) larvae produced in the coastal area. The development of microzooplankton suitable for larval fish feeding was monitored from 23 February to 26 March 1992 at a fixed station in the ice-covered Saroma lagoon, Northern Hokkaido. During the same period, the transport of fish larvae across one of the two inlets linking the lagoon to Okhotsk Sea was also monitored. We conclude that sand lance larvae are transported into the lagoon primarily in daytime during flood tide, most likely as a result of their occupation of the surface layer of coastal Okhotsk Sea in

daytime. Small sand lance larvae effect inverse nycthemeral migrations in the coastal water of Japan, being concentrated above 15 m in daytime and below this level at night. Thus, the net transport of young sand lance into Saroma-Ko could depend on the synchronization (or lack of synchronization) of flood tide with nighttime during the seasonal production of the larvae in coastal Okhotsk Sea."

Keywords: *A. personatus*; Japan; Hokkaido; food; larvae; migration.

**Fortier, M.; Fortier, L. 1997.** Transport of marine fish larvae to Saroma-ko lagoon (Hokkaido, Japan) in relation to the availability of zooplankton prey under the winter ice cover. Journal of Marine Systems. 11(1-2): 221-234.

"To assess the importance of ice-covered saroma-ko lagoon as a winter nursery area for young fish spawned offshore, we monitored the recruitment of marine fish larvae from the Sea of Okhotsk to the lagoon as well as the availability of larval fish prey under the ice cover from 24 february to 23 march 1992. Sand lance (*Ammodytes* sp.) And walleye pollock (*Theragra chalcogramma*) larvae recruited to the lagoon on flood tide whereas snake prickleback (*Lumpenus sagitta*) larvae were exported to the Sea of Okhotsk on ebb. Before the ice breakup, ice microalgae made up the bulk of the microalgal biomass in the lagoon. The production and release of ice algae did not trigger the maturation of the late copepodite stages of copepods, and the proportion of adult females in the copepod assemblage remained low. The production of copepod nauplii (the main prey of fish larvae) under the ice was probably insufficient to insure suitable feeding and growth of fish larvae entering the lagoon in winter. Sand lance larvae, the most abundant species to colonize the lagoon in february-march, had to survive for nearly two months at low food abundance. Based on our results, the importanceof Saroma-ko lagoon as a winter nursery area for fish larvae appears negligible."

Keywords: *Ammodytes*; Japan; Sea of Okhotsk; food; larvae; sea-ice.

**Foster, A.R.; Houlihan, D.F.; Hall, S.J.; Burren, L.J. 1992.** The effects of temperature acclimation on protein synthesis rates and nucleic acid content of juvenile cod *Gadus morhua*. Canadian Journal of Zoology. 70(12): 2095-2102.

"Juvenile cod were acclimated to cold and warm water temperatures and fed sandeels for at least 40 days. After this acclimation period, there were no significant differences in either weight-specific growth rate or weight-specific tissue protein synthesis rates (ventricle, gill, stomach, and intestine) between the cold- and warm-acclimated fish."

Keywords: *Ammodytes*; importance.

**Fourmanoir, P. 1976.** Formes post-larvaires et juveniles de poissons côtiers pris au chalut pelagique dans le sud-ouest pacifique. Cahiers du Pacifique. 19: 47-88.

Pelagic postlarvae of 86 species are listed; some are illustrated. Localities and, for most species, basic counts are provided.

Keywords: *Ammodytes*; distribution; postlarvae; taxonomy.

**Fowler, H.W. 1931.** Studies of Hong Kong fishes no. 2. Hong Kong Naturalist. 11(4): 287-317.

Keywords: *Ammodytes*; Hong Kong; distribution; taxonomy.

**Fowler, J.A.; Dye, A.P. 1987.** Sandeels *Ammodytes marinus* in the diet of the fulmar *Fulmarus glacialis* in Shetland, Scotland. Seabird. 10: 71-74.

"This paper describes the size distribution of Sandeels, calculated from measurements of otoliths recovered from Fulmar regurgitates on Yell, Shetland, and compares it with the size distribution of Sandeels obtained from commercial fishermen in Shetland and with the results of the studies above."

Keywords: *A. marinus*; Shetland; distribution; predators (birds, fulmar); size.

**Fraser, P.J. 1987.** Atlantic salmon *Salmo salar* feed in Scottish coastal waters. Aquaculture and Fisheries Management. 18(3): 243-248.

“The stomach contents of 256 Atlantic salmon, *Salmo sala*r L., of fork lengths 53-66 cm, caught in bag nets on the Scottish west coast near Ullapool, were examined between June 1983 and July 1986. A total of 61 fish contained fish in the stomach or had faecal pellets containing fish bones in the gut. All recognizable whole fish were sandeels, *Ammodytes marinus* Raitt, ranging in size from 4.5 to 15 cm. No evidence for crustacean or other non-fish prey items was found. Results indicate that feeding salmon were caught up to a certain cut-off point in June or early July, after which all salmon sampled were not feeding. It is suggested that either there is a local feeding stock of salmon or that fish feed during migration from the Faroe Isles or other possible distant water origins.”

Keywords: *A. marinus*; Scotland; predators (fish, Atlantic salmon).

**French, R.; Bilton, H.; Osako, M.; Hartt, A. 1976.** Distribution and origin of sockeye salmon (Oncorhynchus nerka) in offshore waters of the north Pacific Ocean. International North Pacific Fishery Commercial Bulletin. 34. 113 p.

Keywords: *A. hexapterus*; north Pacific; predators (fish, sockeye salmon).

**Fresh, K.L. 1979.** Distribution and abundance of fishes occurring in the nearshore surface waters of northern Puget Sound, Washington. Seattle: University of Washington. 120 p. M.S. thesis.

Keywords: *A. hexapterus*; Washington; Puget Sound; abundance; distribution.

**Frick, S.; Becker, P.H. 1995.** Different feeding strategies of common and arctic tern (*Sterna hirundo* and *S. paradisaea*) in the German Wadden Sea. Journal für Ornithologie. 136(1): 47-63.

“In 1991 and 1992 the feeding ecology of common and Arctic terns was studied on the Wadden Sea island of Minsener Oldeoog. Both species preyed on the same food species. Common and Arctic terns differed clearly in their feeding strategies: the Arctic tern fed more crustaceans to the chicks, the common tern more fish like clupeids or sandeels *Ammodytes*. In 1992 the higher percentage of larger prey, especially clupeids, sandeels and Syngnathidae, increased the mean prey-size and reduced the feeding rates. During high water in both species the amount of crustaceans decreased in favour of clupeids, sandeels and larvae, linked with decreasing feeding rates. The Arctic tern covered the energy requirements of chicks by increasing feeding rates of small food items, while the common tern chose the strategy of feeding on large, energy-rich fish.”

Keywords: *Ammodytes*; Germany; Wadden Sea; predators (birds, arctic tern, common tern).

**Friogeirsson, E. 1979.** Notes on capelin and sandeel larvae collected in Icelandic waters 1976-1979. In: ICES Council Meeting 1979 collected papers. Charlottenlund (Denmark). [publisher unknown].

Keywords: *Ammodytes*; Iceland; larvae.

**Friogeirsson, E. 1980.** On sand eel in O-group surveys in Icelandic and adjacent waters 1970-1979. In: Council meeting, 1980, of the International Council for the Exploration of the Sea; [dates of meeting unknown]; Copenhagen, [Denmark]. [Place of publication unknown]: [publisher unknown]: 19.

Keywords: *Ammodytes*; Iceland; distribution; 0-age.

**Fritz, L.W.; Wespestad, V.G.; Collie, J.S. 1993.** Distribution and abundance trends of forage fishes in the Bering Sea and Gulf of Alaska. In: Is it food?: addressing marine mammal and seabird declines: Workshop summary; [dates of meeting unknown]; [location unknown]. Alaska Sea Grant Rep. 93-01. Fairbanks, AK: University of Alaska, Fairbanks: 30-44.

“Little is known of their distribution and abundance: they are rarely caught by trawls. In the Bering Sea, sand lance are common prey of salmon, northern fur seals, and many species of marine birds. Thus, they may be abundant in Bristol Bay, along the Aleutian Islands and Alaska Peninsula. In the gulf of Alaska, sand lance are prey of harbor

seals, northern fur seals, and marine birds, especially in the Kodiak area and along the southern Alaska Peninsula. Given the sand lance's short life span and the large number of species that prey on it, mortality, fecundity, and growth rates of Pacific sand lance are probably high."

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, fish, mammals, harbor seal, northern fur seal).

**Fritzsche, R.A. 1978.** Development of fishes of the mid-Atlantic bight: an atlas of egg, larval and juvenile stages. U.S. Fish and Wildlife Service/OBS-78/12: 283-287.

Keywords: *A. americanus*; description; egg; juvenile; larvae.

Frost, B.W.; Bollens, S.M. 1992. Variability of diel vertical migration in the marine planktonic copepod *Pseudocalanus newmani* in relation to its predators. Canadian Journal of Fisheries and Aquatic Sciences. 49(6): 1137-1141.

"We report results of a 3-yr field study of the vertical distributions and diel vertical migration (DVM) of *Pseudocalanus newmani* in the central basin of Dabob Bay, Washington, USA. Our results include two novel findings. First, a statistically significant relationship exists between strength of DVM in *P. newmani* and the potential predation impact of its planktonic invertebrate predators. Second, a strong 'normal' DVM (up at night, down during the day), unique for *P. newmani* in 5 yr of sampling at this locale, occurred at a time when the zooplanktivorous fish *Ammodytes hexapterus* was unusually abundant and preying on the copepod; this DVM may have been induced by the fish. DVM behavior of *P. newmani* was highly variable, with changes in behavior commonly occurring on a time scale of weeks; in one case the copepod switched from a normal migration pattern to a reverse migration pattern (down at night, up during the day) in less than 5 wk. These observations, combined with those of previous research, indicate that *P. newmani* has an exceptionally diverse repertoire of migration behavior, any particular expression of which is most likely manifested by individual copepods exercising phenotypic behavioral plasticity in response to potential predation."

Keywords: *A. hexapterus*; Washington; food and feeding habits.

**Frost, K.J.; Lowry, L.F. 1981.** Foods and trophic relationships of cetaceans in the Bering Sea. In: Hood, D.W.; Calder, J.A., eds. The eastern Bering Sea shelf: oceanography and resources. Seattle, WA: University of Washington Press; National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment. 2: 825-836.

Keywords: *A. hexapterus*; Bering Sea; predators (mammals).

**Frost, K.; Lowry, L. 1987.** Marine mammals and forage fishes in the southeastern Bering Sea. In: Proceedings of the 1987 forage fishes of the southeastern Bering Sea conference; [dates of meeting unknown]; [location unknown]. Outer Continental Shelf Study MMS 87-0017. [Place of publicaton unknown]: Minerals Management Service: 11-17.

This paper reviews a number of other papers on the food habits of marine mammals in the Bering Sea. Most mammals feed on Pacific sand lance.

Keywords: *A. hexapterus*; Bering Sea; predators (mammals, northern fur seal, Steller sea lion, harbor seal, spotted seal, ribbon seal, ringed seal, belukha whale, harbor porpoise, Dall's porpoise, minke whale, sei whale, humpback whale).

**Frost, N. 1938.** Some fishes of Newfoundland waters (with notes on the distribution of eggs and larvae). Newfoundland Government Research Bulletin. 4: 1-16.

Keywords: *Ammodytes*; Newfoundland; distribution; eggs; larvae.

**Fry, M.D. 1995.** Pollution and fishing threats to marbled murrelets. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 420 p.

Whitehead and others (1991) found the highest levels of dioxins in western grebes, which have a prey base similar to that of murrelets. The oil spill may have impacted forage fish. Prey species for murrelets include Pacific sand lance. Seabird diet studies in Prince William Sound indicated that sand lance were less available in 1989 and 1990 than in prespill years. Many prey species are intertidal spawners and are more susceptible to oil pollution than are pelagic spawners.

Keywords: *A. hexapterus*; Alaska; Prince William Sound; oil pollution.

**Fuchs, E. 1977.** Kleptoparasitism of sandwich terns Sterna sandvicensis by black-headed gulls *Larus ridibundus*. Ibis. 119(2): 183-190.

"The parasitic behavior of black-headed gulls in a mixed colony of terns and gulls at the Sands of Forvie on the NE coast of Scotland is described in some detail. Food-stealing occurred with varying frequency throughout the breeding season. Less than 6% of the terns were attacked during incubation and when their chicks were a few days old, but up to 29% were attacked thereafter. At the same time the percentage of successful attacks rose from 1% or less to 6.5%. Food items brought back to the ternery were predominantly sand eels, clupeids and gadoids. Only a small proportion of terns carrying fish shorter than 7 cm were attacked whether they were sand eels, clupeids or gadoids. Robbing success was higher with clupeids and gadoids than with sand eels. The effect of the black-headed gulls' kleptoparasitism on the sandwich terns' breeding success was probably negligible during incubation and early chick-life, but might have influenced fledging weight and ultimately post-fledging survival."

Keywords: *Ammodytes*; Scotland; predators (birds, black-headed gull, sandwich tern).

**Fuiman, L.A.; Gamble, J.C. 1988.** Predation by Atlantic herring, sprat, and sandeels on herring larvae in large enclosures. Marine Ecology Progress Series. 44(1): 1-6.

"A predation experiment was conducted in 15.5 $m^3$ in situ enclosures to estimate the predation potential of various juvenile and adult fishes on larval Atlantic herring *Clupea harengus*. Predators were herring, sprat *Sprattus sprattus*, and sandeels *Hyperoplus lanceolatus* and *Ammodytes tobianus*. Herring consumed significantly fewer larvae in 24 h with less variability in the results than the other predators. Mean instantaneous daily mortality rate for herring was 0.001 (0.1% $d^{-1}$) whereas it was 0.392 (32% $d^{-1}$) for all the other predators. These values are 2.3 to 3.5 times those obtained in previous studies for jellyfish predators in enclosures. They are also greater than field estimates of natural mortality for herring larvae of comparable size, suggesting that encounters between herring larvae and larger fishes are rarer in the sea than in our experiment."

Keywords: *A. tobianus*; *H. lanceolatus*, food and feeding habits.

**Fujii, Y.; Fujisawa, K.; Hayashi, H. 1992**. Occurrence and distribution of fish eggs and larvae in Bisan-Seto, Seto Inland Sea in fiscal year 1991. Okayama-Ken Suisan Shikenjo Hokoku. 7: 94-98.

Keywords: *A. personatus*; Japan; Seto Inland Sea; distribution; eggs; larvae.

**Fujii, Y.; Fujisawa, K.; Hayashi, H. 1993**. Occurrence and distribution of fish eggs and larvae in Bisan-Seto of the Seto-Inland Sea, in fiscal year 1992. Okayama-Ken Suisan Shikenjo Hokoku. 8: 42-46.

Keywords: *A. personatus*; Japan; Seto Inland Sea; distribution; eggs; larvae.

**Fujiwara, T. 1993.** Comparisions between the power of the sea and that of mankind. Setonaikai Kagaku. 5(1): 21-26.

Keywords: *A. personatus*; Japan; Seto Inland Sea; environmental disturbance.

**Fujiwara, T.; Higo, T. 1986.** Wind-induced current and mass transport in the Seto Inland Sea. Bulletin of Coastal Oceanography. 23: 109-119.

Keywords: *A. personatus*; Japan; Seto Inland Sea; distribution; larvae.

**Fujiwara, T.; Nakada, H. 1992.** Fluctuations in the stock of sand eel in the eastern Seto Inland Sea relationships with the climate and sea conditions. Bulletin of the Japanese Society of Fish and Oceanography. 56(2): 199-200.

Keywords: *A. personatus*; Japan; Seto Inland Sea; abundance; larvae; spawning.

**Fujiwara, T.; Nakata, H.; Tanda, M.; Karakawa, J. 1990.** Biological and physical parameters of the population dynamics of sand eel larvae in the eastern Seto Inland Sea. Nippon Suisan Gakkaishi (Buletin of Japanese Society of Scientific Fisheries). 56(7): 1029-1037.

“An analytical method for estimating the biological and physical parameters of larvae population from field-observed body length distribution was developed and applied to the sand eel (*Ammodytes personatus*) population in the eastern Seto Inland Sea. The total number of hatched larvae was 2.76 x $10^{12}$ (1.79 x $10^{12}$ in Bisan Strait and 0.97 x $10^{12}$ near Akashi Strait), and 86% of the larvae hatched in the Bisan Strait are transported into the Harima-Osaka area within one month after hatching. The eastward transportation of the larvae from the Bisan Strait is well explained by the current driven by westerly monsoon wind.”

Keywords: *A. personatus*; Japan; Seto Inland Sea; hatching; larvae; length; migration; population dynamics.

**Fukataki, H. 1969.** Stomach contents of the masu salmon *Oncorhynchus masou* in the Japan Sea. Bulletin of the Japan Sea Regional Fisheries Research Laboratory. 21: 17-34.

Keywords: *A. personatus*; Japan; Japan Sea; predators (fish, masu salmon).

**Fukuhara, O. 1986.** Morphological and functional development of Japanese flounder in early life stage. Bulletin of the Japanese Society of Scientific Fisheries. 52(1): 81-91.

Keywords: *A. personatus*; aquaculture.

**Fukuhara, O. 1987.** Larval development and behavior in early life stages of black sea bream reared in the laboratory. Bulletin of the Japanese Society of Scientific Fisheries. 53(3): 371-379.

Keywords: *A. personatus*; aquaculture.

**Fullarton, J.H. 1894.** On the oviposition and growth of the lesser sandeels. Report of the Fishery Board of Scotland. 12(3): 313-321.

Keywords: *A. marinus*; growth; spawning.

**Funakoshi, S.; Mukai, R.; Asada, E. 1990.** Test for study of whitebait fishery management: Study on development of optimization system of advanced control of coastal zone fisheries. Aichi–Ken Suisan Shikenjo Gyomu Hokoku. 1989: 123-128.

Keywords: *A. personatus*; Japan; fisheries; larvae.

**Funakoshi, S.; Nakamura, M. 1995.** Mathematical aspects of the fisheries of the fisheries resources management system for fluctuate populations: Reproduction mechanisms of Japanese sandeel supporting resources management system in Ikanago fisheries in and around Ise Bay. Suisan Kaiyo Kenkyu. 59(1): 73-76.

Keywords: *A. personatus*; Japan; Ise Bay; eggs; growth; larvae.

**Funakoshi, S.; Nakamura, M.; Yanagibashi, S.; Tomiyama, M. 1997.** Studies on the reproduction mechanisms of Japanese sandeel for the basis of the resource management system for Ikanago fisheries in and around Ise Bay. Aichiken Suisan Shikenjo Kenkyu Hokoku (Bulletin of the Aichi Fisheries Research Institute). 4: 11-22.

Keywords: *A. personatus*; Japan; reproduction.

**Furevik, D.M.; Valdemarsen, J.W. 1995.** The importance of the Odin oil field as a fishing area. Fisken og Havet. 6: 28.

Keywords: *Ammodytes*; North Sea; distribution; environmental disturbance; fisheries.

**Furness, R. 1993.** Skuas in Shetland. Natural Environment Research Council News. 27: 6-7.

Keywords: *A. marinus*; predators (birds, skua).

**Furness, R.W. 1977.** Studies on the breeding biology and population dynamics of the great skua *Catharacta skua* Brunnich. [Place of publication unknown]: University of Durham. Ph.D. dissertation.

Keywords: *Ammodytes*; predators (birds, great skua).

**Furness, R.W. 1978.** Energy requirements of seabird communities: a bio-energetics model. Journal of Animal Ecology. 47: 39-53.

Keywords: *Ammodytes*; predators (birds).

**Furness, R.W. 1979.** Foods of great skuas (Catharacta skua) at North Atlantic breeding colonies. Ibis. 121(1): 86-92.

“Direct observations of great skuas (*Catharacta skua*) feeding around Foula, Shetland, gave the most reliable results, but examination of pellets yielded the greatest variety of food items. Pellets were collected and examined daily. Dissection of pellets, allowed identification of food to species level in almost every case. The resulting list of food items from this and previous studies are given in a table. From the results it can be seen that the great skua is very catholic in its diet and feeding habits. It is quick to take advantage of novel opportunities. In all areas studied great skuas feed largely on fish, particularly sand eels. Differences between diets in the areas studied could be a result of prey availability.”

Keywords: *Ammodytes*; Shetland; importance; predators (birds, great skua).

**Furness, R.W. 1981.** Sea bird populations of Foula Scotland. Scottish Birds. 11(8): 237-253.

“A census of Foula seabird populations in 1976 showed that the colonies of shags and great skuas are the largest in the British Isles. Fulmar, Arctic skua and guillemot colonies rank 2nd largest; Arctic tern, razorbil and puffin probably 3rd largest. Foula is one of the most diverse seabird communities in the British Isles, with red-throated diver, eider and 18 spp. of seabird, including one of Britain’s 5 known Leach’s petrel colonies. Numbers of breeding gulls are small; herring gull and lesser black-backed gull populations are declining. Gannets recently colonized and red-throated diver, fulmar, great skua, Arctic skua common gull, great black-backed gull, kittiwake, Arctic tern and guillemot numbers have increased during this century although several increases have now stopped, in some cases perhaps due to lack of further suitable nesting habitat. Threats of oil, whitefish and sandeel fisheries and increasing human access are discussed.”

Keywords: *Ammodytes*; Scotland; Foula; human disturbance; importance; oil; predators (birds, arctic skua, arctic tern, common gull, fulmar, gannet, great black-backed gull, great skua, guillemot, herring gull, puffin, razorbill, red-throated diver, Leach’s petrel).

**Furness, R.W. 1982.** Competition between fisheries and seabird communities. Advances in Marine Biology. 20: 225-307.

Keywords: *Ammodytes*; importance; predators (birds).

**Furness, R.W. 1983.** The birds of Foula. Ambleside, [Scotland]: Brathay Hall Trust.

Keywords: *Ammodytes*; Scotland; Foula; predators (birds).

**Furness, R.W. 1984a.** Modeling relationships among fisheries, seabirds, and marine mammals. In: Nettleship, D.N.; Sanger, G.A; Springer, P.F., eds. Marine birds: their feeding ecology and commercial fisheries relationships. Spec. Publ. Ottawa, ON: Canadian Wildlife Service, Minister of Supply and Services: 117-126.

Keywords: *Ammodytes*; importance; predators (birds, mammals).

**Furness, R.W. 1984b.** Seabird-fisheries relationships in the northeast Atlantic and North Sea. In: Nettleship, D.N.; Sanger, G.A.; Springer, P.F., eds. Marine birds: their feeding ecology and commercial fisheries relationships. Proceedings of the Pacific seabird group symposium, Seattle, Washington, January 1982. Ministry of Supply and Services, Canada: 162-169.

“Bionergetics modelling indicated that seabirds consume 29% of pelagic fish production with a 45-km radius of one Shetland colony. Assuming this is typical, it implies that seabirds, predatory fish, and industrial fisheries are in direct competition. Overfishing of whitefish stocks in the North Sea began in the 1880s and, coupled with more recent reductions of herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) stocks, led to an increase in populations of small food-fish, particularly sandlance (*Ammodytes marinus*). Most seabird species have increased in numbers in Scotland since 1900, probably in response to the increased availability of food resulting from these ecosystem changes. Rates of increase have been higher in areas where sandlance have become most abundant. Seabirds breeding in Shetland feed mainly on sandlance. Large scavenging species in Shetland, are dependent on refuse from whitefish boats. Current trends to reduce volumes of whitefish discarding and increase industrial fishing for sandlance are likely to reduce food availability to seabirds.”

Keywords: *A. marinus*; Scotland; Shetland; North Sea; bioenergetics; importance; population dynamics; predators (birds).

**Furness, R.W. 1987.** Seabirds as monitors of the marine environment. Tech. Publ. 6. [Place of publication unknown]: International Council for Bird Preservation: 217-230.

Keywords: *Ammodytes*; predators (birds).

**Furness, R.W. 1989.** Changes in the diet and breeding ecology of seabirds on Foula, 1971-88. In: Heubeck, M., ed. Proceedings of the seminar on seabirds and sandeels: 1988 Oct. 15-16; Lerwick, United Kingdom. Lerwick, United Kingdom: Shetland Bird Club.

Keywords: *Ammodytes*; Scotland; Foula; importance; predators (birds).

**Furness, R.W. 1990.** A preliminary assessment of the quantities of Shetland sandeels taken by seabirds, seals, predatory fish and the industrial fishery in 1981-83. Ibis. 132: 205-217.

“Shetland holds a very high concentration of seabirds that feed to a large extent on sandeels *Ammodytes marinus*. The available data allow an assessment of the quantity of sandeels consumed by seabirds each year 1981-83, and sensitivity analysis suggests that this figure is accurate to about ± 30%. Only very approximate estimates of sandeel consumption by seals and by predatory fish can be made.

“From 1981 to 1983 the Shetland fishery catch averaged 45,000 tonnes of sandeels, with an estimated natural consumption of 47,000 tonnes by seabirds (predominantly Guillemots *Uria aalge* and Fulmars *Fulmarus glacialis*). Based on sensible guesses and the little data available, consumption may have been about 25,000 tonnes by predatory fish and 9,000 tonnes by seals. The figures suggest that natural mortality of the Shetland sandeel stock in 1981-83 was considerably in excess of the figure used in VPA stock assessments. Further information is required for key variables in order to permit better estimates of sandeel stock dynamics. In particular, we need better data on

numbers and diets of seals in Shetland, numbers and diets of predatory fish, diets and foraging distributions of Fulmars, especially outwith the chick-rearing period. In future, sandeel biomass assessments for Shetland should incorporate estimates of predation by seabirds as this is clearly an important part of total mortality for the stock."

Keywords: *A. marinus*; Shetland; commercial fishery; predators (birds, guillemot, fulmar, puffin, gannet, shag, kittiwake, razorbill, great black-backed gull, great skua, black guillemot, arctic tern, herring gull, arctic skua; fish; mammals, grey seal, common seal).

**Furness, R.W. 1996.** A review of seabird responses to natural or fisheries-induced changes in food supply. In: Greenstreet, S.P.R.; Tasker, M.L., eds. Aquatic predators and their prey; Royal Society of Edinburgh conference; 1994 Aug.; Edinburgh, Scotland. Oxford, England; Cambridge, MA: Blackwell Scientific Publications: 166-173. Chap. 21.

Keywords: *Ammodytes*; ecology; fisheries; importance; predators (birds).

**Furness, R.W.; Ainley, D.G. 1984.** Threats to seabird populations presented by commercial fisheries. Tech. Publ. 2. [Place of publication unknown]: International Council for Bird Preservation: 701-708.

"Field studies and bioenergetics models suggest that seabirds can consume an important proportion of pelagic fish production. Established commercial pelagic fisheries generally crop 50-70 percent of fish production so that rather little is left to be shared by all natural predators. Influences of high fishery exploitation rates on food availability to seabirds depend on the type of fishery, its management, and the feeding ecology of the seabirds. We outline several case studies where these influences are documented or can be inferred."

Keywords: *Ammodytes*; commercial fishery; importance; predators (birds).

**Furness, R.W.; Barrett, R.T. 1985.** The food requirements and ecological relationships of a seabird community in north Norway. Ornis Scandinavica. 16: 305-313.

"Most species feed mainly on capelin, but sandeels are important for Brunnich's Guillemots, Razorbills and Shags. Puffins and Razorbills fed largely on immature fish while other species took mostly two year old fish. Seabirds appear to select capelin of high lipid content since they fed predominantly on ripe two year old fish during chick-rearing, when spent fish were of poorer nutritional value."

Presents the percentage of sand eels in the diet of each seabird species on Hornoy sampled between 29 June and 19 July 1983.

Keywords: *A. marinus*; Norway; importance; predators (birds, herring gull, kittiwake, common guillemot, black guillemot, Brunnich's guillemot, razorbill, shag, puffin, fish, cod *Gadus morhua*, haddock, mammals, beluga whale).

**Furness, R.W.; Barrett, R.T. 1991a.** Ecological responses of seabirds to reductions in fish stocks in north Norway and Shetland. In: Furness, R.W.; Nettleship, D.N., eds. Proceedings of the symposium on seabirds as monitors of changing marine environments; [dates of meeting unknown]; [location unknown]. International Ornithological Congress. 20: 2241-2245.

"In Shetland, seabirds, especially dietary specialists that cannot reach the seabed, showed extensive changes in breeding ecology as sandeel *Ammodytes* stock declined." Species of birds that depend on sand eels and cannot reach the seabed are Arctic tern (*Sterna paradisaea*), puffin (*Fratercula arctica*), Arctic skua (*Stercorarius parasiticus*), kittiwake (*Rissa tridactyla*), and razorbill. Common Guillemots and Shags *Phalacrocorax aristotelis* have shown no reduction in breeding success despite feeding chicks almost exclusively on sandeels, but breeding numbers of both species have fallen."

Keywords: *A. marinus*; Norway; Shetland; abundance; importance; predators (birds).

**Furness, R.W.; Barrett, R.T. 1991b.** Seabirds and fish declines. National Geographic Research and Exploration. 7(1): 82-95.

“Major decreases in the stock of capelin in the Barents Sea and sandeels off Shetland have allowed us to examine the ecological responses of seabirds at colonies that were studied before and after the changes in fish stocks. The changes in seabird numbers, breeding success, diets, and behavior are complex and indicate that it will be difficult to use seabirds as monitors of changes in fish stock unless the detailed relationship between fish stock abundance and behavior and the ecological responses of sensitive seabird species is known. Nevertheless, seabirds do indicate changes in marine ecosystems and may elucidate aspects of fish stock ecology.”

Keywords: *Ammodytes*; Shetland; importance; predators (birds).

**Furness, R.W.; Barrett, R.T. 1991c.** Seabirds’ responses to catastrophic declines in fish stocks Shetland and Barents Sea. Research Exploration. 7(1): 82, 84-95.

“Major decreases in the stock of capelin in the Barents Sea and sandeels off Shetland [Scotland] have allowed us to examine the ecological responses of seabirds at colonies that were studied before and after the changes in fish stocks. The changes in seabird numbers, breeding success, diets, and behavior are complex and indicate that it will be difficult to use seabirds as monitors of changes in fish stock unless the detailed relationship between fish stock abundance and behavior and the ecological responses of sensitive seabird species is known. Nevertheless, seabirds do indicate changes in marine ecosystems and may elucidate aspects of fish stock ecology.”

Keywords: *Ammodytes*; Scotland; Shetland; importance; predators (birds).

**Furness, R.W.; Cooper, J. 1982.** Interactions between breeding seabirds and pelagic fish populations in the southern Benguela region. Marine Ecology Progress Series. 8: 243-250.

Keywords: *Ammodytes*; predators (birds).

**Furness, R.W.; Greenstreet, S.P.R.; Walsh, P.M. 1996.** Spatial and temporal variability in the breeding success of seabirds around the British Isles: evidence for distinct sandeel stocks? International Council for the Exploration of the Sea Cooperative Research Report. 216: 63-65. (“Seabird/fish interactions, with particular reference to seabirds in the North Sea”; Hunt, G.L., Jr.; Furness, R.W., eds.).

The authors describe the relation of sand eel stocks around the British Isles to the distribution and breeding success of the kittiwake and other seabird species.

Keywords: *Ammodytes*; British Isles; importance; fisheries; predators (birds, kittiwake).

**Furness, R.W.; Hislop, J.R.G. 1981.** Diets and feeding ecology of great skuas Catharacta skua during the breeding season in Shetland. Journal of Zoology, London. 195: 1-23.

“Great skuas feed their young largely on sandeels. Breeders take more sandeels than nonbreeders. The remainder of the diet is largely discard whitefish. Seasonal and annual variations in diet are discussed in relation to food availability. Sandeels, caught by plunging to surface, appear to be the preferred food. Discard whitefish provide a consistently available secondary supply and allow adults to spend a large part of the day on the territory. Increased sandeel stocks and discard volumes have probably allowed the increase of the British Great skua population.”

Keywords: *A. marinus*; importance; predators (birds, great skua).

**Furness, R.W.; Monaghan, P. 1987.** Seabird ecology. London: Blackie and Son Ltd. 164 p.

Keywords: *Ammodytes*; predators (birds).

**Furness, R.W.; Nettleship, D.N., eds. 1991.** Proceedings of the symposium on seabirds as monitors of changing marine environments; [dates of meeting unknown]; [location unknown]. International Ornithological Congress. 20: 2237-2279.

Keywords: *Ammodytes*; predators (birds).

**Furness, R.W.; Nettleship, D.N.; Sanger, G.A.; Springer, P.F. 1984.** Seabird-fisheries relationships in the northeast Atlantic and North Sea. In: Marine birds: their feeding ecology and commercial fisheries relationships; 1982 Jan. 6-8; Seattle, WA. Ottawa, ON: Canadian Wildlife Service: 162-169.

“Bionergetics modelling indicated that seabirds consume 29% of pelagic fish production with a 45-km radius of one Shetland colony. Assuming this is typical, it implies that seabirds, predatory fish, and industrial fisheries are in direct competition. Overfishing of whitefish stocks in the North Sea began in the 1880s and, coupled with more recent reductions of herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) stocks, led to an increase in populations of small food-fish, particularly sandlance (*Ammodytes marinus*). Most seabird species have increased in numbers in Scotland since 1900, probably in response to the increased availability of food resulting from these ecosystem changes. Rates of increase have been higher in areas where sandlance have become most abundant. Seabirds breeding in Shetland feed mainly on sandlance. Large scavenging species in Shetland, are dependent on refuse from whitefish boats. Current trends to reduce volumes of whitefish discarding and increase industrial fishing for sandlance are likely to reduce food availability to seabirds.”

Keywords: *A. marinus*; Shetland; North Sea; bioenergetics; predators (birds).

**Furness, R.W.; Tasker, M.L. 1997.** Seabird consumption in sand lance MSVPA models for the North Sea, and the impact of Industrial fishing on seabird population dynamics. In: Forage fishes in marine ecosystems; Proceedings of the international symposium on the role of forage fishes in marine ecosystems: [dates of meeting unknown]; [location unknown]. Rep. 97-01. [Fairbanks, AK]: University of Alaska Fairbanks, Alaska Sea Grant College Program: 147-169.

“The industrial fishery for sand lance is the largest single-species fishery in the North Sea, with about 1 million mt harvested each year. Assessment of interactions among seabirds, sand lance stocks, and the industrial fishery in the North Sea has been a major recent concern of an ICES working group. Detailed seabird breeding population census data from the 1980’s for the coasts of the North Sea and the European Seabirds-at-Sea database permit the assessment of energy requirements of seabirds by regions. From dietary data the quantities of sand lance consumed by seabirds can be estimated by seasons and regions. Seabirds consume an estimated 200,000 mt of sand lance, predominantly in summer, with consumption greatest in the northwestern North Sea. These data permit refinement of sand lance multispecies virtual population analyses (MSVPA), and indicate that exploitation of sand lance by seabirds and the fishery is spatially segregated due to constraints imposed by the distributions of seabird breeding sites and by sandy substrates for fishing.

“Consumption of sand lance by seabirds can be high in the vicinity of major seabird colonies, such as around Shetland and Orkney, but is low in central regions of the North Sea and averages overall only about 4% of the North Sea sand lance stock. Thus the potential for the fishery to affect seabirds is much greater than the converse. The extent to which seabirds may suffer reductions in food supply as a consequence of the sand lance fishery depends especially on whether recruitment varies in relation to prevailing levels of spawning stock biomass, but also depends on the age classes of fish selected by birds. Recent major changes in sand lance abundance at Shetland permit us to analyze the shape of functional responses of breeding seabirds to variations in food supply over the period 1974-1995. This case study indicates the critical importance of a minimum abundance of lipid-rich fish for breeding seabirds, but also the complexity of seabird-fish interactions, with different seabird species at the same colony responding in different ways to changes in food supply.”

Keywords: *Ammodytes*; North Sea; importance; predators (birds).

**Furness, R.W.; Todd, C.M. 1984**. Diets and feeding of fulmars *Fulmarus glacialis* during the breeding season: a comparison between St. Kilda and Shetland colonies. Ibis. 126: 379-387.

“Diets and nest attendance of fulmars at Foula, Shetland and St. Kilda, Outer Hebrides [Scotland] were examined during the breeding season. At Foula, sandeels formed the bulk of the diet, with fish offal and pelagic zooplankton of minor importance. At St. Kilda, 71% of regurgitates consisted of pelagic zooplankton, probably captured at night. Dietary overlap between the 2 colonies was 14% by species composition. Foraging trips from Foula shortly after chick hatching generally lasted for less than 10 h: trips from St. Kilda late in chick rearing often lasted more than 24 h. The diurnal pattern of feeding suggested mainly nocturnal foraging from St. Kilda but both diurnal and nocturnal foraging from Foula.”

Keywords: *Ammodytes*; Scotland; Foula; Shetland; St. Kilda; Outer Hebrides; predators (birds, fulmar).

**Furnestin, J. 1939.** Observations diverses sur la ponte de la plie *Pleuronectes platessa* L. de l’Equille *Ammodytes tobianus* L. au “Sandettie” et sur la presence de la sardine *Clupea pilchardus* Walbaum et l’extension de son aire de ponte en Mer du Nord et en Manche. Rapports et Procès-Verbaux des Reunions Conseil International pour l’Exploration de la Mer. 3: 41-54.

Keywords: *A. tobianus*.

**Furukawa, A.; Unezu, T.; Tsukahara, H. [and others]. 1966.** Studies on fish feed for fish. V: Results of the small floating net culture test to establish the artificial diet as complete yellow tail food. (1964). Bulletin of the Naikai Regional Fisheries Research Laboratory. 23: 45-56.

“Three diets were: 1. frozen sand eel, 2. mixed diet and 3. synthetic diet. First diet used 10% corn oil as lipid source. Mixed diet also had corn oil added. Neither diet 2. nor 3. were acceptable for growth of fish.”

Keywords: *Ammodytes*; aquaculture.

**Gabrielsen, G.W. 1996.** Energy expenditure of breeding common murres. Occas. Pap. 91. [Place of publication unknown]: Canadian Wildlife Service: 49-58.

“The doubly labelled water method was used to measure carbon dioxide ($CO_2$) production and food consumption in Uria aalge throughout the chick-rearing period on Hornoya in N Norway. The field metabolic rate (FMR) of foraging birds averaged 3.34 mL $CO_2$ $g^{-1}$ $h^{-1}$, or a daily energy expenditure of 2200 kJ $d^{-1}$. This is 3.8 times the resting metabolic rate (RMR). There was a significant positive correlation between FMR and the time at sea. The high and variable FMR is probably associated with a high cost of flying and diving in common murres. The mean daily change in body mass of each bird studied was 38 plus or minus 21 g. Assuming that body fat is the main energy resource (minimum 17 g and maximum 59 g) and based on a minimum FMR of 959 kJ $d^{-1}$, breeding common murres may rely on these resources for an average of 1.5 days without feeding. The average rate of food consumption by adult common murres, calculated on the basis of the chemical composition and digestibility of capelin *Mallotus villosus* and sand lance (*Ammodytes* sp.), was 440 g fresh matter per bird every day. The population of 1,400 pairs of common murres on Hornoya is estimated to consume a total of 27,580 kg of prey during 20 days of chick rearing.”

Keywords: *Ammodytes*; Norway; importance; predators (birds, common murre).

**Gadomski, D.M.; Petersen, J.H. 1988.** Effects of food deprivation on the larvae of 2 flatfishes. Marine Ecology Progress Series. 44(2): 103-111.

Keywords: *Ammodytes*; predators (fish).

**Gaemers, P.A. 1984.** Fish otoliths from the Bassevelde Sand (Late Tongrian) of Ruisbroek, Belgium, and the stratigraphy of the early Oligocene of Belgium. Afzettingen Werkgroep Voor Tertiaire En Kwartair Geologie. 21(1): 13-57.

Keywords: *Ammodytes*; Belgium; fossils.

**Gaemers, P.A. 1987.** Aanvullend otolietenmateriaal afkomstig uit de Noordzee, 20 kilometer westelijk van Scheveningen. Het Zeepaard. 39(3): 59-62.

Keywords: *Ammodytes*; North Sea; distribution; fossils; taxonomy.

**Gaemers, P.A.; Schwarzhans, W. 1973.** Fisch otolithen aus dem pliozan von Antwerpen (Belgien) und Ouwerkerk (Niederlande) und aus dem plio-pleistozan der Westerschelde (Niederlande). Leidse Geologische Mededelingen. 49(2): 207-257.

Keywords: *Ammodytes*; Belgium; Netherlands; fossils.

**Galbraith, H. 1983.** The diet and feeding ecology of breeding kittiwakes *Rissa tridactyla*. Bird Study. 30:109-120.

Keywords: *Ammodytes*; Scotland; Isle of May; predators (birds, kittiwake).

**Garrison, K.J.; Miller, B.S. 1982.** Review of the early life history of Puget Sound fishes. [Place of publication unknown]: Fisheries Research Institute, School of Fisheries, University of Washington; report to National Marine Fisheries Service, National Oceanic and Atmospheric Administration; contract 80-ABA-3680: 331-337.

Keywords: *A hexapterus*; Washington; Puget Sound; larvae; life history.

**Garthe, S.; Camphuysen, K.C.J.; Furness, R.W. 1996.** Amounts of discard by commercial fisheries and their significance as food for seabirds in the North Sea. Marine Ecology Progress Series (Amelinghausen). 136(1-3): 1-11.

Keywords: *Ammodytes*; North Sea; environmental pollution; fisheries; predators (birds).

**Gaskin, D.E. 1992.** Status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*, in Canada. Canadian Field Naturalist. 106(1): 64-72.

“The region of maximum abundance off the northeast [U]nited [S]tates and southeast Canada seems to be the gulf of [M]aine, where the main item of food is assumed to be sand lance.”

Keywords: *Ammodytes*; importance; predators (mammals, Atlantic white-sided dolphin).

**Gaston, A.J. 1992**. The ancient murrelet: a natural history in the Queen Charlotte Islands. London: T & AD Poyser. 249 p.

Keywords: *A. hexapterus*; Canada; Queen Charlotte Islands; predators (birds, ancient murrelet).

**Gaston, A.J. 1994.** Ancient murrelet. In: Poole, A.; Stennheim, P.; Gill, F., eds. The birds of North America. No. 132. Philadelphia: The Academy of Natural Sciences; Washington DC: The American Ornithologist’ Union.

This review mentions that ancient murrelet chicks are not fed at the nest. Pacific sand lance are an important food, especially for prebreeding birds.

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, ancient murrelet).

**Gaston, A.J.; Cairns, D.K.; Elliot, R.D.; Noble, D.G. 1985.** A natural history of Digges Sound. Rep. Ser. 46(0-660-11785). Ottawa, ON: Canadian Wildlife Service: 63 p.

“The murres take a wide variety of marine life, including small fish, of which the most important are arctic cod, snailfish, sandlance and capelin, and invertebrates, particularly amphipod and mysid crustacea.”

Keywords: *Ammodytes*; Canada; distribution; predators (birds, murre).

**Gaston, A.J.; Cairns, D.; Noble, D.; Purdy, M. 1981.** Seabird investigations in Hudson Strait: report on research in 1981. Canadian Wildlife Service “Studies on Northern Seabirds” Manuscript Report. 130: 1-60.

Keywords: *Ammodytes*; Canada; predators (birds).

**Gaston, A.J.; Dechesne, S.B.C. 1996.** Rhinoceros auklet. In: Poole, A.; Stennheim, P.; Gill, F., eds. The birds of North America. Philadelphia: The Academy of Natural Sciences; Washington DC: The American Ornithologist’ Union. 212 p.

Rhinoceros anklets are frequently seen to surface around sand lance “balls” as though corralling them, with other common participants being glaucous-winged gulls, Heermann’s gulls, and sometimes common murres. May use bubbles, emitted from the mouth, to herd sand lance and herring close to sea surface and prevent the schools from breaking up. During such feeding bouts, fish are usually snatched from underside of ball.

Good information is given on nestling diet, but only fragmentary information on adult diet. At Middleton Island, AK, diet consists of 59 percent first-year sand lance, 36 percent second-year sand lance (n=68). At Semidi Island, AK, 75 percent sand lance, 22 percent capelin (n=82) (Hatch 1984). At Protection Island, WA, sand lance 71 and 64 percent of diet by weight in 2 years (Wilson 1977, Wilson and Manuwal 1986). At Destruction Island, WA, sand lance 6 and 32 percent (Leschner 1976). At Cleland Island, BC, two-thirds of food items delivered were sand lance (Summers and Drent 1979) and most sand lance were 70-110 mm. Sand lance are important in breeding season, except in California. Good table to review in appendix 2; it lists all studies and gives primary and secondary prey.

Keywords: A*. hexapterus*; Alaska; British Columbia; Washington; importance; predators (birds, rhinoceros auklet).

**Gaston, A.J.; Nettleship, D.N. 1981.** The thick-billed murres of Prince Leopold Island—a study of the breeding ecology of a colonial high Arctic sea bird. Ottawa, ON: Canadian Wildlife Service Monograph Series. 6. 350 p.

Keywords: *Ammodytes*; Canada; predators (birds, thick-billed murre).

**Gaston, A.J.; Noble, D.G. 1985.** The diet of thick-billed murres (*Uria lomvia*) in west Hudson Strait and northeast Hudson Bay. Canadian Journal of Zoology. 63: 1148-1160.

Keywords: *Ammodytes*; Canada; predators (birds, thick-billed murre).

**Gauld, J.A. 1990.** Movements of lesser sandeels *Ammodytes marinus* Raitt tagged in the northwestern North Sea. Journal du Conseil, Conseil International Pour l’Exploration de la Mer. 46(3): 229-231.

“Numbers of the lesser sandeel (*Ammodytes marinus* Raitt 1934) were tagged and released at sites outwith the normal sandeel fishing grounds in the northwestern North Sea. The location of tag recoveries indicates that *A. marinus* is capable of travelling distances of at least 64 km.”

Keywords: *A. marinus*; North Sea; migration.

**Gauld, J.A.; Hutcheon, J.R. 1990.** Spawning and fecundity in the lesser sandeel *Ammodytes marinus* Rait in the northwestern North Sea. Journal of Fish Biology. 36(4): 611-614.

“Both immature and mature *A. marinus* were present at all sampling sites. The spawning period, identified from the presence of mature and spent gonads (maturity stages 4 and 5), ranged from early December to late January. This is similar to the period given by Macer (1966) for the southern North Sea.”

Keywords: *A. marinus*; North Sea; fecundity; length-weight relationship; spawning.

**Gayerskaya, A.V.; Kovaleva, A.A. 1984.** Addition to the Myxosporidia fauna (Protozoa: Myxosporidia) of fishes of the north east Atlantic. Gidrobiologicheskii Zhurnal. 20(3): 49-53.

Keywords: *A. tobianus*; Atlantic (northeast); parasites.

**Gerasimova, O.V. 1994.** Peculiarities of spring feeding by capelin (*Mallotus villosus*) on the Grand Bank in 1987-90. Journal of Northwest Atlantic Fishery Science. 17: 59-67.

Poor feeding on euphausiids by prespawning capelin was partly compensated for by increased predation on juvenile capelin and sand eel.

Keywords: *Ammodytes*; Atlantic (northwest); Grand Bank; predators (fish, capelin).

**Gerasimova, O.V.; Kiseleva, V.M. 1996.** Interannual variations in feeding intensity and structure of trophic links of prespawning cod (*Gadus morhua*) on the Newfoundland Shelf (Div. 3L). 12.

“Results from Russian bottom trawl surveys in 1978-1991 indicated that mature cod (*Gadus morhua*) on the Newfoundland Shelf fed rather actively before spawning, and intensity of their feeding showed little or no reduction with gonad maturation. Sand lance were of marked importance in the feeding of prespawning cod until 1985.”

Keywords: *Ammodytes*; Newfoundland; predators (fish, cod).

**Gibson, R.N.; Robb, L. 1996.** Piscine predation on juvenile fishes on a Scottish sandy beach. Journal of Fish Biology. 49(1): 120-138.

“Predation by larger fishes is a major cause of mortality for the populations of juvenile fishes on a sandy beach on the west coast of Scotland. Predation was concentrated on the most numerous species (0-group *Pleuronectes platessa*) in June but with the decline in numbers and growth in size of this species, the fish predators had changed their diet in August to feed principally on small sandeels (Ammodytidae).”

Keywords: *Ammodytidae*; Scotland; predators (fish, cod).

**Gibson, R.N.; Robb, L.; Burrows, M.T.; Ansell, A.D. 1996.** Tidal, diel and longer term changes in the distribution of fishes on a Scottish sandy beach. Marine Ecology Progress Series (Amelinghausen). 130(1-3): 1-17.

Keywords: *A. tobianus*; Scotland; abundance; diel migration; distribution; predators (fish).

**Gilbert, M. 1992.** Distribution and nutrition of larval fish in southeast Hudson Bay: influence of ice cover on the availability of light and prey. [Place of publication unknown]: University of Laval. 85 p. M.S. thesis. Available from: Masters Abstracts International. 30(3): 605. 1992. Order No. MAMM63049. FR 38(1).

Keywords: *Ammodytes*; Canada; Hudson Bay; larvae; seasonal abundance.

**Gilbert, M.; Fortier, L.; Ponton, D.; Drolet, R. 1992.** Feeding ecology of marine fish larvae across the Great Whale River plume in seasonally ice-covered southeastern Hudson Bay. Marine Ecology Progress Series. 84(1): 19-30.

“In ice-covered southeastern Hudson Bay (northern Quebec, Canada), the foraging of first-feeding Arctic cod *Boreogadus saida* and sand lance *Ammodytes* sp. was adversely affected by the plume of the Great Whale River. Before the freshet, marine fish larvae and their potential prey were marginally more abundant offshore where porous sea ice supported the development of ice algae than inshore where freshwater ice prevented algal growth. Larval fish foraging under the ice appeared limited by prey availability in the diluted (S < 5.permill.), 5 m thick, surface layer and by light availability in the underlying marine waters. Arctic cod larvae which avoided the freshwater surface layer

did not feed. The more euryhaline sand lance were present in the surface layer and fed to some limited extent until the freshet when further light attenuation by the turbid waters of the expanding plume completely halted their foraging activity. Feeding resumed in sand lance and started in Arctic cod at the ice break-up when the fragmentation of the ice cover and the vertical mixing of the plume allowed light to penetrate at depth. An anthropogenic reduction of the Great Whale River discharge in spring would generally improve local feeding conditions for marine fish larvae that occur under the ice. The impacts of such a reduction on the productivity of the coastal zone in summer remain to be assessed."

Keywords: *Ammodytes*; Canada; Hudson Bay; food and feeding habits; larvae.

**Gill, T.N. 1904.** On the systematic relations of the ammodytoid fishes. Proceedings of the U.S. National Museum. 28(1388): 159-163.

Keywords: *Ammodytes*; taxonomy.

**Gilman, L.J. 1994.** An energy budget for northern sand lance, Ammodytes dubius, on Georges Bank, 1977-1986. Fishery Bulletin. 92: 647-654.

"For an individual adult northern sand lance on Georges Bank, total production is 10.53 kcal.yr-1 (growth+reproduction), and total consumption is 52.62 kcal.yr-1; therefore, ecological efficiency is 20.0%. Northern sand lance consumed 0.79-19.24% of the annual zooplankton production from 1977 to 1986. The trophic efficiency of the northern sand lance is 20%, according to the present energy budget model.

"By converting population energetic consumption on Georges Bank to consumption per square meter, sand lance consumed from 8.5 to 203.5 kcal.m-2.y-1 from 1977 to 1986. This represents nearly all the consumption attributed to the 'other finfish' at low northern sand lance abundances and over 20 times the total 'other finfish' consumption at high northern sand lance abundances."

Keywords: *A. dubius*; Atlantic; Georges Bank; abundance; energy budget.

**Giovanardi, O. 1981.** Marine fin-fish culture in Japan. Rivista Italiana Piscic. Ittiopatol. 16(3): 70-76.

The most representative is yellowtail culture. Easy to handle, fast growing (1-1.5 kg. in 7 to 8 months), greatly demanded, and highly priced, the yellowtail does not create many problems to obtain seed and feed. More than half the budget is spent on food stuff: frozen and minced sand eels, horse-mackerels, sardines, and anchovies are used.

Keywords: *Ammodytes*; Japan; aquaculture.

**Girsa, I.I. 1975.** The diurnal rhythm in the feeding of under yearlings of some white sea fish at different photoperiods. Journal of Ichthyology. 15(1): 102-110. (English translation of Voprosy Ikhtiologii).

Keywords: *A. hexapterus*; USSR; White Sea; feeding; larvae; seasonal variation.

**Girsa, I.I.; Danilov, A.N. 1976.** The defensive behavior of the White Sea sand lance *Ammodytes hexapterus*. Journal of Icthyology. 16: 862-865.

"During the hours of daylight, the sand lance use schooling maneuvers for defense, disappearing into the bottom only in extreme situations when the school does not ensure safety. The fish constituting the school periodically enter the bottom in order to rest. When artificial darkness is created the sand lance buries itself in the bottom. It probably spends the polar night buried in the sand. The sand lance does not perceive seine fishing gear as a danger. The solitary cod feeds on sand lance, pulling them out of the bottom at the spot at which they dug themselves in or seizing them at dusk as the school begins to desperse. At a time of oxygen deficit, the sand lance, entering the bottom,

evidently reduces the metabolic level considerably. The complicated form of behavior probably supplements or replaces the internal mechanism of adaptation to unfavorable environmental contitions (high temperature and oxygen deficiency), providing the organism with essential amount of physiological activity."

Keywords: *A. hexapterus*; behavior; predators (fish, cod).

**Gislason, A.; Asthorsson, O.S. 1991.** Distribution of zooplankton across the coastal current southwest of Iceland in relation to hydrography and primary production. In: Council Meeting of the International Council for the Exploration of the Sea: La Rochelle [France]: [publisher unknown]: 23:

Keywords: *Ammodytes*; Iceland; distribution; eggs; larvae.

**Gislason, H. 1993.** Effect of changes in recruitment levels on multispecies long-term predictions. Canadian Journal of Fisheries and Aquatic Sciences. 50(11): 2315-2322.

"A multispecies model (MSFOR) is used to predict the relative change in equilibrium yield and spawning stock biomass (SSB) of commercially important fish stocks in the North Sea resulting from a reduction in the fishing mortality generated by the roundfish fishery. However, for haddock (*Melanogrammus aeglefinus*), sprat (*Sprattus sprattus*), and sandeel (*Ammodytes marinus*) the relative change in SSB is found to be either positive or negative depending on the level of recruitment."

Keywords: *A. marinus*; North Sea; fisheries; mortality; recruitment; stock.

**Gjosaeter H. 1987.** Capelin, sand eel and herring in northern Norwegian waters. Var Fuglefauna. 10(3): 148-151.

Keywords: *Ammodytes*; Norway; model; predators (birds).

**Go, Y.B.; Go, G.M.; Kim, J.M. 1992.** Occurrence of fish larvae at Hamduck coastal area, northern part of Cheju Island. Contribution of the Korea Institute of Ocean Science, National Fisheries, University of Pusan. 24: 145-156.

"Fish larvae were collected monthly from coastal water around Hamduck, northern part of Cheju Island from April 1989 to March 1990. During the study period, a total of 64 species, representing 35 genera and 27 families, were observed. Of these 4 species appeared to be major groups which comprised about 66% of total fish larvae abundance, including *Ammodytes personatus* (February-March), *Scomber japonicus* (September-March), *Enneapterygius etheostomus* (June-September), and *Engraulis japonica* (August-November)."

Keywords: *A. personatus*; Korea; distribution; larvae; seasonal variation.

**Goda, T.; Nakata, H.; Kimura, S. [and others]. 1991.** Environmental constraints on the sand lance population in the eastern Seto Inland Sea. Marine Pollution Bulletin. 23: 195-199.

"In this paper, focusing on the recruitment processes, we synthesize the results of our recent analytical and numerical studies on the population ecology of the Japanese sand lance (*Ammodytes personatus*) in the eastern part of the Seto Inland Sea. Among physical processes, the wind-induced current has a significant effect on the transport and distribution of the larvae. Prey-predator interactions, competition for the specific habitats, and other ecological processes could affect the recruitment. In addition to the year to year variability of the larval hatching and apparent survival rates, some recent trends of the variation in the larval population are also discussed."

Keywords: *A. personatus*; Japan; Seto Inland Sea; annual variation; anthropogenic impacts; competition; habitat selection; larvae; predation; population dynamics.

**Goodlad, J. 1989.** Industrial fishing in Shetland waters. In: Heubeck, M., ed. Seabirds and sand eels: Lerwick, [Country unknown]: Shetland Bird Club: 50-59.

Keywords: *Ammodytes*; Shetland; commercial fishing.

**Gordeeva, K.T. 1954.** Pitanie Paltusov v Beringovom More=Food of halibut in the Bering Sea. Izvestiya Tinro. 39.

Keywords: *A. hexapterus*; Bering Sea; predators (fish, Pacific halibut).

**Gordon, D.K.; Leavings, C.D. 1984.** Seasonal changes of inshore fish populations on Sturgeon and Roberts Bank, Fraser River estuary, British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences. 1240: 1-81.

“Results of a beach seine sampling program at 3 low tide refuges on Sturgeon and Roberts Banks, Fraser River estuary, are presented. At Roberts Bank herring, sandlance (*Ammodytes hexapterus*), shiner perch, staghorn sculpin and tubesnout (*Aulorhynchus flavidus*) were the most abundant species. Seasonal trends in catches on Sturgeon Bank appeared to be closely related to seasonal variation in temperature but at Roberts Bank there was greater variability implying that other factors were involved. Dissolved $O_2$ was consistently lower at Iona and may have affected the distribution of some species. Rapid changes in species composition and abundance during the summer at all 3 sites was related to influxes of juveniles of various species. The inter-tidal habitats, both vegetated and non-vegetated, have a substantial capacity for fish rearing and as such deserve further investigation and continuing protection from disruption.”

Keywords: *A. hexapterus*; British Columbia; distribution; seasonal variation.

**Gorelova, T.A.; Krasil’nikova, N.A. 1990.** Feeding of *Maurolicus muelleri* in the areas of the submarine rises Discovery and Nazca and near Africana Mountain, Pacific, Atlantic, Indian Oceans respectively. Voprosy Ikhtiologii. 30(2): 238-245.

Some similarities were found between the feeding of *M. muelleri* and the plankton-eating fish, such as herring, sand lance, and capelin, from northern seas.

Keywords: *Ammodytes*; food; seasonal variation.

**Gotshall, D.W. 1989.** Pacific coast inshore fishes. 3d ed., rev. Monterey, CA: Sea Challengers.

Keywords: *A. hexapterus*.

**Gould, P.J.; Zabloudil, A.E. 1981.** Breeding biology of the seabirds at Middleton Island, June 1981. 14 p. Unpublished Administrative Report. On file with: U.S. Fish and Wildlife Service, Anchorage, AK.

Keywords: *A. hexapterus*; Alaska; Middleton Island; predators (birds).

**Goulden, C.E.; Henry, L.; Berrigan, D. 1987.** Egg size, postembryonic yolk, and survival ability. Oecologia. 72(1): 28-31.

Keywords: *Ammodytes*; eggs; larvae; mortality; starvation; survival.

**Govoni, J.J.; Boehlert, G.W.; Watanabe, Y. 1986.** The physiology of digestion in fish larvae. Environmental Biology of Fishes. 16(1-3): 59-77.

Keywords: *Ammodytes*; feeding; larvae; physiology.

**Govoni, J.J.; Ortner, P.B.; Alyamani, F.; Hill, L.C. 1986.** Selective feeding of spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus*, larvae in the northern Gulf of Mexico. Marine Ecology Progress Series. 28(1-2): 175-183.

Keywords: Ammodytidae; Gulf of Mexico; predators (fish).

**Graham, J.J. 1956.** A mortality of the sand lance, *Ammodytes americanus*. Copeia. 1956(3): 192-194.

“Although the cause of the mortality was not determined, an analysis was made of its effect on the population of sand launce in the area. A comparison of head length relative to body length was undertaken between the ‘dead’ and ‘live’ samples. The data suggested that the smaller-headed fish were selected out by the mortality, probably leaving a more resistant population of sand launce.”

Keywords: *A. americanus*; Rhode Island; Narragansett Bay; mortality.

**Graham, M. 1923.** The annual cycle in the life of the mature cod in the North Sea. London Minister of Agriculture and Fisheries, Fisheries Investigation, Series II. 6 (6).

Keywords: *Ammodytes*; North sea; predators (fish, cod).

**Grainger, E.H. 1953.** On the age, growth, migration, reproductive potential and feeding habits of the arctic char (*Salvelinus alpinus*) of Frobisher Bay, Baffin Island. Journal of the Fisheries Research Board of Canada. 10: 326-370.

The stomachs from 13 arctic char collected at George River, southeastern Ungava Bay, contained 57 percent sand lance.

Keywords: *Ammodytes*; Canada; predators (fish, arctic char).

**Grandy, M. 1987.** The availability of raw material for surimi processing in Atlantic Canada. In: Roache, J.F., ed. Atlantic fisheries development; Atlantic Canada Surimi workshop; [date of meeting unknown]; Clarenville, NF. [Place of publication unknown]: [publisher unknown]: 34-58.

Keywords: *Ammodytes*; Atlantic (northwest); fisheries.

**Grauman, G.B.; Lisheva, K.M. 1990.** Fish spawning in the Lithuanian coastal zone of the Baltic Sea. Fisheries Investigations of GDR and USSR in the Baltic. 28(2): 44-46.

“Reproduction of Baltic herring (*Clupea harengus*), sprat (*Sprattus sprattus*), goby (*Gobius*), and of sand eel (*Ammodytes marinus*) is considered for the Lithuanian coastal zone which is under a high anthropogenic impact. Seasonal species and abundance dynamics of eggs and larvae have been investigated. Fish spawning terms and eggs and larvae growth conditions are given for different depth zones. The areas of high eggs and larvae concentrations have been established. Considerable changes in the spring-spawning herring larvae have been noted. At present their abundance has decreased for an order as compared to the 1950-ties and may be attributed to the reduction of spawning areas within the region.”

Keywords: *A. marinus*; Baltic Sea; Lithuania; anthropogenic impacts; eggs; embryos; larvae; pollution.

**Grauman, G.B.; Lisivnenko, L.N.; Sidrevits, L.L. 1989.** Some aspects of Baltic fish larvae feeding. Fischerei-Forschung. 27(2): 7-13.

“Comparisons have been made between the food compositions and feeding peculiarities of larval sprat (*Sprattus sprattus*), cod (*Gadus morhua*), flounder (*Platichthys flesus*), hake (*Merluccius merluccius*), sand eel (Ammodytidae) and sand goby (*Gobius*) of a length of 4 to 22 mm in spring and summer. According to the body shape, structure of alimentary tract, size of mouth opening, and feeding and movement patterns, the larvae fall into 2 groups: the I group larvae (sprat, sand eel) differ from those of the II group by a stretched body, narrow alimentary tract, small mouth opening, and they are less mobile. The II group larvae are smaller when they begin to feed upon large food items, and percentage of feeding individuals in this group is higher than in the I. Food diversity of sprat is low, and this species is highly sensitive to the food deficiency. Feeding intensity differs between the seasons. The food spectrum of fishes is wider in July than in May and June. The food-selective indices have been calculated for larval fish.”

Keywords: Ammodytidae; Baltic Sea; distribution; food; larvae; size distribution.

**Greenwood, J.J.D. 1992.** Understanding bird distributions. In: Trends in ecology and evolution. London, England: [Publisher unknown]; 7: 252-253.

Keywords: *Ammodytes*; predators (birds, dunlin, guillemot).

**Greer, G.L.; Levings, C.D.; Harbo, R. [and others]. 1980.** Distribution of fish species on Roberts and Sturgeon Banks recorded in seine and trawl surveys. Canadian Manuscript Report Fisheries and Aquatic Sciences. 1596.

"Approximately 80% of the total seine catch was comprised of *Clupea harengus pallasi, L. armatus, P. stellatus, Cymatogaster aggregata, Ammodytes hexapterus*}), and *Oncorhynchus tshawytscha*}. The highest CPUE's for seine-caught fish were in areas of the Banks having topographic depressions which remain flooded at low tides."

Keywords: *A. hexapterus*; Canada; British Columbia; catch; distribution; fisheries.

**Grigorev, S.S.; Sedova, N.A. 1997.** Variability in sand lance larvae (*Ammodytes hexapterus*) from the northwest Pacific. In: Baxter, B.R., ed. Proceedings of the symposium on the role of forage fishes in the marine ecosystem; [dates of meeting unknown]; [Anchorage, AK]. Rep. AK-SG-97-01. [Fairbanks, AK]: University of Alaska Fairbanks, Alaska Sea Grant College Program: 427-430.

"Levels of development of Pacific sand lance larvae were approximately equal in all considered regions of the northwestern Pacific, but in the more southern regions the warmer water causes larvae to grow faster. Therefore larvae of the same level of development were smaller in more northern regions.

"Larvae of sand lance were different in body ratios and pigmentation. Relatively fast development of larvae from northern regions (with approximately equal sizes of larvae) was observed, which was expressed in earlier development of pigmentation, relatively longer head, and deeper body. Based on distinct larval features it is possible to consider the existence of two groups of sand lance: near the Kamchatka Peninsula, including the area of the southwestern Bering Sea, and in the northwestern Bering Sea."

Keywords: *A. hexapterus*; East Kamchatka; Bering Sea; description; distribution; growth; larvae.

**Grimes, C.B.; Kingsford, M.J. 1996.** How do riverine plumes of different sizes influence fish larvae: Do they enhance recruitment? In: Grant, A., ed. Marine and freshwater research (East Melbourne): International larval fish conference: 1995 [dates unknown]; Sydney, Australia. In: [Journal unknown]; 47(2): 191-208.

Keywords: *Ammodytes*; distribution; larvae.

**Grimm, S.K.; Herra, T. 1984.** Spawning cycles of southern Baltic fishes based on surveys of eggs and larvae. In: Council meeting, 1984, of the International Council for the Exploration of the Sea; [dates of meeting unknown]. Copenhagen, [Denmark]. [Place of publication unknown]: [publisher unknown]: 18.

Keywords: *Ammodytes*; Baltic Sea; eggs; larvae; spawning.

**Gritsenko, O.F.; Churikov, A.A. 1977.** The biology of chars (genus *Salvelinus*) and their place in the ichthyocenoses of bays in northeastern Sakhalin. Part 2: Feeding. Journal of Ichthyology. 17(4): 591-599. (English translation of Voprosy Ikhtiologii).

"The feeding behavior of *Salvelinus alpinus kraschenninnikovi* and *S. leucomaenis* from the Bogataya River estuary and the Nisky Bay in the Sakhalin Oblast [Russian SFSR, USSR] was discussed. Diets consisted mainly of sandhoppers, Mysidacea, crustaceans, larvae of caddisflies, stoneflies and beetles, salmon roe, *Osmerus mordax dentex, Pungitius pungitius, Zoarces viviparus elongatus, Ammodytes hexapterus hexapterus* and *Pholis* sp. Age and

seasonal feeding characteristics were analyzed. Mathematical equations were presented for the qualitative evaluation of predator-prey relationships, daily feeding, growth and weight characteristics. Caloric food values of prey were given. Observations showed feeding behavior in char to discontinue upon entering rivers from the open sea and vise versa."

Keywords: *A. hexapterus*; USSR; predators (fish, arctic char).

**Groenewold, S.; Berghahn, R.; Zander, C.D. 1996.** Parasite communities of four fish species in the Wadden Sea and the role of fish discarded by the shrimp fisheries in parasite transmission. Helgolaender Meeresuntersuchungen. 50(1): 69-85.

"Parasites were observed in medium- and small-sized fish taken from the discards of a commercial shrimper during seven different cruises in the tidal channels of the North Frisian Wadden Sea (Suderaue, North Sea) from April to September 1991. In total, 442 fish comprising four species (*Sprattus sprattus, Hyperoplus lanceolatus, Ammodytes tobianus, Pomatoschistus minutus*) were investigated. The parasite fauna consisted of 22 species. The parasite community structure of the 4 hosts was compared. The diet of the hosts seemed to be the main factor determining the structure of the parasite community. Other factors could not be assessed. Eight species of parasites occurred as larval stages. This indicated that fish were intermediate or paratenic hosts in their life cycle. The nematode *Hysterothylacium* sp. (Anisakidae) and the digenean *Cryptocotyle lingua* (Heterophyidea) were the dominant parasites, reaching their highest prevalence and density in sprat and sand eel. Sprat and sand eel play a very important role in parasite transmission to predacious fish and seabirds."

Keywords: *A. tobianus; H. lanceolatus*; Wadden Sea; parasites.

**Gronvik, S.; Klemetsen, A. 1987.** Marine food and diet overlap of co-occurring arctic charr *Salvelinus alpinus* brown trout *Salmo trutta* and Atlantic salmon *Salmo salar* off Senja northern Norway. Polar Biology. 7(3): 173-178.

"Stomach contents analyses and other biological information of Arctic charr (*Salvelinus alpinus* (L.)), brown trout (*Salmo trutta* L.) and small Atlantic salmon (S. salar L.) caught 1982-85 close to the .ANG. elv estuary (69˚ N) on the island of Senja, N. Norway are presented, and extracts of a 1975-85 fishing log given. This appears to be the first case study of the feeding habits of all three European anadromous salmonids in marine sympatry, and also one of very few reports on the marine food of the Arctic charr from Europe. The general feeding habits of the charr were similar to that found in N. Canada. Pelagic fish (herring, sand eel) seem to be preferred. Plankton (crab megalopae, krill) and hyperbenthos (amphipods, mysids) are also taken, especially when suitable fish are scarce. In 1985 high herring densities provided superabundant food, and diet overlap between charr, trout and salmon was high. Salmonid nursery rivers are abundant in N. Norway and during summer the three species coexist in a near-shore, surface-oriented pelagic guild of fishes. The salmon seems to be a relatively specialized piscivore, while the trout takes a wider range of fish and also invertebrate prey. The charr probably is the most euryphagous of the three, being able to exploit the more marginal parts of the prey resources of their common habitat."

Keywords: *Ammodytes*; Norway; predators (fish, arctic char).

**Grosslein, M.D.; Langton, R.W.; Sissenwine, M.P. 1980.** Recent fluctuations in pelagic fish stocks of the northwest Atlantic, Georges Bank region, in relationship to species interactions. Rapports et Procés-Verbaux des Reunions Conseil International pour l'Exploration de la Mer. 177: 377-404.

Keywords: *Ammodytes*; Georges Bank; abundance; distribution.

**Grover, J.J. 1983.** Comparative feeding ecology of five inshore, marine fishes off Long Island, New York. Dissertation Abstracts International Part B—Science and Engineering. Dissertation Ph.D Order No. FAD DA8305746. 43(10). 209 p.

"The food habits of *Meni menidia, M. beryllina, Ammodytes* sp., and young of the year of *Tautoga onitis* and *Tautogolobrus adspersus* were examined from March through December of 1978 in Fire Island Invet, New York. Diet was compared to the composition of the plankton. Copepods were the most commonly ingested prey item for this

assemblage of fishes, and dominated the plankton for most of the year, as well. *Menidia menidia* and *Ammodytes* sp. principally ingested large copepods, while *T. onitis* and *T. adspersus* ingested small copepods. The utilization of non-copepod food resources differentiated the diets of several of the species, which prey selection reflecting seasonal availability rather than absolute abundance in the plankton. To understand the limits morphology may have imposed on the feeding habits of each species, a comparison of head and mouth morphology was made."

Keywords: *Ammodytes*; New York; Long Island; food and feeding habits; morphology.

**Grover, J.J.; Olla, B.L. 1983.** The role of the rhinoceros auklet (*Cerorhinca monocerata*) in mixed-species feeding assemblages of seabirds in the Strait of Juan de Fuca, Washington. Auk. 100: 979-982.

During the day, sand lance swim in schools and forage principally on copepods. They possess two basic strategies to avoid predation. They may bury themselves in the sand, much as they do at night, or they may use their schooling as a defense mechanism, in which case they form tight, cohesive balls or pods. It has been suggested that the tight ball confuses the predator and minimizes the surface area of the school. This balling-up behavior of sand lance in response to a swimming predator effectively moves a dense concentration of prey to the surface, where it can be exploited opportunistically by surface-feeding seabirds. Cod, fin whales, and humpback whales have been observed to induce balling-up behavior in sand lance. This article provides evidence that rhinoceros auklets also may cause a balling.

Keywords: *A. hexapterus*; Washington; behavior; predators (birds, rhinoceros auklet; fish, cod; mammals, fin whale, humpback whale).

**Grygiel, W.J. 1981.** Growth, feeding and economic importance of the greater sand-eel (A. lanceolatus Le Sauvage 1824) in the southern Baltic. In: International Council for the Exploration of the Sea; Woods Hole, MA (USA): 15.

Keywords: *A. lanceolatus*; Baltic Sea; age; fisheries; food and feeding habits; growth.

**Guiguet, C.J. 1972.** The birds of British Columbia. 9: Diving birds and tube-nosed swimmers. Handb. 29. [Victoria, BC]: British Columbia Provincial Museum.

Keywords: *A. hexapterus*; British Columbia; predators (birds).

**Gulland, J.A. 1970.** Food chain studies and some problems in world fisheries. In: Steele, J.H., ed. Marien food chains. Edinburgh, [Scotland]: Oliver and Boyd: 296-315.

Keywords: *Ammodytes*; fisheries; food chain.

**Gunther, A. 1892.** Catalogue of the Acanthopterygian fishes in the collection of the British Museum. Family 4: Ophidiidae. Fourth Group Ammodytina. 4: 384-388.

Keywords: *Ammodytes*; distribution; taxonomy.

**Hain, J.H.W.; Carter, G.R.; Kraus, S.D. [and others]. 1982.** Feeding behavior of the humpback whale *Megaptera novaeangliae* in the western North Atlantic. U.S. National Marine Fisheries Service, Fishery Bulletin. 80(2): 259-268.

"Observations on the feeding behavior of the humpback whale, *M. novaeangliae*, were made from aerial and surface platforms from 1977 to 1980 in the continental shelf waters of the northeastern USA. The resulting catalog of behaviors includes 2 principal categories: swimming/lunging behaviors and bubbling behaviors. A behavior from a given category may be used independently or in association with others, and by individual or groups of humpbacks. The 1st category includes surface lunging, circular swimming/thrashing, and the inside loop behavior. In the 2nd category, a wide variety of feeding-associated bubbling behaviors are described, some for the first time. The structures formed by underwater exhalations are of 2 major types: bubble cloud, a single, relatively large (4-7 m diameter), dome-shaped cloud formed of small, uniformly sized bubbles; and bubble column, a smaller (1-1.5 m diameter) structure composed of larger, randomly sized bubbles, used in series or multiples. Both basic structures are employed in a

variety of ways. Many of these behaviors are believed to be utilized to maintain naturally occurring concentrations of prey, which have been identified as the American sand lance, Ammodytes americanus and occasionally as herring, *Clupea harengus*."

Keywords: *A. americanus*; Atlantic (northwestern); predators (mammals, humpback whale).

**Hain, J.H.W.; Ellis, S.L.; Kenney, R.D. [and others]. 1995.** Apparent bottom feeding by humpback whales on Stellwagen Bank. Marine Mammal Science. 11(4): 464-479.

"Humpback whales, *Megaptera novaeangliae*, on Stellwagen Bank off eastern Massachusetts, U.S.A., apparently bottom feed on northern sand lance, *Ammodytes dubius*. The feeding behavior is characterized by the whales brushing the bottom in depths of less than 40 m, causing sand lance burrowed in the bottom to be flushed up into the water column. The greatest densities of sand lance were in beds of shells and shell debris, termed 'shell hash.' The brushing against or along the bottom, particularly in these shell hash areas, caused the humpbacks to acquire abrasions and wounding, sometimes rather extensive, of the lateral lower jaw, and lateral and dorso-lateral upper jaw, here termed 'jaw scuffing.' Scuffing of the dorsal fin and fluke edges was also common and may be at least partially related to this feeding behavior. Both mature and immature, and male and female, humpbacks exhibited jaw scuffing. The bottom-feeding behavior was not exclusive, as jaw-scuffed individuals were also observed to use other feeding behaviors. In recent years (1991-1993), however, bottom feeding appears to have become relatively more common, particularly among young animals. Overall, in the Stellwagen Bank area between 1979 and 1993, a majority of the population engaged in, or had engaged in, bottom feeding and the associated prey flushing."

Keywords: *A. dubius*; Massachusetts; predators (mammals, humpback whale).

**Haldorson, L.; Pritchett, M.; Sterritt, D.; Watts, J. 1993.** Abundance patterns of marine fish larvae during spring in a southeastern Alaskan bay. U.S. National Marine Fisheries Service, Fishery Bulletin. 91(1): 36-44.

"Ichthyoplankton were sampled weekly in Auke Bay, southeastern Alaska, from March or early April through June, 1986-89. The spring primary production bloom occurred in April, and was found in May by the annual maximum in herbivorous copepods. Each year, the five most-abundant fish larvae were osmerids, Pacific sandlance *Ammodytes hexapterus*, walleye pollock *Theragra chalcogramma* flathead sole *Hippoglossoides elassodon*, and rock sole *Pleuronectes bilineatus*. Each species tended to occur at the same time every year, and could be categorized either as synchronous species that were present at the time copepod abundance was maximized, or early species that were most abundant before the spring phytoplankton bloom. Pacific sandlance and rock sole larvae always reached maximum abundance prior to the spring bloom, whereas larvae of walleye pollock, flathead sole, and osmerids were most abundant at the time of the copepod maximum. Physical and biotic conditions experienced by early and synchronous larvae differ markedly, suggesting that survival through early life history is determined by different processes in the two groups."

Keywords: *A. hexapterus*; Alaska; southeastern Alaska; abundance; food and feeding habits; larvae.

**Haley, D. ed. 1984.** Seabirds of eastern north Pacific and arctic waters. Seattle, WA: Pacific Search Press.

Accounts mostly just mention fish as part of the birds diet. The following was gleaned: arctic tern, Aleutian tern, common tern, and thick-billed murre feed on sand lance. The ancient murrelet later feeds almost entirely on sand launces and sea perch. In Alaska, the most important food of the tufted puffin is capelins and sand launces; farther south, sand launces remain the primary food. Horned puffin chicks consume two species of fish: capelins and sand launces.

Keywords: *A. hexapterus*; predators (birds, arctic tern, Aleutian tern, common tern, thick-billed murre; ancient murrelet; tufted puffin; horned puffin).

**Halley, D.J.; Harrison, N.; Webb, A.; Thompson, D.R. 1995.** Seasonal and geographical variations in the diet of common guillemots *Uria aalge* off western Scotland. Seabird. 17(12-20): [pages unknown].

Keywords: *A. marinus*; Scotland; North Sea; age; predators (birds, common guillemot).

**Hamada, T. 1966a.** Studies on fluctuation in the abundance of larval sand-lance in the Harima-Nada and Osaka Bay. I: Relation between the projeny-abundance and the age compostion of parent fish. Bulletin of the Japanese Society of Scientific Fisheries. 32(5): 393-398.

“The habitats of the parent fish in Harima-nada and Osaka Bay are sandy bottom areas around Awazi Island and occurpy about 1107.6 $km^2$. Shikano-se and Murotsuno-se are two major spawning grounds. The parent group consists of 1- to 3-age fish. The percentage of 1-age fish varies from year to year, the range and the average being 20~77 and 54.7 respectively.”

Keywords: *A. personatus*; Japan; abundance; age; larvae.

**Hamada, T. 1966b.** Studies on fluctuation in the abundance of larval sand-lance in the Harima-Nada and Osaka Bay. II: The distribution and its seasonal change of larval fish. Bulletin of the Japanese Society of Scientific Fisheries. 32(5): 399-405.

“The results of the observation are as follows. 1) In the Harima-nada and Osaka-Bay, the larvae of the sand-lance appear at the end of December when the season is early, or at the middle of January when the season is late. At this time, distribution of the larvae is restricted to the spawning grounds. 2) The material was obtained using a 45 cm, ring net with silk netting GG-50. The net was towed horizontally at the surface (0~5 m.). The body length of the larvae varied from 3.1 mm. to 24.2 mm. Specimens having body length of over 20 mm. were few in number. 3) The pattern of larval distribution varied according to time and duration of spawning season and diffusion of eggs and larvae. The pattern observed from the beginning to the middle of February, every year, is generally thought to indicate the distribution after completion of the diffusion. 4) The waters around Shikano-se in the Harima-nada and Bisanseto seem to be the centers of distribution of the larval sand-lance found in the eastern part of the Seto Inland Sea.”

Keywords: *A. personatus*; Japan; abundance; larvae.

**Hamada, T. 1966c.** Studies on the fluctuation in the abundance of larval sand-lance in the Harima-Nada and Osaka Bay. III: Relationship to weather and sea conditions during the breeding season. Bulletin of the Japanese Society of Scientific Fisheries. 32(7): 579-584.

“Many factors affecting the fluctuation of the abundance of larval sand-lance in Harimanada and Osaka Bay have been considered. The author showed the relationships between fluctuation of abundance and 1) composition of age-class of adults (paper I), and b) distribution of larval forms (paper II). In this paper, the author considers the influence of weather and sea conditions during the breeding season, on the fluctuation of larval occurrence. The following results were obtained. 1) When the water temperature during the breeding season is lower than in average years, especially when it drops suddenly from December through January, catch of the 0-age class tends to be large.... 2) There is a relation r = +0.74 between landing of 0-age class and number of days (within 20 days after peak of spawning) the seasonal west wind blows. In years when fishing is abundant, it is a characteristic feature for the west wind to have blown continuously after the peak of spawning.... 3) Occurrence of larval forms in Harima-nada is influenced by the extent of water mass flowing from the west with chlorinity above 18.00%, which is observed during the period January to March....”

Keywords: *A. personatus*; Japan; abundance; larvae.

**Hamada, T. 1967.** Studies on the fluctuation in the abundance of larval sand-lance in the Harima-Nada and Osaka Bay. IV: Relation between the number of eggs and the catch of 0-age fish. Bulletin of the Japanese Society of Scientific Fisheries. 33(5): 410-416.

“The present paper deals with the relation between the number of eggs spawned and the fluctuation of the abundance of larval sand-lance in Harima-nada and Osaka Bay, using the data obtained between 1956 and 1966. 1-age fish = 81.6 + or - 8.1 mm in total length. 2 and 3 age fish = 118.9 + or - 5.8 mm in total length. In years when catch of adult was large the body length of 1-age fish was small. The sex ratio of adult fish was considered to be 1:1. The catch in weight was transformed into number of individuals by using the age-compostion and the mean body weight of each age-group; and then the relative number of eggs spawned was estimated using the sex ratio and fecundity of females in each agroup, based on the assumption that the fishing rate is constant every year. The number of eggs spawned by 2 and 3 age fish occupies 63-95% average 76% of total number of eggs spawned. A negative correlation between the above mentioned number of eggs spawned and 0-age individuals in catch was obtained, viz. r=-0.811. This is expressed by the formula, Y = 2.459-0.608 X. (Where Y is log. of 0-age individuals in catch, and X is number of eggs spawned.)”

Keywords: *A. personatus*; Japan; abundance; age; distribution; eggs; fecundity; O-age; sex ratio.

**Hamada, T. 1985.** Fishery biology of the sand lance (Ammodytes personatus Girard) in Japan. Suisan Kenkyu Sosho. 36: 86.

“Most sand-lance caught in Japan belong to *Ammodytes personatus*, and a small amount of *A. hexapterus* is caught in the northern part of Hokkaido, together with *A. personatus*. The average sand-lance annual catch in Japan in recent years (1974-1983) amounts to approximately 18,000 tons. The year-to-year fluctuation of the catch varies to a great extent by sea areas because the catch consists mainly of 0-age fish. While sand-lances have been eaten by the Japanese as an important protein food, there has been increasing demand for them as piscicultural feed since 1960. Sand-lance are biologically important species as food for the piscivorous fish among marine fauna which inhabit the area. Their ecology and fishery resources are outlined.”

Keywords: *A. hexapterus; A. personatus*; Japan; catch; fisheries; biology.

**Hamer, K.C.; Furness, R.W.; Caldow, W.G. 1991.** The effects of changes in food availability on the breeding ecology of great skuas *Catharacta skua* in Shetland. Journal of Zoology (London). 223: 175-188.

“Great skuas on Foula, Shetland have responded to a decline in the availability of sandeels since the late 1970s by increasing the proportion of other items in their diets. This change is correlated with the annual recruitment of sandeels in Shetland waters. Since 1983 there has been a 10-fold increase in predation by great skuas upon other seabirds, as Furness & Hislop (1981) suggested might occur in response to a low availability of sandeels. Changes in diet have been accompanied by a 50% reduction in adult territorial attendance as adults increased their foraging effort.”

Keywords: *A. marinus*; Shetland; importance; predators (birds, great skua); recruitment.

**Hamer, K.C.; Monaghan, P.; Uttley, J.D. [and others]. 1993.** The influence of food supply on the breeding ecology of kittiwakes *Rissa tridactyla* in Shetland. Ibis. 135(3): 255-263.

“We measured the breeding performance, body condition, time budgets and foraging ranges of Kittiwakes *Rissa tridactyla* at Sumburgh Head, Shetland [Scotland, UK] in two years of contrasting food availability. Kittiwakes in Shetland generally feed their young almost entirely on sandeels, and fisheries data indicated that stocks of sandeels in Shetland waters were at least ten times higher in 1991 than in 1990. Fledging success of Kittiwakes was nil in 1990 and 68% of eggs laid in 1991, although clutch-size and hatching success were no different between years. Post-hatching foraging trips in 1991 were of comparable duration of those recorded at other colonies in conditions of

good food supply (2-3 h), while trips recorded during incubation or post-hatching in 1990 were approximately three times longer on average than at corresponding stages of the breeding season in 1991. Radio-tracking data indicated that adults generally stayed within 5 km of the colony in 1991 but flew more than 40 km from the colony on each trip in 1990. Eggs were apparently not left unattended in either year, despite the fact that this required adults to incubate for periods in excess of 44 h in 1990. The extent to which adults were able to increase trip durations, foraging ranges and incubation shift lengths between years, while maintaining hatching success, indicates the degree to which Kittiwakes are normally buffered against adverse feeding conditions during incubation. Reduced nest attendance and lower body-condition of adults post-hatching in 1990, in conjunction with complete post-hatching breeding failure, indicate that adults were beyond the limits of their buffering capacity during chick-rearing in 1990."

Keywords: *Ammodytes*; Shetland; predators (birds, kittiwake).

**Hammond, P.S.; Hall, A.J.; Prime, J.H. 1994.** The diet of grey seals around Orkney and other island and mainland sites in north-eastern Scotland. Journal of Applied Ecology. 31(2): 340-350.

Almost 1,000 feces were collected in February, June, August, and November 1985 to quantify the diet of grey seals around Orkney; 82 percent of these contained fish otoliths. Diet composition, by weight, was assessed by identifying and measuring otoliths from the fecal material and correcting for reduction in otolith size as a result of digestion by using experimentally derived species-specific digestion coefficients. Sand eels accounted for almost half of the fish consumed, by weight. The rest of the diet was composed mostly of gadids (particularly cod), flatfish (particularly plaice), and sculpins. Sand eels were more prevalent in February and the summer than in November. They were found least often in the eastern area. No significant regional or seasonal differences were found in the number of cod, haddock, or saithe consumed. Whiting featured strongly to the south in November. Ling occurred most frequently in the west. Of the flatfish, plaice were consumed more in February than in November and more in the east than in the north and west. The largest sand eels and plaice were found when these species were also most prevalent in the diet, suggesting that seals may switch to these prey when and where the fish are larger. This was not found for other species. Some flatfish and sculpins were important in the diet locally, perhaps reflecting their restricted habitat requirements and feeding by seals on locally abundant prey. Mature fish of a number of species were more prominent In the diet in areas and at times of the year when spawning occurs, suggesting that grey seals take advantage of energy-rich prey when these are available.

Keywords: *Ammodytes*; Scotland; predators (mammals, grey seal).

**Hammond, P.S.; Hall, A.J.; Prime, J.H. 1994.** The diet of grey seals in the inner and Outer Hebrides. Journal of Applied Ecology. 31(4): 737-746.

"Faecal material collected in January, June, August and November 1985 was used to investigate seasonal and regional variation in grey seal diet around the Western Isles of Scotland. A total of 511 individual faex was obtained from the Outer and 238 from the Minch/Inner Hebrides; 79% and 67%, respectively, contained fish otoliths and/or cephalopod beaks. The contribution of sandeels to the diet in the Hebrides was less than that found in other areas of Britain (Orkney and the east coast). The significant variation in sandeel occurrence by area (many more sandeels taken off the Outer than the Minch/Inner Hebrides) can be explained by the distribution of the sandeel's preferred sea bed type (smooth area of gravelly sand) in the region."

Keywords: *Ammodytes*; Scotland; predators (mammals, grey seal).

**Hammond, P.S.; Prime, J.H. 1990.** The diet of British grey seals, *Halichoerus grypus*. In: Bowen, W.D., ed. Population biology of sealsworm (*Pseudoterranova decipiens*) in relation to its intermediate and seal hosts. Canadian Bulletin of Fisheries and Aquatic Science. 222: 243-254.

"The diet of British grey seals was investigated by analyses of otoliths from faecal samples collected at haulout sites. Over 1,400 samples from the Hebrides, Orkney, Isle of May, Farne Islands and Donna Nook, Lincolnshire contained 60,000 sandeel (Ammodytidae) otoliths and over 6,000 otoliths from other species."

Keywords: Ammodytidae; British Isles; predators (mammals, grey seal).

**Hancock, M.J. 1975.** A survey of the fish fauna in the shallow marine waters of clam lagoon, Adak, Alaska. [Place of publication unknown]: Florida Atlantic University. M.S. thesis.

Keywords: *A. hexapterus*; Alaska; Adak; abundance; distribution.

**Handa, H.; Moriwaki, N.; Okamoto, S. 1989.** A survey on important fisheries environment of Setonaikai Sea. 3: Survey on distribution of fry of sand lance, *Ammodytes personatus*. Hyogo Kenritsu Suisan Shikenjo Jigyo Hokoku. 1988: 39-45.

Keywords: *A. personatus*; Japan; Seto Inland Sea; abundance; distribution; larvae.

**Hansen, P.M. 1965.** Report on recaptures in Greenland waters of salmon tagged in rivers in America and Europe. [Place of publication unknown]: International Commission Northwest Atlantic Fisheries Redbook: 194-201. Part 3.

Keywords: *Ammodytes*; Greenland; predators (fish, Atlantic salmon).

**Hansen, P.; Jensen, J. 1982.** Bulk handling and chilling of large catches of small fish. Part 1: Quality and storage life. Infofish Mark. Dig. 6: 26-28.

“The main small species taken by trawlers in the North Sea are at present sprat (*Sprattus sprattus*), sandeel (*Ammodytes species*), and Norway pout (*Trisopterus esmarkii*), whereas purse seiners take capelin (*Mallotus villosus*), anchovy (*Engraulis* sp.), sprat (*S. sprattus*), herring (*Clupea harengus*) and sardines (*Sardinops* sp.). Bulk storage of industrial fish in summertime and handling of small food fish are discussed. The effects of chilling at different times after capture on the quality and storage life of small fish are considered.”

Keywords: *Ammodytes*; North Sea; fisheries.

**Harding, D.; Nichols, J.H.; Tungate, D.S. 1978.** The spawning of plaice (*Pleuronectes platessa* L.) in the southern North Sea and English Channel. Rapports et Procès-Verbaux des Reunions Conseil International pour l’Exploration de la Mer. 172: 102-113.

Keywords: *Ammodytes*; North Sea; predators (fish, plaice).

**Harris, C.K.; Hartt, A.C. 1977.** Assessment of pelagic and nearshore fish in three bays on the east and south coasts of Kodiak Island, Alaska. In: Environmental assessment of the Alaskan Continental Shelf, Quarterly Reports of Principal Investigators: April-June. [Place of publication unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration; OCSEAP final report RV0485. Vol. 1.

The prey spectrum of 86 juvenile and adult sand lance caught in the intertidal zone are shown. Primarily pelagic organisms such as calanoids (contributing about 75 percent of the biomass), zoea, larvaceans, and nauplii were the principal food items, which is surprising considering where the samples were taken.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; food.

**Harris, M.P. 1970.** Differences in the diet of British auks. Ibis. 112: 540-541.

“The bulk of the food items brought ashore are sand-eels and small clupeids which are evidently caught near to the colonies because the fish are sometimes still alive when presented to the young auks. In 1962 and 1963 Puffins fed their young almost entirely on sand-eels.”

Keywords: *Ammodytes*; Atlantic (northeast); predators (birds, guillemot, puffin, razorbill).

**Harris, M.P. 1977.** Puffins on the Isle of May. Scottish Birds. 9: 285-290.

Keywords: *Ammodytes*; Isle of May; predators (birds, puffins).

**Harris, M.P. 1978a.** Seabirds and fisheries. Ibis. 120(1): 135.

Keywords: *Ammodytes*; North Sea; fisheries; predators (birds).

**Harris, M.P. 1978b.** Supplementary feeding of young puffins. Journal of Animal Ecology. 47: 15-23.

Keywords: *Ammodytes*; predators (birds, puffin).

**Harris, M.P. 1978c.** Variations within British puffin populations. Ibis. 120(1): 129.

Keywords: *Ammodytes*; Atlantic (northeast); predators (birds, puffin).

**Harris, M.P. 1980.** Breeding performance of puffins *Fratercula arctica* in relation to nest density, laying date and year. Ibis. 122: 193-209.

Keywords: *Ammodytes*; predators (birds, puffin).

**Harris, M.P. 1984.** The puffin. Calton, [United Kingdom]: Poyser.

“The commonest and most widespread fish is the sandeel, an elongated silvery eel-like fish with long dorsal and anal fins, a forked tail and a protruding lower jaw. Sandeels do spend time buried in sand but they also occur in vast shoals in mid-water, or near the surface, where they are eaten in vast numbers by fish and birds. Equally vast numbers of sandeels are now caught by trawlers and processed into fishmeal for animal food and fertilizer. The impact of this ‘industrial’ fishery on other fish and seabirds has yet to be demonstrated but might well be severe as the catch of sandeels in Shetland and elsewhere is doubling each year. Five species of sandeels occur in the north-eastern Atlantic but all species collected from Puffins have been identified as *Ammodytes marinus*. Most sandeels eaten by seabirds are in the first year of life (the 0-group of fisheries biologists) when they grow from transparent larvae into recognizable fish. They reach a length of 80-90 mm at six months and 110 mm when one year old. Larger sandeels (up to 130 mm) are probably in their second year of life. Puffins can handle the latter but nothing larger. Shags and other larger seabirds eat these and older sandeels up to the maximum length of 320 mm. Sometimes Puffins are seen holding large numbers of minute transparent fish—these are usually larval sandeels.”

Keywords: *A. marinus*; abundance; calorific value; commercial fisheries; importance; predators (birds, guillemot, gulls, puffin, razorbill, shag, skua).

**Harris, M.P. 1985.** Morphology and breeding of puffins at Isle of May and St. Kilda, Scotland. Biological Conservation. 32: 81-97.

Keywords: *Ammodytes*; Scotland; Isle of May; St. Kilda; predators (birds, puffin).

**Harris, M.P. 1992.** Isle of May seabird studies in 1992. JNCC report. 127: 1-39.

Keywords: *Ammodytes*; Scotland; Isle of May; predators (birds).

**Harris, M.P.; Birkhead, T.R. 1985.** Breeding ecology of the Atlantic alcidae. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. London: Academic Press: 156-204.

“The amount of food received is presumably related to the availability of fish. However, growth is also influenced by the species of fish delivered to the chicks; the young grow better and fledge at higher weights when fed on oil-rich fish such as sandlance (*Ammodytes* spp.) and sprats (*Sprattus sprattus*) than when fed other fish such as whiting (*Merlangius merlangus*).”

Keywords: *Ammodytes*; importance; predators (birds, Atlantic puffin).

**Harris, M.P.; Heubeck, M.; Suddaby, D. 1991.** Results of an examination of puffins *Fratercula arctica* washed ashore in Shetland in winter 1990-91. Seabird. 13: 62-66.

Keywords: *Ammodytes*; Shetland; predators (birds, puffin).

**Harris, M.P.; Hislop, J.R.G. 1978.** The food of young puffins *Fratercula arctica*. Journal of Zoology, London. 185: 213-236.

“Sandeels and Sprats were by far the most important prey species brought to young Puffins. Information is presented on the percentages by number, weight and calorific value and lengths of sandeels brought to Puffin chicks at 11 colonies. Only when feeding on larval, almost transparent Sandeels, did Puffins bring back more than 10-12 fish at a time and normally the number was 5-10. The maximum number of Sandeels brought to Puffin chicks in a single load was 61.”

Keywords: *A. marinus*, Ireland, Scotland, calorific value, importance, length, predators, weight, weight-length relationships.

**Harris, M.P.; Murray, S. 1977.** Puffins on St. Kilda. British Birds. 70: 50-65.

Keywords: *Ammodytes*; Scotland; St. Kilda; predators (birds, puffin).

**Harris, M.P.; Riddiford, N.J. 1989.** The food of some young seabirds on Fair Isle in 1986-88. Scottish Birds. 15: 119-125.

Fulmar: sand eels were important only in 1987. Shag: all the regurgitations contained sand eels. Kittiwake: all but one regurgitation consisted entirely of sand eels. Guillemot: sand eels made up 98 percent of the 166 fish identified. Razorbill: all fish carried to chicks were sand eels with two exceptions. Puffin: sand eels were by far the commonest prey and made up 75 to 100 percent of the fish fed to chicks. Sand eels were also fed to the chicks of black guillemot. Other bird species found feeding on sand eels included common tern, arctic skua, great black-backed gull, and herring gull.

Keywords: *A. marinus*; importance; predators (birds, fulmar, shag, kittiwake, guillemot, razorbill, puffin, black guillemot, common tern, great skua, great black-backed gull).

**Harris, M.P.; Wanless, S. 1985.** Fish fed to young guillemots *Uria aalge* and used in display on the Isle of May, Scotland. Journal of Zoology, Series A. 207(3): 441-458.

“Guillemots on the Isle of May fed their young on sandeels and sprats, the proportion of the latter being highest late in the day and the season. There was a peak of feeding after dawn when many large sandeels were brought. Weather had no effect on feeding rate but this did increase with the chick’s age. Food appeared to be abundant.

A large sprat was the most efficient return for effort and guillemots may select the most energy-rich prey. Display fish (mainly small sandeels) were brought throughout the season, mostly by females which often ate them later. The significance of the fish-carrying display is obscure."

Keywords: *Ammodytes*; Scotland; Isle of May; predators (birds, guillemot).

**Harris, M.P.; Wanless, S. 1986.** The food of young razorbills on the Isle of May and a comparison with that of young guillemots and puffins. Ornis Scandinavica. 17: 41-46.

"Sand eels were the staple food of young razorbills which were fed, on average, 2.9 times per day. The calculated mean feed weights (and calorific values) for 1982, 1983 and 1984 were 8.5 g (61kJ), 7.2 g (52 kJ) and 6.3 g (43 kJ), respectively. Young aged 3-11 d received the most feeds. Puffin chicks received 4-5 feeds per day of a number of smaller sand eels, herring and a range of other species, while young guillemots received 3-4 feeds of a single large sandeel or sprat. There was virtually complete overlap of the chick rearing periods and a marked similarity in the diets of chicks in the three species. The greatest dietary overlap was between razorbill and puffin. Razorbill chicks received far less food than other young and the species had a relatively low breeding success. Food and breeding performance should be monitored carefully."

Keywords: *Ammodytes*; Scotland; Isle of May; importance; predators (birds, razorbill, guillemot, puffin).

**Harris, M.P.; Wanless, S. 1988.** The breeding biology of guillemots *Uria aalge* over a six year period. Ibis. 130: 172-192.

Keywords: *Ammodytes*; predators (birds, guillemot).

**Harris, M.P.; Wanless, S. 1990.** Breeding success of British kittiwakes *Rissa tridactyla* in 1986-88: evidence for changing conditions in the northern North Sea. Journal of Applied Ecology. 27: 172-187.

"Data on breeding success from 35 British and one Irish kittiwake *Rissa tridactyla* colony were collected between 1986 and 1988. At each colony the mean number of young fledged per completed nest was similar in 1986 and 1987, but at North Sea colonies success was significantly poorer in 1988. Colonies in the northern North Sea showed a negative relationship between breeding success and latitude in 1986 and 1987, whilst in 1988 there was a significant north-south trend in success over the whole length of eastern Britain with colonies in the south being more successful than those in the north. There was no similar pattern amongst west coast colonies. In North Sea colonies most breeding failures occurred at the chick stage, but on the west coast some birds did not lay whilst others failed during incubation or soon after hatching. It seemed likely that food shortage during chick rearing was responsible for the low breeding success; a series of poor recruiting year classes had caused a decline recently in the Shetland stock of sandeels *Ammodytes* spp."

Keywords: *Ammodytes*; North Sea; abundance; predators (birds, kittiwake); recruitment.

**Harris, M.P.; Wanless, S. 1991a.** Population studies and conservation of puffins Fratercula arctica. In: Perrins, C.M.; Lebreton, J.D.; Hirons, G., eds. Bird population studies: relevance to conservation and management. Oxford, England: Oxford University Press: 230-248.

Keywords: Ammodytes; predators (birds, puffin).

**Harris, M.P.; Wanless, S. 1991b.** The importance of the lesser sand eel *Ammodytes marinus* in the diet of the shag *Phalacrocorax aristotelis*. Ornis Scandinavica. 22(4): 375-382.

"Regurgitated food and pellets were collected from shags on the Isle of May, Scotland [UK]. Young shags were fed almost exclusively lesser sandeels. The relative contributions of 0-groups and older sandeels varied markedly between years. Fish were the predominant prey of full grown birds which consumed a wider spectrum of fish than were fed to chicks. Otoliths from at least 4 species were identified but sandeels dominated the diet and were presented in 93% of all pellets and accounted for 97% of otoliths. There was no evidence that clupeids were ever an

important prey. Although most published data suggest that lesser sandeels spend most of the winter buried in the sand they were obviously still available to shags during this time and their otoliths occurred in > 90% of pellets and accounted for > 90% of otoliths. The availability of sandeels, specifically when the fish emerge from the sand in spring is probably a major determinant of the timing of breeding of shags on the Isle of May."

Keywords: *A. marinus*; Scotland; Isle of May; importance; otoliths; predators (birds, shag); seasonal distribution.

**Harris, M.P.; Wanless, S. 1993.** The diet of shags *Phalacrocorax aristotelis* during the chick-rearing period assessed by three methods. Bird Study. 40(2): 135-139.

"This paper describes a study of the diet of shags using regurgitations by chicks, stomach contents and pellets collected concurrently. Sandeels predominated in all collections. Non- and failed breeders took a wider food spectrum than did chicks. Although adults fed their chicks almost entirely on sandeels, they themselves ate some fish from other fish families and probably digested these before they returned to the colony. Pellets are easy to collect and are useful to detect gross changes in diet of full-grown, but possibly non-breeding. Shags between years or colonies. Otoliths recovered from pellets cannot be used for age determination or back-calculations of size of sandeels eaten by shags. Regurgitations can be used to describe the diet of chicks. There is no easy way to determine the diet of adults feeding chicks."

Keywords: *Ammodytes*; Atlantic (northeast); predators (birds, shag).

**Harris, M.P.; Wanless, S. 1994.** Population studies and conservation of puffins *Fratercula arctica*. In: Perrins, C.M.; Lebreton, J.D.; Hirons, G.J.M., eds. Bird population studies: relevance to conservation and management: Collected papers of the first international symposium; [dates of meeting unknown]; [location unknown]. Arles, France: Station Biologique in La Sambuc: 230-248.

Keywords: *A. marinus*; Atlantic (northeast); predators (birds, puffin).

**Harris, M.P.; Wanless, S. 1995.** The food consumption of young common murres (*Uria aalge*) in the wild. Colonial Waterbirds. 18(2): 209-213.

"We measured the food intake and weights of known-aged common murre (*Uria aalge*) chicks over a 10-year period. The bulk of the food was sandlance and the mean calculated mass of a feed was 7.7 g. The average feeding frequency was 4.1 fish per day. There was significant change in the size of fish delivered by parents nor in the frequency of feeding as chicks became older. Chicks received, on average, about 30 g of fish per day during the time they were at the colony. This compared to intakes of up to 130 g per day by captive voting originating from a nearby colony. Therefore, we caution against rising maintenance requirements of captive murre chicks uncritically."

Keywords: *Ammodytes*; Scotland; Isle of May; energetics; predators (birds, common murre).

**Harrison, N. 1994.** Marine life campaign: overfishing. Birds (London). 15(4): 42-44.

Keywords: *Ammodytes*; Atlantic; catch; fisheries.

**Hart, J.L. 1973.** Pacific fishes of Canada. Bull. 180. [Place of publication unknown]: Fisheries Research Board of Canada.

Principal foods of spiny dogfish include herring, hake, sand lance, smelts, and euphausiids. Pacific herring eat sand lance. Sand lance is important for both young and adult coho salmon. Young sockeye salmon eat sand lance larvae. Young chinook eat sand lance larvae and older chinook eat mainly fishes such as herring and sand lance. Steelhead and Pacific cod eat sand lance. The food of Pacific hake off the British Columbia coast consists primarily of euphausiids and sand lance, and to a lesser extent herring, etc. Walleye pollock food in British Columbia is recorded as shrimps, sand lance, and herring. Threespine stickleback eat young sand lance. Sand lance are frequently taken as food by chinook and coho salmon, lingcod, halibut, fur seals, and many marine vertebrates. Chub

mackerel eat sand lance. Lingcod are voracious feeders on fishes including herring and sand lance when available. Buffalo sculpin eat sand lance. Petrale sole, euphausiids, sand lance, herring, and shrimps are the most important foods off British Columbia. Rock sole eat sand lance.

Keywords: *A. hexapterus*; British Columbia; predators (fish, spiny dogfish, Pacific herring, coho salmon, sockeye salmon, chinook salmon, steelhead, Pacific cod, Pacific hake, walleye pollock, threespine stickleback, lingcod, Pacific halibut, chub mackerel, buffalo sculpin, petrale sole, rock sole; mammals, fur seal).

**Hart, P.J.B. 1974.** The distribution and long-term changes in abundance of larval *Ammodytes marinus* in the North Sea. In: Blaxter, J.H.S., ed. The early life history of fish. Oban, Scotland: Dunstaffnage Marine Research Laboratory of the Scottish Marine Biological Association; New York: Springer-Verlag: 171-182.

Keywords: *A. marinus*; North Sea; abundance; fisheries; larvae.

**Hart, T.F.; Werner, R.G. 1987.** Effects of prey density on growth and survival of white sucker, *Catostomus commersoni*, and pumpkinseed, *Lepomis gibbosus*, larvae. Environmental Biology of Fishes. 18(1): 41-50.

Keywords: *Ammodytes*; abundance; predators (fish).

**Hartley, C.H.; Fisher, J. 1936.** The marine food of birds in an inland fjord region of West Spitzbergen. Journal of Animal Ecology. 5: 370-389.

Keywords: *Ammodytes*; West Spitzbergen; predators (birds).

**Hartt, A.C.; Dell, M.B. 1986.** Early oceanic migrations and growth of juvenile Pacific salmon and steelhead trout. International North Pacific Fisheries Commission Bulletin. 46: 1-105.

Keywords: *A. hexapterus*; Gulf of Alaska; predators (fish, Pacific salmon).

**Harwood, J.; Croxall, J.P. 1988.** The assessment of competition between seals and commercial fisheries in the North Sea and the Antarctic. Marine Mammal Science. 4: 13-33.

Keywords: *Ammodytes*; North Sea; fisheries; predators (mammals, grey seal).

**Hashimoto, A.; Arai, K. 1978.** The effects of pH and temperature on the stability of myofibrillar Ca-ATPase from some fish species. Nihon Suisan-Gakkai Shi. 44(12): 1389-1393.

“The effects of pH and temperature on the stability of myofibrils from the following fish species were studied in terms of the first order rate constant (KD) for inactivation of Ca-ATPase: sardine (*Sardinops melanosticta*), chub mackerel (*Scomber japonicus*), mackerel pike (*Cololabis saira*), sand lance (*Ammodytes personatus*), carp (*Cyprinus carpio*), ray (*Raja pulchra*), and Atka mackerel (*Pleurogrammus azonus*). The myofibrils were incubated at various pH values while maintaining the temperature constant, although the temperature applied for incubation was different for each fish species. Myofibrillar Ca-ATPase was more resistant to thermal inactivation in the neutral range of pH 7.0-8.5. The inactivation rates of myofibrillar Ca-ATPases at acidic pH J6.9 and at alkaline pH K8.6 were faster than those observed at neutral pH-2-7 times faster depending upon pH values. The rate constants (KD) were plotted semilogarithmically against the reciprocal of absolute temperature for incubation. Linear Arrhenius plots in the temperature range of 20-35 °C were identifiable for sardine myofibrils at pH 5.8 and Atka mackerel myofibrils at 7.6. The rate of inactivation of the Ca-ATPase of sardine myofibrils at pH 5.8 and 5 °C was comparable with that of Ca-ATPase at 7.6 and 26 °C. The significance of these results is discussed in relation to the rapid deterioration of sardine muscle during storage under various environmental conditions.”

Keywords: *A. personatus*; muscle; physiology.

**Hashimoto, H. 1983.** Two subpopulations of sandeel found off Tottori Prefecture Japan. Bulletin of the Japanese Society of Scientific Fisheries. 49(4): 597-600.

“Two subpopulations of young sandeel *Ammodytes personatus* were found off Tottori Prefecture by examining a combination of the vertebral count and gill raker number. These 2 subpopulations revealed differences also in size and stomach contents. Coexistence of 2 subpopulations in this area seems to be closely related to the oceanographical conditions: eastward Tsushima Warm Current encountering southward Japan Sea Central Water in spring.”

Keywords: *A. personatus*; Japan; food and feeding habits; meristics; taxonomy.

**Hashimoto, H. 1984a.** Population structure of the sandeel around Japan. Bulletin of the Japanese Society of Scientific Fisheries. 50 (8): 1357-1365.

Two species of sand eel, *Ammodytes hexapterus* and *A. personatus*, are distributed around Japan. The former’s range is the northern seas including the Sea of Okhotsk; the latter inhabits the more southern waters. They coexist in the coastal waters off northern Hokkaido.

Keywords: *A. personatus*; Japan; taxonomy.

**Hashimoto, H. 1984b.** Two subpopulations of sand-eel found off Torttori Prefecture. Bulletin of the Japanese Society of Scientific Fisheries. 50: 1089-1095.

Keywords: *A. hexapterus*; *A. personatus*; Japan; distribution; fecundity; meristics.

**Hashimoto, H. 1989.** Fisheries and resources of sandeel (*Ammodytes personatus*) in Sendai Bay. Journal of the Faculty of Applied Biology and Science, Hiroshima University. 28(1-2): 93-101.

“Sandeel *Ammodytes personatus* fisheries in Japan have developed in consequence of the expansion of fish culture. Recently the catch has been declining. This seemed to be the result of overfishing, but the sandeel production in Sendai Bay has only been on the increase since 1977 with the entry of boat seines and trawlers. Pressure on the sandeel resource has therefore been increased greatly, and sandeel fisheries tend toward overfishing. Through the sandeel resource in Sendai Bay has had such a reproductive system as a repeating 3-year cycle of abundance, the system has been changing. The dominant year-class burst on non-cyclic dominant years. It is desirable to establish a management program to identify the optimum level of fishing effort and exploitation of the sandeel resource.”

Keywords: *A. personatus*; Japan; catch; fisheries; overfishing.

**Hashimoto, H. 1991.** Population ecology of Japanese sandeel. Journal of the Faculty of Applied Biological Science, Hiroshima University. 30(2): 135-192.

Keywords: *A. hexapterus; A. personatus*; Japan; catch; fisheries; genetics; morphology; population structure.

**Hashimoto, H. 1992.** Analysis of fluctuations in fisheries catch in Seto Inland Sea until recent times. Journal of the Faculty of Applied Biological Science, Hiroshima University. 31(2): 143-154.

“Although annual catch in fishery in the Seto Inland Sea [Japan] had been increasing ordinarily with eutriphication until 1985 after World War II, since 1986 it decreased from a high level of about 400,000 tonnes to a level of 300,000 tonnes. In this paper analysis of fluctuations in annual catch was carried out on fishery in the Inland Sea. From the fluctuations in catch by fish species it was made clear that a high level catch during 1975-’85 depended on catch in a large amount of sardine which migrated into the Inland sea, and that the reduction in catch after 1986 was caused by decrease in catch of sardine, anchovy, sandeel and shell fishes which had been caught in abundance before that. Moreover, any annual CPUE by type of fisheries, such as small trawl net, purse seine and boat

seiners, changed decreasingly, so it seemed that each resources by fish species also declined. Judging from decreasing in proper type species, such as flat fishes, shrimps, sea cucumbers and shell fishes, in recent times, it is regarded that the bottom environment is becoming worse."

Keywords: *A. personatus*; Japan; catch; eutrophication; fisheries.

**Hashimoto, H. 1993.** Winter feeding of thick-billed murres in coastal waters off the Shakotan Peninsula, Hokkaido. Journal of the Yamashina Institute for Ornithology. 25(2): 166-173.

"Thick-billed murres, *Uria lomvia*, were obtained as an incidental catch during commercial gillnetting for Japan Sea greenling (*Pleurogrammus azonus*) off the Shakotan Peninsula, Hokkaido, in winter. Stomach content analysis revealed only Japanese sandlance, *Ammodytes personatus* (Pisces). In winter Japanese sandlance migrate to waters off the Shakotan Peninsula for spawning, where they are preyed upon by species such as Japan Sea greenling, masu salmon (*Oncorhynchus masou*) and walleye pollock (*Theragra chalcogramma*). It is apparent that the thick-billed murres compete with the above predatory fishes for the Japanese sandlance resource."

Keywords: *A. personatus*; Japan; predators (birds, thick-billed murre; fish, Japan Sea greenling, masu salmon, walleye pollock).

**Hashimoto, H.; Kawasaki, T. 1981.** Population studies of the sandeel, *Ammodytes personatus* (Girard), in Sendai Bay and its neighborhood. Tohoku Journal of Agricultural Research. 31(4): 173-197.

"Two subpopulations of sandeel, *A. personatus*, cohabiting in Sendai Bay and its neighborhood, were examined from several aspects, i.e., morphology, ecology and genetics to clarify their features of life history and the adaptive significance of their cohabitation."

Keywords: *A. personatus*; Japan; ecology; genetics; life history.

**Hashimoto, H.; Shibuno, T.; Ishikawa, S.; Gushima, K. 1995.** Fluctuations in fish catch of middle-sized pelagic fish in the Seto Inland Sea, Japan. In: Bas, C. [and others]. International symposium on middle-sized pelagic fish; [dates of meeting unknown]; [location unknown]. Scientia Marina (Barcelona). [Barcelona]: Universidad del Las Palmas de Gran Carnaria; 59: 499-506.

Keywords: *A. personatus*; Japan; Seto Inland Sea; catch; fisheries; migration; spawning.

**Hatanaka, M.; Okamoto, R. 1950.** Studies on populations of the Japanese sand lance (*Ammodytes personatus* Girard). Tohoku Journal of Agricultural Research. 1(1): 57-67.

Keywords: *A. personatus*; Japan.

**Hatch, S.A. 1984.** Nestling diet and feeding rates of rhinoceros auklets in Alaska. In: Nettleship, D.N.; Sanger, G.A.; Springer, P.F., eds. Marine birds: their feeding ecology and commercial fisheries relationships: Proceedings of the Pacific Seabird Group symposium, 1982; [dates of meeting unknown]; [location unknown]. Spec. Publ. Ottawa: Canadian Wildlife Service.

"Food brought to nestling rhinoceros auklets (*Cerorhinca monocerata*) was sampled by applying tape or cloth muzzles to the chicks and collecting the uningested food from the burrow daily. Limited data were also gathered for tufted and horned puffins (*Fratercula cirrhata* and *F. corniculata*). Auklet chicks received an average of 34.1 g of food per night at Middleton Island in 1978, and 32.8 per night at the Semidi Islands in 1979. Pacific sandlance (*Ammodytes hexapterus*) made up the bulk of the diet at both locations, and large, second-year or older fish predominated in the samples. In contrast, horned and tufted puffins took mostly small, first-year fish during the same seasons."

Keywords: *A. hexapterus*; Alaska; predators (birds, horned puffin, rhinoceros auklet, tufted puffin).

**Hatch, S.A. 1987.** Did the 1982-1983 El Niño-Southern Oscillation affect seabirds in Alaska? Wilson Bulletin. 99: 468-474.

Keywords: *A. hexapterus*; Alaska.

**Hatch, S.A. 1993.** Ecology and population status of northern fulmars *Fulmarus glacialis* of the north Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D., eds. The status, ecology, and conservation of marine birds of the north Pacific. Spec. Publ. [Ottawa, ON]: Canadian Wildlife Service: 82-92.

“Fishes commonly identified in fulmar stomachs from Alaska include Pacific sand lance *Ammodytes hexapterus*, capelin *Mallotus villosus*, walleye pollock *Theragra chalcogramma*, and lanternfishes Myctophidae.”

Keywords: *A. hexapterus*; Alaska; predators (birds, northern fulmar).

**Hatch, S.A.; Hatch, M.A. 1990.** Breeding seasons of oceanic birds in a subarctic colony. Canadian Journal of Zoology. 68: 1664-1679.

Keywords: *Ammodytes*; predators (birds).

**Hatch, S.A.; Sanger, D.A. 1992.** Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. Marine Ecology Progress Series. 80(1): 1-14.

“We sampled the nestling diets of tufted puffins *Fratercula cirrhata* and horned puffins *F. corniculata* in 3 years at colonies from the north-central Gulf of Alaska to the eastern Aleutian Islands, Alaska, USA. Overall, tufted puffins consumed (by weight) 41% sandlance *Ammodytes hexapterus*, 22% capelin *Mallotus villosus*, 19% walleye pollock *Theragra chalcogramma*, 13% other fish, and 5% invertebrates, whereas horned puffins took 85% sandlance, 4% capelin, 2% pollock, 8% other fish, and < 1% invertebrates. All of the pollock consumed were young of the year, whereas 4 year-classes of capelin were present, from young of the year through spawning adults. Puffins took mostly first-year sandlance, but fish in their second year or older were also common at colonies near Kodiak, Alaska. The importance of juvenile pollock in the diet of tufted puffins varied geographically from little or no use in the north-central Gulf and Kodiak areas to moderate use (5 to 20%) in the Semidi and Shumagin Islands to heavy use (25 to 75%) in the Sandman Reefs and eastern Aleutians.”

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, horned puffin, tufted puffin).

**Hatch, S.A.; Byrd, G.V.; Irons, D.B.; Hunt, G.L. Jr. 1993.** Status and ecology of kittiwakes (*Rissa tridactyla* and *R. brevirostris*) in the north Pacific. In: Vermeer, K.; Briggs, K.T.; Morgan, K.H.; Siegel-Causey, D., eds. The status ecology, and conservation of marine birds of the north Pacific. Spec. Publ. Ottawa: Canadian Wildlife Service, Environment Canada: 140-153.

“Sand lance are important prey of black-legged kittiwakes at many colonies in the Gulf of Alaska and also at Bluff and St. Lawrence Island, Cape Peirce and Agattu Island.”

Keywords: *A. hexapterus*; Alaska; importance; predators (birds, black-legged kittiwake).

**Hatch, S.; Nettleship, D.N.; Sanger, G.A.; Springer, P.F. 1984.** Nestling diet and feeding rates of rhinoceros auklets in Alaska. In: Marine birds: their feeding ecology and commercial fisheries relationships; 1982; 6-8 Jan.; Seattle, WA. Ottawa: Canadian Wildlife Service: 106-115.

“Food brought to nestling rhinoceros auklets (*Cerorhinca monocerata*) was sampled by applying tape or cloth muzzles to the chicks and collecting the uningested food from the burrow daily. Limited data were also gathered for tufted and horned puffins (*Fratercula cirrhata* and *F. corniculata*). Auklet chicks received an average of 34.1 g

of food per night at Middleton Island in 1978, and 32.8 per night at the Semidi Islands in 1979. Pacific sandlance (*Ammodytes hexapterus*) made up the bulk of the diet at both locations, and large, second-year or older fish predominated in the samples. In contrast, horned and tufted puffins took mostly small, first-year fish during the same seasons."

Keywords: *A. hexapterus*; Alaska; predators (birds, horned puffin, rhinoceros auklet, tufted puffin).

**Hatch, S.A.; Nysewander, D.R.; DeGange, A.R. [and others]. 1978.** Population dynamics and trophic relationships of marine birds in the Gulf of Alaska and southern Bering Sea. In: Environmental assessment of the Alaskan Continental Shelf: annual reports of principal investigators for the year ending March 1978. [Place of publication unknown]: National Oceanic and Atmospheric Administration. Vol. 3.

No detailed observations were made of prey items taken by cormorants, but incidental notes and observations indicate that capelin and sand lance are probably two of the most important prey species.

Glaucous-winged gulls are catholic in their choices of food. At Sitkalidak Strait, fish comprised the bulk of the diet, with capelin occuring in 78 percent and sand lance in 23 percent of regurgitation samples from chicks. Adults also ate sand lance.

Capelin and sand lance were the predominant prey items for black-legged kittiwake found at all study sites. At Ugaiushak Island, sand lance was the most frequently observed food item during the first half of the nestling period, and walleye pollock and capelin became more important in the latter part of the nestling period. Differences were found at Kodiak Island between the diets of kittiwakes collected offshore and those at colonies, the latter including both adults and chicks. The percentages of capelin were similar, 60 and 61.2 percent by volume, but sand lance were more frequent prey items at colonies: 43.1 percent compared to 8.5 percent.

Seventy-four percent of the diet of arctic terns at Sitkalidak was composed of capelin and sand lance.

Both capelin and Pacific sand lance were identified in the diet of murre chicks at Barren Islands. Stomach contents of 27 adult common murres in the Kodiak region from late May to mid-September contained 11 percent by volume of Pacific sand lance.

Horned puffins depend on a limited number of prey species as food for chicks. At the Barren Islands, capelin, and to a lesser extent sand lance, were the most important fish species brought to young. On Ugaiushak Island, sand lance was the principal prey species.

Food of nestling tufted puffins at Ugaiushak Island, Barren Islands, Chiniak Bay, and Sitkalidak Strait was primarily capelin and Pacific sand lance.

"Recommendations: Studies should focus on variations that are caused by changes in availability of food or those caused by large scale climatic or oceanographic phenomena, which may also relate to food supply, as such factors appear to be of primary long-term importance to establishment of reproductive rates and patterns. Because of the apparent importance of food in determining overall productivity of birds within a region, studies on colonies should be integrated to the greatest extent possible with other studies, in particular those of trophic dynamics, and of distribution patterns of birds at sea, as the latter are almost certainly related to variation in the distribution and abundance of food. We consider the value of trophic studies, regardless of the care or detail with which they are planned and conducted, to be relatively limited, unless the results of such studies ultimately contribute to a better understanding of reproduction, growth, and survival of species which are of primary public concern—commercial fishes, marine mammals, and marine birds."

Keywords: *A. hexapterus*; Alaska; Bering Sea; Gulf of Alaska; importance; predators (birds, cormorants, glaucous-winged gull, black-legged kittiwake, arctic tern, common murre, horned puffin, tufted puffin).

**Hatch, S.A.; Pearson, T.W.; Gould, P.J. 1979.** Reproductive ecology of seabirds at Middleton Island, Alaska. In: Environmental assessment of the Alaskan Continental Shelf: annual reports of principal investigators. Boulder, CO: National Oceanic and Atmospheric Administration, Environmental Research: 233-308. Vol. 2.

For black-legged kittiwake, 40 regurgitations were collected from chicks of various ages. Fish, mostly Pacific sand lance, constitued nearly 80 percent of the diet by weight. The diet of rhinoceros auklet chicks consisted almost entirely of Pacific sand lance. Sand lance constituted 81.3 percent of the food samples from tufted puffin chicks.

Keywords: *A. hexapterus*; Alaska; Middleton Island; importance; predators (birds, black-legged kittiwake, rhinoceros auklet, tufted puffin).

**Hatchwell, B.J. 1991.** The feeding ecology of young guillemots *Uria aalge* on Skomer Island, Wales. Ibis. 133: 153-161.

“Chick diet, provisioning rates, foraging trip duration and chick growth of an increasing population of guillemots *Uria aalge* were studied on Skomer Island, Wales, in 1985-87. Chicks were fed a higher proportion of sandeels *Ammodytes tobianus* (21%) than in 1973-75 (< 1%). There was a seasonal increase in the proportion of sprats *Sprattus sprattus* and the size of prey fed to young, but this was probably a consequence of selection of prey according to chick age rather than an effect of date per se. There was also a diurnal increase in the proportion of sprats fed to chicks and a peak of chick feeding in the early morning. Feeding rates varied with chick age, 6-8-day-old chicks being fed at the highest rate of 4.6 feeds/chick/day, with an estimated daily calorific intake of about 370 kJ. The mean calorific value of prey did not differ from 1973 to 1975 but provisioning rates were significantly higher than in 1973-75 and foraging trips were significantly shorter, suggesting an increase in food availability.”

Keywords: *A. tobianus*; Wales; energetics; predators (birds, guillemot).

**Haug, T.; Gjoesaeter, H.; Lindstroem, U.; Nilssen, K.T. 1993.** Studies of minke whale *Balanoptera acutorostrata* ecology in the northeast Atlantic: preliminary results from studies of diet and food availability during summer 1992. Dublin (Eire). 32.

“Stomach content samples from 92 minke whales *Balaenoptera acutorostrata*, caught during scientific whaling operations in July-August 1992, were collected in five selected areas in Norwegian and adjacent waters. Preliminary results from the stomach analyses indicate a diet almost completely dominated by fish, although there was consi derable heterogeneity in species composition between the areas. Capelin (*Mallotus villosus*) dominated the minke whale diets in the two northernmost study areas (Spitsbergen and Bear Island). Further south, in coastal areas of North Norway and Russia, herring (*Clupea harengus*) was the most important food item, but was accompanied by significant amounts of sand eel (*Ammodytes*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*). A survey aimed to locate and classify fish and plankton resources was conducted simulta-neously with the scientific whaling program. The northern areas were particularly dominated by 0-group cod (which was not found in whale stomachs), while capelin abundance was recorded only sporadically.”

Keywords: *Ammodytes*; Norway; predators (mammals, minke whale).

**Haug, T.; Gjosaeter, H.; Lindstrom, U.; Nilssen, K.T. 1995.** Diet and food availability for north-east Atlantic minke whales (*Balaenoptera acutorostrata*), during the summer of 1992. ICES Journal of Marine Science. 52(1): 77-86.

“Stomach content samples from 92 minke whales, *Balaenoptera acutorostrata*, caught during scientific whaling operations in July-August 1992, were collected in five selected areas in Norwegian and adjacent waters. Results from the stomach analyses indicate a diet almost completely dominated by fish, although there was considerable heterogeneity in species composition between the areas. Capelin dominated the minke whale diets in the two north-ernmost study areas (Spitsbergen and Bear Island). Further south, in coastal areas of northern Norway and Russia, herring was the most important food item, but was accompanied by significant amounts of sand eel, cod, haddock, and saithe. A survey aimed to locate and classify fish and plankton resources was conducted simultaneously with the scientific whaling programme. The northern areas were dominated by 0-group cod (which was not found in

whale stomachs), while capelin abundance was recorded only sporadically. Along the coast of northern Norway and Russia, there appeared to be a greater similarity between prey abundance and minke whale diet. Herring was very abundant both in the resource surveys and in the whale stomachs. The similarity in distribution was particularly evident for 0-group herring."

Keywords: *Ammodytes*; Norway; predators (mammals, Atlantic minke whale).

**Haug, T.; Gjosaeter, H.; Lindstrom, U. [and others]. 1995.** Spatial and temporal variations in northeast Atlantic minke whale *Balaenoptera acutorostrata* feeding habits. In: Blix, A.S.; Walloe, L; Ulltang, O., eds. Whales, seals, fish and man: Proceedings of the international symposium on the biology of marine mammals in the north east Atlantic; 1994 Nov. 29-Dec. 1; Tromsø, Norway. [Place of publication unknown]: [Publisher unknown]: 225-239.

Keywords: *Ammodytes*; Barents Sea; predators (mammals, Atlantic minke whale).

**Hauksson, E. 1984.** Food of the common seal (*Phoca vitulina* L.) and grey seal (*Halichoerus grypus* Fabr.) in Icelandic waters. Hafrannsoknir. 30: 27-65.

"In the period 1979-82 the content of the alimentary canal of 193 common seals and 97 grey seals was investigated for remains of food. Remains of cod (*Gadus morhua* L.) and sandeel (*Ammodytes* spp.), were by far the most common, occuring over 40% of the samples of each seal species. In percent by weight of food, the most important food species of common seal is saithe (33.4%), then cod (23.9%), sandeel (9.9%) and whiting (*Merlangius merlangus merlangus* L.), catfish, dab, capelin, all over 2.5% in importance. The most important food species of grey seal by weight are: cod (22.0%), sea scorpions (12.6%), lumpsucker (11.9%) and catfish (11.1%). Then halibut (*Hippoglossus hippoglossus* L.), saithe, herring (*Clupea harengus harengus* L.) and sandeel with over 5% in importance."

Keywords: *Ammodytes*; Iceland; predators (mammals, common seal, grey seal).

**Hauksson, E. 1992.** Larval anisakine nematodes in various fish species from the coast of iceland. Hafrannsoknir. (43): 107-123.

"In flatfishes and sand eels, larvae of Contracaecum and Hysterothylacium are most abundant."

Keywords: *Ammodytes*; Iceland; parasites.

**Hauksson, E.; Olafsdottir, D.; Blix, A.S. [and others]. 1995.** Grey seal (*Halichoerus grypus* Fabr.), population biology, food and feeding habits, and importance as a final host for the life-cycle of sealworm (*Pseudoterranova decipiens* Krabbe) in Icelandic waters. In: Blix, A.S.; Walloe, L.; Ulltang, O., eds. Whales, seals, fish and man: Proceedings of the international symposium on the biology of marine mammals in the north east Atlantic; 1994 Nov. 29-Dec. 1; Tromsø, Norway. [Place of publication unknown]; [Publisher unknown]: 4.

Seals from the south coast of Iceland feed largely on sand eels in all seasons.

Keywords: *Ammodytes*; Atlantic (northeast); predators (mammals, grey seal).

**Hawkins, A.D. 1996.** Sandeels, salmon smolts, seabirds, seals and sea fisheries. Salmon Net. 27: 33-40.

Keywords: *A. marinus*; Scotland; distribution.

**Hay, D.E.; Healey, M.C.; Richards, L.J.; Marliave, J.B. 1989.** Distribution, abundance, and habitat of prey fishes in the Strait of Georgia. In: Vermeer, K.; Butler, R.W., eds. The ecology and status of marine and shoreline birds in the Strait of Georgia, British Columbia. Spec. Publ. [Place of publication unknown]: Canadian Wildlife Service: 37-49.

“The Pacific sandlance does not fit easily into any category. It is often a shallow-water species, but frequently it inhabits deeper water. We know very little about this species in local waters. Bases on examination of gut contents of avian and fish predators, sandlance frequently are present and are a major component of diets. Sandlance spawns during late winter and early spring, and its larvae are common in nearshore waters in March, April, and May, at which time they provide a substantial source of food to seabirds.”

Keywords: *A. hexapterus*; Canada; Strait of Georgia; distribution; importance; predators (birds).

**Haycock, K.A.; Threlfall, W. 1975.** The breeding ecology of the herring gull in Newfoundland. Auk. 92: 678-697.

Keywords: *A. americanus*; Newfoundland; predators (birds, herring gull).

**Hayes, D.L.; Kuletz, K.J. 1997.** Decline of pigeon guillemot populations in Prince William Sound, Alaska, and apparent changes in distribution and abundance of their prey. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]; [location unknown]. Rep. 97-01. [Fairbanks, AK]: University of Alaska Fairbanks, Alaska Sea Grant College Program: 699-702.

“Pigeon guillemots are cavity-nesting, pursuit-diving seabirds that forage in the nearshore environment on both demersal and schooling fish. Since the late 1970’s and early 1980’s, there has been a dramatic change in the diet of pigeon guillemot chicks on Naked Island in Prince William Sound. In the years 1979-1981 Pacific sand lance (*Ammodytes hexapterus*) were the single largest component (42%) of the diet, while in the four years 1989-1990 and 1994-1995, sand lance accounted for a much smaller fraction (12%) of the diet. The increase in the proportion of gadids has been equally dramatic, from 4% to 23% for these same periods. Demersal fish such as gunnels (Pholidae), pricklebacks (Stichaeidae), and sculpins (Cottidae) have always been an important component of the diet, although their relative contribution has increased. Other schooling fish in the chick diet include herring and capelin, but their relative contributions have varied widely from year to year. The overall population of guillemots at Naked Island has decreased from about 2,200 in 1979 to about 1,300 today. The percent of breeding birds among these also appears to have decreased. The decline of guillemot populations in Prince William Sound, and their failure to recover, may be related to this apparent decline in sand lance. In fact, the presence of schooling forage fish, especially sand lance or herring, may be essential for maintaining large, productive cononies of pigeon guillemots in Alaska.”

Keywords: *A. hexapterus*; importance; predators (birds, pigeon guillemot).

**Hays, H. 1973.** Common tern, arctic tern, roseate tern, and sandwich tern carrying multiple fish. Wilson Bulletin. 85(2): 233-236.

Keywords: *A. marinus*; predators (birds, arctic tern, common tern, roseate tern, sandwich tern).

**Healey, M.C. 1978.** The distribution, abundance, and feeding habits of juvenile Pacific salmon in Georgia Strait, British Columbia. Tech. Rep. 788. [Place of publication unknown]: Fisheries Marine Service. 49 p.

Keywords: *A. hexapterus*; British Columbia; predators (fish, chinook salmon, coho salmon).

**Healey, M.C. 1980.** The ecology of juvenile salmon in Georgia Strait, British Columbia. In: McNeil, W.J.; Himsworth, D.C., eds. Salmonid ecosystems of the north Pacific. Corvalis, OR: Oregon State University Press: 203-229.

Keywords: *A. hexapterus*; British Columbia; predators (fish, Pacific salmon).

**Healey, M.C. 1991.** Life history of chinook salmon (*Oncorhynchus tshawytscha*). In: Groot, C.; Margolis, L., eds. Pacific salmon life histories. Vancouver, BC: University of British Columbia Press.

In general the importance of herring and sand lance increases from south to north; i.e., sand lance are more important north of Washington.

Keywords: *A. hexapterus*; importance; predators (fish, chinook salmon).

**Hedgren, S. 1976.** Om sillgrisslans *Uria aalge* foda vid Stora Karlso. Var Fagelvarld. 35: 287-290.

Keywords: *Ammodytes*; predators (birds, guillemot).

**Heese, T. 1996.** Investigation of the fish fauna in the Parseta and Leba Estuary of the Polish coastal zone. In: Proceedings of the international symposium on usage of the database of selected species; [dates of meeting unknown]; Vilnius, [Lithuania]. [Place of publication unknown]: [publisher unknown]: 25-26.

“In the Leba Estuary (Poland) the existences of only 13 species were confirmed, and the following species were caught: sprat (*Sprattus sprattus*), herring (*Clupea harengus*), small sandeel (*Ammodytes tobianus*), greater sandeel (*Hyperoplus lanceolatus*), garfish (*Belone belone*), flounder (*Platichthys flesus*), turbot (*Psetta maxima*), sea trout (*Salmo trutta*), smelt (*Osmerus eperlanus*), bream (*Abramis brama*), roach (*Rutilus rutilus*), perch (*Perca fluviatilis*) and pikeperch (*Stizostedion lucioperca*). The area near the Perseta mouth is depending on the Pomeranian Bay water (the Odra river estuary) and for that reason the quantitative difference for the species number between the Perseta and Leba estuary is observed. The area near the Leba mouth depends on the open sea water. The greatest fish biomass estimated in the Parseta mouth is formed by sand eels fishes (*Ammodytidae*), and near the Ueba by flatfish-flounder (*Platichthys flesus*) and turbot *(Psetta maxima*).”

Keywords: *A. tobianus*; *H. lanceolatus*; Poland; abundance; distribution; estuaries.

**Hellberg, H.; Moksness, E.; Hoie, S. 1996.** Infection with atypical *Aeromonas salmonicida* in farmed common wolffish, *Anarhichas lupus* L. Journal of Fish Disease. 19(4): 329-332.

“Atypical *Aeromonas salmonicida* is associated with disease in several marine species such as sablefish, *Anoplopoma fimbria*, Atlantic cod, *Gadus morhua* L., sand-eels, *Ammodytes lancea* (Cuvier) and *Hyperoplus lanceolatus* (Lesauvege), turbot, *Scophthalmus maximus* L., shotted halibut, *Eopsetta grigorjewi* (Hevzenstein), flounder, *Platichthys flesus* L., and common wolffish, *Anarhichas lupus* L. Ulcers are frequently demonstrated during infections with atypical *A. salmonicida*. However, other lesions such as intestinal hyperaemia and furuncules have been seen in sand-eels. Laboratory experiments with common and spotted wolffish, *Anarhichas minor* (Olafsen), have been performed a[t] Flodevigen Marine Research Station since 1987. The expected mortality in established laboratory systems is about 0.5% per month. In an experiment comprising 10 spawning stock groups of common wolffish, increased mortality was recorded in five groups from July to October 1993.”

Keywords: *A. lancea*; *H. lanceolatus*; disease.

**Helmich, J.F.; Cahn, P.H.; Siler, W. 1982.** Behavioral studies on a zooplankton feeding forage fish *Ammodytes americanus* the American sand lance. In: Annual meeting of the American Society of Zoologists, American Microscopical Society, Animal Behavior Society, Crustacean Society, International Association of Astacology, and the Society of Systematic Zoology; [dates of meeting unknown]; Louisville, KY. [Place of publication unknown]: [publisher unknown]: 852.

Keywords: *A. hexapterus*; behavior; food and feeding habits; olfaction; vision.

**Hemmings, C.C. 1973.** Direct observation of the behavior of fish in relation to fishing gear. Helgolaender Wissenschaftliche Meeresuntersuchungen. 24(1-4): 348-360.

Keywords: *Ammodytes*; fisheries; net avoidance.

**Hempel, G. 1978a.** Fish eats fish: food chains and catches in the North Sea. Umschau. 78(9): 271-276.

"Total landings of North Sea fisheries have drastically increased in the 1960s and early 1970s. The structure of the fishery has changed by the development of the industrial fishery exploiting hitherto unwanted fish species like sprat, sand-eel and Norway pout. Presently more North Sea fish is used for fish meal than for human consumption. At the same time the productivity of the traditionally exploited stocks has changed. While herring has declined most other fish stocks became more productive by faster growth rate of the young fish and by improved recruitment. The paper discusses the position of fish in the complex food web of the North Sea and the possible effects of climate on food supply for fish larvae and older fish. Eutrophication and pollution seem of minor importance so far. Predator-prey relationships between species and age groups of fish have been upset by the decrease in herring and mackerel stocks. Those indirect effects of fisheries on marine ecosystems should be taken into account in future management of multispecies fisheries."

Keywords: *Ammodytes*; North Sea; catch; ecology; fisheries; food chain; pollution; spawning.

**Hempel, G. 1978b.** North Sea fisheries and fish stocks—a review of recent changes. Rapports et Procès-Verbaux des Reunions Conseil International pour l'Exploration de la Mer. 164: 57-68.

Keywords: *Ammodytes*; North Sea; fisheries.

**Henderson, G.T.D. 1954.** Continuous plankton records; the young fish and fish eggs, 1932-39 and 1946-49. Hull Bulletin of Marine Ecology. 3: 215-252.

Keywords: *Ammodytes*; eggs; larvae.

**Herman, S.S. 1963.** Planktonic fish eggs and larvae of Narragansett Bay. Limnology and Oceanography. 8: 103-109.

Keywords: *Ammodytes*; Narragansett Bay; eggs; larvae.

**Herra, T. 1986**. Field and laboratory studies of herring larvae (*Clupea harengus*) from the Gulf of Gdansk. Ophelia. S4: 63-72.

Keywords: *Ammodytes*; Poland; larvae.

**Herra, T. 1988.** Ichthyoplankton survey in the southern Baltic in August 1987. In: Council meeting of the International Council for the Exploration of the Sea. Bergen, [Norway]: [publisher unknown]: 17.

"This paper deals with the ichthyoplankton material collected onboard the R/V 'Professor Siedlecki' during the interdisciplinary survey in the southern Baltic in August 1987. Sprat eggs and larvae as well as gobies and sandeel larvae predominate in the ichthyoplankton. Low temperatures of surface waters were responsible for late start of sprat summer spawning and low growth rate of their larvae. The appearance of newly-spawned eggs showed that sprat spawned at night. Horizontal changes of mean lengths revealed a drift of sprat larvae from west to east. Low abundance of sprat eggs and larvae in the near-shore areas may be a result of predation on the part of the medusa *Aurelia aurita*."

Keywords: *Ammodytes*; Baltic Sea; larvae.

**Hertling, H. 1928.** Quantitativ Nahrungsuntersuchungen an Pleuronectiden und einigen anderen Fishchen der Ostsee. Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung. 4(1): [page numbers unknown].

Keywords: *Ammodytes*; Baltic Sea; predators (fish, cod).

**Heubeck, M. 1989a.** Breeding success of Shetland's seabirds: arctic skua, kittiwake, guillemot, razorbill and puffin. In: Heubeck, M., ed. Seabirds and sandeels. Proceedings of Shetland Bird Club seminar; 1988 [dates unknown]; Lerwick, Shetland. Lerwick, Shetland: Shetland Bird Club: 11-18.

Keywords: *Ammodytes*; Shetland; predators (birds, arctic skua, guillemot, kittiwake, puffin, razorbill).

**Heubeck, M., ed. 1989b.** Seabirds and sandeels: Proceedings of a seminar; 1988 Oct. 15-16; Lerwick, Shetland, Lerwick, Shetland: Shetland Bird Club.

Keywords: *A. marinus*; predators (birds).

**Heubeck, M. 1990.** Arctic terns and the Shetland sandeel fishery. Devon Birds. 43(3): 51-52.

Keywords: *Ammodytes*; Shetland; anthropogenic impacts; fisheries; predators (birds, arctic tern).

**Hill, J.K. 1994.** Do great skuas *Catharacta skua* respond to changes in the nutritional needs of their chicks? Seabird. 16: 3-7.

Keywords: *A. marinus*; North Sea; Shetland; predators (birds, great skua).

**Hirsa, I.I. 1978.** Peculiarities in the defensive-feeding behaviour of young herring, sand eels, three-spined sticklebacks and bullheads in the White Sea during summer in diurnal currents. In: Lapin, Y.E., ed. Ecology of fish from the White Sea. Nauka, Moscow, [USSR]: [publisher unknown]: 136-153.

Keywords: *A. hexapterus*; USSR; White Sea; food and feeding habits.

**Hislop, J.R.G. 1984.** A new approach to the estimation of natural mortality. Scottish Fisheries Bulletin. 48: 43-45.

"To test hypotheses made in fish stock assessment that natural mortality of fish is approximately equals 10%-20%/yrs, diminishes with fish age and size, and that a major cause is predation, extensive international investigations were instigated to determine numbers of commercially important species eaten by North Sea cod, haddock, whiting, saithe and mackerel. Preliminary analysis of whiting (*Merlangius merlangus*) stomachs sampled by the Marine Laboratory, Aberdeen, in 1981 indicated that the whiting population ate at least 500,000 tonnes of fish annually, mostly small and young ones of commercially important species (particularly cod, herring, whiting, Norway pout, sprats, herring, sandeels). Age composition and numbers of predators and prey must be estimated and co-ordinated with results from other sampled species. Because of annual food variation a follow-up sampling is planned for 1985. It is suggested that North Sea fish stocks might be profitably managed as a group of species forming a complex ecosystem."

Keywords: *Ammodytes*; North Sea; fisheries; importance; mortality; predators (fish, whiting).

**Hislop, J.R.G. 1988.** The influence of maternal length and age on the size and weight of the eggs and the relative fecundity of the haddock, *Melanogrammus aeglefinus*, in British waters. Journal of Fish Biology. 32(6): 923-930.

Keywords: *Ammodytes*; British Isles; predators (fish, haddock).

**Hislop, J.R.G.; Harris, M.P. 1985.** Recent changes in the food of young puffins *Fratercula arctica* on the Isle of May in relation to fish stocks. Ibis. 127: 234-239.

"During the period 1971-76 sandeels and sprats were by far the most important food of young British Puffins. Each year sandeels, sprats and herring together accounted for at least 85% by number, and 90% by weight, of the total food collected. In numerical terms sandeels were more important than sprats and herring in all years except 1975 but the latter two species made the greater contribution in terms of weight during the period 1974-78."

Keywords: *Ammodytes*; Scotland; Isle of May; importance; predators (birds, puffin).

**Hislop, J.R.G.; Harris, M.P.; Smith, J.G.M. 1991.** Variation in the calorific value and total energy content of the lesser sandeel (*Ammodytes marinus*) and other fish preyed on by seabirds. Journal of Zoology, London. 224: 501-517.

“Compares wet and dry calorific values (energy densities) and total energy content of lesser sandeel *A. marinus* to sprat, Atlantic herring, whiting, saithe and cod. The calorific values and body weights of sandeels larger than 10 cm showed marked seasonal trends and in consequence the total energy content of a sandeel of given length in summer is approximately double the spring value. Sandeel have maximum calorific values intermediate between those of gadoids and clupeoids.

“Juvenile sandeels (<10 cm) which have low body weights and a high water content, would seem, on purely energetic grounds, to be low quality food, even though they are usually, or can often be, the commonest prey brought to young puffins, razorbills, kittiwakes, Arctic terns, common terns, sandwich terns and fulmars, species which feed at or within a few tens of metres of the surface. Puffins can carry more than 60 small fish in their beak so that when forced to feed on small sandeels they can still bring back several grams of fish from each feeding trip. There is, however, a significant negative relationship between the weight of the load and the size of the fish comprising the load and puffins feeding their young on small fish, and on low quality gadoids, tend to have low breeding success. Seabirds which can dive deeper guillemot and shag usually feed their young on larger sandeels, of higher energy value, though these also on occasions bring back numbers of small individuals.”

Keywords: *A. marinus*; calorific value; energy density; importance; predators (birds).

**Hislop, J.R.G.; Robb, A.P.; Bell, M.A.; Armstrong, D.W. 1991.** The diet and food consumption of whiting *Merlangius merlangus* in the North Sea. International Council for the Exploration of the Sea Journal of Marine Science. 48(2): 139-156.

“The stomachs of more than 19000 North Sea whiting were examined in 1981. Almost 50% were either empty or were judged to have lost all or part of their contents through regurgitation. The contents of the remaining stomachs (approximately 9800) were analysed. The bulk of the fish prey consisted of seven species (cod, haddock, whiting, Norway pout, sprat, herring, and sandeels), each of which is of considerable economic importance. Although whiting feed on fish representing the entire range of age classes of the smaller fish species (Norway pout, sprat, and sandeels) they eat mainly the youngest (0+ and 1+) age classes of herring, cod, haddock, and whiting. Quantifying the food requirments of fish species is notoriously difficult, but attempts have been made to estimate the annual food consumption by whiting in the North Sea. It is concluded that whiting may be one of the most important piscivorous fish in the North Sea.”

Keywords: *Ammodytes*; North Sea; predators (fish, whiting).

**Hislop, J.R.G.; Webb, J.H. 1992.** Escaped farmed Atlantic salmon *Salmo salar* L. feeding in Scottish coastal waters. Aquaculture and Fisheries Management. 23(6): 721-723.

“Escaped reared salmon, *Salmo salar* L., were distinguished from wild salmon in the catch of a coastal salmon fishery on the west coast of Scotland [UK]. The stomach contents of 54 escaped fish were examined to determine their recent feeding history and 19 (35%) were found to contain food. The predominant prey were juvenile whiting, *Merlangius merlangus* (L.), unidentified Gadidae and sandeels (Ammodytidae), although other fish and invertebrates, mainly post-larval hermit crabs (Paguridae), were recorded. All these prey are pelagic or semi-pelagic. These observations demonstrate that escaped salmon feed on natural prey in coastal waters and extend our knowledge of the diet of salmon in their marine phase.”

Keywords: *Ammodytes*; Scotland; predators (fish, Atlantic salmon).

**Hjort, J. 1914.** Fluctuations in the great fisheries of Europe, viewed in the light of biological research. Rapports et Procès-Verbaux des Reunions Conseil International pour l’Exploration de la Mer. 20: 1-228.

Keywords: *Ammodytes*; fisheries.

**Hobson, E.S. 1986.** Predation on the Pacific sand lance *Ammodytes hexapterus* (Pisces: Ammodytidae), during the transition between day and night in southeastern Alaska. Copeia. 1: 223-226.

“The Pacific sand lance is particularly vulnerable to predators during a changeover between distinctive diurnal and nocturnal modes of behavior. This conclusion developed from observations in southeastern Alaska during 10 days of May 1978. At that time, sand lance (110-150 mm SL) were attacked by a variety of predators in a small cove (area about 2 ha, maximum depth about 25 m) at the head of Steamer Bay, Etolin Island (56° N, 133° W). Twelve hours of general observations spread over the diel cycle showed predation on sand lance concentrated during the transition between day and night.”

Keywords: *A. hexapterus*; Alaska; behavior; predators.

**Hobson, K.A.; Piatt, J.F.; Pitoccheli, J. 1994.** Using stable isotopes to determine seabird trophic relationships. Journal of Animal Ecology. 63: 786-798.

Keywords: *A. hexapterus*; Alaska; Canada; predators (birds); stable isotopes; trophic relationships.

**Hoffman, W.; Heinemann, D.; Wiens, J.A. 1981.** The ecology of seabird feeding flocks in Alaska. Auk. 98: 437-456.

Keywords: *A. hexapterus*; Alaska; predators (birds).

**Hoines, A.; Bergstad, O.A. 1994.** Feeding ecology of haddock (*Melanogrammus aeglefinus* L.) and cod (*Gadus morhua* L.) at a herring spawning ground. Journal of Fish Biology. 45(A): 248.

“Sandeel (*Ammodytes marinus*) was the dominant prey of cod throughout the period, whereas haddock fed mainly on benthic prey such as Ophiuroidea and Polychaeta.”

Keywords: *A. marinus*; North Sea; Norway; predators (fish, cod).

**Holden, M.J. 1966.** The food of the spurdog, *Squalus acanthias* (L). Journal du Conseil, Conseil International pour l’Exploration de la Mer. 30(2): 255-266.

“The stomach contents of 1,080 spurdogs were examined: sandeels were found to be the commonest prey species; herring were found in only 11.5% of the stomachs containing food. Using maintenance and conversion rates obtained by other workers the food intake of the Scottish-Norwegian stock of spurdogs is estimated at 227,000 tons a year.”

Keywords: *Ammodytes*; Britain; predators (fish, spurdog).

**Holleland, T.; Fyhn, H.J. 1986.** Osmotic properties of eggs of the herring *Clupea harengus.* Marine Biology. 91(3): 377-383.

Keywords: *Ammodyte*s; eggs.

**Holmgren-Urba, D.; Baumgartner, T.R. 1993.** A 250-year history of pelagic fish abundances from the anaerobic sediments of the central Gulf of California. California Cooperative Oceanic Fisheries Investigations Reports. 34: 60-68.

Keywords: *A. hexapterus*; California; historical.

**Holmquist, C. 1958.** An observation on young specimens of *Ammodytes dubius*. Meddelser om Grønland. 159(2): 11-13.

Fish collected from pool on piece of iceberg in Disko Bugt, west Greenland: taxonomy, distribution and ecology problems.

Keywords: *A. dubius*; Greenland; distribution.

**Homans, R.E.S.; Needler, A.W.H. 1944.** Food of the haddock. Proceedings of the Nova Scotian Institute of Science. 21: 15-49.

Keywords: *A. americanus*; Nova Scotia; predators (fish, haddock).

**Hoover, A.A. 1983.** Behavior and ecology of harbor seals (*Phoca vitulina* Richardsi) inhabiting glacial ice in Aialik Bay, Alaska. Fairbanks, AK: University of Alaska. M.S. thesis.

Keywords: *A. hexapterus*; Alaska; predators (mammals, harbor seal).

**Hopkins, P.J. 1989.** Herring predation on fish eggs and larvae in the North Sea. Rapports et Procès-Verbaux des Reunions Conseil International pour l'Exploration de la Mer. 191: 459.

"Larvae found in the stomachs were mainly of *Ammodytes* sp., with some unidentified cluepeids."

Keywords: *Ammodytes*; North Sea; predators (fish, herring).

**Hopkins, P.J.; Blaxter, J.H.S.; Gamble, J.C.; Westernhagen, H. 1989.** Herring predation on fish eggs and larvae in the North Sea. In: The early life history of fish: The third ICES symposium; Bergen, [Norway]. Copenhagen, [Denmark]: ICES. Rapports et Procès-Verbaux des Reunions Conseil International pour l'Exploration de la Mer. Cium. 191: 459.

"The incidence of fish eggs and larvae in *Clupea harengus* stomachs was recorded in the North Sea in April/May 1987 and 1988. Larvae found in the stomachs were mainly of *Ammodytes* sp., with some unidentified clupeids. Predation on the larvae appeared to be very localized geographically. In areas of high incidence, large numbers were also commonly found in a single stomach. The condition of the larvae and their location within the stomachs suggested that there has been a recent opportunistic switch in feeding from copepods to larvae. The results indicate that predation on larvae is sporadic and might be intense when patches are encountered."

Keywords: *Ammodytes*; North Sea; eggs; larvae; predators (fish, herring).

**Hori, S. 1990.** Survey project on a countermeasure of the control of cold water fishes: on a sandeel. Ibaraki–Ken Suisan Shikenjo Jigyo Hokoku. 1989: 77-82, 84-107.

Keywords: *A. personatus*; Japan; catch; fisheries; larvae; temperature.

**Hori, T. 1991.** Study program for the management strategy of cold water fish: on sandeel. Ibaraki–Ken Suisan Shikenjo Jigyo Hokoku. 1990: 81-111.

Keywords: *A. personatus*; Japan; annual variation; catch; fisheries; growth; larvae; temperature.

**Hori, T. 1992**. Recent trends of sand-launce stock related to the change of sea temperature. Suisan Kaiyo Kenkyu. 56(2): 142-145.

Keywords: *A. personatus*; Japan; annual variation; catch; development; larvae; temperature.

**Hori, Y. 1995.** On sand lance fishing condition and oceanographic condition of the coast in Ibaraki Prefecture. Ibaraki-Ken Suisan Shikenjo Kenkyu Hokoku. 33: 11-19.

Keywords: *A. personatus*; Japan; catch; fisheries; recruitment; temperature.

**Horst, T.; Lawton, R.; Toner, R.; Scherer, M. 1984.** Seasonal abundance and occurrence of some planktonic and ichthyofaunal communities in Cape Cod Bay evidence for biogeographical transition. In: Davis, J.D.; Merriman, D., eds. Lecture notes on coastal and estuarine studies: observations on the ecology and biology of western Cape Cod Bay, Massachusetts. Berlin, West Germany; New York City: Springer–Verlag: 11: 241-262.

Keywords: *Ammodytes*; Atlantic (northwest); larvae; seasonal abundance.

**Horsted, S.A. 1991.** Biological advice for and management of some of the major fisheries resources in Greenland waters. In: Management under uncertainties related to biology and assessments, with case studies on some north Atlantic fisheries; 1990 Sept. 5; Halifax, NS. [Place of publication unknown]: NAFO Scientific Council Studies: 79-94. Vol. 16.

“The biological knowledge on, advice for and management of some important fishery resources in Greenland waters are considered. Sand eel (*Ammodytes lancea*) and capelin (*Mallotus villosus*) are considered as a group, since both species are potential resources for industrial fisheries but so far have been very lightly exploited, and both are important prey for commercially important fish species and for marine mammals.”

Keywords: *A. lancea*; Greenland; fisheries; stock assessment.

**Hostens, K.; Hamerlynck, O. 1994.** The mobile epifauna of the soft bottoms in the subtidal Oosterschelde Estuary: structure, function and impact of the storm-surge barrier. In: Nienhuis, P.H.; Smaal, A.C., eds. The Oosterschelde Estuary (The Netherlands): a case-study of a changing ecosystem. Hydrobiologia. 282/283: 479-496. FR 39(4).

Keywords: *A. tobianus*; Netherlands; environmental impact.

**Houde, E.D.; Zastrow, C.E. 1993.** Ecosystem-specific and taxon-specific dynamic and energetics properties of larval fish assemblages. Bulletin of Marine Science. 53(2): 290-335.

“Growth rates, mortality rates, and energetics properties of teleost larvae differ among species and among ecosystems. In this synthesis, the ingestion rates required to support mean growth of larvae were estimated and energy budgets were developed. Results of the analyses will be useful to categorize, compare, and model ichthyoplankton assemblages in pelagic communities.”

Keywords: *A. americanus*; energetics; growth; larvae; mortality; temperature.

**Houghton, J.P. 1987.** Forage fish use of inshore habitats north of the Alaska Peninsula. Proceedings of forage fishes of the southeastern Bering Sea; 4-5 Nov. 1986; Anchorage, AK. [Place of publication unknown]: [publisher unknown]: 39-47.

Keywords: *A. hexapterus*; Alaska; abundance; distribution; habitat.

**Houghton, J.P.; Isakson, J.S. 1989.** Fish use of inshore habitats along the north side of the Alaska Peninsula. In: Jarvela, L.E.; Thorsteinson, L.K., eds. Proceedings of the Gulf of Alaska, Cook Inlet, and North Aleutian Basin information update meeting; [dates of meeting unknown]; [location unknown]. OCS study, MMS 89-0041. [Place of publication unknown]: [publisher unknown]: 7-16.

Keywords: *A. hexapterus*; Alaska; abundance; distribution; habitat.

**Hudson, A.V. 1986.** The biology of seabirds utilising fishery waste in Shetland. [Glasgow, Scotland]: University of Glasgow. Ph.D. dissertation.

Keywords: *Ammodytes*; Shetland; predators (birds).

**Hudson, P.J. 1979.** The parent-chick fledging relationship of the puffin, *Fratercula arctica*. Journal of Animal Ecology. 48: 889-898.

“Adult puffins bring loads of fish to their chicks which consist mostly of *Ammodytes marinus* Linn. (56%) and *Sprattus sprattus* Linn. (39.7%).”

Keywords: *A. marinus*; importance; predators (birds, puffin).

**Hudson, P.J. 1985.** Population parameters for the Atlantic Alcidae. In: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic Alcidae. New York: Academic Press: 233-261.

Keywords: *Ammodytes*; Atlantic; predators (birds).

**Hunt, G.L. 1977.** Reproductive ecology, foods, and foraging areas of seabirds nesting on the Pribilof Islands. Ann. Rep. RU 83. Boulder, CO: National Oceanic and Atmospheric Administration-OCSEAP. 179 p.

Keywords: *A. hexapterus*; Alaska; Pribilof Islands; predators (birds).

**Hunt, G.L., Jr. 1995.** Monospecific and mixed species foraging associations of marbled murrelets. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 420 p.

“In each case, the flocks began after marbled murrelets drove a school of sand lance *Ammodytes hexapterus* to the surface, where the fish ‘thrashed briefly in a tightly packed boil.’ Gulls and, if the boil of small fish jumping from the water’s surface lasted sufficient time, other birds were then attracted to this food resource. The feeding flocks observed by Mahon and others had an average 7.7 murrelets and 5.9 glaucous-winged gulls, with a positive correlation between the numbers of murrelets and gulls in the flocks. Flock duration varied between 1 and 79 minutes and was also positively correlated with the number of murrelets present. Clearly the gulls benefit from the acitivites of the murrelets in driving fish to the surface and holding them there. Alternatively, the presence of surface foraging gulls may aid the murrelets by driving fish from their protective balls where they may be less vulverable to underwater predators.”

Keywords: *A. hexapterus*; behavior; predators (birds, glaucous-winged gull, marbled murrelet).

**Hunt, G.L., Jr.; Burgeson, B.; Sanger, G.A. 1981.** Feeding ecology of seabirds of the eastern Bering Sea. In: Hood, D.W.; Calder, J.A., eds. The eastern Bering Sea shelf: oceanography and resources. Juneau, AK: National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment: 629-647. Vol. 2.

“In August, prey fed to black-legged kittiwake chicks were small (3-5 cm) sand lance. The availability of abundant shoals of these fish may be critical to kittiwake reproductive success in the northern Bering Sea.”

Keywords: *A. hexapterus*; Alaska; Bering Sea; importance; predators (birds, red-faced cormorant, black-legged kittiwake, red-legged kittiwake, common murre, thick-billed murre, tufted puffin).

**Hunt, G.L., Jr.; Decker, M.B.; Kitaysky, A. 1996.** Fluctuations in the Bering Sea ecosystem as reflected in the reproductive ecology and diets of kittiwakes on the Pribilof Islands, 1975 to 1991. In: Greenstreet, S.P.R.; Tasker, M.L., eds. Aquatic predators and their prey: Royal Society of Edinburgh conference: 1994 Aug.; Edinburgh, Scotland, Oxford, England; Cambridge, MA: Blackwell Scientific Publications: 142-153. Vol. 19.

“In the SE Bering Sea, sea surface temperatures increased from the late 1970s to the mid-1980s, then decreased. Over the same period, there were inter-annual variations in the water masses surrounding the Pribilof Islands. Subsequent to the mid-1970s, there were changes in the abundance of capelin *Mallotus villosus* and 1-group walleye pollock *Theragra chalcogramma*. Use of capelin by both black-legged kittiwakes *Rissa tridactyla* and red-legged kittiwakes *R. brevirostris* decreased at the Pribilof Islands subsequent to 1978, as did the use of 1-group pollock in the late 1970s. Availability of fatty fishes such as myctophids, capelin and sand lance decreased after the late

1970s. Beginning in the late 1970s, there was a decrease in the number of chicks produced per nest for both black-legged and red-legged kittiwakes nesting on the Pribilof Islands. Inter-annual variation in the availability of fatty fish was at least in part responsible for variations in the production of chicks by red-legged and possibly by black-legged kittiwakes."

Keywords: *A. hexapterus*; Alaska; Bering Sea; Pribilof Islands; predators (birds, black-legged kittiwake, red-legged kittiwake).

**Hunt, G.L., Jr.; Eppley, Z.; Burgeson, B.; Squibb, R. 1981.** Reproductive ecology, foods, and foraging areas of seabirds nesting in the Pribilof Islands, 1975-1979. [Place of publication unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration; OCSEAP final report; vol. 12: 1-258.

Pacific sand lance were eaten by most fish-eating seabirds on the Pribilof Islands, but they did not seem to be an important percentage of the diet, with the possible exception of the horned puffin.

Keywords: *A. hexapterus*; Alaska; Pribilof Islands; importance; predators (birds, red-faced cormorant, black-legged kittiwake, red-legged kittiwake, common murre, thick-billed murre, horned puffin).

**Hunt, G.L., Jr.; Eppley, Z.; Drury, W.H. 1981.** Breeding distribution and reproductive biology of marine birds in the eastern Bering Sea. In: Hood, D.W.; Calder, J.A., eds. The Eastern Bering Sea shelf: oceanography and resources. Juneau, AK: Office of Marine Pollution Assessment, National Oceanographic and Atmospheric Administration: 649-687. Vol. 2.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (birds).

**Hunt, G.L., Jr.; Piatt, J.F.; Erikstad, K.E. 1990.** How do foraging seabirds sample their environment? In: Bell, B.D.; Cossee, R.O.; Flux, J.E.C. [and others], eds. Acta XX Congressus Internationalis Ornithologici. 4: 2272-2279.

"In many areas of the world, small 'forage fish' species that are important links in pelagic food webs are increasingly subject to harvest by man (e.g. anchovies *Engraulis* spp., sandlance *Ammodytes* spp., capelin *Mallotus villosu*s and Antarctic krill *Euphausia superba*). Most of these prey species are patchy in distribution, highly mobile, and difficult to sample using traditional fishing gear. These characteristics pose a challenge to organizations responsible for stock assessment and fisheries regulation."

Keywords: *Ammodytes*; fisheries; importance; predators (birds).

**Hunter, M. 1979.** Food resource partitioning among demersal fishes in the vicinity of Kodiak Island, Alaska. Seattle, WA: University of Washington. 131 p. M.S. thesis.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; predators (fish).

**Hur, S.B.; Kim, J.M.; Yoo, J.M. 1984.** Fisheries resources in Garolim Bay. Bulletin of the Korean Fisheries Society. 17(1): 68-80.

"Garolim Bay (Korea) is an important fishing ground and a proposed area for a tidal power plant. The construction and operation of this plant will change the ecosystem of the bay so the present fisheries stocks need studying. Based on monthly distribution of eggs and larvae, the inner bay was an important nursing ground for larvae spawned outside the bay in winter, e.g., *Ammodytes personatus*, and *Enedrias* sp. After construction of the tidal power plant, the migratory species (larvae of *Enedrias* and *Ammodytes personatus, Mugil cephalus, Konosirus punctatus*) will be damaged by interuption of migration route."

Keywords: *A. personatus*; Korea; anthropogenic impacts; fisheries; larvae.

**Hur, S.B.; Yoo, J.M. 1984.** Distribution of fish eggs and larvae in the western waters of Korea. Bulletin of the Korean Fisheries Society. 17(6): 536-542.

“Fish eggs and larvae in the western waters of Korea are surveyed during the periods from February to August in 1982. Six species of eggs and 42 species of larvae are occurred in the survey area. The dominant species occurred during the study periods are *Ammodytes personatus*, *Enedrias* sp., *Engraulis japonica*, *Callionymus* sp., Gobiidae, etc. Major spawning month and ground of each species are estimated from the data, i.e., occurrence month and abundance of eggs and larvae by survey month and area, as well as the optimum water temperature and salinity for spawning.”

Keywords: *A. personatus*; Korea; distribution; eggs; larvae; salinity; temperature.

**Ida, H. 1976.** Removal of the family Hypoptychidae from the suborder Ammodytoidei order Perciformes to the suborder Gasterosteoidei order Syngnathiformes. Japanese Journal of Ichthyology. 23(1): 33-42.

“The osteology, mode of life and reproduction of *Hypoptychus dybowskii* were compared with a species of the family Ammodytidae [*Embolichthys mitsukurii*], 2 spp. of the family Aulorhynchidae [*Aulorhynchus flavidus, Aulichthys japonicus*] and a species of the family Gasterosteidae [*Gasterosteus aculeatus aculeatus*]. *Hypoptychus* resembles gasterosteids and aulorhynchids in osteological features, mode of life and reproduction. Although Hypoptychus resembles ammodytids in higher number of vertebrae, the family *Hypoptychidae* should be transferred from the sub-order Ammodytoidei of the order Perciformes to the suborder Gasterosteoidei of the order Syngnathiformes.”

Keywords: Ammodytidae; *Embolichthys mitsukurii*; taxonomy.

**Ida, H.; Randall, J.E. 1993.** *Ammodytoides kimurai*, A new species of sand lance (Ammodytidae) from the Osgasawara Islands. Japanese Journal of Ichthyology (Tokyo). 40(2): 147-151.

“An ammodytid fish, *Ammodytoides kimurai*, is described from six specimens collected in 15 m in the Ogasawara Islands. It is distinctive in having 48-49 dorsal fin rays, 23-24 anal fin rays, 14-15 pectoral fin rays. 104-110 lateral-line scales, no small scales dorsally on opercle, 6 + 21-23 gill rakers, 59-61 vertebrae, the suborbital sensory canal interrupted, and dark pigment centrally on the caudal fin.”

Keywords: *Ammodytoides kimurai*; Japan; meristics; taxonomy.

**Ida, H.; Sirimontaporn, P.; Monkolprasit, S. 1994.** Comparative morphology of the fishes of the family Ammodytidae, with a description of two new genera and two new species. Zoological Studies. 33(4): 251-277.

“The generic characters of the fishes of the family Ammodytidae are discussed and two new genera and two new species are described. The new genus *Protammodytes* (type species: *Protammodytes brachistos*) is characterized by the presence of pelvic fins and a symmetric squamation, fewer vertebrate, and a complete series of infraorbitals. These characters are believed to be least derived state among the family Ammodytidae. Another new genus *Lepidammodytes* (type species: *Lepidammodytes macrophthalmus)* is characterized by having strongly ctenoid scales, larger eyes, perforated lacrymals, and a moderate number of vertebrae. The combination of general and derived characters is unique among the family. The fishes placed in the genus *Bleekeria* Gunther are divided into two genera, *Bleekeria* and *Ammodytoides.* The genus *Bleekeria* includes *B. kallolepis, B. mitsukurii,* and *B. viridian-guilla*. The genus *Ammodytoides* is comprised of *A. gilli, A. vagus, A. renniei, A. lucasanus, A. kimurai,* and *A. pylei. Embolichthys* is moved to subgeneric level under the genus *Bleekeria.* The seven genera of the family are grouped into two subfamilies, Bleekeriinae and Ammodytinae. The subfamily Bleekeriinae consists of *Protammodytes, Bleekeria, Lepidammodytes,* and *Ammodytoides,* the subfamily Ammodytinae consists of *Gymammodytes, Ammodytes*, and *Hyperoplus.* The Bleekeriinae share many general features. Ammodytinae is characterized by many derived features. Genera characters of *Ammodytoides* and *Gymnammodytes* fill the gap between the generalized and specialized subfamilies.”

Keywords: *Ammodytoides gilli; A. kimurai; A. lucasanus; A. pylei; A. renniei; A. vagus; Embolichthys; Lepidammodytes macrophthalmus; Protammodytes brachistos;* taxonomy.

**Iglesias, J.; Rodriguez-Ojea, G. 1994.** Fitness of hatchery-reared turbot, *Scophthalmus maximus* L., for survival in the sea: first year results on feeding, growth and distribution. In: Danielssen, D.S.; Moksness, E., eds. Aquaculture and fisheries management: an international symposium on sea ranching of cod and other marine fish species; [dates of meeting unknown]; Arendal, Norway. [Place of publication unknown]: [publisher unknown]; 25(supplement 1): 179-188.

"Three thousand reared turbot, *Scophthalmus maximus* L., juveniles with an initial wet weight of 158 g were externally tagged using T-anchor tags and released in six areas of the Ria de Vigo (NW Spain). Although these fish had been cultured, the natural food of all those recaptured consisted basically of fishes (96%), with a remarkable presence of sand eel, *Ammodytes tobianus* (L.) (78%), in the gut contents."

Keywords: *A. tobianus*; predators (fish, turbot).

**Imai, C.; Tanaka, S. 1987.** Effect of sea-water temperature on egg size of Japanese anchovy. Nippon Suisan Gakkaishi–Bulletin of the Japanese Society of Scientific Fisheries. 53(12): 2169-2178.

Keywords: *Ammodytes*; egg; fisheries; temperature.

**Imler, R.H.; Kalmbach, E.R. 1955.** The bald eagle and its economic status. Circ. 30. [Place of publication unknown]: U.S. Fish and Wildlife Service.

Keywords: *A. hexapterus*; predators (birds, bald eagle).

**Imler, R.H.; Sarber, H.R. 1947.** Harbor seals and sea lions in Alaska. Spec. Sci. Rep. [Place of publication unknown]: U.S. Fish and Wildlife Service; 28: 1-22.

Keywords: *A. hexapterus*; Alaska; predators (mammals, harbor seal, Steller sea lion).

**International Pacific Halibut Commission. 1987.** The Pacific halibut: biology, fishery, and management. Tech. Rep. 22. Seattle, WA. 22: 1-33.

Halibut often leave the bottom to feed on pelagic fish such as sand lance and herring.

Keywords: *A. hexapterus*; predators (fish, Pacific halibut).

**Inoue, A. 1949.** An ecological note on the sand eel, *Ammodytes personatus* (Girard) I. Bulletin of the Japanese Society of Scientific Fisheries. 15(9): 458-568.

Keywords: *A. personatus*; ecology.

**Inoue, A. 1952.** An ecological note on sand-eel, *Ammodytes personatus* (Girard) II. Contribution of the Naikai Regional Fisheries Research Laboratory. 13: 12-30.

Keywords: *A. personatus*; ecology.

**Inoue, A.; Takamori, S.; Kuniyuki, K. [and others]. 1967.** Studies on fishery biology of the sand-launce, *Ammodytes personatus* Girard. Bulletin of the Naikai Regional Fisheries Research Laboratory. 25(121, 122): 1-347.

"The sand-lance, *Ammodytes personatus* (Girard), is one of commercially important fishes in Japan, mainly distribut[ed] along the coastal waters of Hokkaido, in Northern or Middle Pacific, the Seto Inland Sea and East China Sea Region. Its yearly catches range from 40,000 to 110,000 tons approximately during the past 11 years (1953-'63). The forecast of its fishing conditions has been strongly expected for a long time by the fishermen concerned, because the annual catches of this fish had distinctly fluctuated. In this paper, the authors deal with the sand-lance with emphasis on its populations, habit, growth, migration and the environment."

Keywords: *A. personatus*; biology; ecology; fisheries; growth; behavior; habitat; migration.

**Irons, D.B. 1982.** Foraging strategies of glaucous-winged gulls: influences of sea otter predation. Corvallis, OR: Oregon State University. M.S. thesis.

Keywords: *A. hexapterus*; predators (birds, glaucous-winged gull).

**Irons, D.B. 1992.** Aspects of foraging behavior and reproductive biology of the black-legged kittiwake. Irvine, CA: University of California. Ph.D. dissertation.

Keywords: *A. hexapterus*; predators (birds, black-legged kittiwake).

**Irons, D.B. 1996.** Size and productivity of black-legged kittiwake colonies in Prince William Sound before and after the *Exxon Valdez* oil spill. American Fisheries Society Symposium. 18: 738-747.

Small forage fish are kittiwakes' primary prey, and in Prince William Sound diets consist chiefly of immature Pacific herring, Pacific sand lance, capelin, and immature walleye pollock.

Keywords: *A. hexapterus*; Alaska; Prince William Sound; predators (birds, black-legged kittiwake).

**Irons, D.B.; Anthony, R.G.; Estes, J.A. 1986.** Foraging strategies of glaucous-winged gulls in a rocky intertidal community. Ecology 67(6): 1460-1474.

The gulls ate some sand lance on Attu, but 90.6 percent of prey items were *Ammodytes hexapterus, Clupea harengus*, and unidentified species on Amchitka.

Keywords: *A. hexapterus*; Alaska; Aleutian Islands; predators (birds, glaucous-winged gull).

**Isakson, J.S.; Simenstad, C.A.; Burgner, R.L. 1971.** Fish communities and food chains in the Amchitka area. BioScience. 21(12): 666-670.

Pacific sand lance were one of the most common fish species above the inshore and sand-gravel community near Amchitka Island.

Keywords: *A. hexapterus*; Alaska; Amchitka; distribution; habitat.

**Ishigaki, T. 1956.** Fishery of sand eel in waters around Hokkaido I. Monthly Report of the Hokkaido Regional Research Laboratory. 13(9): 394-407.

Keywords: *Ammodytes*; Japan; Hokkaido; fisheries.

**Ishioka K. 1995.** Sea area information (1994). The Inland Sea of Japan (fishing conditions). Suisan Kaiyo Kenkyu. 59(4): 475-477.

Keywords: *A. personatus*; Japan; Inland Sea of Japan; catch; fisheries.

**Ito, J. 1964.** Food and feeding habits of Pacific salmon (genus *Oncorhynchus*) in their oceanic life. Bulletin of the Hokkaido Regional Fisheries Research Laboratory. 29: 85-97. (Translated from Japanese; Fisheries Research Board of Canada Translation Series 1309).

Keywords: *Ammodytes*; predators (fish, Pacific salmon).

**Itokawa, S. 1981.** Report of fisheries conversazione. Japanese Society of Scientific Fisheries. 17: 17-34.

Keywords: *Ammodytes*; Japan; fisheries.

**Itokawa, S. 1990.** On fisheries resourses off Mie Prefecture. Suisan Kaiyo Kenkyu. 54(1): 33-37.

Keywords: *A. personatus*; Japan; fisheries; recruitment.

**Iverson, S.J.; Frost, K.J.; Lowry, L.F. 1997.** Fatty acid signatures reveal fine scale structure of foraging distribution of harbor seals and their prey in Prince William Sound, Alaska. Marine Ecology Progress Series. 151(1-3): 255-271.

“Fatty acid signature analysis was used to investigate the diet and the spatial scales of foraging in harbor seals *Phoca vitulina* in Prince William Sound and elsewhere in the Gulf of Alaska. Although preliminary, analyses suggest that large herring and pollock, as well as flatfish, may have dominated the diet of seals in southern Prince William Sound, whereas diets of seals in northern and eastern Prince William Sound may have been comprised more of small size classes of herring and pollock, and perhaps other items such as cephalopods, sandlance *Ammodytes hexapterus*, cod *Gadus macrocephalus*, and shrimp. We conclude that fatty acid signature analysis will be an important contribution to understanding marine food webs in estuarine and other marine environments.”

Keywords: *A. hexapterus*; Alaska; Prince William Sound; predators (mammals, harbor seal).

**Jacobsen, C.; Borresen, T. 1995.** Formulation of fish diets with reduced phosphorous content. Water Scientific Technological Nutritional Strategies and Management of Aquaculture Waste. 31(10): 167-173.

“The reduction of phosphorous waste from farmed rainbow trout (*Oncorhynchus mykiss*) was attempted by feeding diets of reduced P content. The protein source was fishmeal in which the bone fraction had been removed. This was achieved either by solubilizing the fish material (press cake) by enzymatic treatment and subsequent filtering, or by removing the fish bones by a skin/bone separator. Two fish species were used, sand eel (*Ammodytes marinus*) and sprat (*Sprattus sprattus*). Due to the small size of the fish, only bones were retained in the skin/bone separator. It was not possible to make any final conclusions with respect to the effect of the enzymatic treated fishmeal on the pollution risk from P. This was due to large variation on the P determinations.”

Keywords: *A. marinus*; aquaculture.

**Jacquez, G.M.; Rohlf, F.J. 1986.** Problems in the variance analysis of nine environmental monitoring variables: determining the number of samples needed to detect a change in mean of 50%. In: Oceans ‘86 conference record: science-engineering-adventure: Monitoring strategies symposium; [dates of meeting unknown]; Washington, DC. New York: IEEE Publishing Service: 3: 974-979.

“An analysis is conducted for nine environmental monitoring variables; including the incidence of skeletal anomalies in *Ammodytes.* The direction of change is that expected under the assumption of decreasing environmental quality. Problems in handling and acquiring encountered data are discussed and methods for calculating the appropriate variance estimate and determining the appropriate data transformation are presented.”

Keywords: *Ammodytes*; environmental monitoring; environmental pollution; morphology.

**Jakupsstovu, S.H.I. 1975.** Undersoikelser Av Lodde (*Mallotus villosus*) og sil (*Ammodytes* sp.) ved vest-Grønland 1 Juni-Juli 1974. Fisken og Havet. 1: 14-19.

Keywords: *Ammodytes*; Greenland; abundance; fisheries; hydroacoustics; spawning.

**Jakupsstovu, S.H.; Rottingen, I. 1975.** Investigations on capelin (*Mallotus villosus*) and sand eel (*Ammodytes* sp.) at West Greenland in June-July 1974. ICNAF Res. Doc. 75/53. [Place of publication unknown]: [publisher unknown]. 18 p.

Keywords: *Ammodytes*; Greenland.

**Jangaard, P.M.; Regier, L.W.; Claggett, F.G. [and others]. 1974.** Nutrient composition of experimentally produced meals from whole Argentine capelin sand lance and from flounder and redfish filleting scrap. Journal of the Fisheries Research Board of Canada. 31(2): 141-146.

“Analyses included protein, fat, ash, moisture, minerals, vitamins, available lysine, amino acids, and protein digestibility.”

Keywords: *A. americanus*; aquaculture; composition; energetics.

**Jensen, A.S. 1941.** On subspecies and species of the lesser sand eel (*Ammodytes lancea* S. Lat.): a contribution to the discussion of the species problem in fishes. Kongelige Danske Videnskabernes Selskab Biologiske Meddeleser. 16(9): 1-33.

Keywords: *A. lancea*; taxonomy.

**Jensen, A.S. 1944.** On specific constancy and segration into races in sea-fishes. Kongelige Danske Videnskabernes Selskab Biologiske Meddeleser. 19(8): 1-19.

Keywords: *Ammodytes*; taxonomy.

**Jensen, A.S.; Hansen, P.M. 1931.** Investigation on the Greenland cod (*Gadus callarias* L.). Rapports et Procès-Verbaux des Reunions Conseil International pour l’Exploration de la Mer. 41 p.

Keywords: *Ammodytes*; Greenland; predators (fish, Greenland cod).

**Jensen, H.; Tasker, M.L.; Coull, K.; Emslie, D. 1994.** A comparison of distribution of seabirds and prey fish stocks in the North Sea and adjacent areas. JNCC Report. 207: 1-116.

Keywords: *Ammodytes*; North Sea; abundance; distribution; fisheries; predators (birds, guillemot, puffin, razorbill).

**Jensen, J.O.T. 1988.** Combined effects of gas supersaturation and dissolved-oxygen levels on steelhead trout (*Salmo gairdneri*) eggs, larvae, and fry. Aquaculture. 68(2): 131-139.

Keywords: *Ammodytes*; eggs; fisheries; larvae; oxygen.

**Jensen, N.C.; Keller, S. 1990.** Quality fish meal: specifications and use in aquaculture and fur farming. In: Making profits out of seafood wastes: Proceedings of the international conference on fish by-products; [dates of meeting unknown]; Anchorage, AK. Alaska Sea Grant Report. Anchorage, AK: Alaska Sea Grant Program: 127-130.

“Esbjerg Fiskeindustri is the world’s largest single producer of quality fish meal and fish oil and handles half the total Danish production of fish meal and oil. The raw material consists of small fish normally not used for human consumption, such as sand eel (*Ammodytes*), Norway pout (*Trisopterus esmarki*) and sprat (*Sprattus sprattus*). Environmental problems caused by nitrogen and phosphorus from fish farming will in the future put demands to the fish farmers and feed producers to minimize this pollution. At that time there will be a need for a highly digestible fish meal with a low phosphorus content. In Denmark there are two types of feed for minks: wet feed, based on fish offal and whole fresh industrial fish; and dry pellets based on fish meal. The wet feed also contains up to 6% fish meal, while the dry pellets contain up to 50% fish meal. The composition of the dry pellets is 30%-45% protein, 15%-25% fat, and 3,000-3,850 kilocalories per kilogram metabolizable energy.”

Keywords: *Ammodytes*; aquaculture.

**Jewett, C. 1978.** Summer food of the Pacific cod, *Gadus macrocephalus*, near Kodiak Island, Alaska. Fishery Bulletin. 76: 700-706.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; predators (fish, Pacific cod).

**Jin, Y.; Sasa, Y. 1994.** Research on the promotion of coastal and offshore fisheries. Investigation of the distribution of sandeel fingerlings. Iwate-Ken Suisan Shikenjo Nenpo. 1993: 52-56.

Keywords: *A. personatus*; Japan; catch; distribution; larvae.

**Johnsgaard, P.A. 1987.** Diving birds of North America. Lincoln, NE: University of Nebraska Press.

Keywords: *Ammodytes*; predators (birds).

**Johnson, D.W.; Katavic, I. 1986.** Survival and growth of sea bass (*Dicentrarchus labrax*) larvae as influenced by temperature, salinity, and delayed initial feeding. Aquaculture. 52(1): 11-19.

Keywords: *Ammodytes*; predators (fish, sea bass).

**Johnson, S.R.; Baker, J.S. 1985.** Productivity studies. In: Johnson, S.R., ed. Population estimation, productivity, and food habits of nesting seabirds at Cape Pierce and the Pribilof Islands, Bering Sea, Alaska. Anchorage, AK: U.S. Minerals Management Service; final report; OCS Study MMS 85-0068: 171-231.

Keywords: *A. hexapterus*; Alaska; Bering Sea; predators (birds).

**Johnstone, I.G.; Harris, M.P.; Wanless, S.; Graves, J.A. 1990.** The usefulness of pellets for assessing the diet of adult shags *Phalacrocorax aristotelis*. Bird Study. 37(1): 5-11.

“Each day Shags were fed known numbers of either sandeel, sprat, herring or cod and the contents of the pellets which the birds regurgitated were examined. Normally, each bird produced a single pellet each day which contained otoliths from the fish eaten during the previous 24 hr. The proportion of recovered otoliths varied greatly both from day to day and according to the species of fish. Otoliths from cod had the highest recovery rate, those of herring and sprat were recovered less often and the recovery rate of sandeel otoliths was intermediate. Measurements of otoliths from the pellets gave a very misleading estimate of the size of fish eaten. Fundamental questions need to be answered before pellets can be used in general dietary studies of seabirds.”

Keywords: *Ammodytes*; otoliths; predators (birds, shag).

**Jones, C. 1986.** Determining age of larval fish with the otolith increment technique. Fishery Bulletin. 84(1): 91-103.

Keywords: *Ammodytes*; age; larvae; otoliths.

**Jones, D. 1968.** Exploratory sand lance fishing. Proj. No. 204-268. [Place of publication unknown]: N.S. Department of Fisheries. 39 p.

Keywords: *Ammodytes*; commercial fishing.

**Jones, I.L. 1985.** Structure and function of vocalizations and related behaviour of the ancient murrelet (*Synthliboramphus antiquus*). Toronto, ON: University of Toronto. M.S. thesis.

Keywords: *Ammodytes*; predators (birds, ancient murrelet).

**Jones, L.L.; DeGange, A.R. 1988.** Interactions between seabirds and fisheries in the northern Pacific Ocean. In: Burger, J., ed. Seabirds and other marine vertebrates: competition, predation and other interactions. New York: Columbia University Press: 261-290. Chapter 8.

Keywords: *Ammodytes*; commercial fisheries; importance; predators (birds).

**Jones, P.H.; Dechesne, S. 1994.** Canada's first active marbled murrelet nest. Pacific Seabirds Abstracts. 21(1): 42-43.

"The average number of feedings per day was seven with four taking place after sunrise. Most of the fish fed to the chick were Pacific sand lance."

Keywords: *A. hexapterus*; Canada; predators (birds, marbled murrelet).

**Jones, R. 1954.** The food of the whiting and a comparison with that of the haddock. Marine Research. 1954(2): 1-33.

"Young Ammodytes constituted more than 60% of the fish eaten by small whiting (less than 21 cm. in length) and were recorded in each month except January."

Keywords: *Ammodytes*; importance; predators (fish, haddock, whiting).

**Jones, R. 1983.** The decline in herring and mackerel and the associated increase in other species in the North Sea. FAO Fisheries Report. 291 (vol. 2): 507-520.

Keywords: *A. tobianus*; North Sea; ecosystem; fisheries; population changes.

**Jones, R. 1984.** Some observations on energy transfer through the North Sea and Georges Bank food webs. Rapports et Procès-Verbaux des Reunions Conseil International pour l'Exploration de la Mer. 183: 204-217.

Keywords: *Ammodytes*; North Sea; Georges Bank; food web.

**Jones, R.D, Jr.; Petersen, M.R. 1979.** The pelagic birds of Tuxedni Wilderness, Alaska. In: Environmental assessment of the Alaskan Continental Shelf. Ann. Rep. of principal investigators 2. Boulder, CO: National Oceanic and Atmospheric Administration, Environmental Research Laboratory: 187-232.

"Adult kittiwakes fed their chicks almost exclusively fish, with only a trace of crustacea identified in the regurgitation samples. Pacific sand lance is by far the single most common fish fed to chicks as expressed in both aggregate percent volume and percent frequency of occurrence. Similarly adult kittiwakes collected in 1971 ate predominantly sand lance.

"The single most important food item brought to horned puffin chicks as expressed in occurrence (100%) was the Pacific sand lance. Of the hundreds of fish observed in the bills of adults and found at burrows, all were sand lance.

"We regard the success of the horned puffins in capturing *A. hexapterus* as evidence of their presence near Tuxedni Wilderness in at least fair abundance. We do not know how far the puffins go to find them, but we found sand lance buried in the sandy substrate of an extensive tide flat that begins four miles north of the colony and continues several miles farther north. This tide flat is occupied by a very large stock of razor clams which indicates the existence of large lower trophic level food resources in the water column. We regard the absence of knowledge concering the behavior of this fish a major failure in the effort to understand the ecology of lower Cook Inlet. Indeed, this may be said of all OCS areas in Alaska."

Keywords: *A. hexapterus*; Alaska; Cook Inlet; Tuxedni Wilderness; importance; predators (birds, horned puffin, black-legged kittiwake).

**Jonsgard, A. 1982.** The food of minke whales (*Balaenoptera acutorostrata*) in northern North Atlantic waters, Brighton, (UK), 20 Jul 1981. Report of the International Whaling Commission (Special Issue). 32: 259-262.

"A total of 237 minke whale (*B. acutorostrata*) stomachs was examined, from animals caught in 1943, 1944, 1945, 1950 in northern Norway (Lofoten and Vestergalen), in 1950 (Barent Sea, Spitsbergen and Bear Island), and in 1968 (East and West Greenland). Fish only was found in 104 stomachs (43.9%). The species of fish identified were: cod

(*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), coal-fish (*Pollachius virens*), herring (*Clupea harengus*), capelin (*Mallotus villosus*) and sand-eel (*Ammodytes* sp.). Pelagic crustraceans only (Euphausiids and *Calanus finmarchicus*) were recorded in 74 stomachs (31.2%). It is concluded that economically important species [of] fish and also euphausiids are the basic food sources for minke whales in northern North Atlantic waters, and that large quantities of fish are consumed."

Keywords: *Ammodytes*; Greenland; Norway; predators (mammals, minke whale).

**Jonsson, E.; Fridgeirsson, E. 1986.** Observations on the distribution and gut contents of fish larvae and environmental parameters, south-west of Iceland: Council meeting of the International Council for the Exploration of the Sea; [dates of meeting unknown]; Copenhagen, Denmark. [Place of publication unknown]: [publisher unknown]. 22 p.

"During the spring of 1983 the distribution of fish larvae in relation to environmental parameters was studied south-west of Iceland. The larvae were most abundant in areas influenced by freshwater. The highest densities of fish larvae were found between 10 and 25 m depth, where the food was found to be most abundant. The gut contents of cod, haddock, sandeel and capelin larvae was dominated by the eggs and nauplii of planktonic crustaceans."

Keywords: *Ammodytes*; Iceland; abundance; distribution; larvae.

**Jordan, D.S. 1906.** A review of the sand lances or Ammodytidae of the waters of Japan. Proceedings of the U.S. National Museum. 30 (1464): 715-719.

Keywords: Ammodytidae; Japan; taxonomy.

**Jordan, D.S.; Gilbert, C.H. 1882.** Synopsis of the fishes of North America: Family 69: Ammodytidae. Bulletin of the U.S. National Museum. 16: 414-415.

Keywords: *Ammodytidae*; North America; taxonomy.

**Jourdain, S. 1879.** Sur les *Ammodytes* des côtes de la Manche. Revue des Sciences Naturelles. I: 203-210.

Keywords: *Ammodytes*; taxonomy.

**Kaftanovski, Yu. M., 1938.** Colonial nesting of the murres and factors in egg and chick loss. Zoologicheskii Zhurnal. 17(4): 695-705. In Russian.

Keywords: *Ammodytes*; predators (birds, murre).

**Kajimura, H. 1984.** Opportunistic feeding of the northern fur seal, *Callorhinus wisinus*, in the eastern north Pacific Ocean and the eastern Bering Sea. Tech. Rep. NMFS SSRF-779. [Place of publication unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration. 49 p.

*Ammodytes hexapterus* is a principal forage species used by fur seals in the Gulf of Alaska, western Alaska, and eastern Bering Sea. It is especially important in May and June in western Alaska, when up to 50 percent by volume of stomach contents was sand lance, and in May, June, and July in the Gulf of Alaska, where roughly 25 to 75 percent by volume was sand lance.

*Keywords: A. hexapterus*; Alaska; Bering Sea; Gulf of Alaska; importance; predators (mammals, northern fur seal).

**Kajimura, H.; Loughlin, T.R. 1988.** Marine mammals in the oceanic food web of the eastern subarctic Pacific. Bulletin of the Ocean Research Institute, University of Tokyo. 26(2): 187-223.

"Marine mammal species that are found over continental shelf and slope feed principally on semi-demersal, schooling fishes such as walleye pollock, *Theragra chalcogramma*; Pacific cod, *Gadus macrocephalus*; Pacific whiting, *Merluccius productus*; Pacific sand lance, *Ammodytes hexapterus*; and squids. Marine mammals feeding on this

group are the killer whale; shortfinned pilot whale, *Globicephala macrorhynchus*; Dall's porpoise; Pacific white-sided dolphin, *Lagenorhynchus obliquidens*; northern right whale dolphin, *Lissodelphis borealis*; northern sea lion; and California sea lion, *Zalophus californianus*."

Keywords: *A. hexapterus*; Pacific (eastern); predators (mammals).

**Kamaki, A.; Karasawa, J. 1991.** Occurrence and distribution of fish eggs and larvae in Bisan-Seto, Seto Inland Sea, in fiscal year 1990. Okayama-Ken Suisan Shikenjo Hokoku. 6: 142-145.

Keywords: *A. personatus*; Japan; Seto Inland Sea; annual variation; distribution; eggs; larvae.

**Kamaki, A.; Karakawa, J.; Fujisawa, K. [and others]. 1989.** Occurrence and distribution of fish eggs and larvae in Bisan-Seto of the Seto-Inland Sea. Okayama-Ken Suisan Shikenjo Hokoku. 4: 111-114.

Keywords: *A. personatus*; Japan; Seto Inland Sea; annual variation; distribution; eggs; larvae.

**Kamaki, A.; Karakawa, J.; Fujisawa, K. [and others]. 1990.** Occurrence and distribution of fish eggs and larvae in Bisan Seto of the Seto Inland Sea. Okayama-Ken Suisan Shikenjo Hokoku. 5: 81-84.

Keywords: *A. personatus*; Japan; Seto Inland Sea; annual variation; distribution; eggs; larvae.

**Kamaki, A.; Karakawa, J.; Ukita, K. [and others]. 1989.** The amount of catch and size of sand-eel *Ammodytes personatus* by Fukuromachiami boat in the Bisan-Seto, 1978-88. Okayama-Ken Suisan Shikenjo Hokoku. 4: 157-162.

Keywords: *A. personatus*; Japan; Seto Inland Sea; catch; growth.

**Kamaki, A.; Matsumura, S. 1992.** The amount of catch and size of sand-eel *Ammodytes personatus* by Fukuromachiami (a type of lift net) in Bisan-Seto, Seto Inland Sea in 1989-1991. Okayama-Ken Suisan Shikenjo Hokoku. 7: 124-133.

Keywords: *A. personatus*; Japan; Seto Inland Sea; annual variation; catch; distribution; eggs; fisheries.

**Kamishima, Y. 1975.** Organization of the chromatophore complex in sand eel integument. Zoological Magazine (Tokyo). 84(4): 476.

Keywords: *A. personatus*; morphology; pigment.

**Kamishima, Y. 1978.** Electron microscope study on reflecting platelets in the dorsal iridophores of the sand eel *Ammodytes personatus* Girard. Proceedings of the Japan Academy, Series B, Physical and Biological Sciences. 54(10): 634-639.

Keywords: *A. personatus*; morphology; pigment.

**Kamishima, Y. 1979.** Electron microscopic study on 2 types of reflecting cells in ventral skin of the sand eel *Ammodytes personatus*. Proceedings of the Japan Academy, Series B, Physical and Biological Sciences. 55(3): 141-146.

Keywords: *A. personatus*; morphology; pigment.

**Kanazawa, T. 1995.** Study on the development of effective utilization system of regional important resources. 2: Sandeel resource survey. Fukuoka-Ken Suisan Kaiyo Gijutsu Senta Jigyo Hokoku. 1994: 107-109.

Keywords: *A. personatus*; Japan; catch; fisheries; habitat; larvae.

**Kandler, R. 1937.** Beobachtungen über die Laichzeiten der *Ammodytes*-Arten in Nord- und Ostsee. Zoologisher Anzeiger. 118(1/2): 1-10.

Keywords: *Ammodytes.*

**Kandler, R. 1941.** Untersuchungen über fortspflanzung wachstum und variabilitat der Arten des sandaals in Ostund Nordsee, mit, besonterer berücksichtigung der saisonrassen von *Ammodytes tobianus*. Kieler Meeresforschungen. 5(1): 45-145.

Keywords: *A. tobianus*.

**Kanno, Y.; Hamai, I. 1971.** Food of salmonid fish in the Bering Sea in summer of 1966. Bulletin of the Faculty of Fisheries Hokkaido University. 22: 107-127. In Japanese: English abstract.

Keywords: *Ammodytes*; Bering Sea; predators (fish, Pacific salmon).

**Kapel, F.O. 1994.** Variation in the feeding of harp seals (*Phoca groenlandica*) in southwest Greenland waters. St. John's: 21.

"Analyses of the stomach contents of harp seals (*Phoca groenlandica*) collected between 1990 and 1993 confirm previous information that the dominant prey of harp seals feeding in coastal waters of Southwest Greenland in early summer is capelin (*Mallotus villosus*) and pelagic crustaceans (euphausids). The seals feeding in offshore areas later in the summer take mainly sandeel (*Ammodytes*) and pelagic crustaceans (Parathemisto and euphausids)."

Keywords: *Ammodytes*; Greenland; predators (mammals, harp seal).

**Kapel, F.O. 1995.** Feeding ecology of harp and hooded seals in the Davis Strait-Baffin Bay region. In: Blix, A.S.; Walloe, L.; Ulltang, O., eds. Whales, seals, fish and man: Proceedings of the international symposium on the biology of marine mammals in the north east Atlantic; 1994 Nov. 29-Dec. 1; Tromsø, Norway. Developments in Marine Biology. 4: 287-304.

Keywords: *Ammodytes*; Atlantic (northeast); predators (mammals, harp seal).

**Kapel, F.O.; Angantyr, L.A. 1989.** Feeding patterns of harp seals (*Phoca groenlandica*) in coastal waters of west Greenland, with a note on offshore feeding: Council meeting of the International Council for the Exploration of the Sea no. 6; [dates of meeting unknown]; The Hague, Netherlands. [Place of publication unknown]: [publisher unknown]: 1-29.

"The stomach contents of 661 harp seals (*Phoca groenlandica*) caught in West Greenland 1985-1988 were identified, and the food composition expressed as per cent volume, and as calculated per cent weight of consumed food. In offshore areas the harp seals appear to feed heavily on sandeels (*Ammodytes* sp.) in summer, possibly taking a more varied diet in the fall, but further studies are needed on this issue, and on the year to year variation."

Keywords: A*mmodytes*; Greenland; predators (mammals, harp seal).

**Kapel, F.O.; Blix, A.S.; Walloe, L.; Wltang, O. 1995.** Feeding ecology of harp and hooded seals in the Davis Strait-Baffin Bay region In: Blix, A.S.; Walloe, L.; Ulltang, O., eds. Whales, seals, fish and man: Proceedings of the international symposium on the biology of marine mammals in the north east Atlantic; 1994 Nov. 29-Dec. 1; Tromsø, Norway. Developments in Marine Biology. 4: [pages unknown].

“Results of stomach contents analyses of material collected in West Greenland waters in the period 1986-1993 are reviewed, and compared with published data and circumstantial information from local hunters. The diet of harp seals (*Phoca groenlandica*) feeding in this region is variable but consists mainly of pelagic crustaceans (euphausids and amphipods) and small fish species such as capelin, sandeel, polar cod and Arctic cod.”

Keywords: *Ammodytes*; Canada; Baffin Bay; predators (mammals, harp seal).

**Karakawa, J.; Hamazaki, M. 1995.** Occurrence and distribution of fish eggs and larvae in Bisan Seto of the Seto Inland Sea in fiscal year 1994. Okayama-Ken Suisan Shikenjo Hokoku. 10: 158-162.

Keywords: *A. personatus*; Japan; catch; distribution; eggs; fisheries; larvae; recruitment.

**Karakawa, J.; Kamaki, A.; Koie, K. 1989.** Occurrence and distribution of larvae of sand-eel *Ammodytes personatus* in the coastal waters of Okayama Prefecture, 1989. Okayama-Ken Suisan Shikenjo Hokoku. 4: 149-156.

Keywords: *A. personatus*; Japan; catch; distribution; fisheries; larvae.

**Karakawa, J.; Kobashi, K.; Ukida, K. 1988.** The amount caught and size of sand-eel *Ammodytes personatus* by Fukuromachiami boats in the Bisan-Seto 1983-87. Bulletin of the Fisheries Experiment Station Okayama Prefect. 3: 1-16.

Keywords: *A. personatus*; Japan; catch; fisheries.

**Karakawa, J.; Matsumura, S.; Koie, K. 1985.** Occurrence and distribution of larvae of sand-eel *Ammodytes personatus* in the coastal waters of Okayama Prefecture. Bulletin of the Fisheries Experiment Station Okayama Prefect. 1984: 9-17.

Keywords: *A. personatus*; Japan; catch; distribution; fisheries; larvae.

**Karakawa, J.; Matsumura, S.; Mitani, I. 1980.** Larvae of the sand-eel, *Ammodytes personatus* in Bisan-Seto, the Seto-Inland Sea, 1980. Bulletin of the Fisheries Experimental Station Okayama Prefect. 1979: 64-69.

Keywords: *A. personatus*; Japan; catch; fisheries; larvae.

**Karakawa, J.; Matsumura, S.; Mitani, I. 1982.** Distribution of larvae of sand-eel *Ammodytes personatus* in Bisan-Seto, the Seto-Inland Sea, 1982. Bulletin of the Fisheries Experiment Station Okayama Prefect. 1981: 38-44.

Keywords: *A. personatus*; Japan; catch; fisheries; larvae.

**Karakawa, J.; Matsumura, S.; Mitani I. 1984.** Occurrence and distribution of larvae of sand-eel *Ammodytes personatus* in Bisan-Seto, the Seto-Inland Sea, 1984. Bulletin of the Fisheries Experimental Station Okayama Prefect: 13-19.

Keywords: *A. personatus*; Japan; catch; distribution; fisheries; larvae.

**Karakawa, J.; Sato, J.; Koie, K. 1987.** Occurrence and distribution of larvae of sand-eel *Ammodytes personatus* in the coastal waters of Okayama Prefecture, 1987. Bulletin of the Fisheries Experimental Station Okayama Prefect. 2: 133-139.

Keywords: *A. personatus*; Japan; catch; distribution; fisheries; larvae.

**Karakawa, J.; Sato, J.; Koie, K. 1988.** Occurrence and distribution of larvae of sand-eel *Ammodytes personatus* in the coastal waters of Okayama Prefecture, 1988. Bulletin of the Fisheries Experimental Station Okayama Prefect. 3: 133-139.

Keywords: *A. personatus*; Japan; catch; distribution; eggs; fisheries; larvae.

**Karpenko, V.I. 1979.** Feeding habits of juvenile Pacific salmon in the coastal waters of Kamchatka. Soviet Journal of Marine Biology. 5: 398-405.

Keywords: *Ammodyte*s; Kamchatka; predators (fish, chum salmon, coho salmon, pink salmon, sockeye salmon).

**Karpenko, V.I. 1987.** Growth variation of juvenile pink salmon, *Oncorhynchus gorbuscha*, and chum salmon *Oncorhynchus keta*, during the coastal period of life. Journal of Ichthyology. 27: 117-125.

Keywords: *A. hexapterus*; Bering Sea; predators (fish, chum salmon, pink salmon).

**Karpenko, V.I.; Maksimenkov, V.V. 1988.** Preliminary data on the interactions between Pacific salmon and herring during early ontogeny. Journal of Ichthyology. 28: 136-140.

Keywords: *A. hexapterus*; Japan; predators (fish).

**Karpenko, V.I.; Piskunova, L.V. 1984.** Importance of macroplankton in the diet of young salmons of the genus *Oncorhynchus* (Salmonidae) and their trophic relationships in the southwestern Bering Sea. Journal of Ichthyology. 24: 98-106.

Keywords: *A. hexapterus*; Bering Sea; predators (fish, pink salmon, sockeye salmon).

**Karpenko, V.I.; Safronov, S.G. 1985.** Juvenile pink salmon, *Oncorhynchus gorbuscha*, from the coastal waters of the Okhotsk Sea. Journal of Ichthyology. 25: 54-157.

Keywords: *Ammodytes*; Okhotsk Sea; predators (fish, pink salmon).

**Kartaashev, N.N. 1979.** Materials on biology of Alcidae at Komandorskie Islands. Ornitologiya. 14: 144-149. In Russian.

Keywords: *Ammodytes*; predators (birds).

**Kasamatsu, F.; Tanaka, S. 1992.** Annual changes in prey species of minke whales taken off Japan 1948-87. Nippon Suisan Gakkaishi. 58(4): 637-651.

Keywords: *A. personatus*; Japan; predators (mammals, minke whale).

**Kato, F. 1991.** Life histories of masu and amago salmon (*Oncorhynchus masou* and *Oncorhynchus rhodurus*) In: Groot, C.; Margolis, L., eds. Pacific salmon life histories. Vancouver, BC: University of British Columbia Press.

The main food items of young masu in coastal waters are generally crustaceans and fish, with sand lance (*Ammodytes personatus*) and sand eel (*Hypotychus dybowskii*) as the most common food items. Stomach contents of young masu off Honshu in April and May are mainly small sand lance. In Sakhalin Bay in August and September, the main food item was sand lance (4-6 centimeters in body length).

For amago salmon from mid-March to mid-May, sand lance, anchovy, and sardines are the most abundant food items.

Keywords: *A. personatus*; *Hypotychus dybowskii*; Japan; importance; predators (fish, masu salmon, amago salmon).

**Katona, S.K.; Rough, V.; Richardson, D.T. 1993.** A field guide to whales, porpoises, and seals from Cape Cod to Newfoundland. [Place of publication unknown]: Smithsonian Institution Press. 316 p.

Keywords: *Ammodytes*; Atlantic (north); predators (mammals).

**Kaushik, S.J. 1986.** Environmental effects on feed utilization. Fish Physiology and Biochemistry. 2(1-4): 131-140.

Keywords: *Ammodytes*; aquaculture; composition; fisheries.

**Kawai, T. 1995.** On the relation of sand lance population and sea condition off Joban and Kashimanada Sea. Suisan Kaiyo Kenkyu. 59(3): 327-329.

Keywords: *A. personatus*; Pacific Ocean; catch; environmental factors; fisheries.

**Kawasaki, T. 1980.** Fundamental relations among the selections of life history in the marine teleosts. Bulletin of the Japanese Society of Scientific Fisheries. 46(3): 289-294.

"The modes of fluctuation in numbers of the marine teleosts have evolved in 3 directions. The 1st extreme is subtype IA which makes short-period and irregular variation and the 2nd one is subtype IB which exhibits a large-scale and periodic change. The last one is type II showing a small and steady variation. The species situated close to the extremes are sauries and sandeels, sardines and herrings, and tunas and flatfish in the above order. Each type has selected the particular life history, corresponding to the environment inhabited. The selection of life history is the selection between 2 directions, i.e., one is to put the resources into the preservation of brood and the other is to pour them into that of the individual. The interrelations among the 3 types are shown as a 3-type triangle and a given marine teleost occupies a position somewhere inside this triangle."

Keywords: *A. personatus*; fisheries; life history.

**Kawasaki, T.; Hashimoto, H.; Honda, H.; Otake, A. 1983.** Selection of life histories and its adaptive significance in a snailfish *Liparis tanakai* from Sendai Bay Japan. Bulletin of the Japanese Society of Scientific Fisheries. 49(3): 367-378.

"Food habits shift from number selection depending mainly on crustaceans to size selection relying in particular on sandeel in Oct. when growth is the fastest."

Keywords: *A. personatus*; Japan; predators (fish, snailfish).

**Kelley, D.F. 1987.** Food of bass in U.K. waters. Journal of the Marine Biological Association of the United Kingdom. 67(2): 275-286.

"Stomach contents of 1225 specimens of the European sea-bass, *Dicentrarchus labrax* (L.), are analysed. The samples, from bass aged 3-22 years but mainly from adults aged 6 and above, were collected in 1946-85 from many parts of the English and Welsh coasts and in the Channel Islands. Dominant foods of adults were crabs (chiefly *Carcinus maenas*) and sand eels (*Ammodytidae*)."

Keywords: *Ammodytidae*; British Isles; predators (fish, European sea-bass).

**Kelley, D.F.; Reay, P.J. 1988.** The shallow creek fish communities of southwest England and west Wales, UK estuaries. Journal of Fish Biology. 33(Supplement A.): 221-222.

Keywords: *Ammodytes*; Atlantic (northeast); distribution.

**Kendall, A.W., Jr.; Dunn, J.R.; Wolotira, R.J., Jr. [and others]. 1980.** Zooplankton, including ichthyoplankton and decapod larvae, of the Kodiak shelf. Seattle, WA: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; Northwest and Alaska Fisheries Center Processed Report; contract 80-8. 393 p.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; distribution.

**Kennedy, V.S.; Powles, P.M. 1963.** Plankton collections from the western Gulf of St. Lawrence central Nova Scotian Banks, 1958 to 1962. MS. Rep. Ser. (Biological) 799. [Place of publication unknown]: Fisheries Research Board of Canada. 32 p.

Keywords: *Ammodytes*; distribution; Gulf of Saint Lawrence; Nova Scotia.

**Kenney, R.D.; Hyman, M.A.M.; Owen, R.E. [and others]. 1986.** Estimation of prey densities required by western North Atlantic right whales. Marine Mammal Science. 2: 1-13.

Keywords: *Ammodytes*; North Atlantic; predators (mammals, right whales).

**Kenney, R.D.; Winn, H.E.; Macaulay, M.C. 1995.** Cetaceans in the great south channel, 1979-1989—right whale (*Eubalaena glacialis*). Continental Shelf Research. 15(4-5): 385-414.

Keywords: *Ammodytes*; predators (mammals, right whale).

**Kepp, J. 1979.** Study of demographic structures of catches of Ammodytidae (sandeels) on the eastern coast of Cotentin. Science et. Peche. 295: 1-18.

“Five species of sandeels (Ammodytidae) are found on the eastern coast of Cotentin (Bay of Seine). The evolution of the demographical structures of each population were studied separately. The biological characteristics of the two most important species are expounded and the characteristics of the fishery described.”

Keywords: *A. marinus; A. tobianus; Gymnammodytes semisquamatus; Hyperoplus maculatus; Hyperoplus lanceolatus*; France; distribution; fisheries; growth; life history; spawning; taxonomy.

**Khudya, V.N. 1990.** Sand eel population in La Perouse Strait and Aniv Gulf. Rybnoe Khozyaistvo (Kiev). 1990(11): 27-29.

Keywords: *Ammodytes*; Russia; distribution; population dynamics; temperature.

**Khudya, V.N.; Fedotova, N.A.; Mukhametov, I.N. 1996.** Food habits of the sand lance *Ammodytes hexapterus* in coastal Sakhalin waters. Sbornik Nauchnykh Trudov Sakhniro. Fishery Investigations in the Sakhalin-Kuril Region and Adjacent Areas. 1: 45-50.

“Analysis of material collected in 1986-1994 shows that though a variety of food organisms were recorded in the stomachs of the sand lance (*Ammodytes hexapterus*) the main food constituents are copepods and euphausiids in the fish from southeastern Sakhalin, and euphausiids and cumaceans in zhose [sic] from northeastern Sakhalin. Larval decapods and chaetognaths play a minor role. The daily ration of the fish amounts to 9.62% of the body mass.”

Keywords: *A. hexapterus*; Russia; food and feeding habits.

**Kieckbusch, J.J. 1993.** Observations on food-selection by cormorant (*Phalacrocorax carbo sinensis*) at the sanctuary “Oehe-Schleimuende.” Seevoegel. 14(2): 19-22.

“Between the 14, 8, and 6, 9, 1991, 1768 dives of cormorants were observed at the sanctuary ‘Oehe-Schleimuende’ (Baltic Coast, Northeast Schleswig-Holstein). Most of the fish species could [be] identified by telescope, because larger prey-items were brought to surface before swallowing. The main prey were eel-pouts (*Zoarces viviparus*) whereas eels (*Anguilla anguilla*), sand-eel (*Ammodytes tobianus*) and flatfish (*Pleuronectes* sp.) were caught only at a low number.”

Keywords: *A. tobianus*; Germany; predators (birds, cormorant).

**Kihara, K.; Shimada, A.M. 1989.** Effects of water temperature on prey-predator interactions of yellowfin sole *Limanda aspera*. Bulletin of the Japanese Society of Scientific Fisheries. 55(2): 301-304.

Keywords: *A. hexapterus*; Bering Sea; predators (fish, yellowfin sole).

**Kim, J.M.; Yoo, J.M.; Huh, H.T.; Cha, S.S. 1985.** Distribution of fish larvae in the Ulsan Bay and its adjacent waters. Ocean Research. 7(2): 15-22.

"Seasonal distribution of fish larvae in the adjacent waters of Ulsan was studied during February, April, July and September, 1984. Twenty four species of larvae were identified. The major species found in this survey were: *Engraulis japonica, Omobranchus elegans,* Callionymidae, *Ammodytes personatus* and *Sebastes inermis*. Dominant species differed from month to month. Unknown species of Callionymidae occurred in large number in July and September. Values for species diversity index were low in February and July, and high in April and September."

Keywords: *A. personatus*; Korea; distribution; larvae.

**Kim, J.Y. 1982.** A study on the distribution of fish larvae in the western water of Korea in spring. Bulletin of the Fisheries Research Developmental Agency, Busan [Pusan]. 30: 65-71.

"The distribution of fish larvae in the western water of Korea was investigated during spring in 1980 and 1981. Larvae were classified into 16 species, 17 genera and 16 families. *Enedrias* spp. was the most abundant, dominant species were *Engraulis japonica, Ammodytes personatus, Liparis tanakai* and *Astroconger myriaster*. It was observed that the location of water area, in which larvae of *Enedrias* spp., *A. personatus* and *L. tanakai* were distributed, were moved northerly as they grew. In general, three horizontal distribution patterns were demonstrated as such the nearshore group with *Enedrias* spp. and *L. tanakai* the offshore group with *E. japonica, Sebastes inermis* and omnipresence group, nearshore to offshore, with *A. personatus, Astroconger myriaster,* and *Sardinops melanosticta*."

Keywords: *A. personatus*; Korea; distribution; larvae.

**Kim, Y.H.; Kang, Y.J. 1991.** Food habits of sand eel *Ammodytes personatus*. Bulletin of the Korean Fisheries Society. 24(2): 89-98.

"Food habits of sand eel, *Ammodytes personatus*, in the coastal waters, Shinsudo, Samchunpo, was studied from March to May 1988. Main food item was *Calanus sinicus.* Although food diversity increased with age, evenness decreased with age. Importance indices of food items of *Paracalanus parvus* and *Corycaeus latus* were high in younger age. But that of *Sagitta crassa* and Gammaridae were high in older age. As while, that of *Ca. sinicus* was very high in every age. Food items of *A. personatus* were equal to all groups except 0.5 month group because it had the complete digestive tract after 1.5 month group."

Keywords: *A. personatus*; food and feeding habits.

**Kim, Y.U.; Han, K.H.; Kang, C.B. 1994.** Distribution of ichthyoplankton in Asan Bay, Korea. Bulletin of the Korean Fisheries Society. 27(5): 620-632.

"To study the distribution of ichthyoplankton in Asan Bay, samples were collected with a Bongo net at 8 stations from April, July and October of 1991, and January of 1992. Twenty three species of fish larvae were identified. The predominant species were gobiid fishes accounting for 32.84% of the all fish larvae, and followed by *Ammodytes personatus* (16.69%)."

Keywords: *A. personatus*; Korea; abundance; distribution; eggs; larvae.

**Kimoto, S. 1976.** Methods for analysis on animal community. Tokyo: Kyoritsu Publishing Company. 1: 148-151.

**Kimura, S.; Kishi, M.; Nakata, H.; Yamashita, Y. 1992a.** A numerical analysis of population dynamics of the sand lance (*Ammodytes personatus*) in the eastern Seto Inland Sea, Japan. Fisheries Oceanography. 1(4): 306-320.

Keywords: *A. personatus*; Japan; Seto Inland Sea; population dynamics.

**Kimura, S.; Kishi, M.J.; Nakata, H.; Yamashita, Y. 1992b.** A numerical analysis of population dynamics of the sand lance (*Ammodytes personatus*) in the eastern Seto Inland Sea, Japan. Fisheries Oceanography. 1(4): 321-332.

Keywords: *A. personatus*; Japan; Seto Inland Sea; larvae; model; population dynamics.

**Kimura, H.; Yamada, H. 1996**. Change of nucleic acid and protein quantities with the growth of sand lance fingerling. Nippon Suisan Gakkai Taikai Koen Yoshishu. 1996: 34.

Keywords: *Ammodytes*; growth; juveniles; nucleic acid; physiology; protein.

**Kiorboe, T.; Munk, P. 1986.** Feeding and growth of larval herring, *Clupea harengus*, in relation to density of copepod nauplii. Environmental Biology of Fishes. 17(2): 133-139.

Keywords: *Ammodytes*; food and feeding habits.

**Kiorboe, T.; Munk, P.; Richardson, K. [and others]. 1988.** Plankton dynamics and larval herring growth, drift and survival in a frontal area. Marine Ecology—Progress Series. 44(3): 205-219.

Keywords: *Ammodytes*; distribution; food and feeding habits; larvae.

**Kirillov. 1936.** The sand eel of Novaya Zemlya (*Ammodytes marinus* Raitt). Doklady Akademii Nauk SSSR. 4(13), No. 5: 233-235.

Keywords: *A. marinus.*

**Kishi, M. 1995.** Fishery ecosystem model: problems in aquatic resources evaluation: role of numerical model in aquatic resources evaluation. Gekkan Kaiyo. 27(4): 236-238.

Keywords: *A. personatus*; Japan; Seto Inland Sea; environmental impact; fisheries; larvae; model.

**Kishi, M.J.; Kimura, S.; Nakata, H.; Yamashita, Y. 1991.** A biomass-based model for the sand lance *Ammodytes personatus* in Seto Inland Sea Japan. Ecological Modelling. 54(3-4): 247-264.

“On the basis of the existing physiological and ecological information, a biomass-based ecosystem model of sand lance (*Ammodytes personatus*) in Seto Inland Sea, Japan, was developed for studying the important biological parameters for stock fluctuation and the role of harvest of sand lance. The model shows that the natural mortality rate of the young sand lance, the biomass of zooplankton, and/or aestivation of sand lance play important roles in the stock fluctuation. These results are supported by sensitivity analysis.”

Keywords: *A. personatus*; Japan; Seto Inland Sea; aestivation; food; model; mortality; larvae; physiology.

**Kishida, T. 1986.** Setonaikai chuseibu iki ni okeru sawara no shokusei: Feeding habits of Japanese Spanish mackerel in the central and western waters of the Seto Inland Sea. Bulletin of the Nansei Regional Fisheries Research Laboratory. 20: 73-89.

“Food and feeding habits of Spanish mackerel, *Scomberomorus niphonius* from the Seto Inland Sea, were investigated based on the examination of stomach content of 714 specimens collected from May 1981 to June 1984. The stomach contents consisted almost entirely of pelagic and mesopelagic fishes including squids, viz. Japanese

anchovy *Engraulis japonica*, sardine *Sardinops melanostictus*, sand lance *Ammodytes personatus*, Atlantic cutlassfish *Trichiurus lepturus* and Japanese common squid *Todarodes pacificus*."

Keywords: *A. personatus*; Japan; Seto Inland Sea; predators (fish, Spanish mackerel).

**Kiso, K. 1994.** Feeding habits of adult masu salmon, *Oncorhynchus masou* in coastal waters near Oshika Peninsula, Honshu, Japan. Suisan Zoshoku. 42(4): 521-528.

"Adult masu salmon were collected with set nets or purchased in fish markets near Oshika peninsula (the Pacific coast of northern Honshu) from 1993 to 1989. Their stomach contents were observed and the food composition was analyzed using 3 different indices (number, weight, frequency of occurrence of each kind of prey). The Index of Relative Importance(IRI) was also used to compare the accuracy of the 3 indices. Results were analyzed in relation to the month of catch size classes of masu salmon. Sand lance, *Ammodytes personatus*, anchovy *Eugraulis japonica*, juvenile of Alaska pollack, *Theragra chalcogramma*, sardine, *Sardinops melanostictus* among others constituted the main food independently of season and size but masu salmon also preyed on large-sized plankton such as *Themisto japonica* and *Euphausia japonica*. Overall, sand lance was a major contributor to food in weight and occurrence between March and June whereas *T. japonica* was the major contributor to food in number in April and May. Large-sized masu salmon depended more heavily on fish as food than small-sized masu salmon. Furthermore, the size and composition of prey differed between adult and juvenile masu salmon. Adult masu salmon took 1-age sand lance, large-sized *T. japonica*, and *E. japonica*, and pelagic fish such as sardine. Juvenile masu salmon took 0-age sand lances, small-sized *T. japonica*, *Thysanoessa longipes* (Euphausiasia), and brackish water fishes such as ice goby, *Leucopsarion petersi*. These results indicate that masu salmon change habitat and food-size selectivity as they grow."

Keywords: *A. personatus*; Japan; predators (fish, masu salmon).

**Kiso, K.; Takeuchi, I. 1994.** Feeding habits of young masu salmon, *Oncorhynchus masou* in coastal waters near Oshika Peninsula, Honshu, Japan. Suisan Zoshoku. 42(2): 351-361.

"Young masu salmon were collected with set nets or from fish markets near Oshika Peninsula to observe their stomach contents during the period from 1981 to 1986. Food composition was analyzed with 4 different indices, that is, number of individual, weight, frequency of occurrence and IRI (index of relative importance), every month, size class, year and area. The most important food of masu salmon was found to be juvenile fish of sand lances, *Ammodytes personatus* and other species independently of season and size. Larger plankton as *Themisto japonica* and *Thysanoessa longipes* were also major contributors to food in April and May. The higher dependence as food on *T. japonica* was recognized in the fish of larger size or those caught in the open bay or around islands as the water of open sea. Our results suggested that the masu salmon running into the sea grow up in estuary by feeding mainly juvenile fish to migrate northward, shifting their main food to large plankton."

Keywords: *A. personatus*; Japan; predators (fish, masu salmon).

**Kitagawa, D.; Yamashita, Y. 1986.** Occurrence and distribution of the Japanese sand eel, *Ammodytes personatus*, larvae in the coastal waters of Iwate Prefecture. Bulletin of the Japanese Society of Fisheries and Oceanography. 50(3): 205-213.

"Spawning ground, occurrence and distribution of the Japanese sand eel (*Ammodytes personatus*) larvae with reference to temperature and the abundance of food organisms were studied in the coastal waters of Sanriku, northeastern Japan, from 1981 to 1985. Pre-larvae occurred mainly from late January to late February. Their distribution suggests that the main spawning grounds are located in bays with a high degree of opening. Larvae are transported to the south by the dominant southward coastal current while partially transported offshore by the dominant eastward wind. From the relationship between temperature and larval distribution, it is suggested that larval survival decreases at temperatures lower than 4 or 5 °C."

Keywords: *A. personatus*; Japan; distribution; food; larvae; spawning; temperature.

**Kitaguchi, T. 1979.** A taxonomic study of sand lances (genus *Ammodytes*) in the waters of northern coast of Hokkaido, Japan. Scientific Reports of Hokkaido Fisheries Experimental Station. 21: 17-30.

“Sand lances (genus *Ammodytes*) were caught by Japanese commercial vessels in the waters of Cape Soya, Hokkaido. North Pacific *Ammodytes* are divided into 2 spp., *A. hexapterus* Pallas and *A. personatus* Girard, on the basis of meristic characters. From the analysis and comparison of vertebral, dorsal fin ray and anal fin ray counts made on *Ammodytes* specimens collected from various localities along the northern coast of Hokkaido, it was concluded that 2 spp., *A. personatus* and *A. hexapterus* were distributed in the adjacent waters of Cape Soya. Evidence for this conclusion is based on differences in mean vertebral and mean anal fin ray counts. Each of 2 *Ammodytes* species populations was characterized by the mode of vertebral counts and that of anal fin ray counts. In the *A. personatus* population, the modes of vertebral and anal fin ray counts were 65 or 66, and 31, respectively; in *A. hexapterus*, 68, and 29 or 30, respectively.”

Keywords: *A. hexapterus; A. personatus*; Japan; distribution; meristics; taxonomy.

**Kitakata, M. 1957.** Fishery biological studies of sand lance (*Ammodytes personatus* Girard) in waters around Hokkaido. II: On the age and growth. Bulletin of the Hokkaido Regional Fisheries Research Laboratory.16: 39-48 In Japanese; English summary.

“The author has studied on the age and growth of Sand-lance by the observation of the otolith. The materials were collected from the Japan Sea coast of Hokkaido during the period April 1955 to May 1956. The main results obtained in connection with age are as follows: 1. Border between transparent and opaque band is very distinct. 2. There is a remarkable correlation between the body length and the radius of the otolith. 3. The radius of each transparent band is nearly constant. 4. It has seemed that the transparent band is formed during the period autumn to winter. 5. Modes of the body length frequencies of all specimens fairly well coincided with each mode of the length frequencies classified by number of bands. 6. It has been presumed that one-ring-group is the one year old group, hatched in spring of the previous year.

“Therefore it is concluded that the otolith is fairly favourable material for the age determination of this fish and that the number of transparent bands in it corresponds with the age.

“Furthermore on the growth observations were made: 1. The growth of the Sand-lance in the Japan Sea takes place in spring, while it stagnates after summer. 2. Sand-lance in the northern waters has a higher growth rate than those in the southern waters.”

Keywords: *A. personatus*; Japan; Hokkaido; age; growth; length; otolith.

**Klomp, N.I.; Furness, R.W. 1992.** Non-breeders as a buffer against environmental stress declines in numbers of great skuas on Foula Shetland and prediction of future recruitment. Journal of Applied Ecology. 29(2): 341-348.

“A decrease in the availability of the preferred food, sandeels *Ammodytes marinus*, has been accompanied by a slight fall in AOTs, a considerable increase in foraging effort of breeding adults and a 75% fall in breeding success, indicating that food shortage has put the population under stress.”

Keywords: *A. marinus*; Shetland; predators (birds, great skua).

**Knuzlik, P.A. 1989.** Small fish around Shetland. In: Heubeck, M., ed. In: Proceedings of a seminar on seabirds and sandeels: 1988 October 15-16; Lerwick, Scotland. [Place of publication unknown]: [publisher unknown]: [pages unknown].

Keywords: *Ammodytes*; Shetland.

**Kobayashi, K. 1961.** Larvae and young of the sand-lance, *Ammodytes hexapterus* Pallus from the north Pacific. Bulletin of the Faculty of Fisheries, Hokkaido University. 12: 111-120.

Describes sand lance larvae and young from the northwestern north Pacific including the Okhotsk Sea and the Bering Sea.

Keywords: *A. hexapterus*; Alaska; Bering Sea; Japan; Okhotsk Sea; description; larvae.

**Kobayashi, N.; Nagashima, H.; Kodama, J. [and others]. 1995.** Study on the ecology and resource of the sandeel, *Ammodytes personatus* Girard, in Sendai Bay. Miyagi-Ken Suisan Kenkyu Kaihatsu Senta Kenkyu Hokoku. 14: 37-49.

Keywords: *A. personatus*; Japan; ecology; food and feeding habits; habitat; schools.

**Kodama, J. 1995.** Abundance of sand lance spawner related to the juvenile. Bulletin of the Japanese Society of Fisheries Oceanography. 59(3): 314-317.

Keywords: *A. personatus*; Japan; abundance; competition; larvae.

**Koelink, A.F. 1972.** Bioenergetics of growth in the pigeon guillemot *Cepphus columba*. Vancouver, BC: University of British Columbia. M.S. thesis.

Keywords: *A. hexapterus*; predators (birds, pigeon guillemot).

**Kohler, A.C.; Fitzgerald, D.N. 1969.** Comparisons of food of cod and haddock in the Gulf of St. Lawrence and on the Nova Scotia banks. Journal of the Fisheries Research Board of Canada. 26: 1273-1287.

Sand launce (*Ammodytes americanus*) were the most frequently consumed fish by cod and haddock above 30 centimeter in length. By volume, 47, 76, and 75 percent were consumed by different length groups of cod, and up to 21 percent were consumed by haddock. They were much more common in the stomachs of fish from shoal than from deep water.

Keywords: *A. americanus*; Gulf of Saint Lawrence; Nova Scotia; predators (fish, cod, haddock).

**Kohler, A.C.; Fitzgerald, D.N.; Halliday, R.G. [and others]. 1969.** Length-weight relationships of marine fishes of the Canadian Atlantic region. Tech. Rep. 164. [Place of publication unknown]: Fisheries Research Board of Canada. 17 p.

Keywords: *A. dubius*; Atlantic; length-weight relationship.

**Kolbe, U. 1980.** The little gull *Larus minutus* as a food parasite. Beitraege zur Vogelkunde. 26(6): 365-366.

Keywords: *A. lanceolatus*; *A. tobianus*; predators (birds, little gull).

**Konyukhov, N.B.; Kitaysky, A.S. 1995.** The Asian race of the marbled murrelet. In: Ralph, C.J.; Hunt, G.L., Jr.; Raphael, M.G.; Piatt, J.F., eds. Ecology and conservation of the marbled murrelet. Gen. Tech. Rep. PSW-GTR-152. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 420 p.

“We have observed birds feeding on both capelin and sand lance (*Ammodytes hexapterus*) in the northern Sea of Okhotsk.”

Keywords: *A. hexapterus*; Japan; Sea of Okhotsk; predators (birds, marbled murrelet).

**Kopp, J. 1976.** Étude des structures demographiques des captures d'Ammodytidae (lancons) de la côte est du Cotentin. Science et Pêche. 295: 1-18.

Keywords: *G. semisquamatus*; *A. tobianus*; France; abundance; competition; fisheries; reproduction; sex ratio; spawning.

**Kosaka, M. 1966.** Feeding habits of angler-fish *Lophius litul* on *Ammodytes personatus*, squid octopus. Journal of the Faculty of Oceanography Tokai University. 1: 51-70.

Keywords: *A. personatus*; Japan; predators (fish, angler-fish).

**Kotthaus, A.; Krefft, G. 1967.** Observations on the distribution of demersal fish on the Iceland-Faroe Ridge in relation to bottom temperatures and depths. Rapports et Procès-Verbaux des Reunions Conseil International Pour l'Exploration Scientifique de la Mer Mediterranean Monaco. 157: 238-267.

Keywords: *A. lancea*; *A. marinus*; Iceland; distribution.

**Krasnow, L.D.; Sanger, G.A. 1986.** Feeding ecology of marine birds in the nearshore waters of Kodiak Island. [Place of publication unknown]: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Minerals Management Service; U.S. Department of the Interior, Outer Continental Shelf Environmental Assessment Program; final reports of principal investigator. 45: 505-630.

"For most seabird species in the Kodiak area, distinct seasonal trends were apparent from spring through late summer 1978. Sooty shearwaters, black-legged kittiwakes, marbled murrelets, and tufted puffins exploited a similar suite of prey: sand lance and euphausiids during spring, capelin during early summer, and sand lance during late summer.

"All life stages of sand lance are common in the pelagic and mesopelagic zones of the bays and in the intertidal throughout the summer. Spawning of sand lance has been observed only on beaches along the western shoreline of Afognak Island during the high tide series in October. They disappear from the nearshore zone in fall and may bury themselves in the substrate in deeper water during winter.

"When the feeding habits of black-legged kittiwakes and tufted puffins were compared between summers, capelin decreased and sand lance increased in importance in 1978. The increased use of sand lance appeared to be linked to a change in the abundance of capelin in the epipelagic zone; juveniles were abundant in the surface waters during June-September 1976, but during 1978, most were found along the bottoms of the troughs. Conversely juvenile sand lance increased in abundance in the surface waters during 1978.

"Historically, there could be an increase in numbers of sand lance during periods when capelin are scarce, but in 1978, neither capelin nor sand lance were available to kittiwakes in sufficient quantities to meet reproductive needs.

"In light of interest in the development of commercial fisheries for capelin and sand lance and the importance of these fish in the diets of marine birds, these species deserve further study."

Authors collected 34 marbled murrelets in Chiniak Bay between December 1976 and April 1977 and February 1978; no sand lance were eaten during this winter period. Breeding season samples from Izhut Bay and Northern Sitkalidak Strait of marbled murrelets, tufted puffins, sooty shearwaters, and black-legged kittiwakes showed sand lance and euphausiids were taken during spring, capelin during early summer, and sand lance during late summer.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; distribution; importance; length frequencies; predators (birds, sooty shearwater, short-tailed shearwater, oldsquaw, black-legged kittiwake, common murre, pigeon guillemot, marbled murrelet, tufted puffin).

**Krasnow, L.D.; Sanger, G.A.; Wiswar, D.W. 1979.** Nearshore feeding ecology of marine birds in the Kodiak area, 1978. In: Environmental assessment of the Alaskan Continental Shelf: annual reports of principal investigators for the year ending March 1979. Volume II: Receptors—birds. [Place of publication unknown]: [publisher unknown]: 348-394.

During a winter study of common murre food habits, Pacific sand lance were preyed upon in small amounts. In summer, Pacific sand lance were important in the diet of black-legged kittiwakes, common murres, sooty shearwaters, and marbled murrelets.

Keywords: *A. hexapterus*; Alaska; Kodiak Island; importance; predators (birds, common murre, marbled murrelet, sooty shearwater).

**Krebs, J.R. 1974.** Colonial nesting and social feeding as strategies for exploiting food resources in the great blue heron (*Ardea herodius*). Behaviour. 51: 99-134.

Keywords: *Ammodytes*; predators (birds, great blue heron).

**Kristiansen, A. 1984.** Report of the 0-group surveys in Faroese waters 1981-1984: Council meeting of the International Council for the Exploration of the Sea; [dates of meeting unknown]; Copenhagen, Denmark. [Place of publication unknown]: [publisher unknown]: 13 p.

Keywords: *Ammodytes*; Atlantic (northeast); age; fisheries; larvae.

**Kuhl, H.; Luhmann, M. 1965.** Über Sandspierlinge und Sanspierlingsfischerei in der südlichen Nordsee. Archiv für Fischereiwissenschaft. 16: 182-197.

Keywords: *Ammodytes*; North Sea.

**Kühlmann, D.H.H.; Karst, H. 1967.** Freiwasserbeobachtungen zum Verhalten vos Tobias Fisch-schwarmen (Ammodytidae) in der westlichen Ostsee. Zeitschrift für Tierpsychologie. 24: 282-297.

Keywords: Ammodytidae.

**Kuletz, K.J. 1981.** Feeding ecology of the pigeon guillemot (*Cepphus columba*) at Naked Island, Prince William Sound, Alaska and surveys of the Naked Island complex. Spec. Stud. Anchorage, AK: U.S. Fish and Wildlife Service. 23 p.

Keywords: *A. hexapterus*; Alaska; Prince William Sound; predators (birds, pigeon guillemot).

**Kuletz, K.J. 1983.** Mechanisms and consequences of foraging behaviour in a population of breeding pigeon guillemots. Irvine, CA: University of California. M.S. thesis.

Keywords: *A. hexapterus*; predators (birds, pigeon guillemot).

**Kuletz, K.J. 1996.** Marbled murrelet abundance and breeding activity at Naked Island, Prince William Sound, and Kachemak Bay Alaska, before and after the *Exxon Valdez* oil spill. American Fisheries Society Symposium. 18: 770-784.

“Long-term impacts might result from reduced prey abundance or from consumption of contaminated prey. Murrelets typically forage <2 km from shore and feed primarily on midwater and surface schooling fish, such as Pacific sand lance, capelin, juvenile Pacific herring, and cods. Most of the prey species used by murrelets spawn intertidally and thus are highly susceptible to oil pollution. It is of primary importance to determine if there are long-term effects on the prey species on which murrelets depend.”

Keywords: *A. hexapterus*; Alaska; Prince William Sound; importance; oil pollution; predators (birds, marbled murrelet).

**Kuletz, K.J.; Irons, D.B.; Agler, B.A. [and others]. 1996.** Long-term changes in diets and populations of piscivorous birds and mammals in Prince William Sound, Alaska. In: Forage fishes in marine ecosystems: Proceedings of the international symposium on the role of forage fishes in marine ecosystems; [dates of meeting unknown]; [location unknown]. Prog. Rep. 97-01. [Fairbanks, AK}: University of Alaska Fairbanks, Alaska Sea Grant College: 703-706.

“Populations of some species of marine birds and mammals have declined in Prince William Sound, Alaska, since the early 1970s, while others have remained stable. Declining species, which include marbled murrelets, pigeon guillemots, tufted puffins, arctic terns, harbor seals, and minke whales, feed on schooling forage fish. Stable species, which include harlequin ducks, goldeneyes, and sea otters, prey on benthic invertebrates. Results of a comparison of piscivorous bird diets from 1972-1981 and 1989-1995 demonstrate a major shift in prey from Pacific sand lance to gadids over this period, suggesting that the relative abundance of forage fish species changed in Prince William Sound. We hypothesize that this shift from sand lance, an energy-rich prey species, to gadids, an energy-poor prey species, is related to the decline in piscivorous marine bird populations. A comparison with Kachemak Bay in Cook Inlet lends support to this hypothesis. Piscivorous marine bird populations have remained stable or increased in Kachemak Bay, where sand lance have remained abundant for the past 20 years.”

Keywords: *A. hexapterus*; Alaska; Prince William Sound; importance; predators.

**Kunzlik, P. 1991.** Studying Shetland’s sandeel stocks. Fishing News. 4022: 6-7.

“There are 5 species of sandeel living in British waters. The industrial sandeel fishery is based on just one species, the lesser sandeel, *Ammodytes marinus*; not only at Shetland but also off north west Scotland, and in the much larger North Sea fishery. The other sandeel species make up only a small part of the total sandeel catch. The fishery at Shetland started in 1974 and peaked in the early 1980s; now it is in decline. This article also discusses the relationship between low stocks of sandeels and the failure of certain seabird species on the islands to fledge their young. These fledgling failures were due to starvation owing to the non-availability of young sandeels to feed the chicks.”

Keywords: *A. marinus*; Shetland; catch; fisheries; predators (birds); taxonomy.

**Kunzlik, P.A. 1989.** Small fish around Shetland. In: Heubeck, M., ed. Seabirds and sandeels: Proceedings of a seminar; 1988 Oct. 15-16; Lerwick, [Scotland]. Lerwick, [Scotland]: Shetland Bird Club: 38-49.

Keywords: *Ammodytes*; Shetland.

**Kunzlik, P.A.; Gauld, J.A.; Hutcheon, J.R. 1986.** Preliminary results of the Scottish sandeel tagging project: Council meeting of the International Council for the Exploration of the Sea; [dates of meeting unknown]; Copenhagen, Denmark. [Place of publication unknown]: [publisher unknown]. 15 p.

“A sandeel tagging experiment is currently being carried out at Shetland to estimate the survival and exploitation rates of the lesser sandeel *Ammodytes marinus*. Jolly-Seber type estimates of mortality rates have been made for each of six fishing grounds using tag recapture data from releases made at the start of the 1984 and 1985 sandeel fisheries.”

Keywords: *A. marinus*; Scotland; catch; migration; mortality; tagging.

**Kusakabe, T. 1997.** Integrated measures project for the promotion of resource-controlling fishery: wide area migration resources and natural resources investigations (sandeel). Osaka Furitsu Suisan Shikenjo Jigyo Hokoku. 1995: 80-84.

Keywords: *Ammodytes*; Japan; fisheries.